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SCIENTIFIC PROGRAM OF THE NAVAL RESEARCH LABORATORY

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FOREWORD

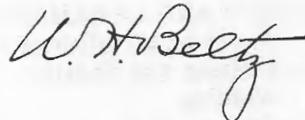
The mission of the Naval Research Laboratory is to support the Chief of Naval Research in his effort to preserve national security by initiating, planning and conducting in the physical sciences, applied research and development to meet the immediate needs for equipment and materials to increase the combat effectiveness of the Navy, and fundamental research and experimentation in anticipation of future requirements.

In an organization of the size and complexity of the Naval Research Laboratory, some means of classification is necessary to bring its varied activities together in an orderly and systematic form for purposes of planning, reporting, and over-all management. The NRL Scientific Program serves this function.

The pages which follow present the current approved program of research and development of the Naval Research Laboratory. This document describes the areas of technology—both fundamental and applied—in which the Laboratory is now working or in which it believes it should work. There is shown a breakdown of the scientific effort into the individual programs specifically identified and systematically catalogued. The sum of the individual programs makes up the Laboratory program.

The program is designed to make the best use of the resources of the Laboratory in research and development to meet the more pressing needs of the material bureaus and operational requirements as defined by the Chief of Naval Operations.

All scientific activities at the Laboratory are classified into twelve fields. Each of these fields is further subdivided into a number of discrete programs designated by a letter indicating the field and a number indicating the sequence of the program in that field. This program is a revision of that dated July 1, 1953 (NRL Report 4185).



W. H. BELTZ, CAPT., USN
Director

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APPLICATIONS RESEARCH

Y01 - DATA PROCESSING

NR 591

The purposes of this program are to study the factors involved and to develop techniques which will increase the effectiveness of combined electronic systems. In particular, attention is concentrated on those systems leading to the rapid and accurate exercise of command. The latter requires techniques and devices for the processing and display of information provided by systems associated with detection, identification, tracking, designation of targets, and control of friendly aircraft.

Electronic processes and techniques are being developed and evaluated for performance of these functions.

Y02 - ENGINEERING PSYCHOLOGY

NR 592

The aim of this program is the development of more easily and effectively operated electronic and mechanical equipment. Studies of human behavior are conducted and are aimed at obtaining information which will guide engineers in the design of the mechanical components of man-machine systems (such as radars, fire-control systems, aircraft, etc.) so that the machine operation requirements match human capabilities.

The ability of the human to perform tasks corresponding to different mathematical processes is being tested as an aid toward developing an operator-oriented servo approach which will be more useful to design engineers than those employed today. In other studies the human is viewed as a communication channel which mediates the transmission of information from the display to the control. In still others, research is being conducted on the capabilities of the human eye, ear, and other sense organs with particular attention to those aspects of sensation and perception related to the operation of man-machine systems.

Finally, development work is proceeding along the following lines: (1) the human engineering aspects of the design of specific gun sights, aircraft and ship control systems, and other military equipment, and (2) the design, development, and initial testing of displays, controls, and electronic control circuits especially adapted to human response characteristics and intended to improve man-machine system performance by a substantial amount.

Y03 - SYSTEMS ANALYSIS

NR 593

It is the purpose of this program to investigate both theoretically and experimentally the operation of naval information-handling systems.

Activity is proceeding along the following general lines: (1) preliminary quantitative evaluation of systems, using mock-ups and simulated inputs, (2) experimental determination of the quantitative parameters of systems, such as data-handling ability, time delays,

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accuracy, etc., (3) theoretical analysis of systems using mathematical and symbolic models, (4) study of the factors entering into decision making in naval systems, (5) operations research on the external factors affecting the ability of a system to accomplish its mission, and (6) operations research studies of new devices and weapons to determine their optimum integration into naval systems.

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ASTRONOMY AND ASTROPHYSICS

A01 - ASTRONOMY

NR 611

The program in astronomy largely involves radio astronomy, with emphasis on studies concerning decimeter, centimeter, and millimeter wave emission from celestial sources. Studies are made on the emission from the sun, for example, to yield the electron density and other properties of the solar body and its parts, and are correlated with observations on terrestrial magnetic storms and cosmic-ray phenomena. Similar measurements on emission from the moon are made to garner information on the moon's surface. For basic understanding of our galaxy and others, the continuous radio emission is monitored from visible celestial objects such as stars and nebulae, and from invisible "radio stars." Important techniques which are used for mapping our own galaxy, the Milky Way, include line spectral studies of the emission from interstellar gases such as hydrogen. Other activities in this program include the application of radio astronomy to navigation and to meteorology, and the development of special radio techniques involving ultrasensitive detectors.

The second phase of this program includes measurements of the spectral intensity of solar radiation in the optical, in the x-ray, and in the extreme ultraviolet regions, by the use of spectrographs installed in rockets. The results lead to a better understanding of the physical processes occurring in the sun.

A02 - ATMOSPHERE

NR 612

Studies of the upper atmosphere using rockets, balloons, and aircraft include measurements of physical parameters such as pressure, temperature, and wind velocities; the effect of solar radiations; the atmospheric composition; natural and induced radioactivity; cosmic rays; and the development of high-altitude photographic techniques. Other phenomena—such as the earth's magnetic field at high altitudes, the auroras, and the incidence of meteors—and their effects on the upper atmosphere are observed. Atmospheric electric phenomena such as the electric field about the earth, the conductivity of the atmosphere, the air-to-earth current, and the type, size, and charge of atmospheric ions and condensation nuclei are important parts of this program; all these are observed at various altitudes and from the earth at widely scattered locations.

Investigations are made of the optical properties of the atmosphere, including the attenuation of ultraviolet, visible, and infrared radiation under various atmospheric conditions, the infrared radiation gradients of the sky, the brightness of the sky, and the selective spectral emission of light by the sky.

Besides improving our basic knowledge of the atmosphere, the results obtained apply directly to many military problems such as those of missile guidance, aerial navigation and communications, landing of aircraft, the visibility of aircraft at high altitudes, and the effects of atomic weapons.

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A03 - METEOROLOGY

NR 613

Research and development are conducted on new and improved methods and instruments for measuring and interpreting phenomena of the lower atmosphere with the objective of reducing meteorological hazards and increasing utilization of meteorological conditions in military operations.

The program includes work on new methods for measuring, telemetering, and recording meteorological parameters (temperature, humidity, pressure, wind velocity, etc.) as a function of time and position of sensors placed on the ground, in aircraft, aboard ship, and on balloons. Studies are made to determine the meteorological significance of parameters not now generally used in meteorological applications by the Department of Defense.

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CHEMISTRY

C01 - FUELS

NR 601

Both current and potential fuels are being investigated for use in rocket, aircraft, and marine propulsion engines. Of immediate concern are the following topics:

- (1) Stability and compatibility of distillate fuels in long-term storage and at temperatures which occur in heat exchangers, with emphasis on development of methods for predicting stability,
- (2) Excessive deposition of carbon in jet engines,
- (3) Behavior of corrosion inhibitors in aviation fuels and contamination of such fuels,
- (4) Fundamental aspects of ignition and combustion of petroleum products with emphasis on pure hydrocarbons, the role played by "cool flames" on ignition, and the effects of high pressures as applied to hydraulic systems,
- (5) Liquid fuels for rockets with emphasis on studying self-igniting and ignition delay properties.

High-energy fuels such as boron hydrides, borohydrides and organo-boron compounds are under investigation to determine methods of preparation, physical and chemical properties, and storage characteristics. Fundamental studies are conducted on slow-burning solid monofuels, and the use of such fuels to furnish specific charges for existing devices (pressurizing containers or driving small turbines) is under investigation.

C02 - SURFACE CHEMISTRY AND LUBRICANTS

NR 602

Exploratory research is being carried on concerning the physical, colloidal, and chemical properties of liquid, gelled, and solid lubricants; emphasis is on synthetic lubricants because of the inability of petroleum products to satisfy some military requirements. Basic research is being conducted on the relation of physical and chemical properties of liquids to molecular structure; on the mechanism of liquid-phase oxidation and mode of action of antioxidants; on friction and wear properties of liquids and solids; and on rheological, physical, and chemical properties of soap- and non-soap-gelled greases. Studies of adsorption-desorption equilibria at solid/liquid, solid/air, liquid/liquid, and liquid/air interfaces are being pursued. Mechanisms involved in desensitization of modern high explosives are also under investigation. Exploratory research is in progress on (1) effects of chemical constitution on micellar behavior and colloidal properties of oil-soluble soaps, (2) the solubilizing power of such soaps, and (3) the mechanisms by which these soaps function as rust inhibitors, oiliness additives, detergents, and gelling agents.

C03 - PROTECTIVE COATINGS

NR 603

Investigations are being made of the chemical and physical phenomena associated with deterioration of material by exposure as well as by action of naturally occurring

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organisms. Paint systems are under development to improve the deterioration-resistant properties of coated surfaces. Methods of preparing metal surfaces prior to receiving protective coatings are being studied. The newer resins and polymers are being evaluated for possible use in organic coatings for such critical surfaces as flying-boat hulls and acoustical surfaces of sonar gear. The coating of both concrete and metal bulk fuel storage tanks is under study. The chemical characterization of creosote, now used extensively for piling, is being determined to assist in developing better repellents for marine borers. The relationship of biological activity to chemical composition is being studied with a view toward development of more potent fungicides. An exposure station is maintained in the Canal Zone to study deterioration of materials and equipment under natural tropical environment.

C04 - HIGH POLYMERS

NR 604

The program in high polymers concerns both chemical studies and application of polymeric materials. New polymers are synthesized and examined with the objective of producing improved or more useful materials. These include plasticizers, organophosphorus compounds and other components or process chemicals used in or for rubber and plastics. The design, compounding, and production of a limited number of special items such as unusual seals and electromagnetic wave absorbers are underway.

C05 - PHYSICAL AND ELECTROCHEMISTRY

NR 605

Physical and chemical properties of liquid-metal heat-transfer media are under study to collect data required for design and operation of liquid-metal systems. Thermal conductivity, specific heat, viscosity, density, and chemical characteristics have been determined on sodium, potassium, and their alloys, and are scheduled for determination on other metals and on sodium hydroxide.

The field of electrochemistry is concerned largely with primary and secondary batteries, with the emphasis on the submarine storage battery. Basic research is conducted on the mechanisms involved in electrode reactions, on the thermodynamics of the systems, and on the physical and chemical conditions which control the kinetics of the reactions. This basic information is needed to effect specific improvements in the submarine battery, such as longer life, better utilization of the active material, faster methods of charging, and reduced self-discharge and hydrogen evolution. Consultation and liaison are carried on with the Navy bureaus on operational aspects of the submarine battery, including ventilation, control of undesired gases, evaluation of new types of batteries, and participation of personnel in shipboard trials.

C06 - RADIOCHEMISTRY

NR 606

Radioactive isotopes are being used as tracer elements to follow the course of chemical and physical processes, with emphasis at present on liquid metals for heat-transfer media, and the solubility of iron in water at high temperature and pressure. The solubility of oxygen and iron in sodium and the influence of sodium oxide and hydroxide on the solubility of stainless steel components are being studied. The radioactive transport phenomenon is also being investigated in stainless steels.

Analytical procedures have been developed for the sequence analysis of complex mixtures containing both radioactive and inactive isotopes. These techniques are being

applied to the problems mentioned above and to the radioactivity of the atmosphere.
(See also A02.)

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C07 - MOLECULAR STRUCTURE

The structures of rubber, plastics, hydrocarbons, organophosphorus and organo-fluorine compounds are being determined. New materials are identified and old ones classified. The techniques used include absorption, infrared, ultraviolet, Raman, and mass spectroscopy.

Details of geometric arrangements of atoms in crystals and motions of atoms in the vapor state are investigated in order to understand the nature of the forces between atoms and to study the electron distributions in bonded atoms as related to chemical valence theory. A new algebraic and statistical treatment of the crystal structure problem has been successfully tested on the naphthalene structure and offers hope for the future solution of highly complex structures such as proteins and antibiotics.

C08 - PERSONNEL PROTECTION

NR 608

Defenses against CW and BW agents are being studied, including measures to insure atmospheres safe for breathing. Current research is confined to defensive aspects and includes: (1) mechanism of aerosol filtration, (2) carbon-oxygen surface complexes, (3) mechanism of electrostatic precipitation, (4) automatic and instantaneous detection of aerosols, (5) protective clothing, and (6) decontamination studies. Current developments include: (1) a new gas mask (Mark V) now being procured for service trials, (2) improved electrostatic precipitators for aerosol removal, and (3) clothing for protection against liquid agents.

The study of safe breathing atmospheres in closed spaces such as submerged submarines involves development of (1) analytical instruments for continuously monitoring the air and (2) methods and chemicals for its revivification. Studies are underway to improve the efficiency of the Navy Oxygen Rebreather Apparatus by development of new oxides and by changes in design.

The chemistry of materials and the development of methods for fire extinguishment in naval ships, aircraft, and shore bases are being investigated. Primary emphasis is on the hazards of hydrocarbon fuels and the use of air-water foams on fires of these and similar fuels. Research on vapor-phase ignition and its prevention by inert vapors or gases is also being conducted. The program includes control of damage from nuclear and guided-missile power plants, and emphasis will vary as new energy sources are adopted.

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ELECTRICITY

E01 - ELECTRIC POWER SYSTEMS

NR 621

The investigations embrace the requirements for and the application of electric power systems to military craft, with emphasis on a study of systems variables which affect design. Techniques of system protection to provide safety and reliability to the electrical system of the vehicles are to be evolved.

Studies have been made principally on the electric power systems of submarines and aircraft. They include work dealing with the transient characteristics of both ac and dc electrical systems, with circuit protection, and with the general problem of system coordination. Under the latter problem the factors effecting good system performance (regulation, stability, etc.) are investigated during both transient and steady-state periods of operation.

E02 - ELECTRIC POWER EQUIPMENT

NR 622

The study includes factors affecting the performance and design of major electrical components such as rotating machinery, control equipment, transformers, switch gear, and cable concerned with the generation, distribution, and utilization of electric power on military craft.

Present research deals with (1) the derating of blast-cooled electrical equipment and with the rating of self-ventilating equipment, (2) the rating of cables singly or in bundles, (3) the evaluation of electric generators and regulators (this has led to the production of a manual to standardize the testing of ac generators and regulators used in naval aircraft), and (4) a study of cooling of electrical equipment in aircraft.

E03 - ELECTRIC INSTRUMENTATION

NR 623

The investigations are concerned with electric instrumentation and equipment for military craft to cover special purposes such as measurement and computation, control, protection, alarm, interior communication, electrical heating, electromagnetic braking, and electromechanical actuation. Under this program special circuitry is devised for the exploitation of newly discovered or improved characteristics of materials, both where the material makes possible development of new components and where it exhibits useful characteristics which require special instrumentation. The program includes theoretical analyses of special components such as magnetic or dielectric amplifiers, new developments in circuitry associated with such physical phenomena as paramagnetic resonance, and applications of other solid-state phenomena. The development and application of computers and computer circuitry represent a continuing part of this program.

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MATHEMATICS

B01 - APPLIED MATHEMATICS

NR 651

This program is devoted to the development of mathematical methods for extending the applicability of existing physical theories and the creation of new ones. Emphasis is placed on the fields of continuum mechanics, dynamics of complex structures, electro-dynamics, statistical mechanics, and other statistical studies.

Completed studies have contributed to the theories of plasticity, fluid dynamics, dislocations, dynamics of finite systems, structural vibrations, and ultrasonic absorption. Present work primarily concerns general stress relations for continuous media, plasticity, the mechanics of finite systems, theories of armoring, and dislocations.

B02 - COMPUTERS

NR 652

This program is designed to supplement and accelerate the scientific researches of the Laboratory by providing modern computing facilities to be applied to those problems which either cannot be solved by known analytical methods or demand machine methods because of the bulk of calculations involved. These needs are met by two devices, a general-purpose electronic differential analyzer and a high-speed digital computer. The program includes as integral parts studies on more effective methods of employing these devices, on the accuracy and stability of solutions, and the development of new computing techniques.

The Laboratory's high-speed digital computer, the NAREC, has been in part-time operation for nearly a year and its further development is being emphasized. The capacity and effectiveness of the differential analyzer is being increased by the addition of new components and by the addition of an all-electronic multiplier, the development of which is nearing completion.

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MECHANICS

F01 - STRENGTH OF SOLIDS

NR 631

Experimentally this program emphasizes study of the progressive development of initially localized plastic flowing and fracturing over a wide range of straining speeds. Suitable techniques are developed for plastic fibers, aircraft glazing, ship plate, armor, and other materials of naval interest.

The physical origins of penetration resistance of armor alloys of iron, aluminum, titanium, and magnesium-lithium are being identified. Instability criteria are being developed and applied to rate the toughness of aircraft glazing and structural materials. Studies of yield strength under dynamic loading, as by shock or ballistic impact, are directed toward disclosure of basic mechanisms and relative evaluation of various metals. Observations are made under cyclic stressing from frequencies of ten million in the elastic range to less than one per second in the plastic range.

A program is in progress to consolidate and publish the results of a twelve-year study of the mechanics of fracturing. Installation of a three million pound capacity loading device of unusual construction is expected to be completed in September 1954. This will permit investigations of strength under single cycle or repeated loadings in a versatile way using test pieces of substantial size.

F02 - STRUCTURES

NR 632

These investigations provide basic engineering for naval devices and structures which are beyond the range of existing theory. Speed and economy are sought by utilization of empirical methods and reduced-scale experiments.

The data obtained in recent underwater explosion tests of the submarine SS428 and models of nuclear-powered submarines are being used in developing a system for designing shock-resistant submarine equipment. The proper motion to simulate shock in submarines is also being defined for application to a new heavy-weight shock machine. Participation in past and future large scale field experiments is concerned chiefly with underwater pressures and mechanical shock motions.

F03 - SHOCK AND VIBRATION

NR 633

Shock and vibration incident to naval service of equipment on ships, planes, and missiles are recorded, analyzed, and simulated. Methods are developed for obtaining designs of adequate strength and for the development of suitable protective mounts.

Shock and vibration data taken of the submarine SS428 and Viking rockets are being analyzed and correlated with similar data of other service conditions in order to develop design guides. Supporting investigations determine the complex stress-strain characteristics of real materials, and have application to such basic elements as wire in tension, shock-loaded bolts and cantilevers, and transversely loaded shafting. Ultrasonic pulse

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techniques and resonance methods are being used to study the changes in internal friction and elastic constant caused by plastic flow, fatigue, and other factors. Shipboard equipment items in the prototype stage are evaluated; weaknesses are identified and remedies applied or recommended.

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This program utilizes laboratory penetration ballistics techniques with the object of extending their usefulness and exploring unknown characteristics of armor penetration and gunfire damage.

A major problem concerns the development of new knowledge of fundamental mechanisms of aircraft damage and, at the same time, appropriate techniques of quantitative analysis applicable to aircraft damage due to missile impact. The considerations being explored are organized under the headings: (1) component-system relations and analyses of vulnerability reduction, (2) measurement and analysis of illustrative models, (3) applicable game theory considerations, (4) penetration dynamics, (5) flash and pressure associated with high-velocity impacts.

F05 - HEAT POWER**NR 435**

Heat power devices are investigated, with particular emphasis on the pulse-jet engine. Experiments are directed at a better understanding of the advantages and disadvantages of this type of engine and at improvement of characteristics such as fuel economy, service life, and thrust-drag ratio.

A new pulse-jet design capable of static operation without an auxiliary air supply and having no moving parts is under development. Engine forms suitable for multiple operation and for ducting are being studied. Characteristics needed in helicopter propulsion and in direct lift are being improved. Exploratory investigation of small power units capable of unattended operation for long periods has been undertaken.

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METALLURGY AND CERAMICS

M01 - PHYSICAL METALLURGY

NR 641

Investigations of the effects of composition, processing, and heat treatment on the properties of metals and alloys are conducted with the aim of developing improved materials for naval use. Armor steels are being investigated with respect to transformations which occur on rapid cooling. The effects of melting practice on development of delayed fracture of high-strength steels used in aircraft structures are under investigation. Studies are also being made of the effects of microstructure on properties of structural steels. A comprehensive survey of refractory materials for holding molten titanium is essentially completed and investigations on the deoxidation of titanium are underway. Studies are being conducted on the basic mechanism of high-temperature creep and on the properties of various types of high-temperature alloys.

M02 - MELTING AND CASTING

NR 642

The objective of this program is to evolve new techniques and procedures required for the solution of casting problems of Navy interest. The major effort is directed to the problem of reliability of castings intended for critical military applications. The investigations include studies of soundness, pressure tightness, variations of physical properties, and castability of complex shapes. Methods and procedures have been established to ensure the elimination of shrinkage regions and hot cracks in steel castings. The practicability of eliminating porosity leading to gas leakage in optical and hydraulic castings has been demonstrated. Inexpensive equipment for vacuum degassing of melts has been developed and its use is being extended to various metals. The fracture resistance of new ductile grades of cast irons was evaluated to assist in establishing procurement specifications. The cause of brittle failures of 12% chromium stainless steel propellers was investigated and a modified alloy highly resistant to brittle fracture was developed.

M03 - WELDING

NR 643

This program is aimed at evolving fundamental information and developing new techniques and procedures required for the solution of welding problems.

The major effort is directed to the evaluation of factors which determine the performance of weldments for ship hull structures, particularly under conditions of explosion loading. Mild steels, armor, and stainless steel weldments are being investigated. It has been demonstrated that the notch ductility of the base steels controls the performance of mild steel weldments while the performance of welded armor steels is controlled by the properties of the weld zone. Tests have been developed to obtain better selection of steel for use at various possible service temperatures. Present studies concern the characteristics of new, lean-alloy armor steels intended as a replacement for the present armor steels. The weld cracking difficulties of stainless steels intended for use in ship propulsion engines are also being investigated.

M04 - CORROSION

NR 644

Basic studies of corrosion mechanisms are being conducted with the object of developing improved corrosion-resistant materials and protective systems for naval use.

This program includes:

- (1) Identification of significant galvanic couples in sea water and development of protective systems for minimizing their effects,
- (2) Study of electrical potentials about ship hulls and development of cathodic protection systems using impressed current and/or sacrificial anodes for both active and inactive ships,
- (3) Development of the theory of surface treatments and painting systems through study of film formation and passivation,
- (4) Investigation of high-temperature aqueous corrosion characteristics of plain carbon steels. This includes evaluation of inhibitors for control of corrosion rates under conditions involving water flow.

M05 - CERAMICS

NR 645

New ceramic materials with particular characteristics for specific applications are under development. Methods for better control of ceramic materials are being studied in order to improve their reliability; emphasis at present is on barium titanate for sonar transducers. This program includes the investigation of such factors as effect of impurities or additives, methods of forming ceramics, firing techniques, etc., for the purpose of developing new and improved ceramic fabrication processes.

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NUCLEAR AND ATOMIC PHYSICS

H01 - NUCLEAR CONSTITUENTS AND STRUCTURE

NR 661

Theoretical and experimental studies concerned with elementary particles, field theory, nuclear structure, and nuclear reactions are being pursued. In particular, these include investigations of the structure of elementary particles, the angular correlation of successive nuclear radiations, orbits of particles in a synchrotron, and elastic and inelastic scattering of fast neutrons. Low-energy interactions of heavy particles are being investigated with the aid of two 2-Mev Van de Graaffs, a 5-Mev Van de Graaff, and two Cockcroft-Walton accelerators. Neutron cross-section measurements are underway and production cross sections for gamma rays are measured at several primary neutron energies. Differential elastic cross sections for some elements at 14 Mev are compared with theoretical calculations.

Studies of high-energy cosmic-ray phenomena are performed using thick nuclear emulsion techniques, and investigations are made of the following: the charge and velocity spectra of the heavy primary nuclei; multiple production of mesons; heavier-than-pi mesons and hyperons; and trident phenomena in the soft component of cosmic rays at high altitudes. In collaboration with Brookhaven National Laboratory, the interactions with hydrogen of cosmotron-generated pions in the Bev range are studied.

Two beta-ray spectrographs with associated automatic counting equipment are used for basic studies of the radiations from radioactive nuclei to bring about a better knowledge of the structure of the nucleus. Precise measurements of beta- and gamma-ray energies are made on fission product radiations and on positron annihilation radiation. A stabilized and monitored 20-Mev betatron is used to determine the thresholds for gamma-induced activities of various kinds, energy-level measurements from breaks in activation curves, and extremely short-lived activities in lead.

Plans are underway for a program to be conducted with the NRL reactor upon its completion.

H02 - NUCLEAR INSTRUMENTATION AND TECHNOLOGY

NR 662

Methods of measuring nuclear radiation are investigated. A search is being conducted for a phosphor suitable for use with a photomultiplier tube for counting epithermal neutrons. Improved forms of Geiger and other types of counters are being developed, with particular reference to the needs of the nuclear-powered submarine program. Standardization procedures are being developed for Navy radiac instruments, and mass spectrometry is being applied to establish a new Co⁶⁰ standard source.

Work is directed toward development of a 100-channel pulse-height analyzer, and the improvement of accelerator sources for both electrons and positive ions. An electron multiplier is being developed to provide wide-band amplification for the extremely short pulses which arise in the detection of nuclear processes. Instrumentation is also being developed for use with the proposed NRL reactor, including crystal diffraction apparatus and a fast chopper.

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Development of a lens-focusing small-aperture air-core electron synchrotron is underway, and the potentialities of a compact electron cyclotron developed at NRL are under investigation. Unusual vacuum pumping methods are being investigated along two lines, studying both a set of fluorocarbon oils and greases to facilitate the handling of halogens in a vacuum system and the design of novel vacuum pumps.

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H03 - NUCLEAR WEAPONS

NR 663

Measurements of optical and nuclear phenomena occurring during and after nuclear explosions are made in support of the AEC weapons development programs at the Nevada and Pacific proving grounds. A part of this work is conducted in direct collaboration with the Los Alamos Scientific Laboratory, and a part is carried out in cooperation with the Armed Forces Special Weapons Project. Additional development work on high-current photomultipliers, amplifiers, high-speed spectrographs, and associated equipment for recording of nuclear signals is being undertaken.

H04 - NUCLEAR POWER

NR 664

Effort is directed toward the problems involved in the utilization of nuclear reactors as sources of power for propulsion of naval vessels and aircraft, and toward the direct use of reactors as sources of radiation. Plans are complete for construction of a research reactor at NRL and construction will proceed as soon as funding is complete. The program includes basic research upon the fundamental parameters affecting power generation and control, particularly in the case of mobile reactors and the NRL reactor.

Research is underway on the penetration and diffusion of radiation through thick barriers. Experimental observations are being made on the spectral distribution changes which result from deep penetration in various materials. Theoretical work is directed primarily toward application of stochastic procedures to the design of reactor shields and eventually toward the complete reactor design itself.

Other research associated with reactors includes the following: (1) studies of the dynamics of a reactor and associated equipment, (2) design of a radiation monitoring system for use with the SAR and SFR reactors, and (3) means for removing power from the reactor core. To study this last basic problem, heat transfer work has been initiated with emphasis on the fundamental properties of the transfer process. The phenomena associated with boiling in nuclear reactors will be investigated. Engineering research will be performed relative to over-all heat transfer coefficients and burn-out power densities.

H05 - RADIATION EFFECTS

NR 665

A program involving both fundamental and applied research is conducted on radiation effects as experienced by reactor materials and coolants under exposure to reactor radiation flux. Experiments are currently being prepared to study effects of high neutron and gamma flux on reactor materials. These experiments will be carried out on the MTR at Arco, Idaho. Current plans call for in-pile operation to start about September 1954.

Basic research is directed currently toward an understanding of radiation effects. This study, which is both theoretical and experimental, involves the basic interaction

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processes of radiation with the lattice structure of solid materials, with amorphous materials, and with liquids. Changes produced by gamma rays, electrons, etc., are being investigated with particle accelerators. Studies of water corrosion of stainless steel under intense radiation have been carried out and have led to a basic understanding of some of the difficulties encountered in use of such materials in power reactors.

H06 - ATOMIC PHYSICS

NR 666

The nonmagnetic type mass spectrometer is being developed and applied to problems of negative ion formation and the measurement of multiple ionization potentials. Properties of magnetically self-focusing streams are under investigation. A novel accelerator, named the "polytron," has been designed; its potential applications will be explored. A working model devised to simulate the earth's magnetic field, called the "Störmertron," is used to chart the orbits of ions in that field.

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OPTICS

N01 - PHYSICAL OPTICS

NR 671

This program relates in a broad sense to the interaction of optical radiation and matter throughout the ultraviolet, visible, and infrared regions of the spectrum. It comprises basic investigations of the scattering and absorption of radiation by the atmosphere and the sea, the absorption and reflection of radiation by optical mirrors, optical crystals and filters, and the absorption by gases. Investigations are made of the spectral intensity of radiation from various sources, and the conditions necessary to the production of desired radiation characteristics. Methods are developed for the study of sources of radiation of extreme low brightness, such as self-luminous radioactive materials of a variety of colors. Spectroscopic investigations are conducted as required in the extreme and middle ultraviolet regions, in the visible, and in the infrared.

N02 - PHYSIOLOGICAL OPTICS

NR 672

The optical properties of the human eye and the physical factors influencing its ability to see, both by day and by night, form the basis of this program. Studies are made (1) to determine the visibility of stars in the daylight or twilight sky for the purpose of navigation in the Arctic, (2) to improve night vision by the correction of night myopia, and (3) to ascertain the properties of the eye involved in the measurement of very low brightnesses by visual photometry in connection with specifications of self-luminous marker buttons and similar devices. Personnel assigned to this program participate in the scientific working sessions of the Armed Services National Research Council Vision Committee.

N03 - OPTICAL COMMUNICATION AND DETECTION

NR 673

Investigations are made of detection, communication, and control systems which utilize ultraviolet, visible, or infrared radiations. The program includes studies of pulsed and RF-excited gaseous discharge sources, the practical application of newly discovered photoconductors responsive to long wavelength radiation, large thermopiles, and other detectors of radiation. Work in progress includes (1) the development of a visible-light station-keeping system for mine-laying aircraft, (2) study of near-ultraviolet pulsed-light communication systems, (3) measurements of the spectral infrared emission from aircraft targets and target contrast against the background sky, and (4) investigations of infrared radiation gradients of the sky and of the sea.

N04 - OPTICAL INSTRUMENTATION

NR 674

This program deals with specific utilization of basic optical information in the conception and construction of devices to meet particular military or scientific needs. Examples are:

- (1) The application of light-scattering phenomena to the development of a slant visibility meter with the aim of improving the landing of aircraft in extremely hazy weather.

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(2) The development of a simple rotating prism attachment for existing naval aerial cameras to eliminate image motion and consequent picture blurring when the cameras are used in high-speed aircraft at low altitudes.

(3) The utilization of photon counters selectively sensitive in the extreme ultraviolet at 1200 Angstrom units together with basic information concerning optical transmission in the atmosphere to produce a simple recording humidity meter.

(4) The exploration of the use of photon counters in poison gas detection.

The program leans heavily on new basic information derived from other programs.

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RADIO

R01 - COMMUNICATION

NR 681

It is the purpose of the program to investigate and develop systems and components to advance short- and long-range communication between subsurface, surface, and super-surface units for all areas, including the polar regions, emphasizing such factors as choice of frequency, spectrum utilization, means for decreasing vulnerability, merits of various types of modulation, and provision for automatic operation. Systems will be studied which utilize audio, graphic, visual, and electromechanical techniques to improve such factors as traffic handling capacity, security, accuracy, flexibility, and reliability. Relay and data transmission systems for the transfer of information or intelligence to achieve increased speed, accuracy, and the extension of communication ranges within a task force will also be investigated.

The work in communication is along two main lines: development of new or better communication services and increase of reliability and utility of present communication services. New services are being developed for the purpose of (1) conserving spectrum space, (2) improving the reliability and capacity of communication circuits, and (3) making communication more secure through the development and application of new techniques and through the use of the propagation properties of extremely short wavelengths.

The reliability and utility of existing services are being improved by redesign and modernization of components and circuits and by exploitation of new components and techniques such as transistors and information quantizing.

R02 - RADAR

NR 682

Investigations are conducted on detection techniques and systems, precision tracking techniques, high-resolution systems utilizing millimicrosecond pulses, and on correlation and signal-storage techniques applied to radio-frequency integration.

The detection program covers (1) long-range surveillance of all radar targets above the radar horizon including functions required for air defense by means of both shipborne and airborne systems, (2) short-range high-information-rate target indication systems for designation to weapon systems, and (3) submarine detection.

The precision tracking program has as its objective the analysis of systems to determine the fundamental limits of tracking accuracy as a function of system parameters and target reflectivity characteristics. The reflectivity characteristics of single and multiple aircraft targets are under study as a function of target size, configuration, motion, and radar wavelength.

The high-resolution program covers (1) short-pulse techniques at X- and Q-bands, including traveling-wave tube and Wamoscope receivers, ferrite duplexers, and simplified modulators, (2) experimental operation of short-pulse systems for determining the characteristics of ship echoes and sea return. This type of system offers many advantages

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in the isolation of individual targets in clutter and the possibility of identifying ship or large aircraft targets by type as a result of their reflection characteristics when illuminated by very short pulses.

The application of crosscorrelation techniques is being investigated. Work is being done on (1) electronic storage devices and applications, (2) coherence of radar echoes, and (3) experimental confirmation of theoretical predictions of system performance. A 26.6-Mc storage radar is being planned as an outgrowth of some of the findings of the initial studies. This will furnish a working system for evaluation of range and range-rate capabilities and for demonstrating display systems.

R03 - RADIO IDENTIFICATION

NR 683

It is the purpose of the program to analyze operational requirements for electronic recognition and identification systems, to evolve techniques and special components applicable to such systems, to develop experimental systems, and to provide consultative services on construction, use, and operation of final equipments.

Current activity follows two lines. The first includes the final engineering and equipment evaluation incident to the present introduction of the Mark X IFF system into military use by Navy, Army, and Air Force. The second is development of coding devices for the Mark X system to provide security against an enemy appearing as a friend.

R04 - RADIO NAVIGATION

NR 684

The program serves to investigate navigation systems with a view to the future program requirements of the Navy. Studies are also conducted to develop (1) specific navigational aids and systems with emphasis on carrier all-weather flying systems enabling aircraft to perform all functions necessary for military missions, (2) short-range navigation systems for small surface or subsurface units providing position or guidance information, (3) long-range systems with provision for security and other military requirements for subsurface, surface, or supersurface units.

Navigational systems in various stages of development are: (1) a system for obtaining long-range "fixes" with increased accuracy and extended coverage, (2) portions of a carrier-based short-range (200-mile) system for carrier-based aircraft, and (3) aircraft navigation by means of integration of ground speed and drift. (Accuracy of one percent of distance flown has been demonstrated.)

Several instruments being developed with application to navigation includes a radio sextant for locating sun and moon through overcast, and instruments for precisely measuring electric and magnetic fields.

Work is being carried out on the analysis of the deck motion of aircraft carriers as it affects the problem of designing automatic landing systems for carrier based aircraft.

The program involves the use of new techniques in navigation of aircraft and ships. These include use of radar, inertial systems, light and radio emission from celestial objects, and combinations of these. The emphasis is on self-contained systems, particularly on those which can be carried on small or medium-size aircraft. Applications to bombing systems, strip-mapping, and automatic or semiautomatic control of aircraft are included.

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R05 - WEAPONS CONTROL

Factors affecting accurate control are being investigated. The program also serves to develop new and improved systems for automatically controlling or assisting in the control of gunfire, the guidance and control of missiles, and the take-off, flight, and landing of carrier aircraft. This program involves the application of servo theory to tracking, stabilization, launching, landing and aerodynamic control systems, and combinations thereof. It includes research on recording, computing, and other equipment or techniques needed for proving-ground instrumentation, and data reduction useful in the development and evaluation of control systems.

The program in automatic control is directed toward the following:

- (1) Control of gunfire from aircraft and ships. This effort consists largely of cooperation with contractors in final stages of development of new systems, and of operational research on complete systems under laboratory controlled conditions.
- (2) Missile guidance, concerned with fundamental measurements on propagation phenomena, development of techniques to overcome propagation limitation, development of instrumentation for research in automatic guidance systems for aircraft and missiles, and consultation with Navy bureaus and with other services on missile-guidance development and its coordination.
- (3) Carrier-based control aircraft for approach and landing. (The approach phase is being readied for operation.)

The program in rocket dynamics and control is directed toward obtaining experimental solutions to two basic problems involved in the military use of ballistic missiles: (1) guidance accuracy and (2) high-speed reentry of the warhead. Radio interferometer, radio doppler, and digital computation techniques are being exploited to obtain guidance accuracy. The dynamics and the aerodynamic heating of a conical warhead are being investigated in full scale, free flight tests.

R06 - RADIO COUNTERMEASURES

NR 686

Techniques for exploration of the complete radio spectrum are evolved, with primary emphasis on such fields as interception, direction finding, signal analysis, and vulnerability, and with work on jamming and deception techniques which can be applied against all radio and radar systems. The vulnerability of U. S. (and, where possible, foreign) radio and radar equipments is being studied as an aid toward developing countermeasures. The program includes devising jamming and deception methods, techniques, and experimental systems for use against all types of radar and radio systems. Experimental devices and systems suitable for use in aircraft and ships for providing technical data to evaluate various newly devised techniques are being developed.

Work is along three main lines:

- (1) For interception, signal analysis, and direction finding of radio signals, techniques and systems are being developed to cover all frequency ranges and all types of transmission.

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- (2) High-power wide-band versatile components are being developed for "jamming" or interfering with enemy radio transmissions.
- (3) Confusion reflectors for deception jamming and decoys are being developed further.

Limited radar-vulnerability studies are being made in support of this program.

R07 - RADIO PROPAGATION

NR 687

The propagation of electromagnetic waves is studied including extraterrestrial, ionospheric, tropospheric, ground-wave, and sea-water propagation. There are investigations also on the attenuation and reflection by propellant gases. Attention is given to reflections from natural and man-made objects and backscattering from the absorption by clouds, rain-storms, and the sea or ground surface, with emphasis on quantitative results and the physical characteristics of the reflected waves. Allied to these are means of radar detection of small targets in the presence of sea return.

The following general types of investigations characterize current work in this field:

- (1) The propagation of electromagnetic waves through the earth's atmosphere, through sea water, and through rocket and jet exhaust flames is receiving continuing study directed toward increasing the reliability of radio links and extending radio communication and control services.
- (2) The reflecting characteristic of radar targets, boundary layers, and surface coatings are being studied to aid in control of "radar visibility" and multipath interference effects.
- (3) Thermal radiation of objects at radio frequencies is being studied for application to passive radio listening as a new method for detection and location of objects.

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R08 - ELECTRONIC COMPONENTS AND INSTRUMENTATION

NR 688

Components and materials associated therewith are investigated to determine possible applications to electronic circuitry as they may contribute to improved stability, simplicity, compactness, and reliability when applied to frequency generation, gain, detection, modulation, synchronization, control, information storage, and economical power and spectrum utilization under a wide range of environmental conditions. The program also includes research in electronic measurements and seeks to develop techniques and instrumentation needed for the laboratory work and for specific requirements of the Navy, including electronic equipment maintenance, and signal and interference levels. Consultation and evaluation services are provided by NRL personnel to the material bureaus and their contractors for test equipment throughout the preproduction period.

In this work there is continuing development and refinement of basic components, circuits, and techniques having widespread application in radio. In addition, two major developments are current: (1) Time and frequency standards on a decade basis, after many years of effort, are being made practical both for laboratory and for field use.

(2) Digital techniques for handling and storing of information and for computation are being exploited on a broad front.

Research is conducted in the field of electron tubes and semiconductor devices with emphasis on projects applicable to improved naval electronic systems. Four electron tube projects are under study: (1) electron storage tubes, having many applications in communication and detection, (2) millimeter-wave oscillator tubes required for navigation devices and for limited-range communication systems, (3) gaseous discharge devices as microwave detectors and noise sources, and (4) new types of thermionic cathodes for more rugged electron tubes. The present semiconductor devices program is intended to investigate the deficiencies of present devices used in detection, frequency conversion, and amplification. Specific requirements to be investigated are: (1) high-level wide-band detectors, (2) low-noise millimeter wave mixers, (3) high-frequency amplification, and (4) stability and life problems encountered in transistors.

R09 - ANTENNAS

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Theoretical and experimental research are directed toward the development of new and improved antennas, antenna components, r-f components closely allied to antennas, and antenna instrumentation.

The work may be classified in three categories: (1) development of antenna systems for specific radar and communication equipments, (2) development of antenna systems and techniques tailored to specific types of application, such as rapid-scan systems for radar, and the use of variable-index dielectric materials for lens design, and (3) research in techniques having general antenna application, such as ferrite control of the propagation of microwaves in waveguide. Stress is placed on simplification of shipboard antenna systems by broadband design and multiple use of single antennas, and on drag-free design of aircraft antennas using slot radiators and strip transmission lines.

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SOLID STATE PHYSICS

P01 - SEMICONDUCTORS

NR 691

This program is concerned with theoretical and experimental analyses of semiconductors. It includes development of new and improved semiconductors such as silicon, cadmium sulphide, and germanium through investigation of different methods of preparation and treatment, and application of these materials to such uses as radiation detectors, rectifiers, transistor diodes, and triodes. The contribution of surface states to electrical and optical properties is being studied to assist in the improvement of semiconductors for certain applications and to further the knowledge of such phenomena as luminescence, contact barriers, photoconductivity, catalytic behavior, and chemisorption.

P02 - MAGNETIC MATERIALS

NR 692

This program includes basic research in such ferromagnetic properties as relaxation times and anisotropy, magnetostriction, g-factor, susceptibility, and saturation moments. Studies at high frequencies are applied to the development of r-f absorbent material and studies of complex permeability and dielectric constants of magnetic oxides and ferrites to the improvement of r-f components. Both electron and nuclear resonance physics are included in this program to provide basic information toward the development of better materials for magnetic detection devices.

P03 - DIELECTRICS

NR 693

This program includes theoretical and experimental investigation of the physical properties of insulators, crystals, and luminescent materials. Studies in thermal aging, fatigue, and breakdown under high-voltage surges, and the effects of electronic and nuclear radiation yield information permitting the development of improved insulation systems for specific engineering applications. Lattice dislocation, ionization, molecular decomposition, and related solid state phenomena are investigated by radiation methods.

Luminescence investigations include studies in mechanisms of luminescence, color centers, and effects of ionizing radiation as well as of structure and composition of luminescent materials and the effects of sensitizing additives. Phenomena of luminescence and coloration are exploited in new applications such as in light production, cathode-ray-tube presentations, and dosimetry of ionizing radiation.

Fundamental research on optical, photoconductive, electrical, and related properties is carried out to obtain basic information needed in the development of improved dielectrics for detection devices, radiation windows and filters, light modulators, transducers, etc.

P04 - GROWTH AND STRUCTURE OF SOLIDS

NR 694

Basic physical phenomena are related to structure in an effort to improve methods of preparation and utilization of materials and exploitation of their characteristics. Investigations of crystal growth involve study of the mechanism and development of specialized

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crystal growth techniques such as water solution, vapor phase, melt, flame fusion, or hydrothermal methods. Growth techniques are applied to the production of special crystals for applications involving optical, piezoelectric, photoconductive, and other properties. Phase diagrams and crystal structures are determined. X-ray diffraction is applied to fundamental investigations of (1) the crystalline state and composition of materials, (2) the effects of temperature and stress on phases in alloys, and (3) X-ray fluorescence analysis for determination of chemical composition of materials.

This program also includes basic investigations in the physics of metals and metal alloys. Plastic deformation, internal friction, band theory, and related phenomena - such as conductivity, Hall effect, permeability, hysteresis, and magnetostriction - are studied.

P05 - CRYOGENICS

NR 695

This program is concerned with basic research in solid state physics at low temperatures where thermal energies are comparable to the interaction energies under study. Coordinated theoretical and experimental studies of low-temperature phenomena are of value in the development of solid state theory and may also result in the utilization of the unusual low-temperature properties of materials in the development of new instruments and techniques of research. With primary interest in metals, research includes studies of electrical and thermal conductivity, lattice dynamics with free-electron effects, superconductivity, magnetoresistance, paramagnetism, and antiferromagnetism. In addition to basic solid state studies, research is performed in the production and utilization of low temperatures and in thermometry and instrumentation at these temperatures.

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SOUND

S01 - SOUND PROPAGATION

NR 581

The interaction between sound and the media in which it is propagated is investigated over a wide range of frequency and intensity. The dependence of such interaction on temperature, temperature gradient, salinity, and depth and boundaries of the ocean is determined. Ambient noise in the ocean and ships' self-noise are studied.

Emphasis is currently placed on studies of sound in the frequency range of 1 to 5 kc in order to obtain information on propagation paths and losses at boundaries. This work will be directly applicable to systems feasibility studies. Reflection from bottom sediment is being measured. The effect of pressures up to 10,000 psi on sound velocity in sea water is being determined with a special interferometer. Laboratory studies of cavitation and absorption in sea water are planned.

S02 - TRANSDUCERS

NR 582

The mission of research in this field is to investigate means for generating underwater sound, for converting sound to electrical power, and for realizing desired directional and frequency response characteristics in sound sources and receivers.

Active projects include the study and development of piezoelectric, magnetostrictive, and electromagnetic transducers. A large percentage of current effort is in the development of suitable transducing elements for use in large plane arrays for high-level directional radiation at low sonic frequencies. Substantial effort is being directed toward the development of lightweight transducers for experimental helicopter and blimp-borne sonar. Electrical beam steering for tactical applications is being studied.

S03 - SOUND SIGNAL ANALYSIS AND PROCESSING

NR 583

Signals and backgrounds encountered in underwater sound work are analyzed. The application of electrical networks to processing these signals and the presentation of the signals to human operators for interpretation are studied. Information theory and computer techniques are applied to the detection of targets and to the interpretation of target characteristics and maneuvers.

Work under this program includes the analysis of sonar signals and backgrounds under a variety of conditions to determine what types of electronic processing are most effective for target detection and classification. The effects of data processing and display characteristics on operator performance are determined. Target-detection systems using visual data presentation, which have provided a significant improvement over existing equipments in both detection range and target information rate, are being further improved.

New analysis techniques using electronic computing equipment are being applied to recorded sonar data, new display techniques for matching the information contained in

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sonar signals to the human aural and visual senses are being studied and tested, and the results of this research are being used in the design of target-detection equipments both for making optimum use of operators and for automatically indicating the presence of a target.

S04 - DOMES AND TOWED BODIES

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Problems attacked in the field of submerged domes and towed bodies include hydrodynamic flow, launching and retrieving, stabilization, and steering. The stresses and strains produced in hydrodynamic structures and their supports are studied. Characteristics of sound windows and absorbers are determined.

S05 - SONAR SYSTEMS

NR 585

Systems for all sonar carriers are studied to extend the detection range; to improve classification, identification, and target resolution; and to obtain more precise tracking and attack information. Systems are tested at sea to obtain scientific data which are correlated with theory.

Experimental equipment has extended maximum echo ranges in the past two years. A new low-frequency system which has been installed on the LSM is aimed at a significant increase in range and marked improvement in dependability. The use of even lower frequencies is planned in blimp, ship, and shore installations. Target classification studies are being made to determine distinguishing characteristics of submerged targets and wakes and to utilize present equipments and devise new ones to permit recognition of these characteristics.

A study of fire-control systems is aimed primarily at the determination of the accuracies of various possible sonar outputs and their optimum employment in fire-control computers.

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SPECIAL SERVICE FUNCTIONS

K01 - SHOCK AND VIBRATION CENTRALIZATION

NR 656

Interchange of information in the field of shock and vibration is coordinated. Methods are devised for channeling related current knowledge to all workers in the field to help eliminate duplication of effort and blind-alley investigations. Planned conferences and symposia are employed to disseminate the information. Policies are set by the Inter-Service Agenda Committee, composed of Army, Navy, and Air Force representatives. The subject for a particular symposium is selected by a nation-wide survey to determine the most urgent shock and vibration problems which need study. Benefits of the series of symposia are extended and consolidated through the publication and distribution of a Bulletin.

Advice is rendered, consultation provided, and recommendations are made upon request from Government Agencies with respect to new test facilities, contemplated research projects, and measurement techniques.

K02 - HARBOR DEFENSE INFORMATION DISSEMINATION

NR 657

Technical and scientific consultation is provided to the Office of Naval Research in matters relating to harbor defense. Information on the various technical aspects of the problem is coordinated and integrated and current knowledge for the over-all program is disseminated.

The Harbor Defense and Countermeasures Bulletin is published and distributed to authorized activities and individuals needing the information. The articles in the Bulletin are written by invited specialists in the fields of magnetism, sonar, radar, mines, torpedoes, nets, etc. (See also S03.)

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