NAVSHIPS 250-660-24

ELECTRICAL SECTION HISTORY

U. S. NAVY DEPARTMENT
BUREAU OF SHIPS

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A historical account of the activities during World War II of the Electrical Section (Code 660) of the Bureau of Ships, Navy Department, with recommendations based on these experiences for future conduct of this Section or other sections having comparable functions.

U. S. NAVY DEPARTMENT
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1. The Electrical Section History is a record of the significant matters with which the Electrical Section of the Bureau of Ships has been concerned during World War II. It describes wartime operating experiences of the Section, indicating the general nature of the problems encountered. It indicates those methods or procedures found inadequate and emphasizes those matters requiring further study and better solutions.

2. This history has been prepared for the future guidance of personnel concerned with the administration of the Electrical Section as well as personnel administering sections having comparable functions. The lessons learned from the experiences of World War II should be a valuable guide in the future.

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CHAPTER I

INTRODUCTION

PURPOSE OF HISTORY

1. This history is a record of the significant matters with which the Electrical Section of the Bureau of Ships has been concerned during World War II. It describes wartime operating experiences of the Section in order that the lessons to be extracted therefrom may be useful in organizing and administering the functions for which such a section is responsible. By pointing out the mistakes made and the solutions found practicable, it should be a valuable guide in future peacetime as well as wartime operation.

SCOPE OF HISTORY

2. This history attempts to indicate the principles and general nature of the problems involved rather than to describe detailed technical troubles or their solutions. Where specific improvements in shipboard electrical equipments or systems are described, the intent is to indicate the nature of things that have been necessary or desirable, and to show the methods and procedures by which the objectives were attained. The history indicates also those methods or procedures found inadequate, and emphasizes those matters requiring further study and better solutions.

BASIS OF HISTORY

3. This account is written on the assumption that future political considerations will make it desirable to maintain an up-to-date Navy ready for military operations. Its chief value rests in the fact that it covers a significant period into which the U. S. Navy entered inadequately prepared for the magnitude and type of operations found to be necessary, and during which it expanded to unprecedented size and power. By reviewing those factors, evident during this war but not-so-evident during previous eras of peace, this history may aid the effective operation of this Section in the future.

CHAPTER II

CONCLUSIONS AND RECOMMENDATIONS

1. A review of the activities of the Electrical Section immediately prior to and during World War II reveals certain facts. In some matters, inadequate preparation for wartime operation had been made in time of peace. In other matters, errors in judgment were made or incorrect policies followed which handicapped the Section in fulfilling its responsibilities associated with the war effort. In almost all matters, a retrospective review reveals certain phases in which improvements could have been made.

2. This portion of the Electrical Section History outlines, in brief form, the various conclusions drawn from such a review together with corresponding recommendations for future guidance. It is recognized that future technical, industrial, or political developments may influence or invalidate some of the recommendations made herein. It is felt, nevertheless, that these conclusions and recommendations will be of value in summarizing the lessons learned from the war.

Part 1—DEVELOPMENT AND DESIGN

1. World War II showed that inadequate attention had been given in time of peace to the development and design of shipboard electrical power and lighting equipment and installations. Peacetime developments in military equipment tend to be limited to developing equipment possessing characteristics found to be desirable as a result of past war experience. While improvements to remedy defects and deficiencies revealed by past experience are desirable, they are inadequate. Peacetime efforts should strive toward developing equipment that will be satisfactory under the conditions that will exist in the next war. Vision and study are needed to anticipate the nature of a future war and to deduce the requirements that it will impose upon naval electrical equipment.

2. Availability of basic materials and manufacturing facilities must be considered along with anticipated conditions of naval warfare. The development of equipment capable of withstanding battle conditions but which, for any reason, cannot be manufactured in adequate quantity during war is as futile as the development of equipment that can be readily manufactured but that cannot withstand battle conditions. Experiences of World War II are of value in formulating the objectives of developmental programs, but it should not be assumed that the conditions of future wars will be the same as those of the past.

3. World War II witnessed a succession of major developments and improvements in all types of shipboard electrical equipment. Maximum cooperation of private industry made this possible. Such cooperation was achieved because of the seriousness of the national emergency and because money was available to industry to finance development work. The Navy's huge purchasing program assured industry of an opportunity to profit from costly development work.

4. Peacetime conditions will provide no such stimulus for equipment development and improvement. Navy purchases will represent only a small percentage of industry's total sales. Expensive development work will not be undertaken by industry unless adequate financial returns are ensured. To continue the development of naval electrical equipment during peacetime will require that contracts be made with industry specifically for this purpose. Prototypes for equipment of improved design must be purchased even though no immediate need for quantity production of the equipment exists. Realistic consideration must be given to the fact that industrial research and development are governed by financial and profit considerations.

GENERAL DESIGN

5. **High-Impact Shock.**—Making shipboard electrical equipment and systems capable of withstanding high-impact mechanical shock was a major problem of the war. The fact that this program was not started until immediately prior to the war handicapped its effectiveness. Even by 1945, much of the electrical equipment installed in naval vessels was of the nonshockproof type.

6. Future work should concentrate upon making electrical systems of all combatant vessels completely shockproof. Even a minor component that is not shockproof may impair the reliability of an electrical system under conditions of shock. H. I. shock (2,000 foot-pounds) was set as a standard; future studies should consider the desirability and possibility of raising this standard, or revising it to more closely simulate actual shipboard conditions.

7. **Critical Materials.**—Difficulties arising during the war due to shortages of critical materials were many. Material substitutions and design changes were often necessary, while production was frequently delayed by shortages of some material.. Inadequate foresight during peace for such wartime shortages was evident.

8. Future designs of electrical equipment should be such that performance does not hinge upon the use of a material liable to become critical. Designs should favor the use of materials obtainable in this country in lieu of imported materials whose supply may be disrupted or curtailed by war. Serious consideration should be given, in designing all electrical equipment, to the possibility of certain materials becoming critical during wartime.

9. **Fire Resistance.**—War experience showed fire hazards of electrical equipment to be a serious threat to electrical system reliability and personnel safety. Extensive development work was initiated to improve the fire resistance of materials of construction. New insulating materials were developed having greatly improved characteristics,

but limitations of time permitted only limited use of these materials.

10. Work should be continued toward improving the fire resistance of all electrical equipment. Particular emphasis should be placed upon the development of completely inorganic insulating materials, paints, etc. Ideal shipboard electrical equipment should not support combustion under any condition and should be affected to a minimum degree by external fires.

11. **Moisture Resistance.**—Other obstacles to electrical system reliability were water and moisture. Water dripping, spraying, or flooding into electrical equipment repeatedly caused interruptions of service. Many design and installation changes were made to improve this condition but the problem remained a major one.

12. Maximum effort should be devoted to improving the ability of electrical equipment to resist water and moisture as well as to improving installation arrangements in this regard. Systems should be capable of operation despite moderate conditions of spray or flooding and, in the event of severe flooding, should be capable of rapid and convenient restoration to operating condition.

13. **Size and Weight.**—Inadequate attention was paid prior to World War II to keeping the size and weight of electrical systems to a minimum. Developments during the war made these factors highly critical. By careful study, design, and application, effective reductions were made of electrical system size and weight.

14. Further reductions can be made by continued effort toward this end. New insulating materials, capable of operation at higher temperatures, should make possible significant reductions in size and weight of many types of equipment. Structural designs, likewise, can be revised to incorporate new materials and methods for similar reductions. Electrical system size and weight promise to become of increasing importance and should merit increasing attention.

15. **Equipment Standardization.**—Inadequate attention was given prior to, and during the early part of the war to equipment standardization. Many difficulties were experienced in the production, procurement, and installation of electrical equipment as a result of this lack of standardization. During the war, considerable equipment standardization was effected with notable accruing benefits.

16. Insofar as is practicable without unduly restricting equipment development and improvement, shipboard electrical power and lighting equipment should be standardized. In particular, overall and mounting dimensions of equipment and similar dimensions of wearing or replaceable parts should be standardized to permit electrical system maintenance with a minimum of replacement-part types. All possible standardization measures should be adopted that will reduce or eliminate duplication of industrial or government efforts. Standardization can make possible great reductions in design work, production time, replacement and spare-part activity, and personnel training; all possible efforts should be devoted to effecting such economy and efficiency.

17. **General Performance and Reliability.**—Many of the difficulties encountered, and much of the work necessary, during World War II could be attributed to laxness during eras of peace. Features such as degaussing, equipment shockproofness, etc., could and should have been developed prior to the war. Standards of equipment performance should have been continually raised to match technical developments in engineering. A tendency existed, however, to accept previously established standards as satisfactory and to overlook new engineering developments and improvements for application aboard naval vessels.

18. A vigorous policy of progressive engineering should be established for future periods. Present standards of electrical equipment and system performance can, beyond doubt, be appreciably—even drastically, improved by future engineering developments. Progress of this nature will require close coordination with industrial research and production developments paralleled with naval research and engineering. Desirable goals for equipment and system characteristics and performance should be clearly established and continued effort devoted toward achieving these goals. Only by such policies can naval shipboard electrical systems be developed to provide the maximum degree of performance and reliability.

ELECTRICAL SYSTEMS

19. The war emphasized several basic factors concerning the electrical systems of naval vessels. It showed the need for spare generating capacity, the importance of which had been neglected in the numerous additions of loads to the existing electrical systems of older vessels. It emphasized the importance to system reliability of the fundamental principles of segregating generating plants, segregating cable runs, and arranging systems and equipment to provide the best inherent protection against damage. It provided much information from battle

experience concerning arrangements and methods for achieving this reliability.

20. Future designs of electrical systems should stress reliability as of paramount importance. Electrical generating plants should be segregated, with minimum interdependence for their operation. Cable runs should have maximum separation, both horizontally and vertically. Cable runs should be carefully planned to avoid all undesirable or vulnerable locations. Locations of equipment should be similarly planned. The multitude of individual lessons learned from World War II should be utilized and their importance realized in planning future ships' electrical systems.

LIGHTING

21. The war's experience made necessary extensive changes in almost all phases of shipboard lighting. The former "battle-lighting systems" were eliminated as their illumination was inadequate for modern battle conditions. Equipment and arrangements for preventing the exposure of light were improved by various changes and innovations. Various developments were necessary to improve lighting reliability under severe mechanical shock. Emergency lighting equipment required considerable improvement. Low-level illumination was improved by a change from blue to red. Considerable work was done to improve undesirable shipboard lighting conditions but only partial success achieved.

22. Modern conditions of naval warfare place increasing emphasis upon visual tasks aboard ship. Utmost attention should be given to providing naval vessels with high quality illumination suitable for long hours of critical visual work. The use of fluorescent fixtures and the improvement of compartment conditions (types of surfaces, surface colors, etc.) should be investigated as a means of improving shipboard lighting. To achieve reliability, all lighting fixtures should be developed to be capable of withstanding high-impact mechanical shock. Light security and all other aspects of darkened-ship operation should be given due consideration in the design of lighting systems. Future lighting systems should be designed to be adequate in all respects for wartime service.

ELECTRIC CABLE

23. Electric cable installations, in general, proved satisfactory during the war. Developments and changes aimed toward saving weight, eliminating critical materials, and improving waterproof characteristics.

24. Future cable research and development work should aim toward making all cable watertight. Cable construction should be capable of completely preventing the longitudinal flow of water, and moreover should not be permanently damaged by water. Stuffing tube designs should similarly be improved in watertightness. Improved insulating materials, improved installation methods, and better application methods should be utilized to reduce the size and weight of electric cable and cable installations.

ROTATING ELECTRIC MACHINERY

25. Improvements were made during the war to the mechanical design and construction of electric motors and generators. Other improvements were made to machinery ventilation and insulation. Voltage regulators of markedly improved designs were developed during the war. Operating experiences revealed the need for several other improvements which were never successfully accomplished.

26. Future developments in rotating machinery should strive toward reducing equipment size and weight. Newly developed insulating materials, permitting higher operating temperatures, give promise to the accomplishment of this aim. The many bearing failures during the war make desirable improved bearing designs and lubricants. The successful application of totally enclosed, water-cooled designs for large machinery makes desirable the future application of these designs to smaller equipment. Commutation of d-c machines proved a constant source of trouble and merits any possible improvement. Voltage regulation characteristics of shipboard electrical systems promise to become of increasing importance and make desirable all possible improvements in generator voltage regulators.

MOTOR CONTROLLERS

27. Motor controllers underwent complete redesigning during the war to meet the special requirements of naval shipboard service. Extensive standardization of designs contributed much to solving production and maintenance problems. The majority of troubles with motor controllers were experienced with commercial marine types installed in non-Navy ships converted for naval use.

28. Standardization of motor controllers should be continued with a view toward increasing shockproofness and general reliability and reducing size and weight. An effort should be made to require controllers installed in commercial vessels to be of a better type so as to be suitable for naval service if wartime conditions make this necessary.

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CIRCUIT BREAKERS

29. Circuit breakers were greatly improved during the war. They were improved in shock resistance, in interrupting capacity, in tripping time characteristics, and in general design. These improvements were vitally necessary in that pre-war circuit breaker designs were inadequate in performance for service in modern naval vessels. Although marked improvements were made, inferior and interim designs of circuit breakers were necessary in many ships constructed, and it was impossible during the war to replace these with ones of better design.

30. Tripping time characteristics of circuit breakers should be further improved. Electrical system reliability hinges directly upon the nature and accuracy of these characteristics and their coordination throughout the system. Interrupting capacities of circuit breakers should be increased where possible to ensure more reliable system fault protection and to permit reductions of size and weight. Designs should be standardized to permit interchangeability of circuit breakers of different manufacture. Moreover, circuit breaker replacement should be made to be simple and rapid. Improving fire resistance of circuit breakers should be a constant aim. Programs should be initiated to replace all inferior circuit breakers on ships in commission with ones of latest design to provide system reliability.

SWITCHBOARDS

31. Switchboard construction was considerably improved during the war. Structural strength and resistance to mechanical shock were increased. Fire and moisture resistance were similarly increased. General performance and reliability were in many ways improved. Switchboard designs in 1945 were far superior to those of before the war.

32. The importance of switchboard performance and reliability warrants every possible effort directed toward their improvement. Switchboard mechanical construction should be improved in every manner possible to provide strength to resist mechanical shocks, hull distortion, and vibration. New or improved electrical insulating materials as well as better structural arrangements should be utilized to increase switchboard fire resistance. Under no condition of short circuit or overload should any switchboard component smoulder or ignite; external fires should have minimum effect upon switchboards.

33. Continued effort is necessary toward decreasing the vulnerability of switchboards to water and moisture. Dripproof and splashproof construction appear a practical military necessity for major combatant vessels, and desirable for other vessels. Waterproof construction would be highly desirable, if practicable within limitations of space and weight. Future designs must recognize water and moisture as constituting serious hazards to maximum switchboard reliability.

TRANSFORMERS

34. Little or no trouble was experienced with transformers during the war. Their design proved both efficient and reliable. Further improvements however are still desirable. Reductions in their size and weight should be sought. Their ability to withstand water and moisture should be improved in every manner possible. Electrical and mechanical improvements are highly desirable for further increasing the reliability and improving the performance of transformers.

BATTERIES

35. The majority of difficulties experienced during World War II with battery design and construction resulted from the necessity of eliminating natural rubber as the major material of construction. Further work should be conducted in developing designs of batteries, utilizing synthetic and substitute materials obtainable in this country. It should be a constant aim to increase battery life while maintaining or improving standards of performance and reliability.

GENERAL

36. Basic recommendations for desirable developments and improvements have been outlined herein for the major types of shipboard electrical power and lighting equipment. Similar improvements, although not specifically mentioned herein, are desirable for all other types of shipboard electrical equipment. In general, each equipment design should be constantly reviewed with the aim of improving its designed performance, its reliability under all possible conditions of service, and its economy of space, weight, and material.

Part 2.—PROCUREMENT OF ELECTRICAL EQUIPMENT

1. The procurement of electrical equipment during World War II became an extremely important and highly complex matter. The many difficulties experienced in this phase of the Section's activities taught many lessons for future guidance. Some of these conclusions and recommendations are outlined below.

PLANNING

2. Considerable effort was made during this war to plan future production of electrical equipment needed for the construction, repair, and maintenance of naval vessels. Innumerable obstacles were encountered in this work principally because of a lack of complete information regarding both requirements and facilities. Despite these obstacles, a planning program was carried out and proved of inestimable value.

3. The value of planning must be recognized. Only by the establishment of sound planned policies can an effective naval war program be conducted. To make possible a planning program, accurate information regarding requirements, production facilities, methods, etc., must be available. Complete information and plans should be obtained from shipbuilders covering details of constructing ships and ship components. Data on ship maintenance and conversion requirements should be accumulated. Methods should be devised to measure production facilities for all types of electrical equipment. Procedures should be instituted to consolidate all planning functions in one activity of the Bureau of Ships. Only by establishing such basic data and methods can effective planning be conducted in future periods.

PURCHASING

4. Limitations of time caused the majority of difficulties experienced with purchasing procedures. The time-consuming nature of existing purchasing procedures made difficult the procurement of electrical equipment in time to meet shipbuilding and maintenance programs. Procurement problems became a matter of continual concern.

5. Future purchasing procedures should tend toward government purchasing, stocking, and distribution of all principal ship components. Thus, the long time cycles involved in purchases by shipbuilders would be avoided. Purchases could be more carefully planned in accordance with shipbuilding and maintenance requirements.

6. Future purchasing methods should also include some provision for the government purchasing, or providing financial backing for the purchasing of the large quantities of raw materials needed for Navy production. Without such a provision, procurement is delayed by the manufacturer obtaining such raw materials after the receipt of the purchase order. Arrangements could be made for the government to provide all such basic stocks with industry purchasing quantities for nongovernmental production to use as "fill-ins" to level off production rates.

7. Purchasing procedures should be given further study with a view toward establishing methods that will make possible planned purchases with a minimum of delays.

DISTRIBUTION

8. Distribution of electrical equipment was never completely satisfactory. The demands of the war made necessary the supply of equipment and parts to far distant locations with little or no advance notice. Complex systems were instituted to meet this problem, but these were never able, during the war, to achieve satisfactory operation.

9. The need for an efficient system for supplying replacement equipment and parts must be recognized. Such a system or systems must be established in adequate time to permit its orderly function. It must be based upon adequate records of probable demands for equipment and parts. Too, future work should aim toward simplifying procedures for ordering and requisitioning equipment and methods for reporting and controlling inventories.

GENERAL

10. Certain general conclusions regarding the procurement of electrical equipment can be drawn from the experiences of the Section during the war. Manufacturing facilities and special machinery necessary for the upkeep of the post-war fleet should be maintained and kept operating. Representative manufacturers should be kept actively interested in Navy business by means of development orders to replace or improve present designs. All production controls should be rescinded during peacetime but plans for control during war should be maintained between the armed services and industry. Detailed studies should be made by the armed services of the procurement procedures established and utilized during this war so as to permit their improvement in future periods.

Part 3.—ORGANIZATION AND ADMINISTRATION

PERSONNEL

1. A large number of qualified professional and clerical employees was required to carry on the work of the Electrical Section during the war. Officer personnel was not desired, except for administrative positions, because of administrative problems associated with naval rank and naval policy. Civil Service could not provide the type and number of civilian personnel needed. Qualified civilian personnel "borrowed" from industry filled the needs of the Section.

2. Future policies should concentrate on the recruitment of the highest possible calibre of personnel for the Section. Many of the difficulties arising during this war can be avoided in future periods by the employment of highly qualified personnel, capable of initiating and pursuing vigorous engineering and administrative policies in times of peace.

ORGANIZATION

3. Changes in technical developments must be matched by corresponding changes in organization. New groups or subsections must be established to handle new problems or projects. Authority for each particular phase of the work must be delegated to the maximum practicable degree. Overlapping or divided authority over a project results in conflict, confusion, and delay.

4. Effective measures to educate Section personnel in naval methods and practices are necessary for the efficient conduct of the Section's work. Methods found most satisfactory include sending engineers on trips to examine naval vessels; conducting lectures on naval engineering, equipment, and developments; and utilizing a Section publication for disseminating general information.

5. Maintenance of adequate records is of great importance because inadequate records lead to needless repetition of work, to negligence in the completion of projects, and sometimes to incorrect decisions. Efficiency requires that complete records be kept of technical studies and developments, long-range projects, battle damage and machinery performance reports, and of any similar information.

6. Some form of control, similar to the mail-control system, is necessary to prevent delay in answering correspondence. Future administrations should utilize such a system as a simple and effective method of ensuring section efficiency.

DISSEMINATION OF INFORMATION

7. Better methods of disseminating technical information to the fleet and to naval activities were shown to be needed. Repeatedly, problems were studied by the Section and their solutions found, but never satisfactorily corrected by the fleet or field activities. No medium existed by which such information could be disseminated with the assurance that it would be received and understood by the proper personnel.

8. Future efforts should be concerned with developing good methods of disseminating information to naval activities. Particular effort should be devoted to the dissemination of general background engineering information—other than that of a directive nature. Too, special attention should be given, in times of peace, to maintaining all specifications and manuals up-to-date. Technical progress of the Navy in the future will be dependent to a large degree upon the free and complete exchange of technical information between the Bureau, the fleet, naval activities, and private manufacturers.

CHAPTER III

DEVELOPMENT AND DESIGN

1. The prospect of a naval war found electrical equipment and systems of U. S. Naval vessels in need of considerable improvement. Inadequate advance preparation had been made since World War I for the new conditions of warfare created by technical developments of aircraft, high explosives, radio, etc. Much effort was therefore necessary during World War II to improve designs of equipment and systems to meet these new conditions of warfare.

2. This portion of the Electrical Section History reviews some of the developments and improvements effected for shipboard electrical equipment and systems. An attempt is made herein to indicate the general types of problems arising, the solutions attempted, the solutions found satisfactory, and those found inadequate or requiring further study.

Part 1.—GENERAL CHANGES AND IMPROVEMENTS

HIGH-IMPACT MECHANICAL SHOCK

1. Probably the most important single factor affecting electrical equipment design during World War II was high-impact mechanical shock. Prior to this country's entry into the war, it was learned from the British that electrical equipment then installed in naval vessels could not withstand the water-borne mechanical shocks from exploding non-contact mines or near-miss bombs. Subsequent experiences of U. S. Naval vessels substantiated these findings. Electrical equipment misfunctioned or was mechanically damaged by these shocks, often resulting in extensive or complete loss of electric power in the vessel. Military considerations dictated that the mechanical shock resistance of all electrical equipment be vastly improved.

2. **Programs Initiated.**—Extensive tests were initiated by the Electrical Section to determine the nature and magnitude of these mechanical shocks. Measurements were made aboard naval vessels subjected to severe nearby under-water explosions. Shock testing machines were built to reproduce the type and magnitude of mechanical shock induced by these under-water explosions. Test procedures were ultimately established, using various sizes of 150 ft-lb and 2000 ft-lb shock machines, which realistically simulated shipboard shock conditions.

3. It was necessary to immediately improve the mechanical shock resistance of existing shipboard electrical equipment. As revising designs of equipment and methods of installation required time and study, interim measures were instituted. Methods for locking closed (or open) the contacts of circuit breakers and controllers were used. Electric lamps were suspended on pendant-type mountings. Other makeshift schemes were utilized to ensure the continuity of electric power even at the expense of nullifying the designed protective functions of equipment.

4. Programs were concurrently initiated to make all equipment capable of withstanding 2000 ft-lb (high-impact) mechanical shock. Shock tests showed that this required extensive changes of design and of basic materials of construction. Materials such as cast iron, aluminum, etc., had to be eliminated. Moving parts such as tripping devices, contactors, etc., had to be balanced or provided with antishock devices. Many types of equipment required complete redesign to enable them to withstand high-impact mechanical shock.

5. **Work Accomplished.**—The shockproofness of all major electrical equipment was steadily improved. Certain equipment was temporarily designed with shock mountings, i.e., supported resiliently upon rubber mounts. Progress was rapid, however, so that by 1945, all major vital electrical equipment could withstand the high-impact shock test. This equipment included generators, motors, controllers, circuit breakers, voltage regulators, instruments, switchboards, etc. Certain nonvital equipment, galley ranges, etc., had not yet been designed to be high-impact shockproof, but work was being done toward this end. Methods for improving the shock resistance of some of the older equipment in service had been developed and modification kits issued for this equipment.

6. War experience demonstrated the value of this work. The increased shock resistance of electrical equipment enabled many vessels to withstand nearby mine or bomb explosions that otherwise might have been crippling. Much equipment installed in naval vessels, however, was still less than adequate in 1945 as regards shock resistance as evidenced by records of failures during battle. Considerable work remained to improve this equipment as well as to investigate the possibility of designing equipment for mechanical shock of higher intensity than 2000 foot-pounds.

CHANGES AND IMPROVEMENTS IN MATERIALS OF CONSTRUCTION

7. Many changes, some immediate, some gradual, were made during the war in the basic materials used in the construction of electrical equipment. These changes were made for one or more of the following fundamental reasons:

(a) Critical shortages of certain materials.

(b) Necessity for improving the fire resistance of equipment.

(c) Necessity for overall reductions in the weight and space of equipment.

(d) Desirability to improve equipment performance and reliability.

8. **Changes Caused by Critical Material Shortages.**—Material shortages during the war were of two general types. One was the shortage

due to mining, refining, or manufacturing facilities being inadequate for the war's building program. The other was the shortage caused by the loss to the enemy of the natural source of the material. The first type was a temporary shortage, relieved if facilities for producing the material could be expanded. The latter type, however, was a shortage that had to be overcome by reducing the use of the material to the existing supply or stockpile.

9. One of the major changes effected was the substitution of steel for aluminum. Aluminum, because of its necessity for aircraft, became highly critical. Aluminum armor of electric cable was replaced by steel armor. Switchboard structures were changed from aluminum to steel. Other similar changes were made in many types of equipment.

10. The source of natural rubber was lost to the enemy early in the war, necessitating immediate and drastic reductions in the use of this material. Fortunately, synthetic rubber and substitutes for rubber had been developed. Although not generally as good in quality, these substitutes were utilized and design changes made accordingly. Rapid developments in these materials by 1945 had made them generally equivalent and in some cases superior to natural rubber.

11. Other critical shortages involved copper, mica, and certain rare metals. Copper was conserved by designing equipment and systems carefully and "close to the line"; substitute insulating materials permitted a major reduction in the use of mica; metallurgical developments devised substitutes for critical rare metals.

12. Although most of the critical shortages arising were solved satisfactorily as described, situations were often critical. Lack of sufficient foresight was evident in that little planning had been done regarding imminent material shortages. Naval equipment designs during peacetime had been established entirely on the basis of peacetime supplies of material.

13. **Changes to Improve Fire Resistance.**—Early war experience showed fire hazards to be a major consideration in the design of equipment. Certain insulating materials used in electrical equipment, while not inflammable, did burn when subjected to high temperatures. The toxic fumes emitted by this burning material were a serious danger to ships' personnel.

14. Work was initiated to develop improved insulating materials. By 1944, a glass-base melamine resin material had been developed having greatly improved insulating and fire-resistant characteristics. This material was used extensively to replace former insulating materials. By 1945 a completely inorganic silicone insulating material had been developed representing a vastly greater improvement in insulation. The use of silicone insulation was still undergoing a trial period however so that, except for experimental installations, no practical usage of it had been made.

15. Changes in designs of equipment, too, reduced fire hazards aboard ship. Switchboard and panel construction formerly had utilized considerable quantities of insulating material. Design studies showed that much of this could be replaced by steel, reducing the use of insulating material to those locations actually requiring material with insulating properties. Other design changes were similarly made such as replacing phenolic lighting fixtures with those of steel, all of which reduced shipboard fire hazards.

16. **Changes to Reduce Equipment Size and Weight.**—The considerable amount of new fighting equipment shown by the war to be necessary on naval vessels made the space and weight requirements of all shipboard equipment highly important. It was necessary to reduce the size and weight of all equipment to a minimum.

17. It has been previously mentioned that many changes in designs involved the replacement of cast iron and steel with fabricated steel. Along with other considerations, these replacements were made toward the goal of reducing equipment size and weight. Effective reductions were thus made. Other design changes were made for the same purpose. In all cases, space and weight considerations were emphasized resulting in many changes in basic materials of construction.

CHANGES TO IMPROVE PERFORMANCE AND RELIABILITY

18. Many changes made in basic materials of construction are not properly classifiable under any of the above groups. These changes were generally made to improve performance or reliability of equipment. Included in these would be the change in transformer core material which permitted considerable improvement in transformer efficiencies, the change to improved magnetic materials in instruments and meters, the change in the type of glass used in lighting fixtures, instruments, and searchlights, and other similar and equally important changes.

IMPROVEMENTS TO COMBAT WATER AND MOISTURE

19. Major obstacles to the reliability of shipboard electrical systems proved to be water and moisture. Water discharged onto electrical equipment from ventilation ducts or electric cables, or water partially flooding compartments as a result of battle damage rendered electrical equipment inoperative. Subsequent reconditioning of this equipment was painstaking and arduous. Even during normal operation, "breathing" of supposedly watertight enclosures frequently "wet" electrical parts, causing short circuits.

20. **Equipment Design Changes to Combat Water and Moisture.**—Extensive equipment design changes were made to combat the effects of water and moisture. The majority of these are described in subsequent parts of this section dealing with particular types of equipment. In general, these changes consisted of providing protective enclosures or shielding for switchboard-type equipment, of improving and utilizing more extensively the drip and spray shielding of rotating machinery, of more widely using watertight equipment, and of redesigning and improving watertight enclosures of fixtures and similar equipment. Materials of construction were similarly changed to eliminate hydroscopic types and to improve their moisture-resistant characteristics.

21. **Ship Installation Changes to Combat Water and Moisture.**—Similar changes were made in ship installation methods and system arrangements to combat the effects of water and moisture. Ventilation duct openings were arranged so that water discharged from these ducts would not directly spray onto electrical equipment. Pumps, fire mains, and other similar equipment in the proximity of electrical equipment were shielded to prevent any drip or spray from falling on the electrical apparatus. Electrical equipment, such as transformers, was mounted a distance above the deck so that partial compartment flooding would be least likely to submerge it. Insofar as practicable, all equipment was installed within enclosed areas rather than on weather deck areas. In these and other ways, it was attempted to protect electrical equipment from water.

22. **Effectiveness of Changes to Combat Water and Moisture.**—Although it was believed by 1945 that much had been done to better protect electrical equipment against moisture, much room existed for further improvement. Water and moisture still remained a major source of trouble. A definite need existed for equipment or equipment installations better protected against water as well as a need for equipment that could be quickly restored to operation if it were submerged.

IMPROVEMENTS IN MAGNETIC AND ACOUSTIC CHARACTERISTICS

23. Several considerations in the design of equipment and systems, previously of little importance, were made significant by wartime developments. Enemy operations made it necessary, insofar as possible, to make ships acoustically and magnetically "invisible". Developments in radio and radar-type equipment made it necessary to consider high-frequency characteristics of all electrical equipment. Some of these considerations are briefly described below.

24. **Reduction of Extraneous Magnetic Fields.**—Protection against magnetic mines was achieved by means of degaussing systems. Extensive tests conducted in conjunction with the Bureau of Ordnance on various classes of vessels determined their magnetic patterns. Combinations of current-carrying coils installed aboard ship were devised to neutralize this external magnetic field. These degaussing coils were so arranged that by varying the current in one or more coils, the external field could be neutralized for any heading and any location of the ship.

25. Degaussing systems were sufficiently effective for most classes of ships. Certain vessels, however, such as submarines, magnetic minesweepers, and electric-drive ships, required additional protection beyond that provided by degaussing alone. Designs of equipment (generators, motors, etc.) installed in these vessels were studied with a view toward reducing their external magnetic fields. Basic changes in design were made which achieved this goal. Much of the information learned was later applied to equipment and systems of all naval vessels to increase the effectiveness of their degaussing systems.

26. **Radio Shielding and Grounding.**—The extensive use of radio and radar-type equipment aboard naval vessels necessitated serious consideration of the high-frequency characteristics of all electrical equipment. High-frequency currents, generated by radio equipment in one part of a vessel, were transmitted along cable conductors or cable armor to produce interference in similar equipment in other parts of the vessel. High-frequency currents generated by switching or commutating electrical equipment were similarly transmitted to produce interference.

27. Reports from operating vessels showed the need for immediate remedy of these conditions. Methods of grounding electric cable armor in "radio spaces" were studied and improved. Grounded metallic braid was provided for flexible electric cable in "radio spaces". Work was initiated and some results achieved in providing electrical equipment with filters to eliminate the emanation of high-frequency currents.

28. This subject remained one definitely requiring more study. Controversy existed as to whether shielding and grounding all equipment represented the best solution, or whether these features should be provided in the basic designs of radio equipment. Too, lack of certainty existed as to the degree of radio shielding required.

29. **Reduction of Noise.**—Enemy acoustic detection devices made it desirable to reduce to a minimum, all operating noises of electrical equipment on submarines. Appreciable reductions were made in equipment "hum" by improving magnetic core structures and improving internal air flow. Noise from antifriction bearings was reduced by careful choice of bearings and their installation. A development considered of major importance was the direct-drive submarine propulsion motor. Eliminating the formerly required mechanical reduction gears, these motors promised to greatly reduce submarine operating noises. By early 1945, the superiority of the direct-drive motors was conclusively demonstrated by actual service experience.

Part 2.—ELECTRICAL SYSTEMS

1. The rapid technical developments of World War II emphasized the importance of electricity aboard ship. Ever increasing reliance was placed upon electric power for almost every shipboard function. The reliability of shipboard electrical systems assumed a critical importance; many improvements were effected to ensure this reliability.

ELECTRIC PLANT GENERATING CAPACITY

2. **Capacity of Ship's Service Systems.**—The installation of additional electrical equipment in all types of naval vessels resulted in a steady increase in their ship's service electrical load. New vessels were designed with far greater generator capacity than was installed in similar older vessels. The installation of additional ship's service generators was necessary in a majority of the older vessels as well as in many built during the war.

3. Installing additional generating capacity in completed vessels was a difficult and time-consuming project. Extensive alterations to the electrical systems were often necessary. Seldom were the resulting installations as satisfactory as would have been the case were the required capacity provided in the original designs. It became increasingly evident that insufficient foresight in designing ships' generating capacity had become a serious obstacle in the attainment of the maximum practicable reliability of ships' electrical systems.

4. Battle experience showed spare generating capacity to be a military necessity. Repeatedly, naval vessels continued engagements with one or more generators damaged. The fact that they could utilize all undamaged armament and machinery represented an incalculable military asset. Design policies, subsequently established, provided that all combatant naval vessels should have at least 100 percent spare generating capacity.

5. **Capacity of Emergency Systems.**—Emergency diesel-driven generators of limited capacity had been installed in certain major vessels as a source of electric power independent of the vessel's steam supply. Battle experience showed these generators to be highly valuable in supplementing the ship's service generators as a source of power during emergencies. Emergency diesel-generator plants were therefore installed in many types of naval vessels, and their capacity increased within practicable limits of weight and space. A later development for certain major vessels was the installation of small, remotely located, diesel-driven generators, designated casualty power generators. for use with the casualty power system. These generators, too, on several occasions proved their worth in supplying power to vital equipment in critically damaged vessels.

ARRANGEMENT OF ELECTRICAL SYSTEMS

6. **Location of Generating Plants.**—Engineering considerations had always shown the desirability of segregating the generating plants of a naval vessel. Machinery arrangement problems, however, had often resulted in compromises in generating plant design; i.e., the emergency generating plant might be located in the same compartment as a ship's service plant. Combat experience showed such a compromise to be a mistake. The majority of electrical casualties were caused by flooding, which rendered inoperative all equipment located in the flooded compartment. Subsequent design policies strived to achieve the maximum practicable amount of physical segregation of generating plants. For emergency and casualty power generating plants, this led to their installation on separate deck levels to achieve vertical separation. In all cases generating plants were designed, insofar as practicable, to be independent units, unaffected by casualties to other plants.

7. **Location of Electric Cables.**—The basic principles of the use of normal, alternate, and emergency power supplies dictated the physical separation of these cable runs. Toward this end, these cables were installed in separate cable banks, i.e., port, starboard, etc. Battle experience showed that cables on the same deck level, whether port or starboard, were susceptible to the same damage. Increased reliability was achieved by installing the normal, alternate, and emergency cables to any load on separate deck levels as well as with horizontal separation.

8. Special consideration in arranging cable runs was shown to be necessary to achieve maximum reliability of the electrical system. Cables installed in or near the bilges were found to be susceptible to damage from bilge water or minor flooding. Cables installed in close proximity to boilers or steam lines

were adversely affected by heat. Cables in the superstructure exposed to stack gases, or cables exposed to chemical fumes in storage lockers, were similarly damaged. Cables located in hangar areas of aircraft carriers were destroyed by any hangar fires of serious proportions. These considerations made it necessary to carefully plan the actual shipboard location of each cable run to obtain maximum reliability.

9. **Location of Equipment.**—Service experience taught similar lessons regarding the location of electrical equipment. As previously mentioned, electrical equipment was mounted away from the deck wherever possible to eliminate damage from minor compartment flooding. Similar considerations made the proximity of vent-duct openings undesirable. Door switches, casualty power terminals, switches, etc., proved unreliable when mounted in weather-deck areas and were therefore specified to be mounted in protected spaces. Other similar lessons were learned concerning the location and mounting of almost every individual piece of electrical equipment installed aboard ship.

10. **Casualty Power Service System.**—Normal, alternate, and emergency cable runs were utilized in shipboard electrical system designs to achieve reliability of service. Despite this multiple supply, enemy missiles sometimes damaged all cables supplying a vital piece of equipment, without damaging the equipment. A need was evident for some means of supplying power to equipment during these emergency conditions.

11. To meet this need, the casualty power service system was developed. Consisting of portable cables stored throughout the vessel, bulkhead and riser fittings to permit transfer of electric power through watertight bulkheads and decks, and terminals on power supplies and equipment, the casualty power service system provided a flexible means of power distribution for emergencies. Electric power could be taken from any available source, transmitted through the casualty power cables and fittings, and fed to any vital apparatus. By supplying power to fire pumps, antiaircraft guns, steering gear and other vital equipment, the casualty power service system was instrumental in saving many badly damaged vessels from complete loss. By 1945 this system had been installed in a majority of the combatant vessels of the Navy.

12. **Network Power Distribution System.**—The radial-type of electrical power distribution system utilized in naval vessels, while satisfactory, had certain limitations in providing the ultimate in service reliability. Extensive studies were conducted to determine whether any other system might provide a higher degree of reliability. These studies indicated that the network type of distribution system offered distinct possibilities for a highly reliable shipboard installation.

13. Network equipment and systems were designed. Calculations and tests were made to ensure the practicability of this type of system. Favorable results led to the construction of experimental full-size equipment so as to permit thorough testing of the equipment and the system. By 1945, this work had not yet been completed. Future plans, however, called for a trial installation of the network system in an auxiliary vessel to determine its practicability for electrical distribution systems of naval vessels.

Part 3.—LIGHTING

1. New conditions of operation during World War II necessitated definite changes in shipboard lighting. Lighting distribution systems were changed, light security was improved, reliability of lighting was increased, and standards of lighting were raised. Some of the changes contributing to these improvements are discussed in the following paragraphs.

LIGHTING DISTRIBUTION SYSTEMS

2. Ship's service lighting distribution systems were changed from a dual to a single system. Formerly two systems—a general and a battle lighting system, had been installed in naval vessels, all general lighting circuits being deenergized during battle conditions. Extended hours of battle-alerted cruising, however, necessitated by enemy offensive weapons and tactics, showed battle lighting to be inadequate. Insufficient illumination was provided for the many critical visual tasks involved in the operation of a combatant vessel.

3. The dual system was replaced by a single ship's service lighting system, continuously energized. Adequate lighting was installed for all conditions of operation. Reliance was placed upon local switching, door switches, etc., for obtaining any special lighting conditions desired in particular spaces. An incidental result of this change was an appreciable saving of space, weight, and labor in the elimination of considerable electric cable, many distribution panels and similar equipment.

LIGHT SECURITY

4. The need for higher levels of lighting throughout naval vessels made necessary improved methods for preventing the exposure of light during nighttime operation. Door-switch designs were improved to ensure their effectiveness in preventing light exposure. Lighting control circuits were designed so that door-switch operation did not rely on precautionary action of personnel, i. e., door switches deenergized all circuits from which light could be emitted regardless of how lights were controlled or how compartment doors were opened.

5. Although effective in preventing light exposure, door switches proved undesirable for many applications in that frequent light interruptions handicapped work being undertaken in these affected spaces. Light traps were designed and installed to remedy this condition. Light traps permitted personnel movement to and from weather-deck areas without affecting the compartmental lighting. Space requirements of light traps limited their use to large vessels, and to selected passages. Service experience, however, clearly vindicated their use.

LOW-LEVEL ILLUMINATION

6. **Red Lighting.**—Blue lights had been used prior to the war to provide low-level illumination in passages, crews' quarters, etc. These lights had been used to provide a minimum of illumination for personnel movement and also to provide maximum protection against detection resulting from inadvertent exposure of light.

7. Study showed red light to be superior to blue light for this purpose. Red light, unlike blue, did not destroy the visual dark adaptation of personnel. Moreover, red light proved superior for security reasons, in that detection of exposed red light was less likely than it was for blue. Low-level illumination of all naval vessels was thus changed from blue to red. Red illumination was similarly installed in exposed locations where some illumination was required (pilot houses, exposed cargo holds, etc.).

8. **Luminous Materials.**—War experience showed that for personnel safety and efficiency, some visual aids were desirable on unlighted weather decks. Luminous material devices were developed for this purpose. Radium-activated marker buttons were developed and used to outline walkways on decks, to mark obstructions and overhangs, to identify personnel, and to aid in other similar manners. Phosphorescent luminous tape and plastic tubing was developed to outline movement areas, ladders, etc., for personnel during amphibious loading operations. Many uses, too, were made of fluorescent materials; viz., paper, inks, paints, etc. All of these materials, properly utilized, proved an aid to efficient nighttime operation.

EMERGENCY LIGHTING

9. The need for emergency lighting had been recognized prior to the war. Emergency power from the emergency generating plant was provided to certain lighting fixtures through automatic

bus-transfer switches. Manual battery-operated emergency hand lanterns were installed in vital operating spaces. Flashlights were issued to a portion of ships' crews.

10. Experiences during the war showed emergency lighting to be of even greater importance than had been realized, both for operating damaged vessels and for saving members of their crews. Relay-operated battery hand lanterns were devised that lighted automatically upon loss of ship's service and emergency power. These lanterns were extensively utilized in both vital operating spaces and in escape passageways. Flashlights were made waterproof and shockproof (from dropping, etc.) and issued to all members of ships' crews.

11. Another lighting development for emergency conditions was the high-intensity flood lantern. Powered by a storage battery, this portable lantern provided a high-intensity beam capable of penetrating heavy smoke or mist. It proved of particular value to damage control and repair parties.

GENERAL LIGHTING IMPROVEMENTS

12. **High-Impact (H. I.) Shock Resistance.**—Early battle experience showed flying glass fragments from lighting fixtures, broken under concussion, to be a serious hazard. Immediate steps were taken to remove all unessential glassware from lighting fixtures. Metal baffles were installed on many of these fixtures, replacing the glass globe, to diffuse the light. Glassware was retained only where it was essential such as on explosion-proof fixtures, red lighting fixtures, and signal lights.

13. Much trouble was experienced by lamps breaking under high-impact mechanical shock. An interim measure adopted to remedy this condition was the installation of pendant lamp holders in vital fixtures. A later development was the H. I. lamp, designed with a rubber insert between the base and the glass, and which successfully withstood much greater values of shock. Production difficulties, however, limited the use of these lamps to vital locations. A later development was a shock mounting for lighting fixtures. By 1945, this latter development had only limited application, but promised to be of real merit for future vessels.

14. Lighting fixtures proved incapable of withstanding H. I. shock. Many fixtures broke or were damaged. Many improvements were made, but in 1945 much work remained to make all fixtures capable of withstanding all conditions of shipboard mechanical shock.

15. **General Illumination.**—The problem of achieving good shipboard illumination had always been a major one. Low overheads with interferences from vent ducts, piping, and machinery constituted almost insurmountable obstacles to good lighting. This problem was increased by the necessity of eliminating glassware from all fixtures. Studies were made to improve lighting conditions; however, results were not satisfactory. Further studies were being conducted in 1945, and with the development of shockproof fluorescent fixtures, promised to achieve some improvements.

SIGNALLING EQUIPMENT

16. Searchlights underwent many design changes during World War II. Steel replaced aluminum as the basic material of construction. Improved corrosion resistance was shown to be necessary, and design changes were made accordingly. The resistance to gun-blast was increased, involving a new type of door glass and its method of mounting. Overall, however, searchlights remained fundamentally the same in form and in operation. New types of signalling lights, smaller in size and weight, including an 8-inch searchlight, portable signalling lights, etc., were developed for the variety of new conditions established by amphibious warfare.

17. Another development in signalling equipment was the NANCY equipment. Because of security classifications, it cannot be further discussed herein, but complete descriptions of this equipment can be found in classified Bureau files and publications. Suffice it to state herein that NANCY equipment represented a major improvement in signalling equipment.

Part 4.—ELECTRIC CABLES

1. Many improvements in shipboard electric cable had been made prior to the war. Armored, heat-and-flame-resistant cable had been developed and installed on naval vessels. Extensive application of synthetic materials to replace rubber had been made in cable construction. Further improvements, however, were shown to be necessary and were made during the war as discussed herein.

CABLE CONSTRUCTION

2. Cable armor, prior to the war, had been of an aluminum, basket weave construction. The critical shortage of aluminum led to a change from aluminum to steel armor. Problems of production, protection against corrosion, and weight were involved in this change, but these problems were overcome and highly satisfactory cable manufactured. Aluminum offered no advantages over steel to warrant any future return to aluminum armor.

3. Wartime operation showed flexible electric cable used to supply gun turrets and directors to have unsatisfactory life. Repeated flexing of the "cross-lay" constructed cables during extended periods of operation caused these cables to break down. Extensive study and development resulted in the change to "unilay" cable, which had a far longer life under repeated flexing service. Other improvements, concurrently made to increase the life of these flexible cables, concerned the methods of supporting the cables within the turret or director tube. These improvements together served to increase tenfold or more, the life of flexible turret and director electric cables.

4. Extensive study was made during the war to reduce the size and weight of shipboard electric cables. Calculations indicated that operating cables at temperatures above 105° C. would be of little value because of the increased resistance losses at higher temperatures, and that no substantial reduction in cable size and weight could be effected by simply reducing the cross section of the copper conductor. Newly developed insulating materials, however, made feasible the reduction of overall cable sizes by reducing insulation thickness. Sample cables of this type were manufactured, and gave promising results. These were not adopted during the war because of the extensive design and production changes required. They held promise for the future, however, in saving space and weight of shipboard electrical systems.

CABLE WATERTIGHTNESS

5. Damage to Naval vessels resulting from enemy action disclosed several conditions involving electric cable or its installation that required improvement. Water from flooded compartments flowed through the interstices between strands of the cable conductor discharging onto electrical equipment in non-flooded spaces deranging electrical equipment and contributing to flooding of the space.

6. A method for sealing the ends of the cable to prevent this was developed and instructions were issued in late 1942 for its application to cable ends in the important spaces of new construction vessels. Subsequently, instructions were issued for its application to ships in service. While this was a practical solution that could be applied to completed ships, the obvious need was for a cable construction that would not permit flow of water. The assistance of the cable manufacturers in developing such a cable was requested, and by the end of 1944 most of the navy cable being produced was provided with a filling compound between conductor strands which effectively retarded water flow. All production difficulties for this type cable had not been eliminated however, and end sealing was still being required in 1945 for this cable as well as for the older types.

CABLE STUFFING TUBES

7. Compartment flooding revealed also the need for improved methods of ensuring watertightness of cable stuffing tubes. New forms of packing material and techniques for applying it in existing stuffing tube designs were developed. New designs of longer stuffing tubes, providing greater reliability as regards watertightness, were evolved for use in vessels under construction. The efficiency of these methods still depended to a large degree upon the quality of materials and workmanship employed. A need existed in 1945 for a more reliable method of achieving stuffing tube watertightness with minimum dependence upon workmanship quality.

CABLE CURRENT RATINGS

8. The increased shipboard uses of cable resulting from war developments, the critical cable material supply situation as well as the need to keep ship-

board space and weight for cables to a minimum emphasized the importance of avoiding cable sizes in excess of requirements. Analytical studies and tests were conducted to reexamine the current ratings of navy cables under typical installation conditions and revised ratings were established. Revised methods to assist in obtaining realistic estimates of current loads to be expected in cables were also devised and promulgated. The net effect of this work as regards reduction (or increase) in the cable installed as compared to what would otherwise have been used was not clear in view of numerous factors rendering a direct comparison difficult. It did provide the means whereby cable sizes could be more accurately matched to installation conditions i sufficient information regarding the conditions were available.

Part 5.—ELECTRIC MOTORS AND GENERATORS

1. Electric motors and generators were a type of equipment for which designs were well advanced prior to the war. As a consequence, few major changes in their design or construction were made. Special conditions arising during the war, however, resulted in certain minor changes as discussed herein.

GENERAL CONSTRUCTION

2. General improvements were made in the mechanical design and construction of rotating machinery. Increasing emphasis was placed upon structural and mounting strength, particularly in regard to resistance to high-impact mechanical shock. Fabricated steel construction was widely adopted to replace cast iron and cast steel construction, with appreciable savings of weight. Corrosion resistance was improved by newly developed metal treatments and by more careful selection of basic materials of construction. Certain substitutions, such as steel in lieu of copper for collector rings, were successfully made to limit the use of critical materials.

BEARINGS

3. A repeatedly arising problem during the war was the relative superiority of sleeve and antifriction bearings. Antifriction (ball) bearings had the advantages of being grease lubricated and thus capable of operation in any position, and of being capable of withstanding a certain amount of end thrust. They had the disadvantages, however, of being precision type equipment obtainable from only a limited number of bearing manufacturers and of being subject to damage by slight amounts of dirt, by overgreasing, or by deviations of shaft or housing dimensions. They could not be manufactured or repaired by shipboard personnel.

4. Sleeve bearings were used in all large motors and generators. Ball bearings were used in smaller machines where their advantages justified their use. Single-shielded bearings were adopted as offering better protection than open bearings against the entrance of dirt, and as less subject to damage from overgreasing, than double-shielded bearings. Various types of bearings, housings, and lubricants were tested in order to minimize failures but it was felt that better solutions were still desirable for a reliable type of antifriction bearing.

VENTILATION

5. Electric generators installed in naval vessels prior to the war were generally of the open, self-ventilated type. War operating experience revealed certain undesirable aspects in the use of these machines. Machinery space ambient temperatures, particularly when in tropical areas, usually exceeded design values while oil laden air in these spaces proved detrimental to insulation.

6. Careful study of this problem resulted in the adoption of totally enclosed, water-cooled construction for all alternating current generators, 500 kw. and larger. Although desirable for smaller a-c machines, the necessary increases in size and weight could not be justified.

7. Direct current propulsion motors and generators were made totally enclosed, water-cooled. Smaller d-c machines however, with certain exceptions such as submarine auxiliary generators, were all of open, self-ventilated construction. The major difficulty with d-c machines was that carbon dust from the brushes accumulated on the internal windings, necessitating frequent cleanings. Air filters were installed in the air path of totally enclosed machines to remove this carbon dust. The limited success of this method led to the experimental installation of electrostatic (Precipitron) filters on a few totally enclosed d-c machines. Although it was expected that electrostatic filters would greatly minimize trouble from carbon dust, insufficient operating experience had been obtained by 1945 to substantiate this expectation.

8. Service experience with totally enclosed, water-cooled motors and generators was highly satisfactory. Considerations of space and weight were the principal factors limiting their use. It was felt that future developments in the reduction of machinery size and weight and in the improvement of machinery cooling systems might lead to wider adoption of totally enclosed, water-cooled machinery.

INSULATION

9. Insulation of rotating machinery underwent few changes during the war. Increasing emphasis upon reducing the weight and size of equipment led to greater use of Class B insulation in lieu of Class A. Glass-based melamine material to a limited extent was used to replace phenolic insulation for

slot wedges, etc. The major problem concerning insulation was insuring that the smaller manufacturers, previously unacquainted with marine requirements, employed proper and sufficient insulation in Navy equipment.

10. It has been previously mentioned that silicone insulating materials were developed during the war, with great promise for their future application. Experimental motors and generators were designed and constructed employing silicone insulation. These machines were given exhaustive life tests, and proved capable of withstanding temperatures far in excess of those of any previous type of machine. It was felt that the characteristics of silicone insulation could well be utilized in future designs for reducing machinery size and weight by increasing their designed operating temperatures, and also for increasing the overload capacity of important electrical machinery.

CARBON BRUSHES

11. Carbon brushes on d-c machines proved an annoying source of trouble throughout the war. Most of these troubles were caused by manufacturers employing improper types or grades of brushes in the machines or brushes of a grade not replaceable by a standard Navy grade. Too, pigtail connections often were unsatisfactory for shipboard service, causing selective action, brush overload, poor commutation, etc. Each of these troubles were remedied by individual studies and corrective measures. The numerous cases of brush trouble, however, indicated that more attention should have been given to this subject, with special attention to brush maintenance and replacement.

A-C GENERATOR VOLTAGE REGULATORS

12. Indirect acting voltage regulators, utilizing high speed contactors and a motor-driven rheostat in the generator field, were installed on all a-c ship's service generators prior to the war. Service experience showed that these regulators required considerable maintenance and adjustment for satisfactory operation, and that they were susceptible to damage and maloperation from high-impact shock. Moreover, their performance was slow under large changes in load, making voltage fluctuations a serious factor in electrical system design and operation.

13. Direct acting voltage regulators, acting to vary a resistance in the generator-exciter field, were developed for shipboard use. These regulators represented a major improvement over the indirect type in that they were much smaller and lighter, were appreciably better in performance, and had fewer moving parts and devices requiring adjustment. Action was taken to install this type of regulator on the majority of vessels under construction and on many vessels in commission, replacing the installed indirect acting type.

14. Shortly thereafter, a further improvement was made in the development of a rotary-amplifier-type voltage regulator. This regulator had only a static control circuit together with an exciter of special design. Its performance was superior to that of both the indirect and direct type voltage regulator. In view of its superior performance and static nature (i. e., it required no adjustments or periodic maintenance), the rotary-amplifier type of regulator was adopted for all vessels under construction. It was extensively used also to replace indirect acting regulators in major vessels or vessels undergoing repair.

15. By 1945, it was felt that generator voltage regulators had been vastly improved. Calculations indicated that the rotary-amplifier-type regulator approached the theoretical limit for speed of response and accuracy for this type of voltage regulator. Work was being continued, however, to increase regulator reliability, to standardize regulators of various manufacture, and to simplify regulator control and switching circuits.

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Part 6.—MOTOR CONTROLLERS AND CIRCUIT BREAKERS

MOTOR CONTROLLERS

1. Prior to World War II, motor controllers for naval shipboard use were nonstandard, "tailor-made" equipment. Adapted from commercial marine types, these controllers were usually relatively large and heavy, and not ideally suited for naval vessels. Production of the many varied types, sizes, and styles of motor controllers during the naval shipbuilding program became a "bottleneck". In 1942, an industry committee was therefore formed and a program initiated to improve and standardize Navy motor controllers.

2. Navy shipboard motor controllers were completely redesigned. By careful design and the elimination of unnecessary components, controllers were reduced 65 percent in size and 50 percent in weight. Sizes and types were standardized at a minimum practicable number. All controllers were made H. I. shockproof.

3. By so standardizing motor controller types and sizes, production difficulties were largely overcome. Controllers could be manufactured in quantity without reference to their shipboard application. The addition of proper sized relay coils, suitable nameplates etc., adapted them for the particular shipboard application required. The motor controller program of the Navy proved highly satisfactory in supplying adequate numbers of controllers that performed reliably during battle service.

CIRCUIT BREAKERS

4. The improvement of circuit breakers and circuit breaker application was largely dictated by the rapid expansion of naval shipboard electrical systems during World War II. Circuit breakers designed and installed on naval vessels prior to the war were incapable of withstanding H. I. shock, were incapable of interrupting the short-circuit currents of the larger shipboard electric plants, and were inadequately selective in operation to provide system reliability under fault conditions.

5. **H. I. Shock Resistance.**—Probably the most critical problem was making circuit breakers capable of withstanding the effects of near-miss bombs and noncontact mines. Under these concussions closed circuit breakers were often tripped open, while open circuit breakers were jarred closed. This condition seriously impaired the reliability of all shipboard electrical systems.

6. Work was begun redesigning circuit breakers to withstand H. I. shock. The seriousness of the situation, however, demanded an immediate remedy. Circuit breaker lock-in devices were therefore devised as an interim measure. These devices, when locked in, rendered inoperative the operating mechanism of circuit breakers, including all overload and short circuit protective mechanisms. Lock-in devices were installed on all circuit breakers to be used on such circuits and at such times when the importance of maintaining service continuity outweighed the desirability of retaining the protective functions of the circuit breaker. Obviously lock-in devices did not represent a satisfactory ultimate solution. Design work was rapidly continued and improvements made until in 1944 all Navy circuit breakers being manufactured were capable of withstanding H. I. shock. Work was also carried out and some progress made by 1945 to improve the mechanical shock resistance of circuit breakers already installed and in service.

7. **Selective Tripping.**—Oil-film dashpots had been installed on type ACB circuit breakers prior to the war to give an inverse time current tripping characteristic. Type AQB circuit breakers were provided with instantaneous overcurrent tripping only. Service experience showed that these devices did not provide shipboard electrical systems with reliable fault protection. Faults sustained in operation often resulted in loss of electric power to a major portion of a vessel. A need was evident for a selective protective system that would disconnect faulted portions of a system with minimum disturbance to the remainder of the system.

8. Circuit breaker tripping mechanisms were completely redesigned. Accurate inverse time-current characteristics were provided for type ACB circuit breakers by means of mechanical, inertia, and oil displacement devices. Similar characteristics for type AQB circuit breakers were obtained by thermal devices. Extensive studies and tests were conducted on the coordination of these circuit breakers and their settings to obtain the most reliable protective shipboard electrical systems. Selective tripping fault protective systems were installed on all major vessels

under construction as well as those already in service. Service reports, although not extensive, indicated that these protective systems proved invaluable in providing greater reliability of shipboard electric power.

9. **Interrupting Capacity.**—Extensive tests of various designs of circuit breakers were conducted during this circuit breaker program. The information gained from these tests made it possible to appreciably increase the current interrupting capacity of almost all sizes of circuit breakers. Thus, the redesigned circuit breakers with improved time-current characteristics and H. I. shockproofness also had greater current interrupting capacity than those of pre-war design.

10. **General Improvements.**—Other general improvements in circuit breaker design were made during this period. Terminals were redesigned to minimize the possibility of arcing between terminals due to moisture or dirt—an occurrence indicated in several reports from the fleet. Glass-base melamine material was adopted for as many applications as practicable to replace phenolic material, thus improving insulating properties and decreasing fire hazards. Circuit breakers were designed as steel-backed draw-out types and dimensions standardized among manufacturers, facilitating the replacement of damaged breakers. Similarly the thermal elements of type AQB circuit breakers were standardized in dimensions to permit rapid replacements.

BUS-TRANSFER SWITCHES

11. Early in the war, vessels reported trouble with automatic bus-transfer switches. Transferring under load following damage to the normal supply, these switches frequently arced-over, welded closed, or tripped out their feeder supply circuit breaker. Investigation showed these difficulties to be caused by the high transient currents induced by the back, out-of-phase voltage of induction motors during the transfer. As a remedy, automatic bus-transfer switches were replaced by manual transfer switches. The operating time of manual switches allowed the induced back e.m.f. to decay to a safe value and eliminated these troubles.

12. Further study was made of bus-transfer switches and their application and new requirements established. Bus-transfer switches were required to be installed closely adjacent to the equipment being supplied to increase the reliability of power supply. Electrically operated non-automatic switches were eliminated as being unessential and not as reliable as the manual type. Automatic bus-transfer switches for power service were required to have a time-delay transfer to eliminate transfer current-transients. Lighting transfer switches were made with instantaneous operation.

GENERAL SYSTEM PROTECTION

13. Although major improvements were made during the war in system protective equipment and its coordination, further improvements were still desirable. Naval vessels could be expected to suffer almost every type of damage to electrical systems, and an ideal protective system was considered one that would maintain electrical power service under all conditions. In 1945, tests and studies were being continued to improve all types of circuit-protective equipment.

Part 7.—SWITCHBOARDS AND PANELS

SWITCHBOARDS

1. Many improvements in switchboard construction had been made prior to the war. Switchboards for a-c vessels were dead-front, single section, of aluminum construction, utilizing flush-mounted circuit breakers. Switchboards for d-c vessels were live-front, of ebony asbestos, utilizing circuit breakers and knife switches with fuses. Service experience, however, during the war showed several desirable improvements in design and construction as discussed herein:

2. **Mechanical Strength.**—Battle conditions showed a need for increased switchboard structural strength to withstand mechanical stresses and shocks. Aluminum construction was therefore replaced by steel and increased emphasis given to framework design. Extensive tests showed bolted construction to have several weaknesses under mechanical impacts, and thus welded construction was adopted. Additional battle experience led to the use of overhead bracing designed to shear free under abnormal stress, thus minimizing switchboard damage due to hull distortion. The latest type of switchboard design adopted for naval vessels, and the one best able to withstand shipboard mechanical stresses, was the sectionalized design. This type consisted of several independent, self-supporting switchgear units, connected by cable in lieu of buswork. This design proved least affected by hull or deck distortion, and thus most reliable under conditions of high-impact mechanical shock.

3. **Fire Resistance.**—Switchboard fires proved to be a serious hazard aboard ship, both for personnel and for electrical system reliability. Foreign particles or moisture entering the switchboard enclosure would cause short circuits which in turn frequently developed into serious insulation fires. Several switchboard design changes were made to improve this situation.

4. A cellular steel switchboard construction was adopted, segregating circuit breakers from one another and from the buswork. Any fire would thus be confined to a single section instead of spreading throughout the board. The use of insulating material was drastically reduced by replacing panel circuit breaker mountings with steel mountings and insulated bushings. Glass-base melamine material was adopted to replace phenolic for switchboard insulating material. A number of fire tests were conducted on switchboards to determine the effectiveness of these various measures and to determine the best methods of combating such fires. These tests showed that the fire resistance of switchboards had been considerably improved by 1945, but also that increased resistance to fire was still highly desirable.

5. **General Design Changes.**—Numerous reports were received of switchboard derangements caused by water dripping or spraying into the switchboard from ruptured pipes, leaking valves, spraying pumps, etc. Top, bottom, and end sheets were installed on switchboards to prevent this type of derangement. Too, more consideration was given to equipment and piping arrangements in the vicinity of switchboards so as to minimize the causes of this difficulty. Study was being given, in 1945, to methods of making switchboard installations watertight, but no actual conclusions or designs had as yet been made.

6. Pre-war switchboard designs were single section units with all switching equipment, control equipment, instruments, etc., mounted thereon. Design studies showed it to be more satisfactory to mount all control equipment on a separate unit. Thus switchboards were designed with a control unit of the benchboard type. Special attention was given to the arrangement of controls to facilitate switchboard operation and to the mounting of instruments, controls, etc., so as to minimize the effects of mechanical shock, vibration, heat, or other damaging factors.

7. Studies were conducted to determine methods of saving copper used in switchboard buswork. Both aluminum and steel were considered as substitutes for copper without satisfactory results. Considerations of space, weight, corrosion resistance, and fabrication made copper the most satisfactory material. Appreciable savings in copper were made, however, by employing cables in lieu of buswork to connect to distribution circuits of small current ratings.

8. The improvements cited above, during the first part of the war, were confined to switchboards for major combatant vessels. Switchboards for small vessels; viz., patrol craft, small auxiliaries etc., were purchased from smaller switchboard manufacturers according to commercial switchboard standards.

These switchboards proved unsatisfactory. It was found necessary to establish rigid standards and to exercise rigid control over the manufacture of these switchboards in order to ensure that the performance and reliability of these switchboards would meet naval standards.

PROPULSION CONTROL UNITS

9. Propulsion control units, being similar to ship's service switchboards except that voltages, types of control equipment, and operational equipment differed in size and installation, underwent similar changes and improvements in design and construction. Structural designs were improved, new insulating materials and new design arrangements were adopted to improve fire resistance, changes were made to minimize the likelihood of damage from water and moisture, and general improvements were made to improve performance of propulsion control units.

PANELS AND CONNECTION BOXES

10. Damages to naval vessels revealed that panels and connection boxes were not watertight. Water entered these enclosures during submergence through leaking gaskets, faulty welded joints, and other locations. Increased emphasis was placed upon methods of ensuring the watertightness of this equipment. Air-test fittings were installed and an air test required on all such equipment to ensure its watertightness. Other improvements in design were made to increase structural strength, to reduce weight and space, and to standardize replacement parts.

Part 8.—MISCELLANEOUS EQUIPMENT

TRANSFORMERS

1. Little or no trouble with transformers was experienced during the war. Nevertheless many improvements were made in transformer design, construction, and installation.

2. Transformer operating temperatures were increased from 105° C. to 125° C. and later to 130° C., with resulting reductions in weight up to 65 percent. Core materials, core designs, insulating materials, insulating methods, and cooling methods were improved. Transformer ratings and transformer mounting dimensions were standardized to permit interchangeability or replacement without regard to manufacture. Methods of making connections to ships' distribution systems were improved from the standpoint of saving space, facilitating installation, and increasing reliability. Resistance to high-impact mechanical shock was similarly improved in all transformer designs and installation methods.

INSTRUMENTS

3. Instruments were redesigned early in the war and remained standard throughout the remainder of the war. Requiring completely new designs to withstand high-impact shock, instruments were concurrently reduced in size from the former 6″ scale size to the $4^1/_2$″ size. These instruments gave satisfactory performance on all types of naval vessels.

FUSES

4. Critical supplies of fibre case material for fuses made necessary extensive testing to develop suitable alternate materials. The results of these tests were highly satisfactory, not only in developing suitable alternate materials, but also in increasing fuse current interrupting capacities. Current interrupting capacities of certain fuse sizes were increased as much as 400 percent with possibilities of greater increases as development work progressed.

BATTERIES

5. Supplies of natural rubber, the major material of battery construction, became highly critical during World War II. As a consequence, design and experimental work centered about the development of suitable alternate materials of construction. Wooden, "Fibrite", and polystyrene battery separators were successively used with considerable success. In 1945, synthetic rubber separators were being developed promising to be superior to all other types. Natural hard rubber monobloc cases were replaced by those of reclaimed rubber and subsequently by those of synthetic rubber—results being highly successful. Similar substitutions were made for battery retainer sheets. As could be expected, many design and production difficulties were experienced during these development programs, but in general battery designs proved successful for naval applications.

GALLEY AND HOSPITAL EQUIPMENT

6. Galley and hospital electrical equipment (ranges, ovens, griddles, sterilizers, toasters, etc.) installed in naval vessels prior to 1941 was fundamentally of commercial design. During the war, this equipment was redesigned to be shockproof. Designs were standardized among manufacturers. Other changes were also made such as designing ranges, etc. to operate at 440 volts, thus eliminating the need for step-down transformers on a-c ships. General improvements of this type were continuing in 1945.

GENERAL

7. Reviewed herein, have been some of the developments and improvements of various types of electrical power and lighting equipment made during World War II. The number of such developments were too numerous to permit them to be completely reviewed herein. Other developments were made in all of the types of equipment reviewed as well as in types not mentioned. Shipboard electrical power and lighting equipment and systems in 1945 were far superior in performance and reliability to those prior to the war. Further details of these developments can be found in Bureau files and publications.

Part 9.—EQUIPMENT STANDARDIZATION

1. Prior to World War II, specifications for shipboard electrical equipment established requirements for performance and materials of construction. Except for limiting maximum weights and sizes, few or no requirements existed for physical and mounting dimensions of this equipment. As a result, electrical equipment of different manufacture varied widely in size, construction, and installation.

STANDARDIZATION SHOWN TO BE NEEDED

2. The accelerated naval shipbuilding program constantly emphasized the need for standardization of equipment sizes and mounting dimensions. Repeatedly, delays in ship construction were threatened by a lack of certainty as to the manufacture and consequent size and mounting of particular equipment. Too, changes in building programs frequently necessitated the installation of equipment of a different type of manufacture than was originally contemplated. Extensive rearrangements of equipment were often necessary in these instances. It was a distinct handicap to the shipbuilding effort that ship designs could not be made independently of individual manufacturers' designs and production schedules.

3. Service experience further substantiated the desirability of equipment standardization. Repair and maintenance of electrical equipment in advance areas were handicapped by the fact that available parts and spares were often of the wrong manufacture and unsuitable for the application. An attempt to supply all bases with adequate quantities of electrical equipments, components, and spare parts to repair and maintain all types of vessels showed a prohibitive quantity of material to be required. Similarly, identification of these various parts became almost an insurmountable problem. It was necessary during the war to provide bases with as many types and sizes of replacement material as was practicable and to rely upon these activities making necessary alterations, fabrications, etc., to effect repairs.

4. The naval shipbuilding program showed, in still another way, the need for equipment standardization. Manpower shortages in manufacturing industries seriously impaired their engineering, design, and drafting facilities. Production was slowed down by every change in design necessitating new drawings, tests, and approval. The exigencies of the shipbuilding program showed it necessary that designs be standardized to a maximum practicable degree in order that electrical equipment production could be kept at a maximum.

STANDARDIZATION ACCOMPLISHED

5. **Master Plan System.**—One of the first standardization measures taken was the institution of the Master Plan System. Whereas formerly a complete set of plans was required for each application of electrical equipment aboard ship, the master plan system required only one set of plans for each particular type of equipment. Certification Data Sheets were used for the individual applications aboard ship and contained all application data that varied with the particular installations. For instance, data such as terminal lug sizes, bearing types and sizes, fuse sizes, associated auxiliaries, and contract information were omitted from the plans and included in the certification data sheets. Thus one master plan for a particular type of equipment could be used for innumerable shipboard applications.

6. As the master plan system was a distinctly new procedure, many difficulties arose in its usage and many revisions were required to correct them. These disadvantages of the system, however, were far outweighed by its potential advantages. The master plan system was not in sufficiently widespread use early enough in the war to be of maximum effectiveness. However, it was effective in saving time and labor required for the preparation, approval, and handling of plans, in standardizing designs and thereby aiding interchangeability of equipment and plans, and in expediting the production and procurement of electrical equipment.

7. **Equipment Standardized.**—Standardization programs were concurrently initiated for many types of electrical equipment. These programs were progressive in nature so that where complete standardization was not achieved, at least partial standardization was accomplished. Some of the equipment standardization accomplished is described below.

8. Submarine propulsion generators and motors were standardized in sizes and dimensions to permit

interchangeability of complete units of different manufacture. Certain sizes of ship's service generators were standardized in ratings and in mounting dimensions to permit similar interchangeability. Standardization of motors for use with close-coupled pumps was likewise planned but never satisfactorily achieved because of innumerable problems associated with such standardization. Circuit breaker mounting dimensions were established uniformly to permit interchangeability of those of different manufacture. Too, overload elements of type AQB circuit breakers were made interchangeable between sizes as well as between manufacture. Transformer, instrument, and meter sizes were standardized. Considerable work was done to permit greater interchangeability of ball bearings. Motor controllers, as has been mentioned previously, were standardized in application and function. Fixtures and fittings were purchased in accordance with 9–S and 9000 series Bureau standard plans and thus were standardized prior to the war. It was found possible, however, to greatly reduce the number of types and sizes of such equipment and thus greatly simplify their procurement and replacement. Similar standardization measures were effected for many of the other types of shipboard electrical equipment. Studies and work toward this end were continuing in 1945.

STANDARDIZATION PROBLEMS

9. Equipment standardization was inherently opposed in principle to equipment development and improvement. While developments and improvements in equipment were vitally necessary, problems of procurement, manufacture, and maintenance, as described above, made standardization necessary as well. A compromise was thus necessary between these two objectives. In general, an attempt was made to standardize physical sizes and mounting dimensions as well as wearing parts (brushes, bearings, etc.), but not to restrict the internal or electrical design of the equipment. Too, standards were never made so rigid that a major improvement to a type of equipment could not result in the establishment of a new set of standards. In this way, the maximum practicable advantage was made of standardization without seriously impairing the development and improvement of electrical equipment.

10. Equipment standardization required maximum cooperation from equipment manufacturers. It was directly opposed to the normal system of design competition among manufacturers. Cooperation was effectively achieved, however, by the establishment of industry committees, heretofore described, and the exchange of patent licenses among manufacturers for equipment manufactured for the Navy.

11. It was evident during the war that insufficient attention had been paid in times of peace to measures for standardizing shipboard electrical equipment. Although the benefits of equipment standardization were considerable, many additional benefits would have accrued had these measures been instituted in times prior to the war.

CHAPTER IV

PROCUREMENT OF ELECTRICAL EQUIPMENT

1. The procurement of electrical equipment for naval vessels changed from a relatively simple matter prior to World War II to an elaborate and highly critical matter during the war. The exigencies of the war made delivery dates of equipment, previously of secondary importance, a matter of major import. The war's various building programs made it necessary to plan procurement so as to distribute work load among all available manufacturers, to coordinate the procurement of equipment with changing shipbuilding schedules, and to coordinate this procurement with that of other wartime activities.

2. This portion of the Electrical Section History reviews briefly the problems arising in these procurement functions, some of the solutions found satisfactory, and those problems remaining still unsolved.

Part 1.—PLANNING REQUIREMENTS

1. Planning the procurement of electrical power and lighting equipment for naval vessels required information as to the types and quantities of equipment needed and the dates by which this equipment would be needed for the orderly progress of the shipbuilding program and the efficient maintenance of the ships of the fleet.

ESTABLISHING REQUIREMENTS

2. Statistics concerning electrical equipment required were obtained by making studies of the types and quantities of such equipment installed in various types of vessels. These figures were used as a basis for estimating the requirements of the entire naval shipbuilding program. Percentages were added for maintenance, conversion, and repair to arrive at the total Navy requirements. These figures, subject to revision when actual requirements were shown to differ, served as the basis for estimating the quantities of electrical equipment required by the Navy.

3. The quantities thus estimated were grouped into types common to the same industry or production line. This information was correlated with similar information obtained by other war agencies and the results circulated to industry through the War Production Board.

4. In cooperation with industry, additional studies were conducted to obtain the basic raw material requirements of each type of equipment. Averaging various manufacturers' requirements and coordinating these with the component studies referred to above, estimates were obtained for the raw material requirements of electrical equipment for the Navy. These estimates were utilized in the functioning of the national Controlled Materials Planning whereby industrial production was controlled by controlling the allocation of raw materials.

DIFFICULTIES IN ESTABLISHING REQUIREMENTS

5. In making accurate estimates of the equipment and raw material requirements of the Navy, many difficulties were experienced. One of these difficulties was the lack of specific information concerning the quantity and type of equipment installed in many types of vessels. Many small vessels were constructed in accordance with general specifications; standardized equipment was not required, nor was the submission of plans to the Bureau required. Moreover, designs of many future vessels were not sufficiently stable or specific in detail to permit an accurate forecast of the equipment to be required. Estimates consequently were difficult and subject to considerable error.

6. Considerable difficulty was experienced in establishing delivery dates of equipment to be installed in vessels because of the wide variation between shipbuilders in the method of erecting a ship. Required delivery dates for similar equipment would vary as much as a year for different shipbuilders. This difficulty was partially overcome during the war by the establishment of a uniform procedure among shipbuilders for assembling a ship. Converted to a percentage of the building time, this gave a basis upon which future delivery dates could be forecast.

7. Information concerning requirements for maintenance and conversion was lacking. Analysis of known requirements compared to orders received by manufacturers showed that equipment requirements for the new ship construction program constituted only about 50 percent of the needs of the Navy. The balance included maintenance, conversion, stock distribution, and inventory needs. These factors to a large extent were unrelated and indeterminate.

8. Changes in shipbuilding schedules throughout the war interfered with planning schedules. In many instances, changes made requirement studies obsolete shortly after their completion. During some phases of the war extreme emphasis was placed upon quick delivery of landing craft and small ships. Inadequate time existed to make detailed requirement studies and as equipment was not interchangeable between many ship classes, completed studies were used only as a guide for estimating specific questions arising.

9. Difficulties arose in estimating raw material requirements because of variances among manufacturers in methods of constructing equipment and in materials used. Too, forced substitutions arising from shortages in certain critical materials made the planning of Navy requirements difficult.

10. Other difficulties were introduced by the methods and procedures inherently necessary for this type of program. As centralized control over the procurement of similar equipment in the Navy

was never fully consummated, planning was handicapped by the number of sections and persons that had to be contacted to arrive at total Navy figures. In summarizing the results of these studies, further difficulty was encountered in grouping equipment in a form suitable for the armed forces and industry. Although this was attempted in various ways, no standards for gaging production capacity or for classifying equipment were devised to be entirely satisfactory.

Part 2.—PRODUCTION FACILITIES

1. Closely associated with the program of planning the requirements of the Navy for shipboard electrical equipment was the problem of surveying the nation's industrial facilities for meeting these requirements. Effectual conduct of the naval program demanded that production facilities be capable of fulfilling the needs of the Navy; if not, that facilities be expanded to do so; and if this were impossible, that plans be altered to fit production facilities.

PROCEDURES

2. The requirements of the Navy were coordinated by the War Production Board with the requirements of the other branches of the armed services and of other war agencies. These requirements were measured against the surveyed production facilities of the country. These surveys were supplemented, where necessary, by independent surveys by each agency of the armed services. Where productive capacity for any particular material or equipment proved insufficient, steps were taken to expand the particular facilities necessary. This was done either by financing the expansion with federal funds or by granting tax amortization within a five-year period by a "certificate of necessity".

3. Frequently other associated factors indicated the need for expanding production facilities Where only one source of supply existed for a certain material or type of equipment, wartime safety measures usually indicated expansion or the creation of another source of supply. Substitutions of alternate materials for critical ones oftentimes indicated, in advance, the need for expanding certain production facilities. Also, any changes contemplated in specification requirements necessitated production surveys to determine whether expansions were to be required.

PROBLEMS

4. One difficulty associated with the surveying and control of industrial facilities was the limited range of the Navy's planning program. The expansion of production facilities usually required one or two years' time. Without a shipbuilding program extending two to three years into the future, proving the need of additional facilities was difficult. As an example, the expansion of electric-motor manufacturing facilities could never be proved necessary, but later in the war shortages of motors threatened to jeopardize the shipbuilding program.

5. A second difficulty was the lack of any accurate method of measuring the productive capacity of a manufacturing plant. No standard method could be devised either prior to, or during the war for gaging productive capacities for equipment such as switchboards, controllers, motors, or generators. Many methods utilizing various groupings and classifications were used but all proved somewhat unsatisfactory in actual usage.

Part 3.—PURCHASING

1. The actual purchasing or placement of contracts for shipboard electrical equipment during the war was handled in one of two different manners. Equipment was either "shipbuilder-purchased" or "Government-furnished".

SHIPBUILDER—PURCHASED EQUIPMENT

2. Shipbuilder purchases were, in general, a long and time-consuming process. Contracts for ships were placed by the Navy upon a shipbuilder or design agent. Plans for the ships were prepared by the shipbuilder or design agent and submitted to the Supervisor of Shipbuilding or Bureau of Ships for approval. After approval of the plans, purchase orders for basic equipment were placed with prime manufacturers. The prime manufacturers in turn placed orders upon subcontractors who in turn often repeated this process one or more times. This chain of "order placing" consumed a great deal of time. In some unusual cases, to obtain orderly production would have required the delivery of subcomponent parts prior to the receipt of their order.

GOVERNMENT—FURNISHED EQUIPMENT

3. Government purchases of equipment, although complicated within the Navy, were far more satisfactory from the standpoint of obtaining orderly production and delivery. Government contracts for equipment were usually placed upon the prime manufacturer with concurrent arrangements made with subcontractors for the manufacture of subcomponents prior to the formal order from the prime manufacturer. Only through the full cooperation of industry were many urgent delivery dates met. Emergency measures of telephones or telegraphic awards were frequently made and accepted by industry for starting production prior to price negotiation and award of a formal contract.

PURCHASING PROBLEMS

4. Two problems constantly confronting the Electrical Section in its procurement of electrical equipment were shortages of production capacity for some type of equipment and the inability of manufacturers to meet planned delivery dates. These problems were generally caused by one or more of the following conditions.

5. Changes in shipbuilding programs, resulting from changes in the war's progress, upset planned programs and required last-minute revisions of production schedules. The late placement of orders frequently made it difficult or impossible for manufacturers to meet desired delivery dates. Often, manufacturers overestimated or were unable to accurately gage their productive capacity. Often, production capacity was inequitably divided between branches of the armed services due to inadequate control by the War Production Board. Similar difficulties arose from the lack of control over orders placed by shipbuilders and their contractors.

6. Another problem involved the acquisition by the manufacturer of the raw materials needed for Navy equipment. Many companies were hesitant in taking the risks involved in purchasing large quantities of special material prior to the receipt of a formal order. Equipment delivery dates were thus often seriously delayed. The two obvious solutions to this problem,—placing orders sufficiently in advance to permit the acquisition of raw materials and subcomponents, or the government financially sponsoring these advance purchases, could not be achieved during the war, and this problem remained a major one.

OPEN-END CONTRACTS

7. "Open-end" contracts were devised during the war as an arrangement for simplifying, both for the Navy and for industry, the complicated government purchasing system. By this system, contracts were awarded in advance to certain manufacturers for values of equipment and services. Job orders could be released against these "open-end" contracts whenever the need for equipment or services was urgent and the delays inherent in arranging contracts could not be tolerated. "Open-end" contracts, although not extensively used, proved highly satisfactory in accelerating the delivery of urgently needed equipment.

PURCHASE OF ELECTRIC CABLE

8. A system was established in July 1943 for completely controlling the purchase and distribution of electric cable. The effectiveness of this system in eliminating the majority of purchasing problems warrants a detailed description of its operation.

9. The Bureau of Ships, the principal consumer of Navy shipboard and merchant ship degaussing electric cable, requested and received official designation as the national control agency for this equipment. Engineers and production control specialists, obtained from the cable industry, analyzed the Navy cable production facilities of industry and existing unfilled orders. Types and sizes of electric cables were arranged into groups and coordinated with the productive ability of the individual manufacturers of Navy cable.

10. In April 1943, private shipbuilders and naval activities were informed that all outstanding purchase orders and contracts for Navy shipboard cable specified for delivery on or after 1 July 1943 were to be cancelled. A "Master Cable List" was distributed listing the types and sizes of cable to be controlled. Instructions were issued to all activities describing the system established for controlling the purchase and distribution of this cable.

11. In cooperation with the Bureau of Supplies and Accounts, "annual" contracts were awarded to each of the fourteen manufacturers of Navy cable. These were "open-end" contracts, obligating the Navy to purchase the quantity of cable allocated for production each quarter. The quantity of cable actually purchased by the Navy was the amount delivered to Naval activities after deducting that delivered to private shipbuilders.

12. Under this system, private shipbuilders and specified naval activities reported quarterly their inventories and their monthly cable requirements for the ensuing twelve months. These latter requirements were identified as to their use, i. e., particular ships under construction, maintenance, repair, etc. These reports when received by the Bureau were analyzed and total cable requirements obtained for the next consecutive quarter. Both maximum and minimum cable requirements were calculated—maximum requirements calling for a 60-day working inventory and a 6-month inventory for maintenance and battle damage and minimum requirements allowing only a 60-day inventory for all purposes. Total requirements for the quarter were matched with total manufacturing capacity for the quarter. Any shortages or surpluses were thus revealed in advance permitting appropriate action to be taken.

13. Cable production was then scheduled with the various manufacturers. All probable obstacles to efficient production were eliminated by assigning each manufacturer with a minimum number of cable types and sizes. The production capacity level for each manufacturer was established on the basis of previous production performance and adjustments made quarterly where necessary. When "cut-backs" in production were necessary, each manufacturer was "cut" an equivalent percentage.

14. Delivery schedules were distributed to the cable manufacturers approximately 45 days in advance of the beginning of the production cycle for the quarter. These schedules became integral parts of the "annual" contracts. Based on those schedules, manufacturers sent price quotations to the shipbuilders who in turn placed formal purchase orders with the cable manufacturer. Selection of manufacturers by the Bureau was determined on the basis of the shipbuilder's stated preference within the limits of the quantities of cable types and sizes scheduled with each manufacturer. Cable not purchased by private shipbuilders was assigned to naval activities in accordance with previously determined requirements.

15. Under the cable procurement system, compliance with planned delivery schedules steadily increased with on-time shipments in the last quarter of 1944 of 97 percent of the Navy's authorization of over 100 million feet of cable. A further foreseen advantage of this system was that contract "cut-backs" would involve only 14 contracts in lieu of the many hundreds that would have otherwise existed.

Part 4.—DISTRIBUTION

1. The distribution of shipboard electrical equipment constituted an important phase of the procurement functions of the Electrical Section. Equipment required for immediate installation presented little problem. This equipment was shipped on government bills of lading directly from the manufacturers to the installing private or Navy yard. Other equipment, however, required additional concern.

STOCKS

2. Equipment and material in excess of current needs and purchased for future programs, for replacement, or for maintenance were shipped to various naval activities for stock. During the early part of the war, this equipment and material was stocked at various activities where its use or installation was most likely. It was later found more practicable and efficient to concentrate these stocks at supply depots. The majority of this equipment and material was stocked in four major inland supply depots. Degaussing equipment and searchlight equipment were stocked in separate coastal supply depots. Also, reserve stocks of standard electrical fittings and electric cable were concentrated at one or two locations with the stocks at other yards and coastal supply depots held to the minimum required for local needs.

3. Control of stocks at the inland supply depots was exercised by the Bureau of Ships. In late 1944, control of maintenance spare-part stocks was established in these depots with the Bureau retaining control of equipment stocks. Stocks of degaussing and searchlight equipment and electric cable were controlled by the Bureau. Stocks of standard electrical fittings were controlled by Navy Yard, Portsmouth under active Bureau of Ships supervision.

EQUIPMENT PRESERVATION

4. In view of the long manufacturing cycles for most types of electrical equipment and in anticipation of accelerated maintenance or replacement needs, advance stocking of many electrical components was required. This resulted in large quantities of electrical material being held in store. Particularly in tropical areas, but even in normal warehousing conditions in this country, serious deterioration of equipment occurred from the effects of moisture and fungus. Starting in early 1944, in conjunction with other governmental agencies and several manufacturers, methods of preserving, packaging, and packing electrical equipment were given more serious consideration. Revised and standardized methods were developed but their adequacy had not been established by 1945. Preservation of electrical equipment during shipment and storage remained a problem for continued study.

FIELD REPRESENTATIVES

5. A distinct aid in the distribution of electrical equipment was the semipermanent Electrical Section representatives established in the four inland supply depots. These four civilian engineers performed the following types of activities associated with the distribution of electrical equipment.

6. These representatives maintained liaison with their respective depots regarding the receipt of equipment and material under the cognizance of the Electrical Section and regarding the issue and shipment of this material as instructed by the Bureau. They aided the depots in interpreting requisitions and shipment orders for electrical equipment. They also made inspections of depot stocks and stock records recommending the redistribution or disposal of any obsolete or surplus items of electrical equipment as well as recommending and supervising minor repairs to electrical equipment in store. Other responsibilities were to advise the depot in the proper and adequate preservation, packaging, and packing of electrical equipment. These representatives were delegated authority to act as direct representatives of the Electrical Section in all other general matters. Depots reported that the services of these Electrical Section representatives had been of great value in solving their many problems in the distribution of equipment and material.

DISTRIBUTION OF SPARE PARTS

7. A network of "Spare Parts Distribution Centers" was initiated in 1943 to provide field stocks of spare parts for all Bureau of Ships equipment. By 1945, this sytem was not functioning in a satisfactory manner. At that time a majority of the electrical parts required by forces afloat and maintenance activities was still being ordered individually from the manufacturers. Adequate supplies of these parts were not available either at advance area distribution centers or at the inland supply depots intended to serve as reserve stocking activities.

Part 5.—SPARE PARTS

1. While the necessity for spare parts for naval vessels was recognized and provided for long before World War II, the magnitude of the problem as encountered during the war was not realistically visualized. During peacetime, ships were not operated for prolonged periods between overhauls or under the adverse conditions incident to combat service. Spare parts were replenished as used by direct purchases from manufacturers who had ample facilities to produce and who could expedite deliveries as necessary to meet emergencies. In many cases, replacement parts could be and were manufactured by the vessels or by tenders or Navy Yards.

PROBLEMS

2. With the advent of wartime conditions, a number of factors affected the supply of spare parts. Prime emphasis was placed on the manufacture of complete equipment for the shipbuilding program, partially submerging the importance and magnitude of spare parts requirements. Too, the requirements of the building program limited the facilities available for the manufacture of spare parts. Coincident with these conditions, wartime operation of the fleet increased equipment wear and accelerated replacement requirements. Supply lines were continually lengthening, requiring large quantities of parts to fill "pipelines" and stock advance areas. Losses were sustained due both to military action and to deterioration. Damages sustained in battle further increased the need for spare parts and replacement equipment.

SYSTEM ESTABLISHED

3. Spare parts for equipment installed aboard ship were classified as follows:

(a) *On-board spares.*—These spare parts were normally procured with the prime equipment and were stowed aboard ship for installation by the ship's force.

(b) *Shore-based spares.*—These spare parts were also normally procured with the prime equipment but were stored ashore because their size, weight, or complicated installation requirements precluded their being carried on board.

(c) *Replenishment spares.*—These were spare parts stored ashore and used to replenish on-board spares.

(d) *Battle-damage spares.*—These were complete components stored ashore and used to replace similar components damaged beyond practical repair.

4. Wartime operation soon made it evident that spare parts were of great importance. A policy was established by the Chief of Naval Operations that no vessel could sail without a complete complement of on-board spares. A high priority rating was placed on spare parts to ensure meeting this requirement. To meet the anticipated replacement needs, a stock spare parts program was initiated in May 1943. This program involved a thorough analysis of equipment installed in all types of naval vessels coordinated with spare parts production figures obtained from manufacturers. Based upon this analysis, stock contracts for quantities of spare parts were initiated. The initial procurement of these stocks was made by the Bureau; replenishment of the stocks was made by the Naval Supply Depot, Mechanicsburg. This stock spare parts program was fundamentally a practical solution to the spare parts supply problem. Actually, the lack of basic data as to the types and quantities of spare parts required prevented the system from becoming but partially successful during its wartime period of operation.

CHAPTER V

ELECTRICAL SECTION ORGANIZATION AND ADMINISTRATION

INTRODUCTION

1. This chapter of the Electrical Section History reviews the organization of the Electrical Section during the period from 1938 to 1945. It discusses the organizational changes, the administration, and the administrative problems occurring during this period.

2. Prior to 1940, the Electrical Section was a part of the Bureau of Engineering. In 1940, the Bureau of Engineering and Bureau of Construction and Repair were combined to form the Bureau of Ships. This combination of Bureaus, although a major change, had little effect upon the responsibilities or organization of the Electrical Section. Those sections in each of the two Bureaus concerned with particular types of equipment were in essence continued in the new Bureau of Ships' organization as technical sections. The Electrical Section of the Bureau of Engineering thus became the Electrical Section of the Bureau of Ships with essentially the same responsibilities and organization as before. Consequently, no differentiation is made herein between the organization and administration of the Section as a part of the Bureau of Engineering and those of the Section as a part of the Bureau of Ships.

3. The rapid changes and developments in naval warfare during World War II greatly affected the responsibilities of the Electrical Section. The great increase in the use of electricity in naval vessels multiplied the work of the Section. New developments in naval warfare, both offensive and defensive, opened new fields for study. The unprecedented magnitude of World War II made necessary the greatest practicable coordination of industrial knowledge and facilities. Necessary increases in Section personnel required extensive programs of education and training. These factors were all reflected in the organization and administration of the Electrical Section discussed on the following pages.

Part 1.—GROWTH OF ORGANIZATION

1. The organization of the Electrical Section underwent many revisions to meet constantly changing requirements. Significant events in the development of this organization are reviewed herein in approximate chronological order.

ORGANIZATION PRIOR TO 1938

2. In 1934 the Electrical Section was composed of three officers and approximately fourteen civilians. The officers consisted of the Head of the Section (Commander or Lt. Commander) and two assistants (Lieutenants)—one for surface ships and general electrical matters, and the other for submarines and storage batteries. One civilian engineer was responsible for large ships (battleships, cruisers, etc.), another for small ships (destroyers, gunboats, etc.), and a third for submarines. Each had one or more assistants and in general handled all electrical matters pertaining to his ships. These matters comprised technical action on all items of electrical equipment under cognizance of the Section for both new construction and maintenance. A fourth civilian engineer was responsible for all matters pertaining to submarine and portable storage batteries as well as primary batteries. In addition, certain engineers in these groups acted as specialists for individual types of electrical equipment. For example, one engineer acted as a specialist for electric-propulsion equipment, another for searchlights, etc. These engineers were concerned primarily with equipment design details and worked with the groups responsible for specific types of ships as regards application of the equipment.

3. The naval expansion program during the period 1934 to 1938 increased the work load of the Section. Personnel was increased but no changes were made in the Section organization. The organization at the beginning of 1938 therefore consisted of four subsections—large surface ships, small surface ships, submarines, and storage batteries. This organization is shown in Figure 1.

ELECTRICAL SECTION ORGANIZATION IN 1938

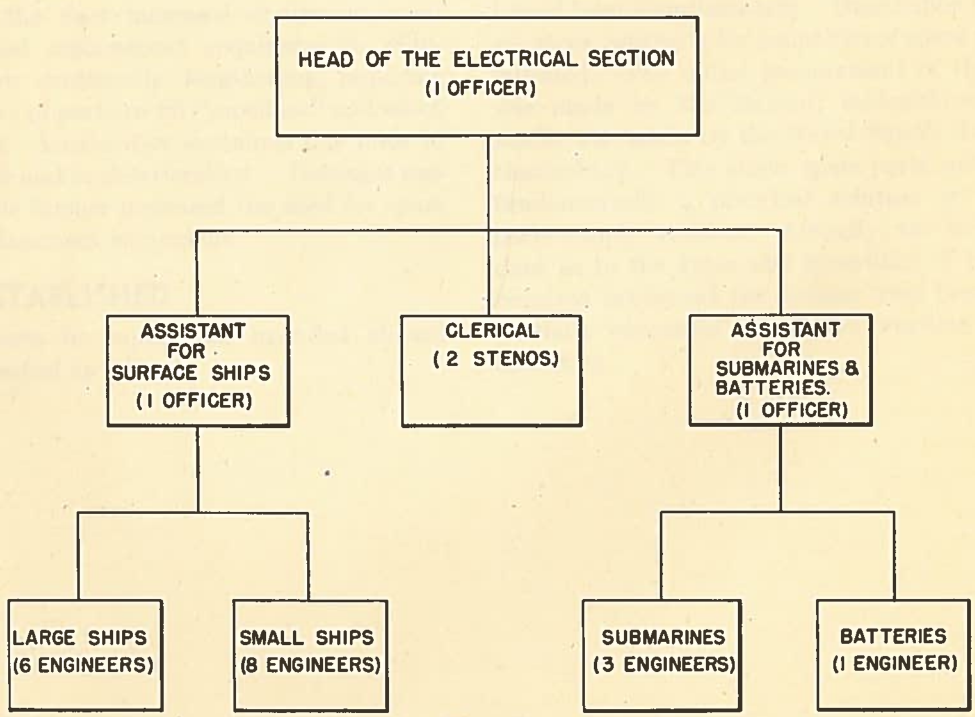


Figure 1

MAINTENANCE AND CONVERSION SUBSECTION

4. The first distinct subsection to be added to the organization was the maintenance and conversion subsection formed in 1938. To this subsection was given the responsibility for obtaining material and equipment required to maintain, repair, or modernize ships in commission. Its responsibilities expanded to include all electrical matters (except degaussing) involved in converting merchant vessels or private boats acquired by the Navy. As responsibilities for obtaining material and equipment for maintenance and repair were later transferred to other subsections, the duties of this maintenance and conversion subsection became similar to those of the existing ship subsections. Thus in 1945, this subsection was responsible for all electrical matters pertaining to a definite group of vessels which comprised the majority of converted naval vessels. The number of personnel in this subsection increased from one engineer in 1938 to one officer and ten civilians in 1945.

DEGAUSSING SUBSECTION

5. Germany's use of magnetic mines against British ships early in World War II indicated the need for countermeasures in the U. S. Navy. As these mines were primarily electrical in character, responsibility for developing, designing, procuring, and installing such countermeasures became the responsibility of the Electrical Section.

6. With one officer and two engineers, a degaussing subsection was formed in June 1940. A program was instituted and actively prosecuted to develop, design, and install degaussing systems on all existing and new construction naval vessels and American merchant ships. The magnitude of this design and procurement program rapidly expanded the degaussing subsection to three officers and thirty-five civilians in 1941.

7. When the United States entered the war, practically all of its ships had either degaussing systems installed, or equipment available for installation. Degaussing work subsequently consisted of improving designs, simplifying installation and operation, and preparing instructions and manuals for maintenance and repair of degaussing systems. Responsibility for the design of individual items of degaussing equipment was transferred to the equipment-design subsection; responsibility for its procurement and distribution was transferred to the procurement subsection (Details of the organization of these subsections are included in following paragraphs). Consequent reductions in work load reduced the personnel of this subsection by 1945 to ten civilians and one officer who was also responsible for the equipment-design subsection.

MINESWEEPING SUBSECTION

8. Germany's use of magnetic mines also showed the need for equipment to "sweep" magnetic mines. A minesweeping subsection was therefore established in 1940. This subsection was made responsible for the special generators, control equipment, buoyant cable, and other electrical equipment required on minesweepers. Considerable concentrated effort was required to develop, produce, and apply this special equipment in the shortest practicable time. At the peak of its work load in late 1942, this subsection consisted of one officer and eleven civilians. In 1943 and 1944, the work load gradually decreased as designs became stabilized and procurement became current with new-construction requirements. In 1945, this subsection comprised five civilians under the administrative supervision of one officer also responsible for the submarine, propulsion, and storage battery subsections.

STRAY-MAGNETIC-FIELDS SUBSECTION

9. Problems arising in degaussing and minesweeping work showed a need for reviewing all electrical installations aboard ship with a view toward reducing extraneous or stray magnetic fields. Toward this end, a stray-magnetic-fields subsection was formed in December 1941. This subsection made studies of existing electrical equipment designs and installation methods, developed methods of reducing stray magnetic fields, and instituted methods and principles for accomplishing this stray-field reduction. Starting with two physicists, this subsection expanded to include five in 1942. As its work neared completion, it was reduced in size until in late 1943 it was disestablished and its responsibilities transferred to other subsections.

ELECTRIC PROPULSION SUBSECTION

10. Prior to 1941, all matters pertaining to electric-propulsion equipment and systems were handled by one or more specialists within the submarine subsection in conjunction with the particular ship's subsection. As the naval shipbuilding program expanded, this type of work load greatly increased. As a result an electric propulsion subsection was formed in early 1941. This subsection was assigned responsibility for all matters (design, application, maintenance, procurement, etc.) pertaining to electric propulsion on all types of surface vessels.

Starting with two engineers, this subsection increased in size until in 1945 it consisted of seven civilians under the administrative supervision of one civilian and one officer who was also responsible for the submarine, minesweeping, and storage battery subsections.

EQUIPMENT-DESIGN SUBSECTION

11. As previously stated, the Electrical Section organization had included engineers within the ship subsections who served as specialists for particular items of electrical equipment. Their responsibilities in this regard consisted of preparing purchase specifications, reviewing manufacturers' proposals and plans, and acting as consultants for the technical details of these items of equipment. These duties were conducted in conjunction with other duties related to the particular ship subsection. As work loads increased, it became evident that more consideration should be given to detail design of widely-used shipboard electrical equipments. Too, it became apparent that a number of engineers, experts in their particular field, should be obtained and utilized in these duties.

12. An equipment-design subsection was therefore established in 1941. Originally consisting of three engineers handling motors, motor controllers, and generators, this subsection was rapidly expanded with specialists to handle all electrical equipment under the cognizance of the Section with the exception of highly specialized equipment (minesweeping equipment, storage batteries, propulsion equipment, etc.). In 1945 the equipment-design subsection consisted of two officers and forty-two civilians.

13. When established, this subsection was made responsible for all matters concerned with procurement as well as with design. Thus this subsection prepared requisition requests for equipment, progressed this request through the Bureau, gave technical advice concerning award of contracts, assisted manufacturers in obtaining material, scheduled delivery dates, etc. Upon the formation of the procurement subsection (details of this subsection are given in following paragraphs), the equipment-design subsection was relieved of the majority of these procurement functions. From that date, the equipment-design subsection was responsible for design functions, viz., design specifications, design approval, testing, application, maintenance, etc.

DEVELOPMENT SUBSECTION

14. Early in World War II, information became available from the British concerning the operation of shipboard electrical equipment and systems during combat. This information showed a definite need for certain improvements in electrical equipment and systems; it also showed the desirability of many other improvements.

15. To establish a group within the Electrical Section that could concentrate on such work independently of production and application design work associated with the shipbuilding program, a development subsection was formed in May 1941. One officer and three engineers, reassigned from within the Section, comprised this subsection. Additional personnel recruited from Navy Yards and industry expanded this subsection to a total of fifteen persons in six months. These engineers as well as those subsequently obtained for this subsection were all selected for the particular type of development work being undertaken.

16. The responsibilities assigned to this subsection were wide and varied. In general they constituted problems not properly concerned with any other specific subsection. For instance, the problem of improving the mechanical-shock resistance of all types of shipboard electrical equipment was one of the first assigned. Later assigned was the development of battery-operated emergency lanterns, recognition signal lights, etc. The development of NANCY signalling equipment was the responsibility of this subsection. Other developments assigned included casualty power systems and equipment, improved insulating materials, motor and controller standardization, and many other new devices. When development work on any particular project progressed to the point that the system or equipment could be widely applied, cognizance of the project was transferred to the ship or equipment subsection concerned.

17. The repeated success of these development programs led to the continued expansion of this subsection. In 1945, the development subsection consisted of four officers and forty-four civilians.

PROCUREMENT SUBSECTION

18. The rapid expansion of the naval shipbuilding program prior to, and during World War II necessitated detailed planning of material and production-facility requirements. Little or no data being available on this matter, a statistics group was formed in 1941. This group made studies of raw material and production facility requirements for proposed shipbuilding programs in order to better plan delivery dates, necessary plant expansions, etc.

19. Concurrently, equipment procurement functions, assigned to the equipment-design subsection,

became more complex in view of increased government planning necessitated by the tremendous increases in production for the armed forces. This fact made it necessary for several men to devote full time to procurement activities.

20. These various procurement responsibilities were assigned in 1941 to a newly-formed procurement subsection. From an original complement of one officer and twenty civilians, this subsection expanded gradually to five officers and one hundred and twenty-five civilians in 1945.

21. The value of a separate procurement subsection was demonstrated repeatedly. With the progress of the war, shipbuilding schedules were repeatedly altered to meet changing needs. Delivery dates of equipment were consequently changed; equipment was diverted from its intended use to others of greater urgency. Emergency repairs required replacement parts and equipment with minimum advance notice. In all of these activities the procurement subsection made invaluable contributions.

22. In 1944, four engineers from the procurement subsection were stationed at the four major continental depots. These engineers served to aid personnel in these depots in identifying electrical equipment and spare parts, in interpreting incoming requests or requisitions, and in other similar ways. In addition, two other engineers from this subsection were designated to visit various Navy Yards, depots, etc., to aid in a similar manner and also to make engineering decisions concerning the feasibility of reconditioning, salvaging, or scrapping damaged electrical equipment.

SPECIFICATIONS SUBSECTION

23. As a need was evidenced for a development subsection to improve shipboard electrical equipment, likewise a need was evidenced for a group to study possible improvements in shipboard electrical systems. Toward this end, a distribution-systems group was established in 1942. Concurrently another group was formed for similar reasons to study possible improvements in installation methods, arrangements, etc.

24. It soon became apparent that responsibility should be vested in one group for establishing basic principles for electrical system design and installation, bettering these principles, and maintaining pertinent specifications and plans. (Lack of this single responsibility had resulted in General Specifications being woefully obsolete.) Thus early in 1943, a specifications subsection was established embodying the two groups mentioned above and several additional personnel. One officer and approximately fifteen civilians comprised this subsection from 1943 to 1945.

25. The work of this specifications subsection was quite varied but in general covered those matters of general electrical system design and installation. Electric cable end-sealing, for instance, was developed by this subsection and established as an installation requirement. Standardization and improvement of electrical fittings, improvements in cable installation practices, etc. were similarly effected. Likewise, studies were conducted and basic principles established for electrical system overload and fault protection, system voltage regulation, electric cable current carrying capacities, etc. In being able to conduct these studies independently of individual production problems associated with the shipbuilding program, this subsection was able to make numerous electrical-system improvements and was able to concentrate the Electrical Section's efforts in maintaining General Specifications and Bureau Standard Plans up-to-date.

ELECTRICAL SECTION MAIL CONTROL SYSTEM

26. An advantage of the original (1934–1938) Electrical Section organization was that all correspondence and plans for any particular ship were received, handled, and answered by one man or one group. Any information desired concerning electrical equipment or systems of the ship was obtainable from the particular man or group. As the Section expanded with subsections designated for specific technical functions, section activity became more complex. Correspondence was segregated according to its technical nature and handled by the corresponding subsection. Many items, by necessity, were handled jointly by two or more subsections.

27. Difficulties arose from this situation. Valuable time was often wasted searching for correspondence believed to be within the Section but its exact whereabouts not known. Moreover, natural procrastination of individuals resulted in long delays in answering correspondence with no effective administrative procedures available for its correction.

28. Methods were attempted whereby individual subsections "logged in and out" their correspondence. These methods were partially successful, by virtue of vigorous administrative control, in eliminating delay in answering correspondence. They failed however to provide a means of locating correspondence within the Section.

29. In June 1942, a central mail control system was established within the Electrical Section. In this sytem all incoming correspondence and plans were received by a central mail room. Mail Control Slips were prepared in quadruplicate for each piece of correspondence. Sufficient information was included on these forms to identify the correspondence (subject, file number, date, addressee, etc.). All intra-section routing and all outgoing correspondence passed through the mail desk where progress records of this correspondence were kept. One copy of the Mail Control Slip attached to the correspondence served as a Section route slip; another, retained by the subsection, served as their reference; a third, as a mail room reference as to the location of the correspondence in the Section; and the fourth, as a mail room file for subsequent reference. A "due date" on each Mail Control Slip (one week's time for correspondence, two week's time for plans) established the limiting date for answering the correspondence.

30. The mail control system effectively aided the administration of the Electrical Section. A daily report of all "overdue" mail provided close administrative control of Section activities. The central record of correspondence routing provided instant information as to location of correspondence within the Section. At later dates it provided a ready reference as to the action taken on any particular item of correspondence.

31. The mail control system was conducted entirely by clerical and stenographic personnel. Five civilians comprised the mail room in 1942 increasing to eight in 1945.

GENERAL

32. The steadily increasing work-load resulting from the shipbuilding program caused a marked increase of personnel in the subsections which were already in existence in 1938. The large-ship subsection increased in size from six engineers in 1938 (see Figure 1) to a total of twenty persons in 1945 (see Figure 2); the small-ship subsection increased from eight to thirty-two; the submarine subsection increased from three to five; while the storage-battery subsection increased from one to eight. A corresponding increase was also necessary in the Section administrative staff from one officer in 1938 to three officers and seven civilians in 1945.

33. The overall size of the Electrical Section thus expanded from three officers and fourteen civilians in 1934 to eighteen officers, two hundred and nineteen engineers or professional employees, and one hundred and six civilian or enlisted WAVE clerical and stenographic personnel—a total of three hundred and forty-three persons in May 1945.

Part 2.—ELECTRICAL SECTION FUNCTIONS AND ORGANIZATION IN 1945

1. Upon the formation of the Bureau of Ships in 1940, the Electrical Section as well as all other technical sections was made a part of the Design Division (later changed to Shipbuilding Division). Actually technical sections worked with all other divisions of the Bureau, but the magnitude and importance of the naval shipbuilding program gave prime emphasis to shipbuilding and made the Design Division the logical place for administrative control.

2. In 1945, the progress of the war placed increasing emphasis upon ship maintenance and repair. Accordingly a Bureau of Ships reorganization made corresponding changes to meet this condition. The previously existing ship sections for construction and separate ship sections for maintenance were combined into ship sections responsible for both the construction and maintenance of the types of vessels under their cognizance. The technical sections were placed under the Ship-Technical Branch which was administered jointly by the Shipbuilding and Ship Maintenance Divisions. Aside from the gradual shift in the work of the Section from construction to maintenance, the functions and organization of the Electrical Section remained the same and were as described below:

FUNCTIONS OF THE ELECTRICAL SECTION

3. The responsibilities of a technical section in 1945 are defined in "Organization of the Ship-Technical Branch of the Shipbuilding and Maintenance Divisions" of 1 May 1945. Briefly, technical sections were responsible for the following technical matters concerning equipment under their cognizance:

(a) Detail design, action on plans, technical decisions, and standardization of practice with respect to systems, structures, arrangements, fittings, equipment, and materials.

(b) Recommendations for General Specification requirements.

(c) Establishing requirements and initiating procurement of Bureau-supplied ship components.

(d) Establishing production schedules.

(e) Furnishing requirements to be included in Bureau, Navy, Joint Army-Navy (JAN), or Federal specifications.

(f) Furnishing technical requirements for equipment-purchase specifications.

(g) Initiating or recommending the initiation of developments, researches, and improvements of equipment.

(h) Furnishing consulting and advisory service in design, installation, and operation of equipment. In fulfilling these duties, technical sections served and worked with all Divisions and Branches of the Bureau of Ships.

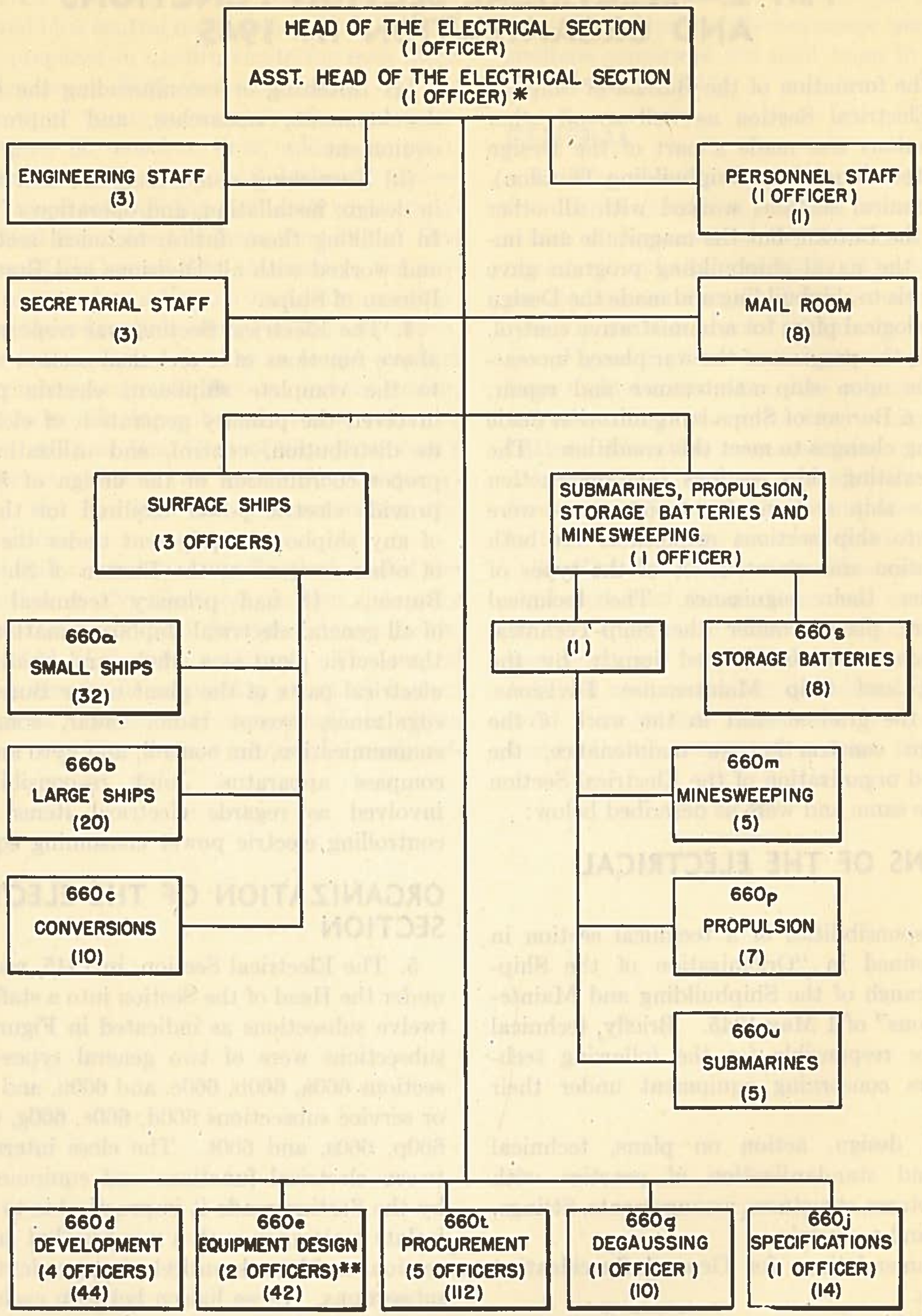
4. The Electrical Section was responsible for the above functions of a technical section with respect to the complete shipboard electric plant. This involved the primary generation of electric power, its distribution, control, and utilization, and the proper coordination of the design of the plant to provide electric power required for the operation of any shipboard equipment under the cognizance of other sections of the Bureau of Ships or other Bureaus. It had primary technical cognizance of all general electrical shipboard matters involving the electric plant as a whole, and of all component electrical parts of the plant under Bureau of Ships cognizance, except radio, radar, sonar, interior communication, fire control, and gyro and magnetic compass apparatus. Joint responsibilities were involved as regards electrical items driving or controlling electric power consuming equipment.

ORGANIZATION OF THE ELECTRICAL SECTION

5. The Electrical Section, in 1945, was organized under the Head of the Section into a staff group and twelve subsections as indicated in Figure 2. These subsections were of two general types—ship subsections 660a, 660b, 660c, and 660u, and component or service subsections 660d, 660e, 660g, 660j, 660m, 660p, 660s, and 660t. The close interrelation between electrical functions and equipment handled by the Section made it impracticable to completely isolate matters in such a manner that any one subsection could work entirely independently of other subsections. Close liaison between each was maintained and when necessary, decisions were made by the Head of the Section or his designated assistants. However, the functions of the subsections could be classified into general categories as described in the following paragraphs.

6. **Head of Section and Staff.**—Working directly under the officer-in-charge of the Section (Captain) and his assistant (Commander) was a

ELECTRICAL SECTION ORGANIZATION IN MAY 1945



THE NUMBERS IN PARENTHESES GIVE THE TOTAL NUMBER OF PERSONS, EXCEPT OFFICERS, COMPRISING EACH GROUP.

* THIS OFFICER ALSO SERVED AS THE OFFICER FOR SUBMARINES, PROPULSION, STORAGE BATTERIES AND MINESWEEPING (660 u,p,s AND m).

**ONE OF THESE OFFICERS ALSO SERVED AS THE OFFICER FOR DEGAUSSING (660 g).

Figure 2

staff including the civilian head engineer and other technical assistants who advised and assisted in technical matters involving the Section as a whole. The staff also included the secretarial, stenographic, and clerical personnel required for general administration of the Section as well as the Section mail room personnel.

7. **Ship Subsections.**—There were four ship subsections, as follows:

660a—Small Ships (Destroyers, Escorts, Landing Craft, small auxiliaries, and similar classes as specifically assigned).

660b—Large Ships (Battleships, Cruisers, Aircraft Carriers, etc.).

660c—Converted Ships (Miscellaneous auxiliary vessels as assigned but generally of types converted to naval use).

660u—Submarines.

8. The responsibilities of these ship subsections included those electrical matters related to a vessel's complete electric plant. These subsections coordinated all engineering action related to the electric plant of specific vessels or types of vessels under their cognizance. Thus they were responsible for correspondence and action on plans involving such matters as power analyses, distribution systems, switchboards, wireways, etc. They maintained liaison between the Electrical Section and the ship sections of the Bureau and were concerned with ships under construction or repair as well as ships in service. Matters concerning specific vessels were generally referred to these subsections who in turn called upon other subsections for assistance or advice concerning particular equipments or matters in which the other subsections specialized.

9. **Specifications Subsection 660j.**—660j handled all electrical requirements covered by the General Specifications and Bureau standard plans. It conducted special tests and studies pertaining to cable installation requirements, distribution systems, and similar matters as assigned. Its work was closely related to the ship subsections and involved matters concerning ships in general rather than specific ships.

10. **Development Subsection 660d.**—660d was assigned several developments and projects which in 1945 included several of a highly classified nature. One of the continuing developments assigned was the responsibility for making shipboard electrical equipment H. I. shockproof. It advised all other subsections concerning shockproofness, conducting tests and studies to improve shock resistance of all electrical equipment and installations. 660d was responsible for developing or assisting in the development of new or improved types of equipment such as motor controllers, bus transfer equipment, high-temperature insulating materials, special lighting devices, etc.

11. **Equipment Design Subsection 660e.**—660e was responsible for design and technical requirements for certain items of electrical equipment as assigned. These included motors, motor controllers, generators (except when these items were used for minesweeping or ship propulsion), voltage regulators, searchlights, transformers, rectifiers, circuit breakers, galley equipment, and electric cable. Its work included the preparation of technical requirements for this equipment in purchase specifications, Bureau of Ships (INT), Navy Department, Joint Army-Navy, and Federal specifications. It included action on correspondence and plans for this equipment, consultation with manufacturers and inspectors, and furnishing advice concerning its construction, installation, maintenance, and repair.

12. **Degaussing Subsection 660g.**—660g was responsible for the design of degaussing equipment and installations including technical advice for its maintenance and repair. This included compass-compensating coils and equipment to compensate for degaussing effects on compasses.

13. **Minesweeping Subsection 660m.**—660m was responsible for the design of generators, controllers, and cables used for magnetic minesweeping including technical matters involved in the installation and maintenance of this equipment.

14. **Electric Propulsion Subsection 660p.**—660p was responsible for electric ship propulsion motors, generators, and controls including their design and technical matters involved in their installation and maintenance.

15. **Storage Battery Subsection 660s.**—660s was responsible for all functions of the Section as regards storage batteries including those for submarines as well as all portable types. It also had technical responsibility for primary batteries (dry cells, etc.).

16. **Procurement Subsection 660t.**—660t was responsible for matters involved in the procurement, expediting, scheduling, and distribution of electrical equipment and material under the cognizance of the Section. It was responsible for all functions of the War Production Board's Controlled Material Plan involving the Electrical Section. 600t prepared manufacturers' schedules, progressed action as necessary to ensure required deliveries, allocated electrical material from Bureau-controlled

stocks, maintained records of status of deliveries and inventories, arranged redistribution, etc. In brief it was responsible for obtaining electrical equipment by the time required for either new construction or repair. It was responsible also for obtaining new or additional facilities as necessary to produce the electrical materials required.

17. **Section Personnel.**—In May 1945, the Electrical Section had a total of three hundred and forty-three persons. Eighteen of these were officers; one hundred and eighty-five were professional personnel employed under Civil Service; thirty-four were professional personnel employed under contract; seventy-seven were civilian clerical or stenographic personnel; and twenty-nine were enlisted WAVE personnel.

18. **Future Electrical Section Organization.**—While the organization described above proved itself highly satisfactory for the fulfillment of the responsibilities of the Section, certain factors made some revision appear desirable in 1945. The defeat of Germany and the marked progress of naval warfare against Japan had shifted prime emphasis in technical work from new developments and devices to the improvement of existing designs of equipment. Toward this end, the development subsection (660d) and the equipment design subsection (660e) were merged in July 1945 into one equipment subsection (660e). It was felt that this merger would allow closer liaison between new developments in equipment and material and the design and construction of electrical equipment for installation.

19. To permit closer coordination of the work being done by the degaussing subsection (660g) and the minesweeping subsection (660m), and to take advantage of an opportunity for simplification afforded by the decrease in the work load of each subsection, these two subsections were merged into a mine defense subsection (660m).

20. A realization that by concentrated effort, shipboard lighting conditions could be improved led to the establishment, in the specifications subsection (660j), of a lighting group. This group was given responsibility for studying shipboard lighting and developing improved lighting fixtures and installations and to coordinate with the ship subsections in their application.

21. While these organizational changes were made effective in July 1945, insufficient informamation is available at the date of this writing to permit any discussion of their merits. No further mention will therefore be made of this change, and all later discussions will concern the Section as it was organized prior to July 1945.

Part 3.—ADMINISTRATIVE PROBLEMS

1. Many problems were encountered in developing and administering an organization capable of meeting the responsibilities befalling the Electrical Section during World War II. Certain of these problems were solved satisfactorily; others were not. The following paragraphs discuss these problems, the solutions attempted, and the degree to which these solutions proved satisfactory.

RECRUITMENT OF PERSONNEL

2. The steadily increasing work load of the Electrical Section required corresponding increases in personnel. While the nature of the work of the Section required specialized engineering personnel, the national situation was such that this type of personnel was not readily available. Several methods were used for recruiting these personnel and are discussed herein.

3. **Civil Service.**—Although established as the normal channel for recruiting personnel for government employment, Civil Service failed to provide the Electrical Section with the number and type of personnel required. The demands of war necessitated that highly specialized professional personnel be obtained upon relatively short notice to meet particular conditions arising from developments in naval warfare. Moreover, these demands were often such that relatively large numbers of these personnel were needed almost immediately.

4. Experience showed that personnel available through Civil Service channels almost inevitably failed to possess the special qualifications needed for particularly urgent demands. Furthermore, it became evident repeatedly that a large percentage of personnel seeking employment through Civil Service were those who were incapable of retaining positions in private industry and were consequently unsuited for key work in the Bureau of Ships. Another weakness of this method of recruiting personnel, the relatively long period of time required, often made this method impracticable.

5. A limited number of qualified professional personnel were obtained through Civil Service. A majority of the stenographic and clerical personnel were so obtained. Civil Service channels were utilized to the maximum possible degree and supplemented by other methods described herein.

6. **Private Industry.**—The source from which the majority of the Section's professional personnel were obtained was private industry. Only in private industrial firms could there be found the highly specialized professional personnel needed. Arrangements were consequently made with these firms to "borrow" necessary types and numbers of men for employment in the Electrical Section until work-load conditions made it possible to release these men to their former positions.

7. It must be realized that industrial firms were not eager to part with such personnel particularly during this period when manufacturing schedules were greatly accelerated and when professional men were difficult to obtain. Industrial firms were shown, however, that it was to their advantage as well as to that of the Navy to have highly qualified personnel in the Electrical Section dealing with engineering matters that would affect manufacturers' designs and production. Moreover, it was shown that these personnel could be given positions in the Electrical Section of greater and broader responsibilities than was generally possible in their respective commercial organizations. The value of this training to the industrial firms was shown to be significant in their post-war utilization of these personnel. These factors made it possible to "borrow" many professional personnel from private industry for employment in the Electrical Section.

8. Most personnel so obtained from industry were placed in positions established by Civil Service, and were placed on the government payroll. Salaries given were approximately equal to those received by these personnal in their respective companies. Industrial firms in most cases granted these men leaves-of-absence for the duration of the national emergency.

9. Certain personnel, particularly a few top-notch ones needed in the organization but whose salaries were difficult to pay under existing Civil Service regulations, were obtained by means of contracts with the individual firms. This method was discouraged administratively later in the war because of the feeling that too close a liaison might exist between the employee and his company. A few men however were retained under contract.

10. A distinct disadvantage of this latter method was that contracts could be made for only one year's time. They thus required annual renewal and were subject to termination by the contract-

ing firm. Continuous service of Section personnel therefore was not as definite by this means as it was under Civil Service appointments. The chief value of the method of employing personnel under contract was that it enabled the Section to obtain a few necessary key men otherwise difficult or impossible to obtain.

11. **Naval Personnel.**—The Electrical Section, as indicated in previous descriptions of its organization, utilized naval officers in administrative positions. These officers, limited in number, provided the military liaison necessary in the organization of such a section. Civilian personnel, however, by far constituted the majority of Section personnel. Other sections of the Bureau of Ships and other Bureaus utilized naval personnel throughout, or for the greater part, of their organizations. This was purposely not done by the Electrical Section because of its foreseen drawbacks.

12. The use of naval personnel throughout the Section would have seriously hampered the efficient administering of the Section. Naval personnel under existing naval policies were subject to periodic rotation. Technical personnel within the Section would have thus been removed at periodic intervals and replaced by others. No permanent organization based upon each individual's background and experience would have been possible. Too, each transfer would have represented the loss of considerable "know how" to the Section.

13. A further disadvantage of utilizing naval personnel in engineering positions would have been that naval rank, based on an individual's qualifications as an officer, was not necessarily indicative of his technical qualifications. Desirable adjustments in the organization to utilize proven technical abilities of individuals thus would have been hampered or prevented by considerations of naval rank.

14. The merits of the type of organization used by the Section, consisting mostly of civilians but under the administration of officers, were amply proven during World War II. A serious disadvantage of this personnel system, however, is becoming apparent at the date of this writing. Civilian professional personnel under thirty years of age, hitherto deferred from military service by virtue of their essential services to the Navy, appear likely under national administrative policies to be "drafted" for military service. Prosecution of such a policy would to some extent nullify the advantages accrued under previous Section administrative policies.

15. **Qualifications of Personnel.**—It was felt that the responsibilities of professional positions in the Electrical Section necessitated the employment of the highest practicable grade of personnel. Concurrent demands of the armed forces and industry, however, made it extremely difficult to obtain professional personnel having a wealth of practical experience. A solution found practicable and often desirable was the employment of young engineers with good scholastic backgrounds and with some engineering experience in private industry, usually one to three years. Under the guidance of a few engineers of more experience, these young engineers were rapidly trained for positions of considerable responsibility. The somewhat specialized work of the Section enabled these young engineers to soon become as valuable as engineers of long experience.

16. National Selective Service laws required that all but the most essential men serve in the armed forces. Under these laws, it was impossible to retain any subprofessional men of military age. Similarly, it became increasingly difficult and eventually impossible to retain professional men employed directly from college. It was necessary therefore to arrange the organization with female clerical personnel working under the close supervision of engineers to handle all subprofessional work. It should also be mentioned herein that an attempt to utilize enlisted male personnel for clerical work proved unsuccessful when naval policies dictated that all such personnel be utilized for active duty. These positions however were rapidly filled as enlisted WAVE personnel became available.

17. The organization of the Electrical Section during the war therefore comprised a nucleus of experienced Bureau personnel, a limited number of naval officers in administrative positions, a few engineers and administrators of long industrial experience and proven ability, while the remainder of the professional personnel were young engineers. Female clerical and stenographic personnel (civilian and WAVE) comprised the subprofessional and stenographic personnel.

DEVELOPMENT OF ORGANIZATION

18. As reviewed in Part I, the responsibilities and work load of the Section increased greatly during the period 1938 to 1945. During the earlier part of this period, there was a tendency to add new responsibilities to existing subsections without changing the Section organization. This proved to be unsatisfactory. The exact responsi-

bilities of individual subsections became indefinite. The multitude of factors associated with each type of work resulted in excessive overlapping of functions with consequent difficulties in prosecuting any particular program.

19. **Delegation of Responsibilities.**—The most efficient type of organization was found to be one incorporating groups or subsections to which were delegated responsibilities for definite phases of the Section's work. It was for this reason that the development, procurement, specification, and other subsections were formed. Even for supplementary responsibilities of the Section, viz., maintaining manuals up-to-date, preparing articles for Bureau publications, etc., it was found most satisfactory to clearly delegate each responsibility to a particular group or subsection.

20. **Organizational Adjustments.**—The delegation of such undivided responsibility, particularly under the varying conditions arising during World War II, made necessary a flexible Electrical Section organization. Thus, groups or subsections such as the degaussing, stray-fields, minesweeping, and many other special groups were established to handle particular problems. As these problems were solved or minimized, these groups were reduced in size or were disestablished. This flexibility in the organizational structure proved highly satisfactory and desirable.

21. **Mail Control System.**—Part I describes the development and operation of the Electrical Section mail control system and mentions that it appreciably aided the efficient administering of the Section. Prior to the institution of such a system, considerable difficulty was experienced in ensuring that urgent matters were given prompt attention. Individuals failed to recognize the importance of the many minor details associated with each important work. Only with an overall picture of the work of the Section did these many details assume their proper relative importance.

22. By the mail control system, a definite time was allowed for answering each piece of correspondence. Any correspondence unanswered at the end of this time was brought to the attention of the Head or Assistant Head of the Section. With an overall picture of the work of the Section, he could exercise good judgment as to the relative importance of answering each of these "overdues".

23. One weakness did exist in the mail control system. Vigorous administrative insistence upon promptness sometimes resulted in a sacrifice in thoroughness and correctness. This sacrifice however was of a minor nature and was far outshadowed by the value of the mail control system.

24. **Maintenance of Records.**—As the work load of the Section increased rapidly during the early stages of the war, prime emphasis was placed upon solving the immediate problems on hand. Little attention was given to interpreting and recording these actions for future record. As a result, work done by one group was frequently duplicated at a later date by another group. Lack of complete records often resulted in some confusion and duplication of efforts when civilian personnel were transferred or officer personnel rotated. To improve this situation various systems as described herein were established and utilized.

25. A specifications subsection was established (see Part I) to translate into the General Specifications all methods and procedures developed for the design and installation of shipboard electrical systems. This subsection maintained a file of all Bureau pilot letters pertaining to shipboard electrical systems. In addition to constituting a convenient reference for Section personnel, this file represented a record of all major decisions affecting electrical systems and was used in keeping specifications up-to-date, revising chapters of the Bureau of Ships Manual, etc.

26. Another responsibility assigned to this subsection was the so-called "trip-report follow-up system". Reports submitted by all Section personnel of official trips were routed to the specifications subsection. Here, a record was made of every item noted for which remedial action should be taken by the Section. Close follow-up for these items was maintained to ensure that proper action was subsequently taken.

27. A system applying to all subsections was the project system. Each problem assigned to, or undertaken by a subsection was recorded and assigned a project number. These records were available to the respective subsection heads and to the Head and Assistant Head of the Section. In this way records were available, for administrative purposes, of all major projects being undertaken by the Section. This system eliminated for major projects, as the mail control system eliminated for correspondence, unwarranted delays caused by procrastination of individuals.

28. Information obtained from battle-damage, machinery-derangement, and other similar reports was maintained by individual subsections. For instance, any information concerning damage from mechanical shock was recorded by the develop-

ment subsection; information concerning equipment operation, by the equipment design subsection, etc. Responsibility for recording and utilizing such information was left to the individual subsections. Systems were attempted wherein such information was centrally recorded and a follow-up system utilized. These systems did not prove satisfactory however and were abandoned.

29. The value of these and other methods of maintaining records was repeatedly demonstrated. They aided materially in the formation of definite technical policies and thus contributed greatly to coordinating Section activities. Moreover, they contributed immeasurably to saving time and avoiding duplication of efforts.

30. **Staff Functions.**—The increasing size of the Electrical Section made necessary many duties of a general administrative nature. These duties were varied comprising such matters as establishing overall Section engineering policies, coordinating intra-Section functions, preparing or coordinating the preparation of general Section publications, arranging personnel employment, promotions, and transfers, and many other general Section activities. As the Section administrative personnel originally consisted of only the Head of the Section and his assistant, it was necessary to assign all such work that involved appreciable time and study to some individual or group within a subsection.

31. It was found much more satisfactory to establish a staff group to perform these duties. This staff group, by 1945, comprised the Head Engineer and his assistant, an engineer assistant to the Assistant Head of the Section, a personnel officer, and clerical assistants.

32. The value of a staff group was evinced by the increased efficiency with which general duties were performed. Full time could be devoted by this staff to problems involving several or all of the subsections and not properly assignable to any individual one. The staff aided appreciably in coordinating policies and activities of the Section.

EDUCATION OF SECTION PERSONNEL

33. The majority of the personnel comprising the Electrical Section during World War II had little or no experience in naval or marine work prior to the war. It was necessary therefore to institute methods and programs for educating professional personnel in naval methods and practices in order that maximum utility could be derived from their services.

34. No special methods were found to be necessary for educating an individual in the engineering associated with his particular position. Placed under the supervision of an experienced engineer, the individual rapidly progressed to assume definite responsibilities contributing to the functions of the Section. A need was evidenced, however, for acquainting all personnel with a broad picture of the work and policies of the Section and the Bureau.

35. One program, inaugurated early in the war and continued throughout, was arranging for Section engineers to make periodic trips to examine naval vessels at Navy Yards or shipyards. In this way, engineers could study electrical installations aboard ship and obtain a better understanding of fundamental principles governing ship installations.

36. Another practice continued for a limited time and found highly satisfactory was that of conducting a series of weekly lectures for all Section personnel. Technical subjects were chosen and discussed by outstanding engineers from private industrial firms and shipyards. From these lectures, Section personnel became familiar with new developments in materials and equipment utilized in naval vessels.

37. Despite these efforts, it became apparent that some better means was necessary to inform Section personnel of general programs and accomplishments of the Section. Toward this end, an unofficial publication, "Electrical Section Notes", was instituted in 1944. Prepared at irregular intervals, this publication informally described various programs, developments, policies, etc. Its value had not been thoroughly proved however at the date of this writing. Education of Section personnel still remained a problem requiring more regard and a better solution.

DISSEMINATION OF INFORMATION

38. Disseminating sufficient and proper technical information to forces afloat, naval shore activities, and private shipbuilders and manufacturers constituted one of the major problems of the Electrical Section during World War II. Some of the problems and some of the efforts of the Section in this regard are discussed in the following paragraphs.

39. **Problems Associated with Disseminating Information.**—To disseminate effectively information to all activities engaged in naval research, development, design, construction, operation, and maintenance, it was necessary to utilize a wide

range of means. Many types of specifications, manuals, plans, publications, etc. reflected the technical requirements of the Navy and had to be maintained current with technical developments and improvements. Some of the mediums available to the Section in 1941 for disseminating information were:

General Specifications
Special Specifications
Conversion Specifications
Contract Plans
Purchase Specifications
BuShips Manual
Allowance Lists
Circular Letters
BuShips Bulletin of Information
BuShips Shop Notes
BuShips Ad Interim Specifications
Navy Department Specifications
Joint Army-Navy Specifications
Federal Specifications
BuShips Standard Plans
Various Publications
Training Films
Instruction Books
Conferences
Correspondence

40. One difficulty associated with disseminating information concerning technical developments and improvements was that many of these mediums had been allowed to become obsolete. For instance, little or no effort had been devoted, in years prior to the war, to keeping up-to-date the instructions contained in the Bureau of Ships Manual. Many specifications similarly were out-dated by years of technical development. As a consequence, much work was necessary during the war to bring these publications up-to-date before current developments could be included.

41. A further difficulty encountered in disseminating information was that none of the existing means was suitable for circulating general background engineering information to forces afloat and naval shore establishments. Plans and specifications by their nature were not suitable; the Bureau of Ships Manual was of a directive nature requiring the signature of the Secretary of the Navy; the Bureau of Ships Bulletin of Information was suitable in tone but was a periodical and not suitable for permanent reference. Similarly, other means were not satisfactory.

42. Until better methods were established, background engineering information by necessity was disseminated by correspondence. This did not prove satisfactory as the quantity of correspondence so necessary served to nullify its own value. Letters often failed to reach the personnel most directly concerned with their technical content. Moreover, periodic rotation of naval personnel resulted in newly assigned personnel being unacquainted with technical information disseminated by correspondence prior to their assignment.

43. **Methods Used for Disseminating Information.**—Every effort was made to use all available means for disseminating technical information. Revisions were made continually to all specifications to embody developments in materials, equipment, and systems. Plans were similarly revised to embrace all developments. The Bureau of Ships Manual was revised to include chapters on specific types of shipboard electrical equipment, and these chapters prepared so as to incorporate the latest available information and instructions. Articles were published in the Bureau of Ships Bulletin of Information to inform naval personnel of technical changes and developments of widespread interest. Correspondence, circular letters, instruction books, special publications, etc. were similarly utilized.

44. To enable the Electrical Section to circulate general background engineering information to design and construction activities, a general engineering reference manual was conceived. Termed the "Reference Book for Ship's Service Electric Power Plants and Electric Propulsion Systems," this manual was contrived to include basic engineering discussions and principles governing the design and construction of ships' electrical systems. Information, not properly capable of being interpreted as specification requirements, yet highly important and necessary for design and construction work, was discussed in detail herein. The probable value of this reference book was apparent even before its preparation. The time required for its preparation, however, it being a detailed and lengthy work, prevented its early distribution. As its publication had not been completed by June 1945 it was not available during the war period.

45. Another publication, initiated by the Section to more widely disseminate technical information, was the "Compilation of Letters for Improvement of Power and Lighting Installations on Naval Vessels." This publication was designed to provide every naval vessel, in convenient reference form, the important Bureau letters concerning improvements in shipboard electrical equipment and systems, many of which might have been distributed prior to the commissioning of the vessel. Revised at six-month intervals, this compilation served a valuable purpose in keeping ships' engineering personnel up-to-date.

46. To aid in the solution of the many problems associated with the design and installation of shipboard electrical systems, periodic conferences were arranged with representatives of Navy Yards, Supervisors of Shipbuilding, shipbuilders, and Inspectors of Naval Material. Papers were prepared and talks were given by Section engineers covering background engineering of specific shipboard electrical matters. Problems of design and installation were discussed between representatives and with Section personnel. These conferences proved highly successful in giving all personnel a clearer understanding of technical policies, aims, problems, etc. and noticeably improved cooperation between these field activities and the Bureau.

47. Other means of disseminating information included movie films for training shipboard electrical personnel, miscellaneous training booklets for the same purpose, and technical instruction books for particular types of electrical equipment.

48. Despite the special efforts made to disseminate information, the results could not be considered outstanding. During the latter part of the war, shipboard and field personnel were being kept up-to-date far better than during the early part. Nevertheless more thought and better methods were still desirable at the time of this writing for disseminating technical information to naval field and fleet personnel.

INDUSTRY COMMITTEES

49. Industry committees, conceived and formed by the Electrical Section during the war, immeasurably aided technical developments and production. A committee was formed for each major type of shipboard electrical equipment; viz., switchboards, cable, motors, generators, meters, etc., and was comprised of specialists for the particular type of equipment from the major suppliers of that equipment.

50. To these committees were given technical problems concerning the particular type of equipment, objectives desired or required for military usage, and desired production schedules. The committees studied design and manufacturing improvements, specification requirements, the use of new materials and methods, etc. By the cooperative effort of representatives from the major suppliers of the equipment, major improvements could be made that were practicable for all manufacturers. The advance planning possible with this method resulted in a minimum slow-down of production during transitory periods. Industry committees helped to obtain the maximum cooperation of industry during the war program.

SUMMARY

51. This Section of the Electrical Section History has reviewed the organization and administration of the Electrical Section during World War II. Certain problems and certain solutions attempted have been reviewed. While necessarily incomplete, the factors cited illustrate the growth and consequent problems of the Section during this period. Further details of any particular subject mentioned can be found in Bureau records and files.

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