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RESEARCH REVIEWS

- NUCLEAR SHIELDING
- UNIVERSAL REACTION—AN INDICATOR OF HEALTH
- MEASURING GAMMA—RAY WAVELENGTHS
- ON THE NAVAL RESEARCH RESERVE

OFFICE OF NAVAL RESEARCH
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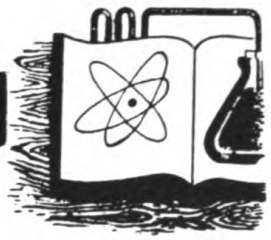
COVER PHOTO: Clark Goodman, director of an ONR research project on nuclear-radiation shielding at the Massachusetts Institute of Technology, is shown adjusting a spherical ionization chamber. This chamber is one of the methods of measuring neutron energies as described in **NUCLEAR SHIELDING.** See story on page 1.

Approved by Bureau of the Budget, 13 April 1948.

RESEARCH REVIEWS

● *Informs the Fleet of ONR-sponsored Research*



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Editorial Notes

The increasing interest in research in the past few years has brought with it a corresponding interest in the men who conduct this research and in the particular problems of scientific personnel.

In November, 1945, a report was submitted by a special committee appointed by Rear Admiral T. G. Crisp, then Chief of Industrial Relations for the Navy, to study major problems of Navy scientific and professional personnel. An over-all recommendation by this Committee was that there be established a group to give special attention to the problems of scientific and technical personnel as distinguished from industrial personnel. In January, 1946, such an activity was established in the Office of Naval Research and is now a part of the Personnel Division of ONR.

A number of the recommendations of the Committee related to the need for a more effective scientific personnel recruitment program. Action on the recommendations has resulted in the following specific advances in this field:

- Most scientific positions in major Naval research laboratories are now being filled from examinations announced specifically for each Naval establishment. This permits and assures candidates that they are being evaluated by their scientific peers. Scientists themselves advise the Civil Service Commission on examination requirements.

- In general, examinations above GS-13 level are held continuously open.

- Close relationships with the universities and other sources of supply of scientists are maintained through planned visits each year by representatives of the Naval laboratories. They describe to the faculty and students the opportunities offered to technically qualified personnel by the Naval establishments.

Another group of recommendations of the Committee related to salary and working conditions and professional development. Action on these recommendations has resulted in:

- The passage of Public Law 313, amended by Public Law 758, which provided 13 positions in the Department of Navy at salaries of $10,000 - $15,000 per year. Eleven of these positions are now filled.

- An increase of funds made available to professional personnel for attendance at meetings of scientific and technical societies.

- New opportunities for scientific and technical personnel to continue their professional development thereby increasing attractiveness of employment in Naval laboratories. Last year at some 10 Naval activities in and around Washington, 44 graduate courses were conducted with 700 students enrolled and 25 undergraduate courses in which 322 students were enrolled. Courses were sponsored by the University of Virginia, University of Maryland, University of Pennsylvania, Catholic University, and the U. S. Department of Agriculture Graduate School.

- The obtaining of legislative authority to detail professional staff members to universities or other organizations for instruction and training directly related to their work which was specifically granted to the Department of Defense in Public Law 464 (the appropriation bill of 1950).

This very brief description shows that some real progress has been made in solving certain of the significant problems facing Naval civilian scientists. It also provides concrete evidence of the continuing intent and interest of Navy management to give special attention and effort to the unique problems of its scientific personnel. ONR is proud of its part in contributing to the leadership that has high-lighted attention on scientific personnel problems.

Nuclear Shielding

by
Clark Goodman and Gardner A. Norton
Massachusetts Institute of Technology

Nuclear science is a field not fundamentally new but one which developed rapidly under the forced draft of war and which culminated in the most gigantic experiment ever undertaken—the development and production of the atomic bomb. Out of this development, a host of new military and scientific problems related to nuclear energy have arisen.

The Nuclear Shielding Project at the Massachusetts Institute of Technology is an unclassified study of the fundamentals of one of these created problems—specifically, the shielding of high-intensity neutron and gamma-ray sources. The other rays from such sources (alpha and beta rays or electrons) are easily absorbed and constitute no great problem.

Why nuclear shielding? It has been found that nuclear reactors, or "piles," radiate tremendous amounts of penetrating rays. Living organisms can be seriously injured if these intense nuclear radiations are absorbed in large doses. The precise determination of the fundamental physical processes by which neutrons and gamma rays (the same as highly penetrating X-rays) are absorbed in matter should yield information of value both to nuclear science and to those groups associated with specific design problems for nuclear power reactors.

Some years ago the Navy started a long-range program of supporting research in the field of nuclear physics. The present project at M.I.T. is sponsored by the Bureau of Ships through the Office of Naval Research in cooperation with the Atomic Energy Commission. This project has been in progress for two years and is expected to continue for at least two more years. About 28 people in all; physicists, engineers, research workers, and technicians, constitute the working group.

Reactors radiate both neutrons and gamma rays in an energy spectrum, much as a radio transmitter might put out electromagnetic waves

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Clark Goodman received a B.S. degree in chemical engineering from the California Institute of Technology and a Ph.D. in physics from the Massachusetts Institute of Technology. He was consultant, Manhattan District, 1943-46; technical aide, National Defense Research Council, 1945-46; and senior physicist at the Clinton Laboratories in 1946. Dr. Goodman is project supervisor of the Nuclear Shielding Research Group under Bureau of Ships and Office of Naval Research contract at M.I.T. and an associate professor there.

Gardner A. Norton received an A.B. degree from Harvard College and an Sc.D. from the Harvard Graduate School of Engineering. He was research engineer with Arthur D. Little, Inc. from 1934-38 and served with the Navy from 1940-46. His present rank is CDR S(E), USNR (ret). Dr. Norton, an instructor in electrical engineering at the Massachusetts Institute of Technology from 1948-49, is a member of the Nuclear Shielding Research Group at that institute.

in the RDF, long wave, LORAN, VHF, SHF, and UHF bands. To determine this energy distribution is one of the most difficult problems of the present experimental work. Every measurement on materials for shields must be related to the energy of the radiations.

Some idea of the problem of shielding against gamma radiation may be obtained from an example. The radiation from an unshielded one-gram radium source is of such strength that at a distance of 26 feet, the human tolerance dose is absorbed in an eight-hour day. Any greater total amount of radiation would, in time, seriously affect the blood count. With a two-inch-thick lead shield, the distance could be shortened to eight feet, and behind four and one-half inches of lead, the distance need be only two feet from the one-gram radium source for the same total time.

Fast neutrons, however, can pass through large amounts of lead with great ease, but are slowed down by light elements such as carbon and hydrogen which are poor absorbers for gamma rays. For this reason, water, paraffin, and other hydrogenous materials are highly effective in slowing down neutrons which are then more readily absorbed in certain elements.

When speaking quantitatively of this "slowing down" process for neutrons, which involves their interactions with nuclei, it is necessary to use the physicist's concept of "cross-section." The absorption cross-section is a measure of the probability that a nucleus will absorb a neutron. Cross-sections for these reactions are generally stated in terms of a unit called the "barn," which is 10^{-24} cm^2. The name is derived from the fact that the absorption cross-section for slow neutrons as compared with that for other higher energy interactions is "as big as a barn." It is believed that substantial savings in weight and cost of shields may be made if additional data on cross-sections are obtained.

Although portable sources are of some value for testing shielding elements, the fundamental data can only be obtained with accurately controlled sources of monoenergetic neutrons. For this purpose an electrostatic generator (shown in Figure 1) is being used. This generator was designed to operate up to a peak potential of 5,000,000 volts. Some idea of the size of the generator may be obtained from the illustrations.

The generator consists, essentially, of a Van de Graaff high-voltage generator of the belt type, a 16-foot-long discharge tube, called a "positive ion accelerating tube," and a large 10-ton magnet at the bottom of the accelerating tube which analyzes the ion beam. Various targets are used to produce neutrons of different energies (ranging from a few kilovolts to 14 million electron volts). A complicated arrangement of auxiliary equipment such as voltage control, magnetic field control, and safety devices is also required. A team of five men is required to conduct a given neutron experiment. Although the discharge tube operates in a high vacuum state, the complete apparatus is housed in a pressurized one-inch-thick steel vessel 16-1/2 feet high and 66 inches in diameter (Figure 1). It will be filled with Freon and nitrogen under pressure to provide gas insulation at high voltages.

The tube now used has 108 glass sections, each glass section separated by metal electrodes. The conductivity of the glass, and the

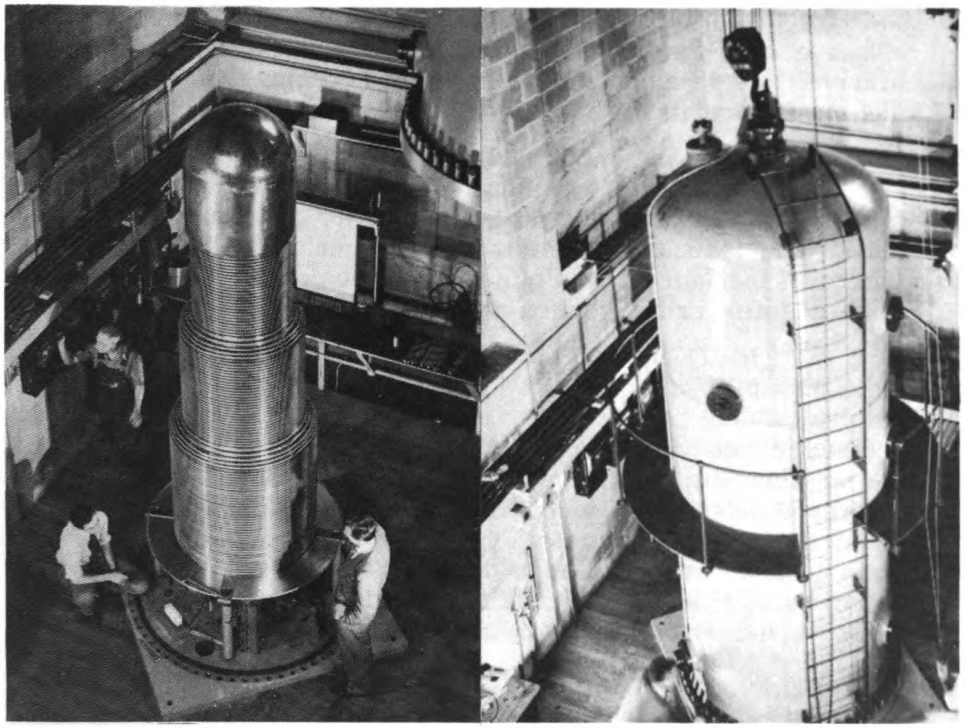

Figure 1. (Left) Rings spread the five million volts of this M.I.T. electrostatic generator equally from storage dome to base. Insulation between rings is accomplished by gas under high pressure, pumped into the machine after its cover (right) is securely fastened. Inside of the potential rings (left) are located the positive ion tube, the Van de Graaff electrostatic generator, and the ion source. Directly below in the basement are the beam-splitting magnet and the target assembly, from which controlled energy neutrons are emitted. The control console is in an adjacent shielded room.

necessary high degree of polish of the electrode materials (buffed aluminum has been found to be the best to date) have presented major problems for the research group.

In addition to the construction of the new generator and refinement of its operating technique another large portion of the project is devoted to instrumentation for detecting and measuring neutron energy. Although this problem is receiving attention at other nuclear research centers in this country, notably at the AEC research laboratories in Los Alamos, Oak Ridge, and near Chicago (Argonne National Laboratory), many problems peculiar to fast neutron energy measurements are being concurrently studied. The chief methods of measuring neutron energies today are the following:

(1) The activated indium foil method. Metallic foils of indium give an index to incident neutron radiation. After being exposed to neutrons they emit beta rays which may be counted by standard methods.

(2) The "long counter" technique using boron trifluoride gas-filled counters embedded in paraffin. This is an indirect process in which the neutron strikes a boron nucleus inside the tube, and the alpha and lithium particles which result create enough ionization to register an electronic counter.

(3) The photographic technique, using "nuclear track plates." This is also an indirect process in which recoil proton tracks formed by collisions of fast neutrons (greater than one Mev) can be measured by means of a microscope.

(4) The spherical ionization chamber as shown in the Cover Photo. Though neutrons do not ionize a gas directly when they pass through it, the collision of neutrons with gaseous atoms causes secondary ionization effects and the spherical ionization chamber becomes therefore a type of neutron pulse counter. It is being used in absorption cross-section measurements.

(5) Finally, the scintillation counter technique. This technique uses crystals such as anthracene, naphthalene, and lithium fluoride, on which neutrons impinge, and which generate tiny light flash pulses of extremely short duration (0.01 microsecond) which can be detected by the modern multi-stage photomultiplier tube and finally counted by pulse amplifier circuits. This modern development of an old art actually rests in great part on the special circuitry developed for radar during the war, such as fast-gating circuits and blocking oscillators for detecting and distinguishing between nearly coincident pulses. All of the above techniques are being used.

Progress in nuclear shielding must be closely allied with parallel developments in health physics, both for protection of our own research men and because improved instrumentation may be an outcome of the project for health and area monitoring. Already, neutron radiation has been found to be extremely damaging to the human system, notably to the eye mechanism. Several scientists are now suffering from permanent glaucoma resulting from exposure to fast neutron radiation during experimental work on cyclotrons or atomic machines. History seems to be repeating itself: in the X-ray field many pioneer workers were badly burned before protection and monitoring techniques were developed.

Officially it has been agreed recently that the "Roentgen biological effectiveness" or RBE of fast neutrons as compared to gamma rays is about 10:1. In other words, neutrons of equivalent energy can do about 10 times as much biological damage as gamma rays. Considerable clinical experience has been obtained with gamma rays, and therefore these electromagnetic radiations are generally used as a reference standard for other radiations, even though their biological effects may be quite different.

Present work is being done on the development of an area-monitoring device sufficiently sensitive to measure the tolerance level of fast neutrons. In the United States this is generally taken to be 200 fast neutrons/cm^2/sec. The Canadian National Research Council advises using 100, and for human eyes the figure 20 fast neutrons/cm^2/sec may soon replace the higher value. Instruments of this sensitivity are not as yet commercially available.

The significance of nuclear shielding is becoming more and more appreciated as we realize that the human tolerance dose for fast neutrons and gamma rays over long periods of time is not large. Indeed the radiation tolerance of human operators may constitute the most serious limitation in future military or peacetime applications of nuclear power.

Universal Reaction-- An Indicator of Health

by
Reuben L. Kahn
University of Michigan

This is the first of two articles on the universal reaction. Dr. Kahn's second article will deal with this reaction in various diseases.

Might we in due time have a blood test for health as we now have blood tests for various diseases? A blood test apparently associated with health was evolved in this laboratory several years ago which has given positive reactions with the blood serum of all persons tested. These reactions are technically referred to as "universal serologic reactions" and they are differentiated in different persons by variations in "serologic patterns." One person may give one type of a serologic pattern and another person, another type. Occasionally, it is found that two persons give similar serologic patterns. But each healthy person has been found to give on repeated testing essentially the same serologic pattern during a period of two years. This finding indicates that in health the serologic pattern of a given person remains constant.

It is believed that these reactions in health belong to the category of immunity reactions. This immunity apparently is developed against chemical products liberated in normal tissue wear and tear. These products are very complex chemical substances which chemists call "lipids." The lipids with which we are particularly concerned are phospholipids, including lecithins, cholesterol and very likely others not yet identified. Traces of these lipids are set free from cells as they die in the course of normal metabolism, and some of these lipids are apparently capable of calling forth the production of specific antibodies. These antibodies, in turn, react with an alcoholic extract of tissue lipids in the test tube. Universal reactions of definite serologic patterns result. These patterns given by healthy persons have been found to undergo changes in different diseases. It is possible therefore that a repeatedly normal serologic pattern in an individual may in due time prove to be one of the medical indicators of health.

While spending several days in Washington in the spring of 1946, I made a Sunday call at the office of Admiral Harold W. Smith. I knew

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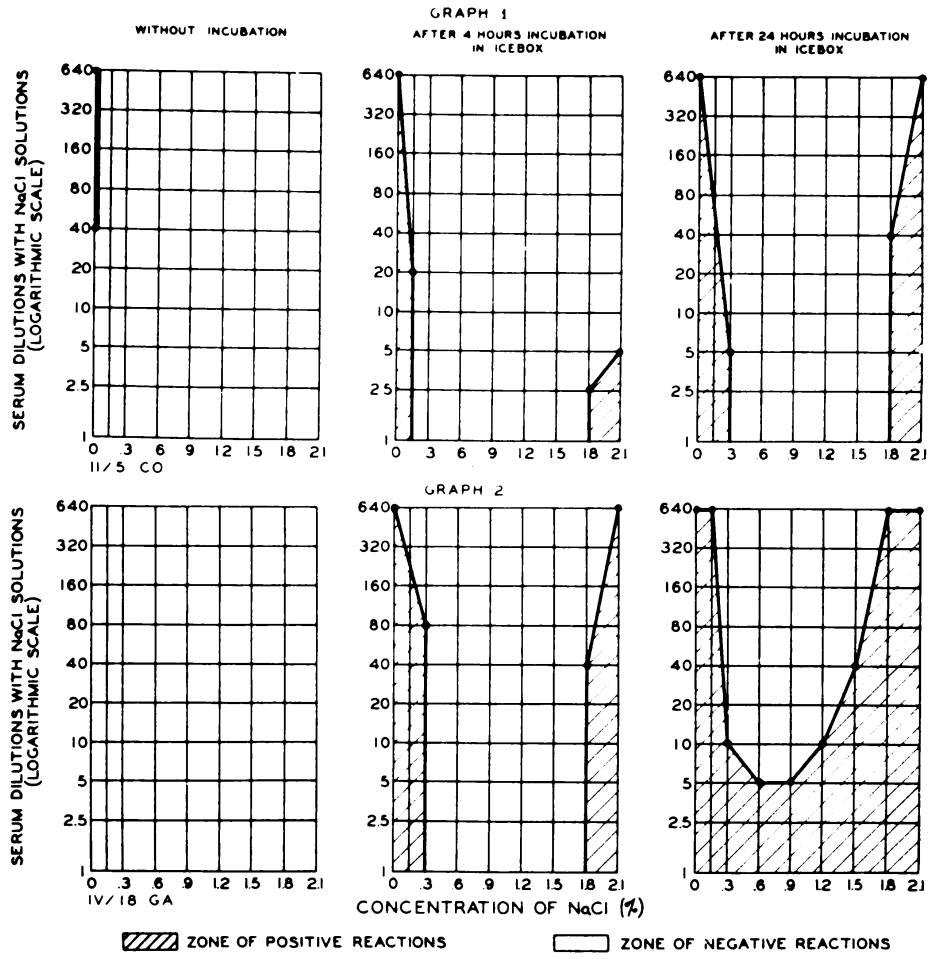

Chart 1. Universal reactions given by normal human beings.

from previous experience that I would find Doctor Smith in his office and I wanted to discuss with him some new experimental data—undisturbed by the telephone or by callers. This data had to do with a serum precipitation reaction with a lipid reagent, referred to as "antigen." This reaction was apparently of a biologically universal nature, since it was obtained in all human beings and animals tested. The technique employed in eliciting the reaction was rather elaborate. It consisted of: (1) serial dilutions of serum with solutions containing different concentrations of sodium chloride; (2) an antigen consisting of a specially prepared extract of tissue lipids; and (3) three readings of the results—the first, on mixing the lipids with the serum dilutions, the second after keeping the mixtures for four hours in the icebox, and the third after keeping the mixtures for 24 hours in the icebox. With this technique, the positive reactions were found to be of a definite pattern. This pattern was based on the degree and arrangement of precipitation as recorded in each of the three readings of the results. Of 100 healthy persons examined, 80 are likely to give universal reactions of different serologic patterns and 20 of similar patterns.

Admiral Smith considered my preliminary data of sufficient importance to suggest that I apply to the Office of Naval Research for a grant to enable me to undertake more comprehensive studies of the universal

reaction in health and disease. The first ONR grant was made available in August, 1946. Since that time we have studied universal reactions in normal human beings and in animals; also in five diseases, syphilis, tuberculosis, leprosy, malaria and yaws. The current ONR grant is limited to tuberculosis in which the universal reaction is showing promise of particular value.

Differences in serologic patterns of universal reactions in health are shown in five graphs in the accompanying Charts 1 and 2. Graphs 1 and 2 of Chart 1 illustrate serologic patterns of two normal individuals. Each graph consists of three sections based on the three readings of

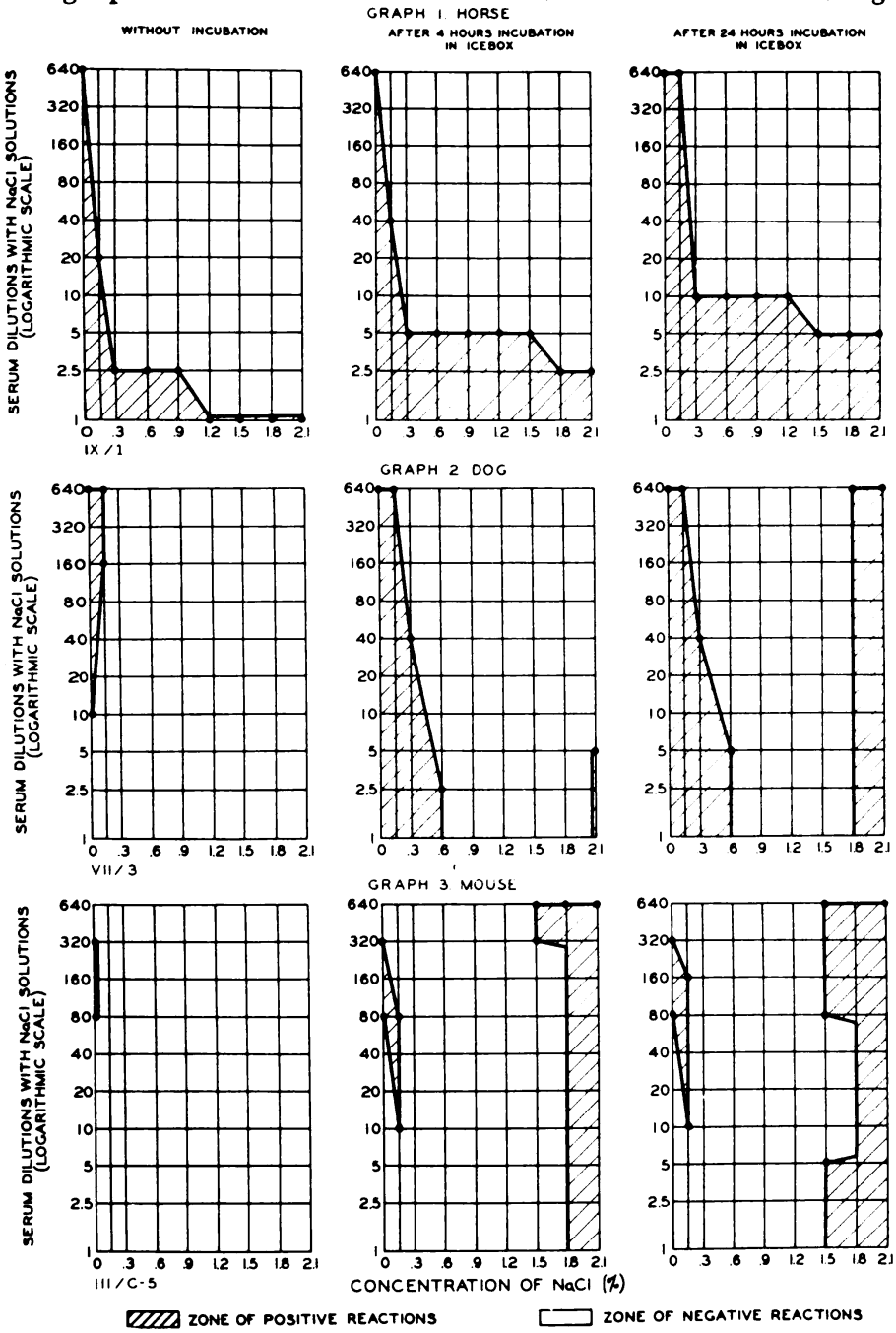

Chart 2. Universal reactions given by animals.

the results, the first reading being made on mixing the serum dilutions with the antigen, the second after four hours, and the third after 24 hours at cold temperature.

The "zone of positive reactions" in each of the two graphs represent precipitate formation which consists of white flake-like particles suspended in the serum dilutions. It is evident that the serologic pattern in Graph 1 differs from that in Graph 2. Graph 2 shows considerable more precipitation than Graph 1, especially after an overnight period at cold temperature.

Let us now examine Chart 2 illustrating universal reactions given by animals. Graph 1 presents a serologic pattern given by horse serum; Graph 2, a serologic pattern given by dog serum, and Graph 3, a pattern given by mouse serum. It is evident that Graphs 1 and 3 are quite different from the graphs of human universal reactions. Graph 2 of the universal reaction of dog serum may be said to be similar to Graph 1 of the universal reaction of human serum.

Probable Nature of Universal Reaction

The universal reaction in health is believed to be due to the presence in the blood stream of natural antibodies to tissue lipids. These lipids, as indicated at the beginning of this article, are probably liberated in the course of normal tissue wear and tear. Since such wear and tear are most likely relatively constant in a given individual or animal in health, the lipids liberated are correspondingly constant, leading in turn to a constant antibody response and to a constant serologic pattern.

In different individuals, the amount of lipids liberated in tissue wear and tear are apparently not the same. The result is that the antibody response is not the same. It may be also that one individual may possess a greater capacity for antibody production than another. Of the two individuals giving universal reactions, illustrated in Graphs 1 and 2 of Chart 1, one individual obviously shows a greater antibody response than the other, resulting in more marked precipitation.

When examining the graphs of universal reactions given by horse, dog, and mouse serum, we find that they are quite different from the graphs of human universal reactions. These latter reactions are quantitatively different from one another, but qualitatively they are probably the same. The animal graphs, however, show qualitative differences from one another.

These qualitative differences must be due to distinctive lipids liberated by these animals in the course of their tissue wear and tear. We will say that the horse liberates lipids X; the dog, lipids Y; and the mouse, lipids Z. Lipids X call forth corresponding antibodies x; lipids Y, corresponding antibodies y; and lipids Z, corresponding antibodies z. The result is qualitatively different serologic patterns of the universal reactions of these animals.

One can begin to comprehend the complexity of these reactions. Perhaps the chemist will someday differentiate lipids X, Y, and Z and others that are responsible for distinctive serologic patterns in human beings and animals, in health and disease.

There is a close relationship between the universal reaction and the reaction given by blood tests for syphilis. Both are serum reactions and both are obtained with an antigen consisting of tissue lipids; yet, they are quite different from one another. The syphilis reaction is based on a restricted technique which favors particularly the detection of syphilis. The universal reaction is based on a comprehensive technique which favors the detection of the serum response in health as well as in various diseases.

Elsewhere[1], we compared the syphilis reaction to the peak of an iceberg and the universal reaction to the entire mass of iceberg. The illustration is not altogether true, since the mass of iceberg is quite limited in relation to the peak, while the potentialities of the universal reaction in health and disease have hardly been explored.

Future Studies

The universal reaction opens up a large field for the study of human beings and animals in health. For example, do different human races give similar or different serologic patterns? Do people in Africa, Asia and in the tropics give serologic patterns similar to those given, let us say, by midwestern Americans? How about the serologic patterns in infancy, youth, middle age and old age, are they the same or different in a given individual?

In the study of universal reactions in animals, the field is also very extensive. To survey different species in relation to their universal reactions might throw light on the classification of species. The universal reaction might also be studied in relation to the age of animals, their diet and to differences in their environment. It is thus evident that the universal reaction in health gives promise of enlarging our knowledge of factors governing health, both in human beings and in animals.

[1] Kahn, Reuben L: "An Introduction to Universal Serologic Reaction in Health and Disease" (in press). The Commonwealth Fund, New York.

Measuring Gamma-Ray Wavelengths

by
Jesse W. M. DuMond and David A. Lind
California Institute of Technology

The layman usually gasps with incredulity when told that physicists measure wavelengths of light only a few millionths of an inch in length with a precision such that the probable error is sometimes considerably better than one millionth of these tiny wavelengths themselves. Such work in the visible or ultraviolet region of the electromagnetic wave spectrum is now, however, a familiarly accepted fact. The latest advance here to be described is quite new. It concerns the precision measurement of the much shorter wavelengths of gamma rays, the invisible "light" that comes out of nuclei.

If one divides an inch into a million equal parts and then divides one of these in its turn into twenty-five thousand equal parts, these latter subdivisions will each be approximately one milliangstrom in length (a milliangstrom is 10^{-11} cm). This is the unit in terms of which we shall chiefly talk. The shortest gamma-ray wavelength measured at the California Institute of Technology to date (the 1.3 Mev line from the radioisotope Co^{60}) was about nine milliangstroms in length and the precision of this shortest wavelength measurement was represented by an uncertainty of one one-thousandth of the wavelength measured. This is the shortest wavelength ever directly measured in the history of physics, and its precision is several hundred times better than ever before attained in crystal diffraction studies of nuclear gamma-rays. Furthermore, this precision is not only a matter of relative accuracy, i.e., the ratios of different gamma-ray wavelengths to each other, it is absolute in the sense that to the stated high precision it puts all these tiny wavelengths on the same scale of length units as the standard meter or, better still, as the wavelength standards of the optical spectrum. This work then may be said to have effected the precision

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Jesse W. M. DuMond is professor of physics at the California Institute of Technology where he received his doctorate degree in 1929. He became acting associate professor of physics at Stanford University in 1930. During World War II, Dr. DuMond served as consulting physicist with the National Defense Research Council at the Bureau of Standards. He is now director of an ONR project devoted to the work described in this article. Dr. DuMond has been a research physicist for 25 years conducting investigations in X-rays, atomic and nuclear physics, determinations of the atomic constants, acoustics of ballistic shock waves, and precision instrument design.

David A. Lind is Senior Research Fellow on the ONR contract at the California Institute of Technology, working under the direction of Dr. DuMond. He graduated from the University of Washington, Seattle, in 1940 and finished his doctorate in physics at the California Institute of Technology in 1948. He has been associated with Dr. DuMond on the development of the curved crystal gamma-ray spectrometer since the fall of 1945. Dr. Lind formerly held engineering and technical positions with Boeing Aircraft Co., Seattle, and engaged in World War II research work at the California Institute of Technology and the University of Washington.

juncture of the already well-known parts of the spectrum with its last frontier the nuclear gamma-ray region.

The instrument with which this is done is the two-meter curved crystal focusing gamma-ray spectrometer. Its place as an advance in X-ray and gamma-ray spectroscopy can be best appreciated by the following comparison. For the spectroscopy of optical light, Henry Rowland in the last century invented and applied the concave ruled grating spectrograph, a great forward step in experimental physics, since at one stroke it greatly improved both the resolution and luminosity (light handling power) of spectroscopic work. In X-ray spectroscopy, the epoch-making discovery revealed by the Laue, Friedrich, and Knipping experiment in Germany (1912) and the work of the Braggs and of Moseley in England (1914) taught physicists how to use the natural lattice structure of the atoms in crystals (such as rock salt, calcite, quartz, gypsum, and mica) as a three-dimensional diffraction grating for X-rays. The periodicity of the atomic planes in crystals affords a much closer spacing than the artificial ruled lines of the optical grating so that they serve similarly for measuring the much shorter wavelengths of X-rays. The X-ray "lines" characteristic of the various atoms of the periodic table have wavelengths which range from some thousands to about a hundred milliangstroms in length. The intensities of X-rays normally obtainable from X-ray tubes are enormous, however, in comparison to the nuclear gamma-ray intensities which can ordinarily be obtained from radioactive sources. Nuclear gamma-ray wavelengths range from about 200 milliangstroms down to less than one milliangstrom. The advance represented by the curved crystal focusing gamma-ray spectrometer over the ordinary (flat) crystal X-ray spectrometer may be compared to the advance accomplished in Rowland's concave grating spectrograph relative to a flat grating spectrograph without any lenses (to collimate a parallel incident beam and refocus the diffracted beam).

The great increase in both intensity and resolving power represented by the curved crystal focusing gamma-ray spectrometer was necessary in order to extend the utility of the new instrument over a large field of work in the establishment of precision standards of nuclear gamma-ray wavelengths (and the establishment of nuclear energy levels on an absolute precision c.g.s. scale); but another factor which has greatly contributed to this program is the development of chain reacting piles under the American atomic energy program which now makes possible, and convenient, through the cooperation of the AEC., the purchase at reasonable prices of literally hundreds of artificial radio-isotopes suitable in strength and decay period for gamma-ray measurements with the new instrument. Sources in which the gamma-ray photons to be studied are emitted (in all directions) at a rate of about fifty millicuries are usually sufficiently strong with our present instrument. (Here one millicurie means 37 million photons per second.) We confidently expect to improve the technique eventually to the point where five millicuries (of emitted gamma-rays) will be sufficient.

The new spectrometer utilizes as its most essential element a monocrystalline quartz plate, our newest sample being two millimeters thick and about 7.6 cm square. This plate is accurately cut so that atomic planes having the Miller indices (310) are quite closely normal to the large flat faces of the plate and nearly parallel to two of its edges. The plate is carefully polished on both sides to a true optically flat

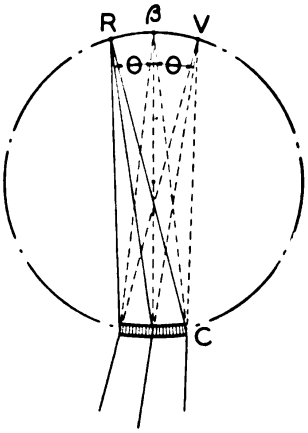

Figure 1. Geometry of focusing curved crystal gamma and X-ray spectrometer of the transmission type. R and V are the real and virtual foci, θ is the Bragg angle, and β is the point at which the reflecting atomic planes of the crystal lamina would converge if produced. The crystal, at C, with initially optically-flat faces is curved in a precision profiled clamp to a radius equal to the diameter of the focal circle shown here.

plane surface. High accuracy here is of cardinal importance. The quartz plate is then compressed between the two jars of a vise-like holder consisting of two massive stainless steel blocks whose pressing surfaces are carefully profiled with optical accuracy, the one to a convex, the other to a concave circular cylindrical arc. These circular cylindrical surfaces have radii of curvature of about two meters and are finished by all-important special processes worked out for the purpose which space limitations unfortunately do not permit us to describe here[1] The axes of the cylindrical arcs are vertical when the holder is mounted in the spectrometer. Rectangular holes are pierced through both vise jaws giving an aggregate aperture of about 50 cm^2 for the passage of the gamma radiation. In the convex vise jaw, the hole is traversed by two horizontal ribs integral with the steel jaw. A neoprene gasket is placed between the crystal slab and the concave vise jaw but the convex jaw which defines the curvature of the crystal must make extremely perfect contact with the quartz plate, all foreign matter of even submicroscopic size being very carefully eliminated. When the quartz plate is compressed in this vise, it has been found possible by these procedures to cause the atomic planes in the quartz plate to converge so accurately that X-ray tests prove that they would all, if projected, intersect to within 0.05 mm of a single point at two meters' distance from the crystal.

It is worth pausing for a moment here to call attention to this example of the marvelous uniformity of nature's building blocks, the atoms. Here is a quartz crystal whose atomic planes, counting them across the width of the slab are so numerous that they may be likened to the floors of a sky-scraper one thousand million (one billion) stories high erected by "dead reckoning" as it were without surveying (so that its accuracy must rely merely on the uniformity of the myriad cells of which it is constructed) and the billionth floor turns out to be parallel to the ground floor to within about five seconds of arc!

The fundamental geometry of the curved quartz crystal focusing spectrometer[2,3] is shown in Figure 1. β is the point at which the atomic planes in the crystal slab C would converge if extended. The focal circle of the instrument represented with the dot-and-dash line has a diameter of two meters. As they pass through the crystal slab, the gamma-ray waves are selectively reflected at very grazing angles by the internal atomic planes in the crystal, each little plane of atoms acting like a small flat mirror working in grazing incidence. The reflection takes place following the mirror law of equal angles of incidence and reflection

on each plane. In addition, however, the mutual interference of the different individual reflections from great numbers of these planes (stacked adjacent to each other with a regular periodicity in the direction normal to the mirrors) causes the reflection to be highly selective as regards the wavelengths reflected so that a very rigid law (known as the Bragg law) connects the wavelength of the gamma radiation with the grazing angle θ at which that wavelength can be reflected by the planes. This law is

$$n \lambda = 2 d \sin \theta$$

where n is simply a small whole number, e.g. 1, 2, 3 . . . (the "order" of the interference), λ is the wavelength which the interference phenomenon selects from a heterogeneous beam (rejecting all the others so that they pass straight through the plate without being deflected), d is the interplanar spacing and θ is the angle of grazing incidence of the radiation on the planes. In our present case, only the first order for which n = 1 is used. Thus, for a given crystal, each wavelength is reflected at a different angle with the atom planes. Referring to Figure 1, the radiation approaching the crystal from the convex side will, after selective reflection by the planes, consist of one and only one very narrowly defined spectral band of wavelengths which will focus at one point R on the focal circle. Other wavelengths will be focused by the crystal at other points on the focal circle and the longer the wavelength the larger will be its Bragg angle λ and the farther will be its focal point R from the point β. The point marked V is a virtual image point toward which the incoming rays before striking the crystal must converge.

In the manner described, the spectrometer has been used for the photographic study of X-ray spectra. The spectrum is formed on a photographic film placed in a cylindrically curved film holder so that this film coincides with the focal circle. This is not, however, the way in which the instrument is operated for the study of nuclear gamma rays.

When gamma rays are to be studied, the gamma-ray source is placed in very concentrated form at the real focus R on the focal circle. The gamma rays are propagated in the reverse direction to that just described so that they enter the quartz on the concave side of the curved crystal slab. Provision is made so that the source can be moved along the focal circle. At each point in its progress the rays will strike the planes of the crystal at a slightly different wavelength for reflection from the beam. Note that because of a familiar geometrical property of the circle all the rays from source at R wherever they strike the planes in the crystal slab do so at essentially the same angle, θ. The gamma rays reflected by the planes proceed outward from the convex side of the crystal in a divergent beam which has for its virtual origin the point V on the focal circle. The point β, where the crystal planes (extended) mutually intersect, is midway on the focal circle between R and V. The remainder of the original heterogeneous beam from R which is not selectively reflected by the crystal planes goes straight on. This remainder is many thousands of times as intense as the very small fraction which is deflected, for at these extremely short wavelengths, the reflection coefficients[4] (even at the Bragg angle and for the corresponding Bragg-selected wavelength) are very small indeed. The problem is then to be able to measure the intensity of this weak reflected beam with a very sensitive device, a special Geiger counter, without permitting the far stronger directly transmitted beam to reach this

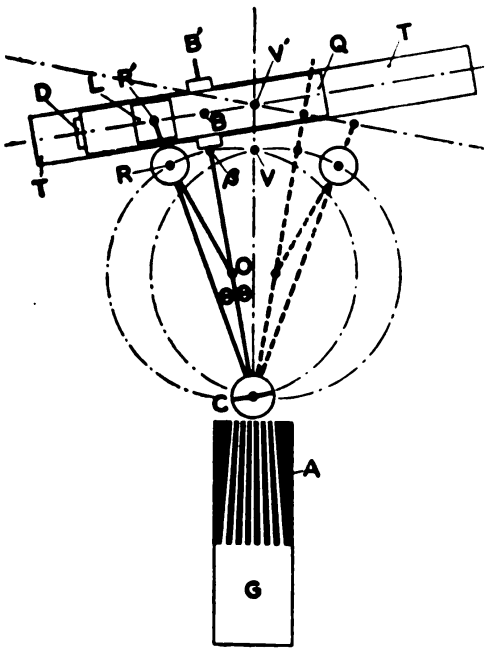

Figure 2. Schematic plan view of focusing curved crystal gamma-ray spectrometer with the source at the focus and arranged so as to maintain the selectively reflected beam stationary as the wavelength is explored. The Bragg angle θ is here greatly exaggerated relative to its value for gamma rays.

counter (for if it did so the weak radiation to be measured would be completely lost in the avalanche of the direct beam). About the only way to discriminate between the two beams is to take advantage of the difference in their directions, the undesired one coming from R, the much weaker desired beam coming from V. At the shortest gamma-ray wavelength so far measured this difference in direction is only about 20 minutes of arc so this problem is not too easy. It is at present solved by means of a fan shaped "collimator" of 24 long, tapering, lead partitions separated by tapering openings of equal width. The collimator is diagramatically indicated at A in Figure 2, (not to scale, of course, for the angles are much too small to show conveniently in a drawing). In Figure 2, A is the lead collimator which stops the transmitted beam and transmits only the reflected beam. G is the multicellular Geiger counter. C is the curved crystal mounted on a support which is rigidly attached to the beam CB'. R is the shielded source at the focus of the curved crystal. L and Q are screw-driven carriages and T is a track swiveling at V'. These last impart the appropriate motions to arms CR' and CB' so that wavelengths can be read directly on a drum at D. The full and dotted lines show, respectively, the positions for observing reflections of one and the same wavelength to left and to right of the (310) planes of the curved crystal.

The present collimator has die-cast lead alloy partitions and openings 0.040 inches wide at the smaller entry end and 0.053 inches wide at the exit end. It is 30 inches long and the openings are about two inches high at the entry end. The special Geiger counter is placed at G in Figure 2 and is heavily shielded on all sides with four inches of lead (not shown in the Figure). The collimator openings have a geometrical (not physical) angular discrimination of eight minutes of arc and while this has nothing whatever to do with the spectral resolving power of the instrument, it does determine the shortest wavelength that can be studied before the direct beam starts leaking through the collimator to the counter. This limiting minimum wavelength, theoretically computed from the geometry of the collimator, corresponds (for the crystal planes now

in use) to about four milliangstroms (or a gamma ray quantum energy of three Mev). Because of leakage by transmission obliquely through the lead partitions, scattering on the lead surfaces, and geometrical irregularities of construction, the limiting point is indefinite; the leakage sets in gradually instead of suddenly so that to date we do not yet know the very shortest wavelength gamma-ray line which this collimator might permit us to study; but the shortest we have studied so far (nine milliangstroms) certainly does not exhaust the possibilities since the "contrast" (ratio of line intensity to collimator scattering background) was still ample. Plans are now under way for an improved collimator with tungsten partitions which if successful will greatly improve both the luminosity and the angular discrimination.

Some skepticism has been expressed by one European physicist as to our "opinion" that our collimator has nothing whatever to do with the spectral resolving power of the instrument. Such doubts are easily answered for this is not a matter of opinion but of readily measurable fact. The spectral resolving power, which comes uniquely from the excellence of focusing of the atomic lattice planes of the curved quartz crystal, is easily calculated and reduced to angular measure from the observed spectral widths of the gamma-ray lines. These have an angular width $\Delta\theta$ of the order of 20 seconds of arc, much smaller than the angular discrimination of the collimator partitions which is about eight minutes of arc. In the present spectrometer, the heavy collimator and shielded counter are stationary and all the remaining components move as the spectrum is explored. The mechanical design of the spectrometer is such that the source can explore the different wavelength locations

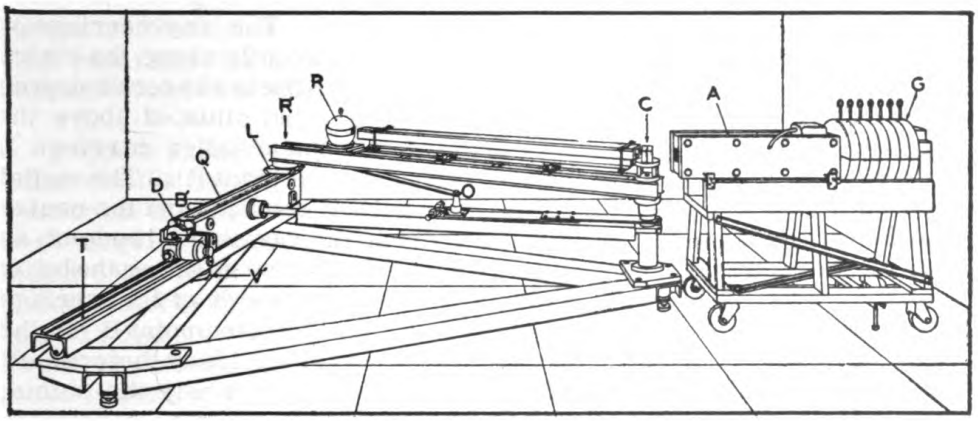

Figure 3. Perspective line drawing of curved crystal gamma-ray spectrometer. A rough idea of the scale can be formed by recalling that the source (in its shielded holder) at R is two meters distant from the curved crystal at C. A is the lead collimator in its steel supporting sheath. G is the heavy lead shielding surrounding the multicellular Geiger counter. R is the shielded source mounted on the sliding carriage which is maintained on the focal circle by the radius bar pivoted at O on the lower beam. The crystal table at C is rigidly connected to the lower beam by an axle while the upper beam turns freely and independently of these on a cone bearing on this axle. Its weight is supported by ball thrust bearings. Where corresponding parts or points are designated the same letters are used in Figures 2 and 3. The instrument is here shown at one extreme of its travel corresponding to the position for a setting of about 500 x.u. The wavelength drum D, the revolution counter, and the motor driving the two precision screws can be seen at the end of carriage Q.

on the focal circle and at the same time, the focal circle and crystal are turned at the appropriate rate to maintain the outgoing selectively reflected divergent beam always in accurate alignment with the (stationary) divergent collimator partitions. The mechanical feeds which determine the motion of the source on the focal circle (relative to the crystal and its β-point) are so designed that the motion of carriage L (Figures 2 and 3) relative to carriage Q (by means of a very accurate screw drive) is strictly proportional to the sine of the Bragg angle θ and hence, (because of the Bragg law) is strictly proportional to the wavelength of the radiation selectively reflected at each setting. The carriage Q runs on a rigid track bed, T, which is pivoted so as to swing about a point V' fixed on the frame of the machine. The two major instrument beams CR' and CB' each pivot independently about C. The lower beam CB', which carries, about midway of its length, the defining pivot O of the focal circle, has the crystal clamp (on a small circular table at C) rigidly attached to it (the beam CB') by means of a vertical axle which passes up through the bearing of the upper beam CR'. The focal circle (dotted in Figure 2) is swept out by a radius bar OR pivoted at O and linked to the source R. This latter is contained in a heavy spherical lead shield which is free to travel a short distance longitudinally along the beam CR' on a carriage and ball-bearing ways. Thus, the focal circle, the focusing crystal, and the beam CB' form one rigid (though mobile) system of reference and beam CR' which carries the source at R (constrained always to lie on the focal circle by the radius bar OR) forms an independent system. As the spectrum is explored, the upper beam CR' moves at twice the angular velocity of the lower beam CB' so as to maintain the direction of the reflected radiation invariable. This is accomplished by the system of a pivoted track T and two carriages Q and L situated one on top of the other. The long carriage Q contains two precision right-hand screws, one directly above the other, geared to turn at equal rates in opposite senses. The lower screw drives the carriage Q along the track T by means of a nut situated above the pivot V' of track T. The upper screw drives the smaller carriage L relative to Q by means of a nut situated below the pivot R'. The radial distances CR' and CV' are at all times equal and constant and the center line of the lower beam CB' therefore forms the variable altitude of an isosceles triangle CR'V'. A cylindrical steel shaft terminating the beam CB' passes through two ball-bearing slides on either side of the carriage Q so as to permit the change in the length CB. Thus, the point B (on the center line of beam CB') remains always exactly midway between R' and V'. The center point of travel of the carriages where the points, R', B, and V' are in the same vertical line is the point of zero wavelength setting. This geometry is clearly such that the travel of the upper screw, which determines the distance BL, is proportional to the sine of the Bragg angle θ so that rotation of this screw as read on the drum D gives a strictly linear scale of wavelengths. It is also clear how precision wavelength settings on the same screw can be made for reflections from either side of the atomic planes in the quartz crystal. The positions in which two such settings might be made are shown schematically by the dotted and full lines, respectively, in Figure 2. In this figure the Bragg angle is, of course, greatly exaggerated.

This feature permits exploration of the spectrum from the position for reflection of a given wavelength on one side of the crystal planes right through the zero wavelength point (point β on the focal circle) over to the point of reflection of the same wavelength from the other side of

the crystal planes all with one and the same precision screw whose displacements are strictly linear with the wavelength selected. This is of great importance. It permits the wavelengths to be accurately determined by measuring the amount of screw rotation required to go from the gamma-ray line reflection point on one side to the corresponding gamma-ray line reflection point on the other side of the β-point. It also has the advantage that it places no mechanical limit on the smallest Bragg angle (and hence the smallest wavelength) that can be measured. The limit fixed by the aforementioned leakage of the direct beam through the collimator is thus the only restriction limiting the shortest measurable wavelength. Another advantage in this mechanical design is that the source can be brought into exact alignment with the collimator and counter so that the intensity of the direct beam (after attenuation by absorbers) can also be measured and the direct transmission characteristic of the collimator studied (by displacement of the source in this region).

In Figure 3, a graduated drum at D can be seen. This is attached to the principle wavelength screw in the carriage Q and the instrument has been so designed that one rotation of this drum is very closely equal to one milliangstrom. The drum rotation can be divided into 1000 parts by a scale and vernier. The exact conversion factor between readings on this drum and true milliangstroms has been determined to six significant figures by measuring accurately known X-ray wavelengths[5] (of the tungsten K-spectrum) on this same screw scale. (With this in mind the two-meter spectrometer has been designed from the start with a more than sufficient range of screw displacements to include these much longer wavelength measurements in the X-ray region.) The accurate uniformity of the pitch of the screw has been carefully checked by comparator methods and there are also certain very satisfactory internal evidences[6] of its reliability.

Space hardly permits detailed description of the all-important multicellular Geiger counter[7] with which the gamma-ray intensities are measured. Briefly, the counter consists of a gas-tight metal box somewhat larger in cross-section than the gamma-ray beam and about eight inches long filled with thin transverse metal septa (some 30 in number in our latest examples). Fine longitudinal wires passing through 3/8" holes in these septa are held at about 1200 volts positive potential relative to the latter. About one percent of the gamma-ray beam traversing these septa successively is absorbed in each one and photo-, Compton, and "pair" electrons are ejected into the intervening spaces. The resulting ions formed in the mixture of argon and petroleum ether which fills the counter are drawn into the strong electric fields surrounding the anode wires and produce discharges which register (through amplifiers and scaling circuits) as "counts." The counter must be thoroughly shielded from the background of "local" gamma radiation (radioactively in walls, building materials, air, ground and elsewhere) and also from cosmic rays. Four-inch-thick lead shielding serves for the former but is, of course, useless for fast cosmic ray particles. To reduce the background caused by these latter the main multicellular counter is surrounded (in our latest design on all four of its lateral sides) with a battery of 24 "protective anticoincidence" counters. Cosmic ray particles when they pass through these protective counters trigger circuits which prevent the count they might otherwise occasion in the main counter from being recorded. The gamma-ray beam does not traverse

these protective counters and the resolving time and the counting rates are such that it is easy to show that a negligible fraction of gamma ray counts is lost by accidental coincidences.

The gamma-ray lines are plotted by exploring the spectrum in small steps and recording the counting rate associated with the diffracted beam at each setting. In the neighborhood of a line when good detail is desired settings can be easily made every 0.02 of a milliangstrom. These measurements are then plotted as a curve with wavelength screw settings as abscissa and counting rates as ordinates and the spectrum lines show up clearly as peaks on this curve. Three such curves (taken from published papers[3,8] are shown herewith in Figures 4, 5 and 6, the captions being self-explanatory. A very large part of the distance traversed by the screw carriage L of Figures 2 and 3 in going between the left- and right-hand counterparts of the lines must necessarily be omitted on the abscissa scales of Figures 4 and 5 in order to show them in reasonable compass. In Figure 4, for instance, if the entire center part of the wavelength scale were shown, the lines would be separated by more than eight times the separation they have in this illustration.

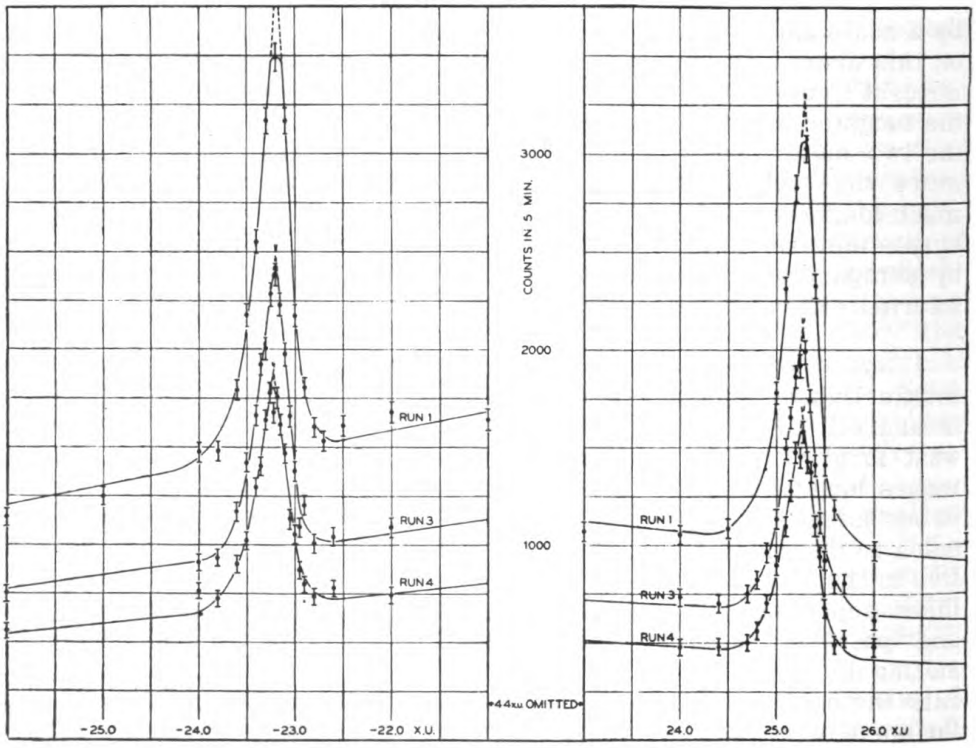

Figure 4. Spectral curves of the annihilation radiation as reflected to left and to right of the (310) planes of quartz. These curves have been corrected for the decay of the source during the time of each run as explained in the text but the background from scattering of the direct beam in the collimator has not been subtracted. The ordinates of all three curves refer to the same zero at the bottom of the chart. To save space, many background observations taken at considerable distance from the lines (for the purpose of establishing the background profile with greater certainty) are here omitted. The zero of the wavelength drum scale is not exactly centered on the point of zero wavelength of the instrument so that the wavelength determinations are calculated by taking half the difference between the right- and left-hand readings.

As may well be guessed, taking readings of the Geiger counting rate and making settings on the wavelength screw is a tedious business. To make matters worse, when short-lived expensive sources are studied this tedious work must be scheduled for 24 hours per day performance. To circumvent these difficulties, a robot mechanism is now nearly completed which does all this automatically according to a schedule of wavelength settings which can be completely predetermined for a run lasting 48 hours, if necessary. The schedule need not call for uniform spacing of the wavelength settings. This robot prints on a paper strip the number of counts, the time of day, and the spectrometer setting for each point observed. The time intervals over which counts are accumulated is widely adjustable, and the counts accumulated at the end of

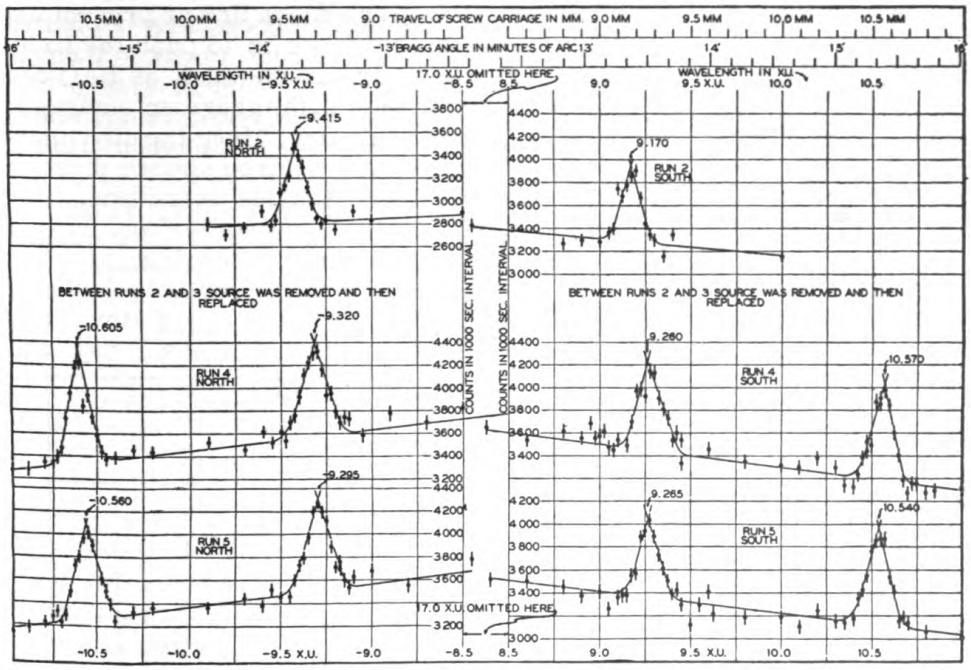

Figure 5. Three spectral curves showing the 1.1 and 1.3 Mev lines from Co^{60} as reflected from both sides of the planes of the curved crystal. Run 1 (not shown) was exploratory, to locate the 1.3 Mev line. Run 2 shows the 1.3 Mev line while runs 4 and 5 show both 1.1 and 1.3 Mev lines. The source was removed from its holder after run 2 to permit temporary study of another much shorter-lived source which had just been received, Ta^{182}. The Co^{60} source was then replaced in the instrument and another exploratory run (run 3, not shown) was made to relocate the lines. This removal and replacement of the source accounts for the slight shift in the wavelength position of the lines on the instrument scale, a shift corresponding to a displacement of the source in its holder of about 0.07 mm. The separation however between the respective reflections from the two sides of the crystal planes (which is used as the measure of the wavelength) is very reproducible from run to run. Scales at the top show the Bragg angle in minutes of arc and displacements of the screw carriage L (relative to Q) in millimeters. The wavelength scales shown are in nominal milliangstroms. Their differences are converted to true milliangstroms (10^{-11} cm) by multiplying by 1.00179, the factor determined by the X-ray calibration. More than three times the total width of this figure is omitted from the wavelength scale in the space at the counter. The ordinate scales are indicated by numbers giving the total number of counts accumulated at each setting in a 1,000 sec time interval.

as many as 10 equal sub intervals for each spectrometer setting can be recorded as a check on the good (statistical) behavior of the counter. We believe that the robot mechanism will give more reliable results than a human observer subject to inevitable fatigue and boredom.

A heavy program of precision wavelength measurements is projected including a complete precision exploration of the gamma-ray spectrum from radium in equilibrium with its daughter products. Well over 25 different radioisotopes available from Oak Ridge are planned for study. One of these alone, Ta^{182}, has recently been reported[9] to have as many as 30 different gamma-ray lines. The improvements constantly being made here in the fundamental technique of focusing crystal spectrometry as regards luminosity and resolving power will undoubtedly greatly increase this already large program of work by making feasible for inclusion in it an expanding list of sources which are at present too weak or expensive. One of the present objectives is to push the technique to the point where cyclotron activated sources (such as Be^7) can be studied at costs within reason. Another part of the program envisages the study of sources activated by neutron capture. Here the life times of the excited states are so short that a strong neutron source must be available at the spectrometer to maintain continuous activation. Designs for a new crystal spectrometer with stationary source and moving detector are now under consideration for this application. A great advantage of the neutron capture activation is that the unstable isotopes so formed are activated to energy levels of the order of six Mev above their ground states so that a much richer supply of lines and energy

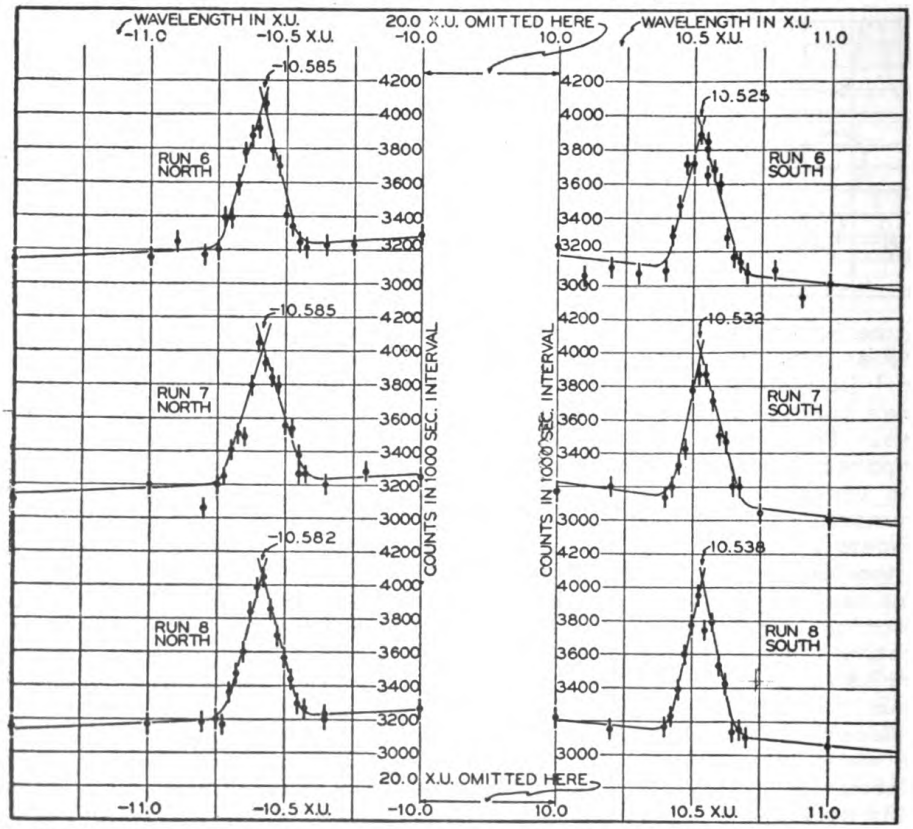

Figure 6. Three more runs taken on the Co^{60} 1.1 Mev line alone. Here the source was not disturbed and this gives a good idea of the reproducibility of the measurements, when the instrument is at its best. The scales on this figure are similar in all respects to those of Figure 5.

levels can be studied. Finally, construction of a magnetic β-ray spectrometer designed to have unprecedented resolving power for its luminosity and also, very high absolute precision is now well advanced, and this device, it is hoped, will become an important companion instrument complementing the two-meter focusing curved crystal instrument in many ways which space here does not permit describing.

Enough has been said to show that this work in precision standardization of nuclear gamma radiation wavelengths and nuclear energy levels bids fair to develop into an important major project of nuclear precision spectroscopic standardization. More important than this however, in the opinion of the writer, is the possibility, which at present of course can be no more than a hope, that with the accumulation of a large supply of highly accurate numerical wavelength and energy measurements on the excited levels of nuclei, numerical regularities can be discovered which will lead to the unravelling of the mysteries of nuclear mechanics and nuclear forces. This was largely the way in which the mechanics of the outer electronic structure of the atom was finally brought to systematic understanding. Some theoretical physicists take the stand that the nucleus is far too complicated a thing to be unravelled by such a procedure and that the answers must come from the study of even more elementary particles than nuclei such as mesons. To anticipate in this way just what facts will or will not be useful before the facts have been gathered seems unwise. It certainly cannot involve risk, or be anything but pure gain, to have accurate data concerning the structures one is trying to understand. The financial support this project has received by the joint cooperation of ONR and the AEC has greatly facilitated our progress in these directions.

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On the Naval Research Reserve

Pasadena Unit Wins Trophy

The Commandant's Trophy, awarded each fiscal year to the outstanding Volunteer Research Reserve Unit in the Eleventh Naval District, was presented to VRR Unit 11-2, Pasadena, at their regular monthly meeting on February 16 at the U. S. Naval Reserve Training Center. CAPT Thomas C. Thomas, USN, Commanding Officer, Office of Naval Research, Pasadena Branch, made the presentation.

From left to right in the above photograph are LT H. D. Strong, present Commanding Officer of the Unit; LCDR John H. Biggar, Jr., Commanding Officer during the award period; and CAPT Thomas C. Thomas, USN.

VRR Unit 4-3 Cooperates in Scientific Personnel Tests

Pittsburgh Research Reserve Unit 4-3 recently assisted in the review of the technical content of certain test items concerning scientific personnel in connection with an ONR contract sponsored by the Manpower Branch, Human Resources Division, ONR. The project was concerned with the development of an aptitude test for the selection of scientific personnel. Louis J. Sparvero, ONR Resident Representative at Pittsburgh and member of the Pittsburgh Unit, secured the cooperation of 4-3 members to serve as critics of the test; other critics were drawn from scientific personnel at NRL and NOL, and from the University of Pittsburgh faculty.

One of the objectives of the project was to develop a test that would be applicable to the selection of candidates for advanced training in natural science and engineering, as well as to the selection of junior professional workers in research laboratories. It was designed as a test of potentiality for, rather than proficiency in, research work. Each test item was developed as an attempt to predict a specific critical behavior identified in a preceding study concerning the critical requirements for research personnel.

The project resulted in the development of a test of approximately 170 items organized in three groups or subtests. These items are intended to predict (1) job performances related to formulating problems and hypotheses and planning and designing the investigation; (2) behaviors related to conducting the investigation and interpreting research results; and (3) behaviors related to preparing reports, administering research projects, and accepting organizational and personal responsibility.

Sample items illustrative of those contained in the test as well as all details of the work are presented in a report entitled "The Development of a Test for Selecting Research Personnel" issued by the American Institute for Research at Pittsburgh in January 1950.

Princeton Unit Presents Certificate

Princeton VRR Unit 4-1 recently presented a certificate of appreciation to Miss Joan D. Spokes for her assistance in the operation and administration of the unit. Above, left to right: CDR H. Gordon Dyke, the Unit's new Commanding Officer; Rear Admiral Luis de Florez, founder of the Special Devices Center; LCDR Frank A. Parker; Miss Spokes, who is employed at the Princeton University Aeronautical Engineering Laboratory, and LCDR Paul Busse, the Unit's past commander.

Officially Activated
Volunteer Research Reserve Units

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
1-1	2000, 1st & 3rd Mon. Auditorium, Navy Bldg. 60 495 Summer St. Boston, Mass.	CAPT J. W. Hammond, USNR ONR Branch Office 495 Summer St. Boston, Mass.
1-2	1930, 2nd & 4th Tues. USNROTC Bldg. Brown University Providence, R. I.	CDR Carl Pfaffman, USNR (ONC) Psychology Department Brown University Providence, R. I.
1-2 Sub-Unit	1600, 1st & 3rd Tues. Ranger Hall, Rm. 305 Rhode Island State College Kingston, R. I.	CDR Charles J. Fish, USNR (ONC) Narragansett Marine Lab. Kingston, R. I.
1-2 Sub-Unit	2000, 1st & 3rd Tues. Oceanic Institute Woods Hole, Mass.	LCDR F. C. Ryder, USNR (ONC) County Road Woods Hole, Mass.
1-3	1900, 1st & 3rd Tues. University of Massachusetts Amherst, Mass.	LCDR E. D. Emerson, USNR Dept. of Mech. Engineering University of Massachusetts Amherst, Mass.
1-4	2000, 1st & 3rd Tues. Coburn Hall University of Maine Orono, Maine	LT Francis J. Sullivan, USNR 25 Myrtle St. Orono, Maine
1-5	2000, 1st & 3rd Mon. Stratton Hall Worcester Polytechnic Inst. Worcester, Mass.	CDR Emerson A. Wiggin, USNR 25 Bay State Rd. Worcester 6, Mass.
1-6	1930, 1st & 3rd Mon. Smith Hall, Rm. 104 Lowell Textile Institute Lowell, Mass.	LTJG Joseph B. Masaschi, USNR 3 Hilltop Terrace Chelmsford, Mass.
1-7	2000, 1st & 3rd Tues. Wentworth Hall Dartmouth College Hanover, N. H.	CDR George Z. Dimitroff, USNR Shattuck Observatory Dartmouth College Hanover 30, N. H.
3-1	1930, Alt. Thurs. (17 Nov.) Auditorium Cornell Univ. Med. College 1300 York Ave. New York 21, N. Y.	CDR J. D. Hardy, USNR Cornell Univ. Med. College 1300 York Ave. New York 21, N. Y.
3-2	1930, 2nd & 4th Mon. Special Devices Center Engineering Bldg. Port Washington Long Island, N. Y.	CDR L. E. Yoder, USNR Special Devices Center Port Washington Long Island, N. Y.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
3-3	2000, 1st & 3rd Mon. USNRTC & MCRTC 3 Porter Ave. Buffalo, N. Y.	LCDR Ralph Bloom Jr., USNR USNRTC & MCRTC 3 Porter Ave. Buffalo, N. Y.
3-4	1930, 1st & 3rd Tues. USNRTC & MCRTC 900 East Main St. Rochester, N. Y.	CDR Henry C. Sheve, USNR USNRTC & MCRTC 900 East Main St. Rochester 7, N. Y.
3-5	1930, 2nd & 4th Thurs. USNRTC Fort Nathan Hale Park New Haven, Conn.	CDR D. S. Howell, USNR USNRTC Fort Nathan Hale Park New Haven 13, Conn.
3-6	2000, 2nd & 4th Mon. USNRTC Syracuse (Liverpool), N. Y.	LT H. W. Isleib, USNR USNRTC Syracuse (Liverpool), N. Y.
3-7	2000, 2nd & 4th Thurs. USNRTC Scotia, N. Y.	LCDR Edward E. Vezey, USNR USNRTC Scotia, N. Y.
3-8	247 Park Avenue New York City, N. Y.	LCDR M. Jennings von der Heyde, USNR c/o Douglas T. Johnson & Co., Inc. 247 Park Avenue New York, N. Y.
3-9	2000, 1st & 3rd Wed. Brookhaven National Lab. Upton, Long Island, N. Y.	CDR John S. Medd, USNR Brookhaven National Lab. Upton, Long Island, N. Y.
4-1	2000, 1st & 3rd Wed. Nassau Tavern Princeton, N. J.	CDR Herbert G. Dyke, USNR 21 Lilac Lane Princeton, N. J.
4-2	1930, Alt. Thurs. Franklin Institute 20th St. & Parkway Philadelphia, Pa.	LCDR William G. Amey, USNR Electronics Section Franklin Institute 20th St. & Parkway Philadelphia 3, Pa.
4-3	2000, 2nd & 4th Thurs. 303 Thaw Hall University of Pittsburgh Pittsburgh, Pa.	CDR Neil D. Cole, USNR Office of Naval Research University of Pittsburgh 303 Thaw Hall Pittsburgh, Pa.
4-4	1930, 1st & 3rd Wed. Elec. Eng. Bldg., Rm. 110 Pennsylvania State College College Station, Pa.	CDR E. R. Queer, USNR c/o Engineering Experiment Sta. Pennsylvania State College College Station, Pa.
4-5	2000, Alt. Mon. (21 Nov.) USNRTC Foot of Madison St. Wilmington, Del.	LCDR Donald MacCreary, USNR USNRTC Foot of Madison St. Wilmington, Del.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
4-6	USNRTC Bethlehem, Pa.	LCDR George W. Petrie III, USNR USNRTC Bethlehem, Pa.
W Battalion	2000, 3rd Thurs. Auditorium, Interior Dept., Washington, D. C.	CDR Fred C. Wiesner, USNR Navy Dept., Bldg. T-3, Rm. 2714 ONR, Code 429; RE 7400, Ext. 5755 Washington, D. C.
W-1	2000, 1st Thurs. Navy Dept., Bldg. T-3, Rm. 1515 Washington, D. C.	CDR W. M. Richardson, USNR Navy Dept., Bldg. T-3, Rm. 2602 ONR, Code 427; RE 7400, Ext. 2135 Washington, D. C.
W-2	1900, 1st Thurs. NRL Auditorium, Bldg. 8 Washington, D. C.	LCDR H. A. Tanner, USNR Naval Research Laboratory Bldg. 8, Rm. 152 NRL, Code 3210; JO 3-6600, Ext. 256 Washington 20, D. C.
W-4	2000, 2nd & 4th Wed. Navy Dept., Bldg. T-3, Rm. 1803 Washington, D. C.	LCDR Lawrence Gardiner, USNR Atomic Energy Commission Public Health Bldg. Rm. 102 ST 8000, Ext. 233 Washington, D. C.
W-5	2000, 2nd & 4th Thurs. NMRI Conference Rm. Bethesda, Md.	CDR Barry G. King, USNR 8517 Bradmoor Drive OL 7097 (Office, ST 9200, Ext. 4058) Bethesda, Md.
5-1	1930, 1st and 3rd Wed. Rouss Physics Lab. University of Virginia Charlottesville, Va.	LTJG Gilmer T. Fitchett, USNR Cobb Chemistry Lab. University of Virginia Charlottesville, Va.
5-2	1915, 1st and 3rd Fri. Virginia Polytechnic Institute Bldg. 364 Blacksburg, Va.	LCDR E. D. Harrison, USNR P. O. Box 575 Blacksburg, Va.
5-3	2000, each Tues. Camp Detrick Frederick, Md.	CAPT LeRoy D. Fothergill, USNR Camp Detrick Frederick, Md.
5-4	2000, 2nd & 4th Tues. Maryland Hall, Rm. 217 Johns Hopkins University Baltimore, Md.	LCDR Francis J. Taylor, Jr., USNR 401 Oak Forest Ave. Baltimore 28, Md.
6-1	2000, Alt. Thurs. Physics Bldg., Rm. 103 Georgia Institute of Technology Atlanta, Ga.	CDR J. E. Boyd, USNR Physics Bldg. Georgia Institute of Technology Atlanta, Ga.
6-2	1915, 1st & 3rd Mon. Ross Laboratory, Rm. 204 Alabama Polytechnic Institute Auburn, Ala.	LTJG J. E. Land, USNR Chemistry Department Alabama Polytechnic Institute Auburn, Ala.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
6-3	2nd & 4th Tues. A.E.C. Townsite Oak Ridge National Lab. Oak Ridge, Tenn.	LCDR D. J. Mallon, USNR P. O. Box P Oak Ridge, Tenn.
6-4	1930, 1st & 3rd Tues. Engineering Bldg. University of Florida Gainesville, Fla.	LCDR E. G. Rietz, USNR Chemistry Department University of Florida Gainesville, Fla.
6-5	2000, 1st & 3rd Thurs. USNRTC Gulfport, Miss.	LT V. O. Smallwood, USNR 2412 East Ave. Gulfport, Miss.
6-6	1945, 2nd & 3rd Wed. USNROTC Armory University of North Carolina Chapel Hill, N. C.	LT Robert F. Schenkkan, USNR 103 Stephen St. Chapel Hill, N. C.
6-7	2000, 2nd & 4th Thurs. (Irreg.) Biology Bldg. Duke University Durham, N. C.	LCDR John H. Roberts, USNR 2813 Legion Ave. Durham, N. C.
8-1	1930, 1st & 3rd Tues. USNROTC Bldg. Tulane University New Orleans, La.	LCDR John M. Scott, USNR Chemistry Department Tulane University New Orleans, La.
8-2	2000, 1st & 3rd Wed. Coates Laboratory, Rm. 221 Louisiana State University Baton Rouge, La.	LTJG H. B. Williams, USNR Chemistry Department Louisiana State University Baton Rouge, La.
8-3	1930, 2nd & 4th Mon. PMA Bldg. or Bolton Hall Texas A & M College College Station, Tex.	LCDR Norman F. Rode, USNR Electrical Engineering Dept. Texas A & M College College Station, Tex.
8-4	1930, Alt. Wed. (23 Nov.) USNROTC Bldg. The Rice Institute Houston, Tex.	LCDR L. J. Castellanos, USNR 6513 Rutgers St. Houston, Tex.
8-5	2000, Alt. Tues. & Wed. Chemistry Bldg., Rm. 15 University of Texas Austin, Tex.	LCDR G. H. Ayers, USNR Chemistry Department University of Texas Austin, Tex.
8-6	1930 Last Mon. USNRTC Galveston, Tex.	LTJG C. N. Sechrist, USNR 1235 3rd Ave., North Texas City, Tex.
8-7	2000, 1st & 3rd Wed. USNRTC 1805 South Yale Ave. Albuquerque, N. M.	LCDR Sherman A. Wengerd, USNR P. O. Box 346 Albuquerque, N. M.
8-8	2nd & 4th Wed. Senior High School Bartlesville, Okla.	LCDR E. O. Box, Jr., USNR 1642 Hickory St. Bartlesville, Okla.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
8-8 Sub-Unit	Stillwater, Okla.	LCDR Olan H. Hamilton, USNR 503 Pine St. Stillwater, Okla.
8-9	Room B-117 Los Alamos Scientific Lab. Los Alamos, N. M.	CDR Norris E. Bradbury, USNR P. O. Box 1663 Los Alamos Scientific Lab. Los Alamos, N. M.
9-1	1900, 2nd & 4th Tues. Navy Pier Campus University of Illinois Chicago, Ill.	CDR Charles E. Tweedle, USNR Askania Regulator Co. 240 E. Ontario St. Chicago, Ill.
9-2	1930, 1st & 3rd Mon. Gregory Hall, Rm. 319 University of Illinois Urbana, Ill.	CAPT Chauncey M. Louttit, USNR Psychology Department University of Illinois Urbana, Ill.
9-3	1930, Alt. Wed. Angell Hall, Rm. 18 University of Michigan Ann Arbor, Mich.	CDR Freeman D. Miller, USNR 1912 W. Washington St. Ann Arbor, Mich.
9-4	1930, 2nd & 4th Tues. Old Armory, Rm. 107 Ohio State University Columbus, Ohio	LCDR Karl E. Krill, USNR Engineering Experiment Sta. Ohio State University Columbus, Ohio
9-5	1930, Wed. USNROTC Bldg. Iowa State College Ames, Iowa	LCDR O. C. Kreider, USNR Mathematics Department Iowa State College Ames, Iowa
9-6	1930, 1st Mon. & 3rd Tues. Mechanical Eng. Bldg., Rm. 4 University of Minnesota Minneapolis, Minn.	LCDR J. A. Wise, USNR 220 Aeronautical Eng. Bldg. University of Minnesota Minneapolis, Minn.
9-7	1930, 2nd & 4th Thurs. Stanley Coulter Hall, Rm. 111 Purdue University Lafayette, Ind.	LT L. M. Baker, USNR Psychology Department Purdue University Lafayette, Ind.
9-8	2000, 1st & 3rd Thurs. Crew Hall, Rm. 101 Washington University St. Louis, Mo.	CDR R. M. Varney, USNR Physics Department Washington University St. Louis, Mo.
9-8 Sub-Unit	Louisiana, Mo.	LT Herbert B. Sachs, USNR Synthetic Fuels Plant P. O. Box 316 Louisiana, Mo.
9-9	1930, 1st & 3rd Thurs. Mechanics Hall, Rm. 204 Missouri School of Mines & Metallurgy Rolla, Mo.	CDR R. A. Cooley, USNR Missouri School of Mines & Metallurgy Rolla, Mo.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
9-11	2000, 1st & 3rd Mon. USNRTC 1089 E. Ninth St. Cleveland, Ohio	LCDR Viktor Schreckengost, USNR 2366 Noble Road Cleveland 21, Ohio
9-12	1930, 2nd & 4th Thurs. Botany Bldg. Annex, Rm. 2 Colorado A & M College Ft. Collins, Colo.	LTJG W. D. Thomas, USNR Botany & Plant Pathology Dept. Colorado A & M College Ft. Collins, Colo.
9-12 Sub-Unit	Boulder, Colo.	LTJG George J. Maler, USNR Dept. of Electrical Eng. University of Colorado Boulder, Colo.
9-13	1930, Wed. USNRTC 9th & Pleasant Sts. Des Moines, Iowa	LCDR J. R. Maloney, USNR 2920 48th St. Des Moines, Iowa
9-13 Sub-Unit	Iowa City, Iowa	CDR Arthur L. Benton, USNR Psychology Department State University of Iowa Iowa City, Iowa
9-14	1930, Wed. or Thurs. (2/month) USNRTC University of Wisconsin Madison, Wis.	CDR W. B. Sarles, USNR 310 Agricultural Hall University of Wisconsin Madison 6, Wis.
9-14 Sub-Unit	Appleton, Wis.	
9-15	1900, 1st & 3rd Thurs. Conference Rm. Dow Chem. Co., Pers. Bldg. Midland, Mich.	LTJG D. D. McCollister, USNR 1220 Michigan St. Midland, Mich.
9-16	1900, 2nd & 4th Mon. EE Bldg., Rm. 206 Michigan State College East Lansing, Mich.	LT Elbert S. Churchill, USNR Bacteriology Department Michigan State College East Lansing, Mich.
9-17	1930, 1st & 3rd Mon. Engineering Bldg., Rm. 103 University of Wyoming Laramie, Wyo.	LTJG Fred K. Elder Jr., USNR Physics Department University of Wyoming Laramie, Wyo.
9-18	Dayton, Ohio	LT Nathan L. Wener, USNR 1007 Amherst Pl. Dayton 6, Ohio
11-1	2000, 1st & 3rd Tues. 1030 E. Green St. Pasadena, Calif.	LCDR Frederick P. Dillon, USNR 1030 E. Green St. Pasadena 1, Calif.
11-2	2000, Alt. Thurs. USNRTC Pasadena, Calif.	LT Herbert D. Strong, USNR 3437 Las Palmas Ave. Glendale 8, Calif.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
11-3	2000, Alt. Mon. USNR & MCRTC 851 Chavez Ravine Rd. Los Angeles, Calif.	CDR L. P. Delsasso, USNR Physics Department University of California Los Angeles, Calif.
11-4	2000, 1st & 3rd Wed. USNRTC San Pedro, Calif.	LCDR Myron S. Allen, USNR 3130 East Second St. Long Beach 3, Calif.
11-5	1930, 2nd & 3rd & 4th last Tues. USNRTC San Diego, Calif.	CDR Gifford C. Ewing, USNR 1205 Muirlands Dr. LaJolla, Calif.
12-1	2000, 2nd & 4th Mon. 801 Donahue St. San Francisco, Calif.	CDR J. E. Laurance, USNR ONR Branch Office 801 Donahue St. San Francisco, Calif.
12-2	1945, 2nd & 4th Mon. Donner Laboratory, Rm. 201 University of California Berkeley, Calif.	LCDR Nello Pace, USNR Life Science Bldg., Rm. 2519 University of California Berkeley, Calif.
12-3	2000, 2nd & 4th Wed. Engineering Corner, Rm. 208 Stanford University Stanford, Calif.	CDR L. S. Jacobsen, USNR Mechanical Eng. Dept. Stanford University Stanford, Calif.
12-4	2000, 2nd & 4th Thurs. McLane Hall, Rm. M-103 Fresno, Calif.	CDR R. A. Jack, USNR Physics Department Fresno State College Fresno 2, Calif.
12-5	1930, 2nd & 4th Wed. LeConte Hall, Rm. 208 University of California Berkeley, Calif.	CDR C. F. Garland, USNR Div. of Engineering Design University of California Berkeley, Calif.
12-6	1945, 2nd Mon. Tower Rm., Animal Science Bldg. University of California Davis, Calif.	LT Arthur H. Smith, USNR Div. of Animal Husbandry University of California Davis, Calif.
13-1	1930, 2nd & 4th Mon. Health Science Bldg., Rm. G-516 University of Washington Seattle, Wash.	CDR H. S. Bennett, USNR Anatomy Department School of Medicine University of Washington Seattle, Wash.
13-2	1900, 2nd & 4th Tues. American Legion Hall Richland, Wash.	LT W. W. Gonder, USNR 95 Atkins Ave. Richland, Wash.
13-3	1930, 2nd & 4th Mon. YMCA Pullman, Wash.	LCDR W. G. Gnaedinger, USNR Community College Serv. State College of Washington Pullman, Wash.
13-4	1930, 1st & 3rd Mon. Swan Island Portland, Ore.	LCDR Richard F. Stevens USNR 811 N.E. Oregon St. Portland, Ore.

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Designation	Time and Place of Meeting	Commanding Officer and Mail Address
13-5	Oregon State College Corvallis, Ore.	LCDR Albert V. Logan, USNR Chemistry Department Oregon State College Corvallis, Ore.

Units in Process of Being Organized and Activated

1-	Harvard Biological Unit Cambridge, Mass.	
1-	Springfield, Mass.	
3-	New London, Conn.	LCDR Birk, USNR
9-	Argonne Nat. Lab. Chicago, Ill.	
11-	2000, 1st & 3rd Wed. USNRTC Phoenix, Ariz.	LCDR J. A. Benedict, USNR 929 McAllister Ave. Tempe, Ariz.
11-	2000, 2nd & 4th Thurs. USNRTC Tucson, Ariz.	LCDR Charles Tribolet, USNR c/o Graduate Mgr's Office University of Arizona Tucson, Ariz.
11-	Pomona College or Claremont College Pomona, Calif.	LCDR L. M. Dean, USNR
11-	USNRTC Bakersfield, Calif.	
11-	Las Cruces, N. M.	LT Calvin I. Ricketts, USNR Box 548 State College, N. M.
12- (S.D.)	San Francisco, Calif.	
13-	Moscow, Idaho	
13-	Hamlin, Mont.