● OCTOBER 1949

RESEARCH REVIEWS

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- ON THE NAVAL RESEARCH RESERVE

OFFICE OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

NAVEXOS P-510

COVER PHOTO: Fleet Admiral Chester W. Nimitz recounted the story of victory in the Pacific to members of Research Reserve Units 3-1 and 3-2 at a recent joint meeting at the Special Devices Center, Long Island, New York. The war-time Commander in Chief of the Pacific Fleet described the Pacific action from the days before Pearl Harbor to the signing of the Japanese surrender document aboard the USS MISSOURI in Tokyo Bay, September 2, 1945.

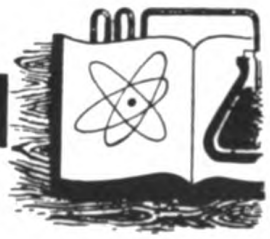
Admiral Nimitz, now United Nations Plebescite Administrator Designate for Jammu and Kashmir, told how the Japanese planned and rehearsed in detail the Pearl Harbor attack, and then failed to follow up their initial success. The fact that the fleet was caught in Pearl Harbor was actually a "blessing in disguise" according to the Admiral, for personnel losses would have been 10 times as great had the modern Japanese vessels, with a speed at least two knots greater than ours, met our fleet at sea.

The victorious action was a "three-service operation," the Army, Navy, and Air Force working shoulder to shoulder, said the Admiral.

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 best utilization of the nation's scientific and engineering talent is a matter of growing importance to the Department of Defense. Results of World War II which further emphasized the significant role of the scientist and the critical need for an integrated research program, also brought increasing recognition of the need for a system which would permit the proper classification and assignment of personnel during an emergency. It is no overstatement to say that one miscast specialist might well mean one new idea that goes unborn, one new development or innovation that goes unmade, one new test that goes untried.

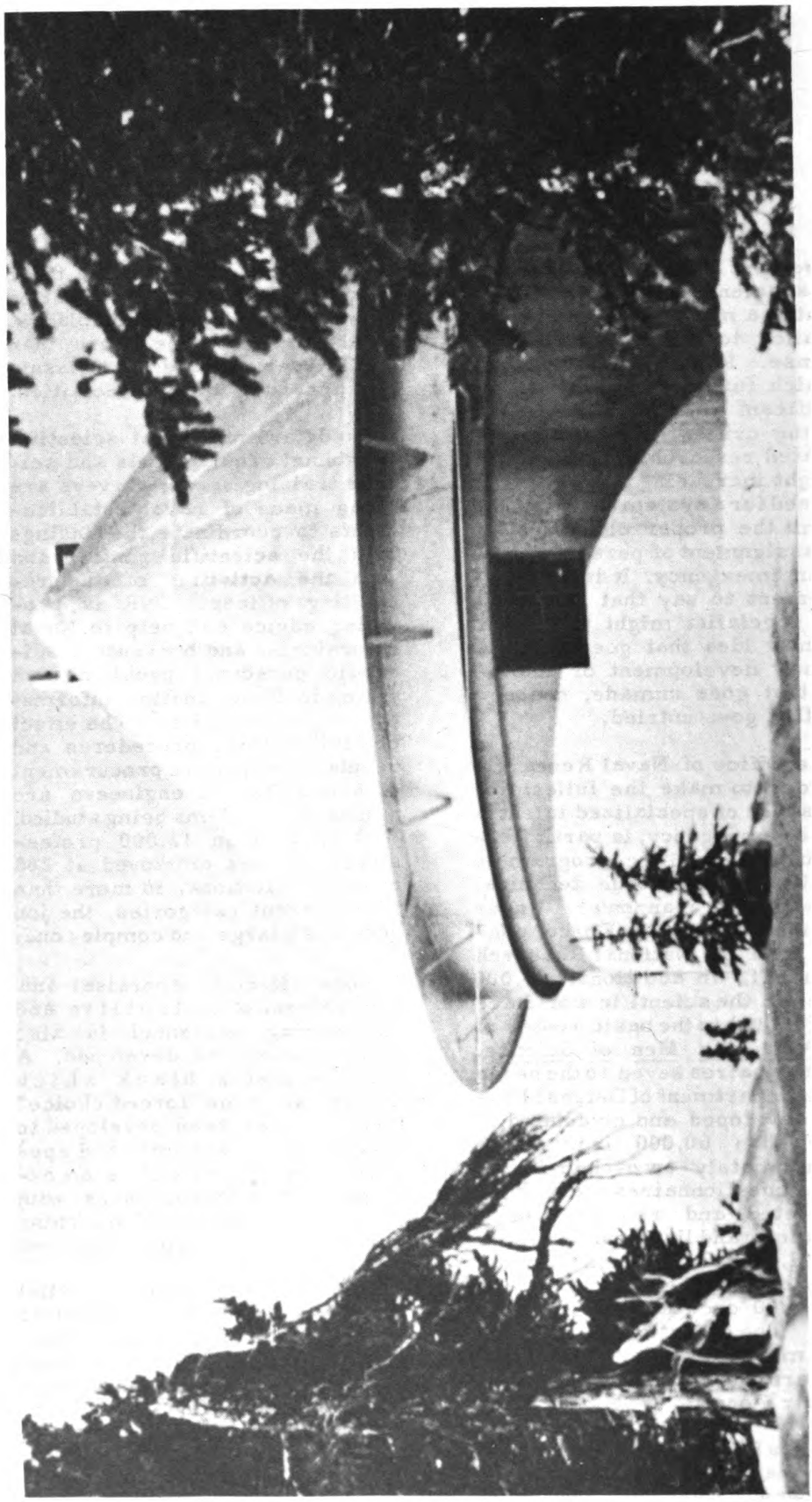
The Office of Naval Research, in order to make the fullest and wisest use of specialized talent in time of emergency, is participating in a specific program to identify and catalogue technical and scientific manpower. Under an Army-Navy-Air Force contract with the National Research Council, an additional 45,000 names in the scientific world are being added to the basic roster of the American Men of Science. Questionnaires keyed to the needs of the Department of Defense have been developed and circulated to more than 60,000 individuals. Approximately two-thirds of these questionnaires have been completed and returned for a breakdown and listing under first, second, and third fields of competence, with the fields covering some 600 occupational specialties. The questionnaires have been microfilmed and complete sets furnished to the Army, Navy, and Air Force.

ONR's Research Reserve office also has a classification plan underway. Reserves are being card-indexed according to their specialties through information obtained from application blanks. At the present time more than 1500 Reserves have been classified according to 162 specialties.

To determine Naval scientific personnel requirements and science training needs, surveys are being made of naval establishments to coordinate the findings with the scientific rosters and with the activities of the recruiting offices. ONR is providing advice and help to Naval laboratories and bureaus on scientific personnel problems and aiding in disseminating information on these studies. The effect of Civil Service procedures and regulations upon the procurement of scientists and engineers are among the problems being studied. With more than 12,000 professional persons employed at 268 naval installations, in more than 120 different categories, the job becomes a large and complex one.

More effective appraisal and recruitment of scientific and engineering personnel is also being studied and developed. A recommendation blank which makes use of the "forced choice" technique has been developed to produce more accurate and specific information, and is an example of the thoroughness with which the problem of matching men to jobs is being attacked.

The foregoing is only a partial picture of a realistic approach to efficient placement of specialized personnel and the proper evaluation of needs and supplies of manpower. Such efforts can mean the conservation and most effective use of the skills of America's specially trained citizens.



Early November photograph of the High Altitude Observatory at Climax, Fremont Pass, Colorado, taken from the south.

New Studies of the Sun

Donald H. Menzel and Armin Deutsch
Harvard College Observatory

Radio communication beyond the visible horizon is possible only because the air is strongly ionized in several layers near the top of the atmosphere. A radio wave impinging from below on one of these high, electrified layers, behaves very much like a light wave falling on a mirror. The wave is reflected back towards the surface of the earth. Too often, however, these natural radio mirrors lose their lustre. The radio signals arrive, weak and confused, at their destinations. Sometimes the reflection at the ionosphere fails altogether, and radio communication over half the surface of the earth comes to an abrupt, dead stop.

Probably men will never be able to control the electrical properties of the atmosphere at heights of over 100 miles, and thus insure the proper functioning of the ionospheric mirrors essential to long-distance radio communication. But if we cannot hope to control the behavior of the ionosphere, we can at least try to predict it. The ability to know in advance the reliability of our radio communications channels becomes of first importance in time of war or peace.

Only the daylit half of the earth experiences the sudden, total radio fade-outs. This fact points squarely to the sun as the culprit. Something that happens in that vast sphere of white-hot gas, 93 million miles away, causes the interruptions of radio communication here on earth. But ordinary astronomical observations of the sun before and during a radio fade-out reveal nothing unusual. The conventional kind of telescope discloses the dead-white face of the sun, perhaps marked with one or more dark spots. No unusual activity appears.

But there is more to the sun than meets the eye, even through the most powerful of conventional telescopes. From the measurements of the intensity and color of sunlight, astronomers find that the solar surface possesses a temperature of about 6000° Centigrade. We readily calculate that the sun is gaseous throughout. The external semi-transparent gaseous fringe we call the "atmosphere." We cannot see all the

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Professor Menzel was director of the Harvard - MIT eclipse expedition to the USSR (Siberia) in 1936 and the US-British eclipse expedition to Canada in 1945. He is the author of a number of books and articles including Stars and Planets, Story of the Starry Universe, and a new book Our Sun which has just been published by the Harvard University Press.

Armin J. Deutsch, is an instructor of astronomy at Harvard University. He received his S.B. from the University of Arizona in 1940 and his Ph.D. in astrophysics from the University of Chicago in 1946. He was associated with Perkins Observatory, Delaware, Ohio before joining the faculty at Harvard.

way down to the surface of the sun at the bottom of the atmosphere, because there is no surface and no bottom. The gases become opaque at a small fraction of the distance to the center. The apparent surface of the sun - the photosphere - lies at the level where the gas just becomes opaque. Almost all the light we receive from the sun is emitted at this level. The light from lower levels cannot directly penetrate the higher levels; the higher levels, where the gas is very tenuous, emit almost no light at all.

Only when the dark bulk of the moon screens from our atmosphere the millionfold brighter light of the photosphere, at times of total solar eclipse, can we detect the faint radiation from the sun's upper atmosphere. And what a revelation! The weak light we then see discloses an "upper atmosphere" of the sun extending hundreds of thousands of miles into space! This faint extension comprises the sun's corona: a vast mysterious envelope of gas, so thin and transparent that we can look right through it. It shines so weakly compared with the brilliant photosphere that, without a total solar eclipse, we never should have discovered it. But total eclipses are few and far between. Their maximum duration is about seven minutes at best.

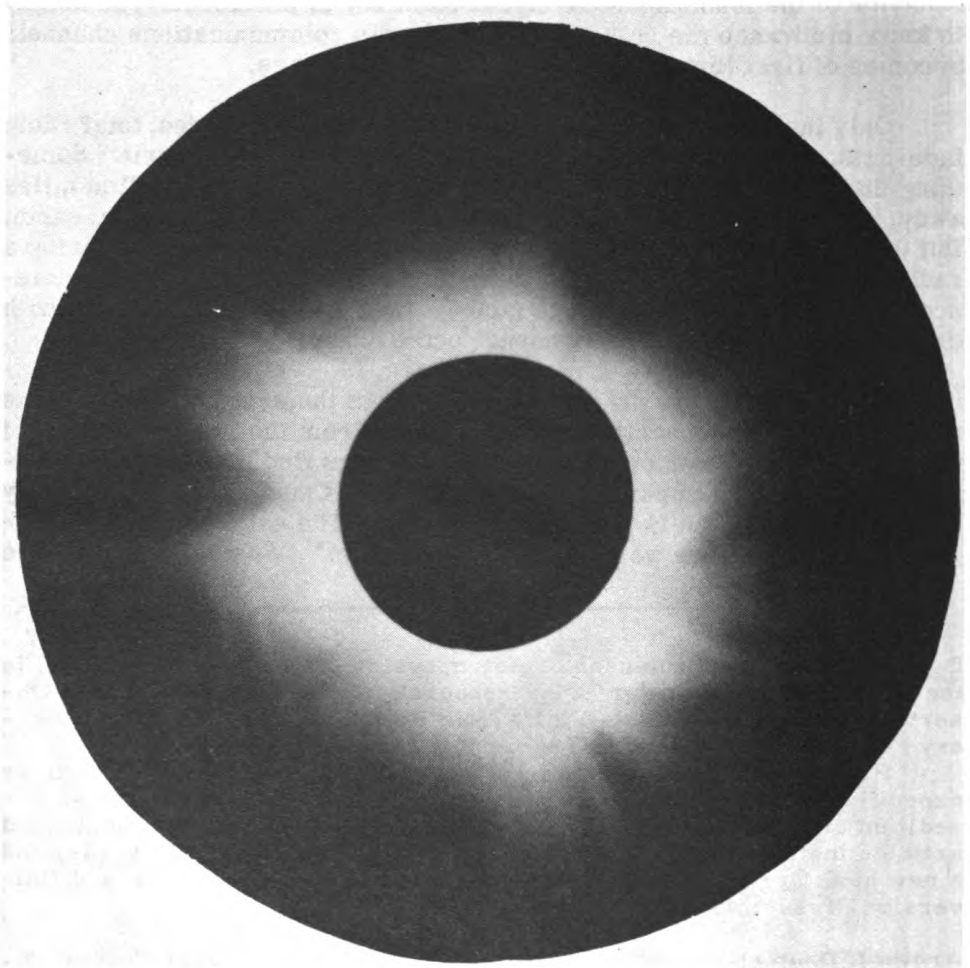

Figure 1. The Solar Corona. This picture was taken at total solar eclipse.

To maintain a continuous watch on the solar phenomena that directly affect the earth, Harvard College Observatory established a unique observatory more than two miles above sea level. Climax, Fremont Pass, in the Colorado Rockies, seemed to offer the best conditions for sky clarity and atmospheric steadiness of all the sites investigated. Yet not even the clear, dark sky above Fremont Pass will reveal the corona in an ordinary telescope. In 1930 the French astronomer B. Lyot invented the type of instrument needed for this research.

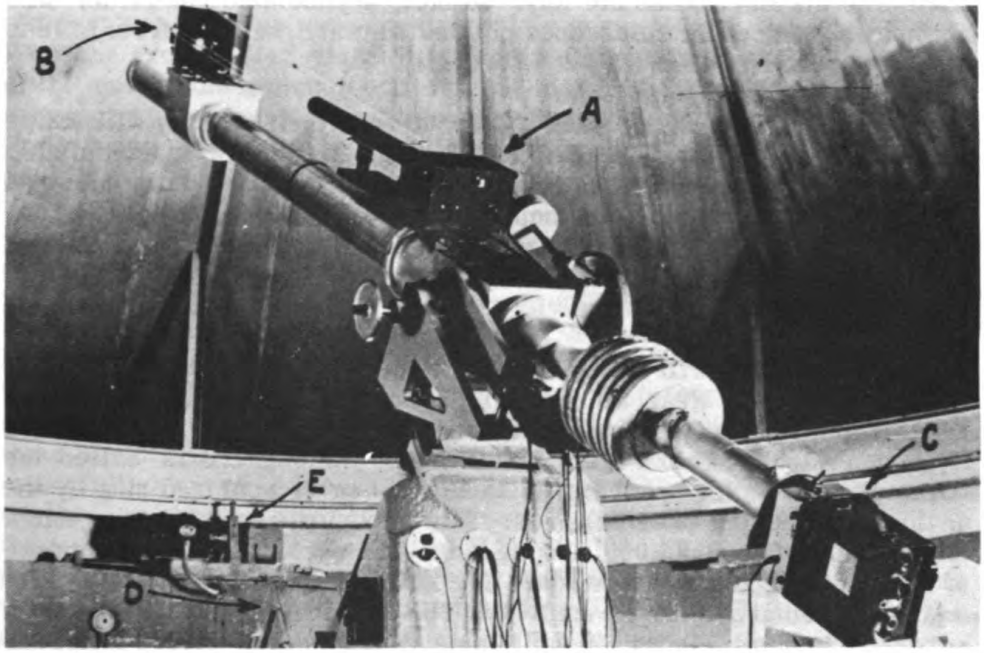

Figure 2. The coronagraph, showing the photoelectric guider at A and the guider lens at B. At C is the 35-mm motion-picture camera. Part of the spectrograph shows at D. At E is one of the two motor driven wheels used to rotate the observatory roof.

Prior to this time, although many had tried, no one had ever seen the corona outside of a total eclipse. Lyot termed his special telescope a "coronagraph." Within the coronagraph, an opaque screen in the focal plane produces an artificial eclipse. The instrument differs from conventional telescopes mainly in the elaborate precautions that have been taken to avoid the scattering of unwanted light from the face of the sun into the faint coronal image. The objective lens must be flawless, for the smallest scratch or bubble will scatter sunlight. The lens surfaces must be absolutely dustfree. Within the tube of the telescope, diaphragms are located to trap all minute remnants of scattered or diffracted sunlight.

Experience in the use and construction of this most delicate of all telescopes has already been gained by the Harvard astronomers at their High Altitude Observatory at Climax, where a pilot-model coronagraph has been in operation since 1940. The only coronagraph in the western hemisphere, this instrument was used on every clear day throughout the war for the measurement of light intensities in the corona. The results of each day's observations were coded and quickly transmitted to scientists in Washington, who combined the solar data with results of other studies in order to predict conditions in the ionosphere. Harvard

University and the University of Colorado, who jointly operate the observatory under a contract with the Office of Naval Research, are now developing new and more powerful equipment for the Climax station. The new coronagraph that has been designed for the High Altitude Observatory will be the world's most powerful and versatile instrument for the study of the solar atmosphere. The device will be, in effect, a triple coronagraph, with three large coronagraphs mounted side by side on a single mounting specially engineered for rigidity and precise following of the sun across the sky. In fact, a photoelectric guider will automatically keep the telescopes pointed sunward, with an error of less than one second of arc.

As the coronagraphs track the sun across the sky, they will rotate around a polar axis that is hollow. Through this hollow tube, suitable mirrors, prisms, and lenses conduct the sunlight into a fully equipped optical laboratory. Since the solar image will remain stationary, despite the motion of sun and coronagraph, devices more powerful and massive than could be attached to a moving telescope can be employed to study the solar phenomena.

Observations will ordinarily be made in light of only one wavelength at a time. Near the base of the corona occurs a layer of gas several thousand miles thick that shines brilliantly red in the light of Hydrogen alpha. This region of the solar atmosphere is called the chromosphere (color sphere), for it can be seen as a colored ring by the unaided eye during total eclipses. The chromosphere normally has a temperature of about 25,000° Centigrade. The chromospheric appendage of the sun is jagged and irregular. It appears to consist of blades, tufts or filaments that overlap irregularly. The individual blades are dynamic surges of hot gas. In height the filaments may reach 10,000 miles or more. And if we liken the tangled blades of the chromosphere to a lawn, we can extend the simile by supposing that the bushes, trees and hedges also exist. The chromosphere displays a variety of formations that project out into space. These enormous clouds of luminous gas,

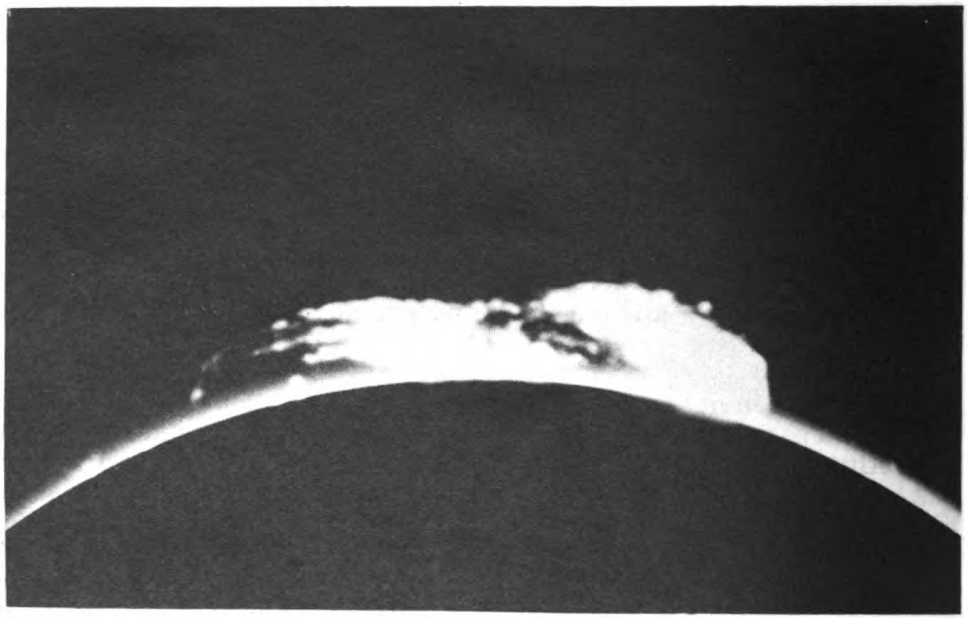

Figure 3. A prominence.

known technically as prominences, change form - sometimes slowly, sometimes rapidly.

Occasionally, prominences in the vicinity of an active sunspot become many times brighter and hotter, to produce what we usually call a "chromospheric flare." These flares seem to be responsible for most, if not all, of the sudden radio fade-outs occurring on earth. Flares begin suddenly, and at the same time short-wave radio sets, on the sunlit hemisphere, seem to go dead. Because of their excessively high temperatures, flares undoubtedly radiate powerfully in the ultra-violet. When the excess ultra-violet light from a flare arrives at the ionosphere of the earth, the molecules in the air absorb it. The sudden influx of energy into the upper atmosphere enormously increases the ionization. Radio waves are absorbed in the electrified layers and a radio fade-out results.

An hour or two after the flare occurs, there may be nothing to indicate its former position in the chromosphere. But the earth has not yet felt the full fury of this solar eruption. After the lapse of perhaps a day, other manifestations often appear. Bright displays of the aurora, sometimes reaching down into low latitudes, occur. And, simultaneously, the magnetic field of the earth is violently disturbed. Radio reception suffers further disturbances. Scientists usually attribute these terrestrial phenomena to the impact of a shower of ionized particles upon the upper atmosphere of the earth. Just before these particles reach the earth, they circle around it like a great electric current. The resulting magnetic field distorts the normal field of the earth, and induces powerful earth currents that may seriously impede even load-line as well as radio communication. The aurora itself results when the ions strike the upper atmosphere, exciting the molecules and making them glow.

But we still do not know what flares really are, how they arise, or when they will occur. Studies with the new coronagraphs will undoubtedly

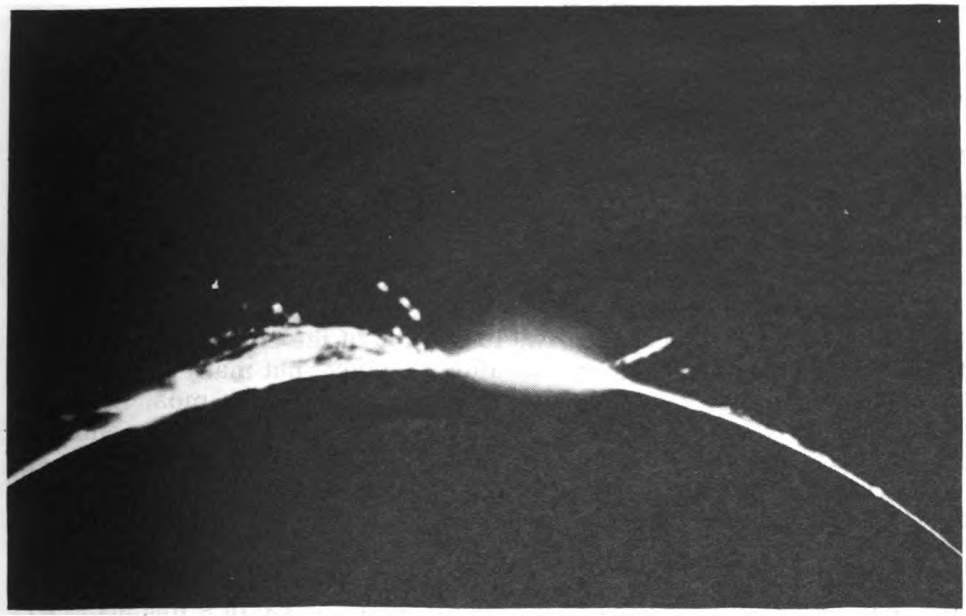

Figure 4. A prominence. The sun is hidden behind the black occulting disk.

teach us much about the physical processes in the sun that give rise to a flare. The present indication is that the flares are something like the electrical discharges, induced by the powerful and changing magnetic fields known to exist in sunspots. Detailed laboratory analysis of the light from solar flares should disclose whether we are on the right track, for the polarization and wavelength characteristics of light emitted in strong electromagnetic fields are different from those of ordinary light.

Although the evidence for the ejection of ionized particles from the sun at about the time of a solar flare is fairly convincing, we have never observed the actual ejection. Observing in Hydrogen-alpha light, we have watched clouds of incandescent gas far larger than the whole earth burst from the chromosphere with speeds up to a third of a million miles per hour. But enormous as these speeds are, they are still too low for the gas to escape from the sun, and so we see it descend again into the chromosphere. The particles that actually do pelt the earth must, indeed, travel at least ten times as fast as the ones we have so far observed.

Slowly moving prominences above the chromosphere, or even quasi-stationary ones, appear in Hydrogen light at almost any time. Unlike the chromospheric flares, these so-called prominences are not necessarily associated with sunspots. Large ones may persist almost unchanged for days at a time. The prominences assume a variety of shapes and sizes; within them, the solar gases exhibit intricate patterns of motion. The forces under which these motions take place are not understood, but in many cases the trajectories suggest electromagnetic processes. At Climax, Dr. Walter O. Roberts has discovered that millions of miniature prominences come surging up through the roof of the chromosphere all the time. These are the so-called "spicules." They and the larger prominences of all types will be studied intensively with the new coronagraphs. Spicule activity is most intense, apparently, near the poles of solar rotation.

All these phenomena are characteristic only of the "lower levels of the sun's upper atmosphere." From the chromosphere itself far out beyond the tops of the highest prominences extend the streamers of the faint and tenuous corona. The coronal gas is far too hot for hydrogen to shine. Almost all the atoms of hydrogen have been dissociated into protons and electrons. In fact, at the temperature of the corona, there are practically no atoms left intact. In a sense, this region comprises a sort of solar "ionosphere." In the most strongly electrified part of the earth's ionosphere, however, only about one molecule out of every hundred thousand is ionized. The ionization of the corona exceeds one hundred per cent! Not only are all atoms ionized, but many are ionized several times. For example, the corona usually shines most brightly in green light of wavelength 5303 Angstrom units, a special color emitted only by iron atoms that have lost 13 of their 26 electrons. To strip so many electrons from iron atoms, the temperature in the corona must be about one million degrees!

What makes the corona so hot? Why does its spectrum change? Why are the changes related to the condition of the earth's ionosphere? How are the changes related to the chromospheric activity, to the myriad spicules, to the hundred-thousand-mile prominences, to the furious

flares that spray the earth with ultraviolet light and thousand - mile - per - second corpuscles? These questions and many others, we shall expect the new coronagraphs to answer. The solar studies have a surprisingly wide range of practical applications. In addition to radio and magnetic effects, the possibility of a relationship between solar activity and weather cycles is particularly exciting. The possibility of obtaining long-range weather forecasts, in terms of solar-induced disturbances, adds potential value to the studies.

Radiation of the sun in range of high-frequency radio waves adds a touch of interest. These waves, one should note, were sufficiently intense at times to cause interference with radar operation during World War II.

Even the field of atomic research overlaps with solar investigations. First, the solar energy itself is a product of atomic nuclear reactions. But even more important, Cosmic Rays - an important tool for atomic studies - appear to be associated with the sun and solar activity. There is a possibility that the cosmic radiation may result from the interaction of electrically charged atoms and variable solar electromagnetic fields.

As important as these practical benefits may be, in the long range, the general basic information in the field of pure science is by all odds the most spectacular for the solar astrophysicist. To understand the reason for the motions of clouds of luminous gas in the sun's atmosphere and to learn the real reason for variable solar activity are exciting possibilities. And the new solar instrumentation, provided by the Office of Naval Research, furnishes a real physical laboratory where the scientist can study cosmic physics and solar relationships.

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Although ONR supports a modest program of astronomical research in which some of the facilities and personnel for the reported work have been involved to a greater or lesser degree, the actual work herein described was carried out without direct ONR support.

Alloys for High-Temperature Service

Arthur R. Elsea
Battelle Memorial Institute

This is the first in a series of articles prepared by members of the staff of Battelle Memorial Institute who are conducting research for ONR on heat-resisting alloys.

Many new alloys have been developed in recent years as a result of the wartime requirements for materials suitable for high-temperature service in exhaust turbosuperchargers and jet aircraft engines. This development has been chiefly on an empirical basis, with various combinations of alloying elements being used together as a result of previous experience in their behavior. There has seldom been any clear understanding of the functions of the various alloying elements. Little is known even now of the phases or compounds formed which contribute to the high-temperature strengths of these materials.

"Vitallium", and a later modification known as Stellite 21, are cast alloys used for exhaust turbosupercharger buckets and for gas-turbine buckets in the J-33 jet engine used to power the Lockheed F80 fighter. Vitallium is a cobalt-base alloy, with substantial additions of chromium, nickel, and molybdenum, and with smaller but still significant contents of carbon, iron, and nitrogen. Although this alloy has given satisfactory service, the fundamental factors which promote its good high-temperature strength are not known. If these factors were understood, improvements in the alloy might be effected by minor composition changes; alloys of equal strength but with considerably lower percentages of the strategic elements cobalt, chromium, nickel, and molybdenum might be possible; or new alloys of greatly improved properties might be developed. Furthermore, techniques developed in the study of this particular alloy would be of value in similar studies of other alloy systems.

With these objectives in mind, an investigation was undertaken to determine the fundamental factors promoting high-temperature strength in alloys, with the first studies directed toward cobalt-chromium alloys of the Vitallium type.

The internal structure of an alloy is undoubtedly one of the most important factors influencing its strength at elevated temperatures. The first phase of this research was, therefore, a study of the internal structure of cobalt-chromium binary alloys. Since the available equilibrium diagrams appeared inaccurate or inadequate, the cobalt-rich portion of the binary cobalt-chromium system was studied.

Arthur R. Elsea, a metallurgical engineer on the research staff of Battelle Memorial Institute, Columbus, Ohio, has been associated with the Institute since 1939. During his ten years at Battelle, Mr. Elsea has engaged in numerous studies on the effects of composition, heat treatment, and mechanical work on the structure and properties of metals. He is a graduate of Ohio State University.

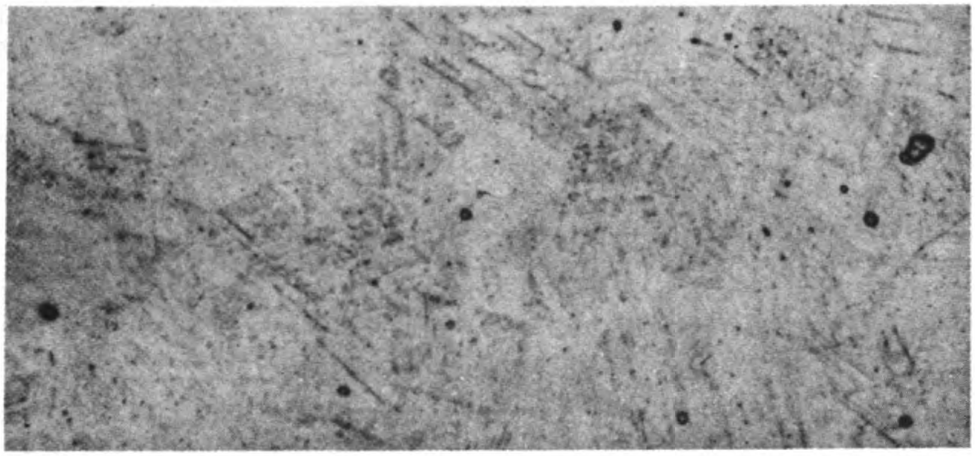

Figure 1. The alpha phase has a characteristically roughened surface without well-defined grain boundaries.

Cobalt, like many other metals, can exist in more than one crystalline form. When heated, it undergoes a transformation or change in internal structure at about 425° C. Above 425° C, cobalt is in the high-temperature or alpha state with the atoms arranged in a face-centered cubic pattern. Below 425° C, in the low-temperature or beta state, the atoms are arranged in a close-packed hexagonal pattern.

An experienced metallographer can determine whether cobalt metal or cobalt-chromium alloys are in the alpha or beta state by their appearance under the microscope when suitably polished and etched. The metallographic etchants were standardized using several specimens whose phases were previously identified by X-ray diffraction analyses.

Figures 1 and 2 are photomicrographs at a magnification of 500X, which show the structures of a cobalt-chromium binary alloy containing 20 percent chromium, aged 65 hours at temperatures of 900 and 750° C, respectively.

Chromium, when added to cobalt, progressively raises the temperature at which the change from the beta to the alpha structure occurs.

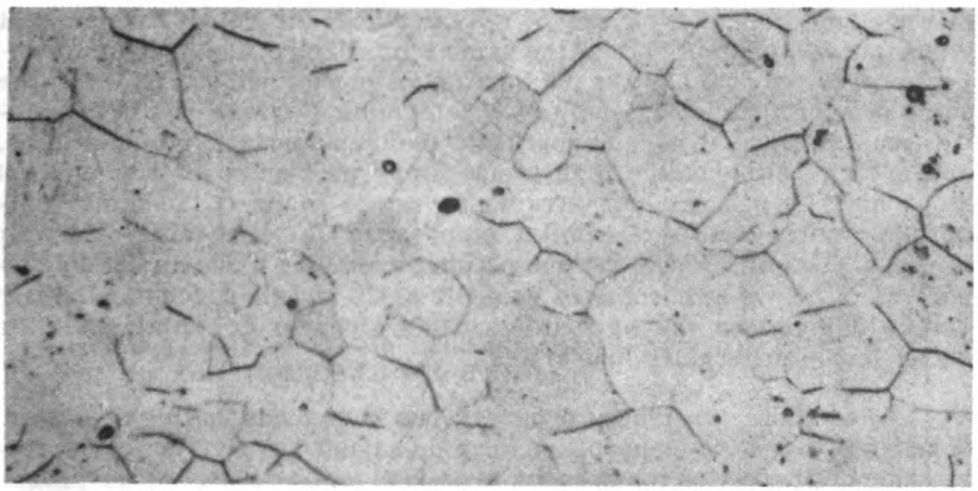

Figure 2. The beta state has a smooth surface with clear-cut grain boundaries.

With an addition of about 35 percent chromium (the maximum amount that cobalt will take into solution), the transformation temperature is raised to about 900°C.

The cobalt-base alloys used for high-temperature service contain 20-30 percent chromium, and for these alloys the beta-to-alpha transformation occurs between 800 and 925°C. This is just about the temperature range in which the cobalt-base alloys operate in high-temperature service. The high- and low-temperature phases would be expected to have different properties. But, at the present time little is known about the effect of change in internal structure on the high-temperature properties of cobalt-base alloys.

In addition to studying the effects of chromium additions to cobalt, studies have been made on additions of iron, nickel, and nitrogen to cobalt-chromium alloys containing 20-30 percent chromium. Stellite 21 alloy may contain several percent of iron as an impurity. Nickel is a desirable addition because it improves the high-temperature properties. Both iron and nickel additions progressively lower the transformation temperature.

Nitrogen, another impurity, is picked up from the air, and is contained in cobalt-base alloys in uncontrolled amounts. This also lowers the temperature of the structural change from beta to alpha in cobalt-chromium alloys. During this investigation, it was found that cobalt-chromium alloys pick up or lose nitrogen quite readily at high temperatures depending on the nitrogen content of the surrounding atmosphere. Thus, it is possible that the nitrogen content of these alloys will change in service with an accompanying change in transformation temperature.

Development of the cobalt-chromium alloys has indicated that molybdenum, tungsten, and carbon contribute most to their high-temperature strength. Future work will include studies of how their addition affects the alpha-beta transformation and the resulting phases.

One part of the investigation is a testing program to determine the effects of variations in composition and testing temperature on the properties of cobalt-chromium-base alloys. Variations in temperature alone have an effect upon the mechanical properties of an alloy. Since alloys of the same composition cannot co-exist with the cobalt 100 percent alpha and 100 percent beta at the same temperature, the high-temperature properties of the alpha and beta forms cannot be determined at the same temperature; other methods of determining differences in properties must be used. Nitrogen depresses the transformation temperature, and determination of the high-temperature properties of 100 percent alpha and 100 percent beta structures can be made at the same temperature using alloys of similar compositions, which differ only in nitrogen content. These determinations are being made in the cobalt-chromium alloys at chromium contents of 20 and 30 percent. Thus, it can be determined whether alloys in the alpha or beta state have the better high-temperature properties.

When more substantial progress has been made in this research, it is hoped that alloy compositions can be adjusted to give the best combination of properties for specific practical applications.

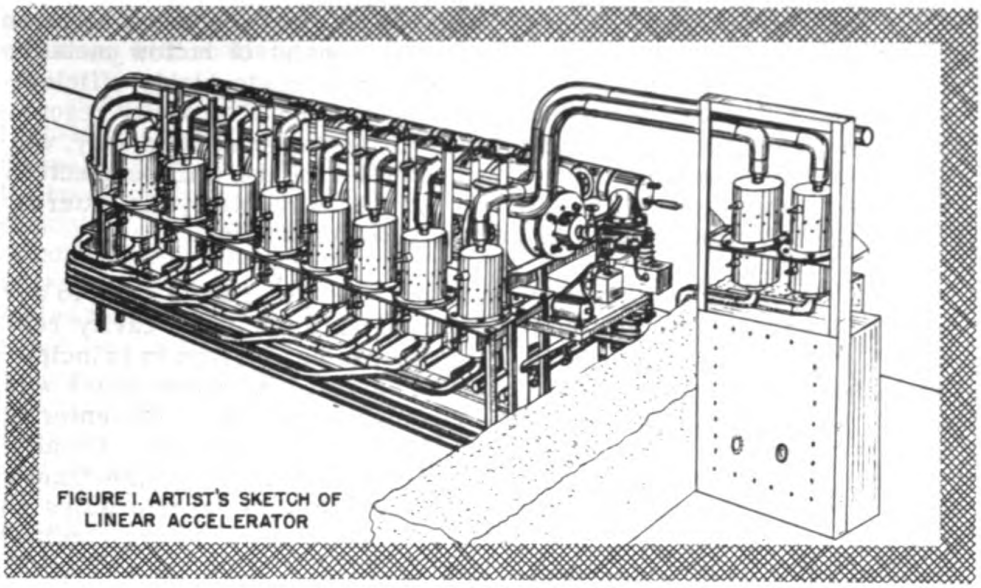

FIGURE I. ARTIST'S SKETCH OF LINEAR ACCELERATOR

The Yale Linear Electron Accelerator

H. L. Schultz and W. G. Wadey
Sloane Physics Laboratory,
Yale University

One of the outstanding engineering achievements of the recent war was the development and utilization of extremely high power radio frequency oscillators for use in radar. As these devices are operated under pulsed conditions, peak power outputs exceeding a million watts can be produced over time intervals of a few microseconds. Average power requirements can be kept low by choice of the pulse repetition rate. Wavelengths from approximately one meter down to the one centimeter range are readily obtainable at the peak power level.

At very high frequencies, wavelengths and circuit dimensions become comparable in size; it is no longer possible to separate and uniquely define inductance and capacitance. Therefore, one must

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Howard L. Schultz, associate professor of physics at Yale University, received his Ph.D. at the same institution in 1937. Since then he has engaged in teaching and research at both Yale and the University of Buffalo. During the period 1941-1945, he was a staff member at the Massachusetts Institute of Technology Radiation Laboratory. He rejoined the Yale staff in the fall of 1945.

Walter G. Wadey, instructor in physics at Yale University, received B.S. and M.A. degrees from the University of Michigan. During the war, he was a research associate at the Radio Research Laboratory, Harvard University. After the war he did research at the University of Michigan and received his Ph.D. in 1948.

resort to electromagnetic theory. Ordinary coil and condenser circuits are no longer applicable—instead circuits consist of hollow metallic cavities and pipes. Circuits of this type can be made highly efficient. Consequently it is possible to construct tuned circuits or cavity resonators which, when supplied by peak power at the resonant frequency, will develop an instantaneous alternating potential in the million electron volt (mev) range across the cavity. At the same time, the external surface of the resonator may be held at ground potential.

It is immediately apparent that such voltages can be used to accelerate electrons and protons. By arranging a series of cavity resonators in line, almost any particle energy can be realized in principle. Of course, individual resonators must be operated in proper phase with respect to adjacent ones in order that accelerated particles entering the next resonator receive a further increment in energy. Usually, these resonators are placed in a straight line, hence the name "linear accelerator" — in contradistinction to such particle accelerators as cyclotrons, betatrons, and synchrotrons in which particles are confined to spiral paths by strong magnetic fields.

The basic idea for such a machine is by no means new. Long before the war, a number of investigators, notably Sloan and Lawrence, used what were then considered high frequency sources to accelerate mercury ions to about a million electron volts. Such projects received little encouragement at the time because of the difficulty of obtaining sufficient power at wavelengths short enough to make the scheme feasible. Therefore attention was turned to the development of circular devices employing magnetic fields, such as the cyclotron and betatron and more recently the synchrotron.

Within the last few years, the trend in nuclear physics has been toward the achievement in the laboratory of very high energies in the billion electron volt (bev) range. At such energies, circular devices have limitations and are costly in terms of magnet construction as well. One limitation in some machines of the circular type involves the electromagnetic radiation loss of charged particles as they execute circular orbits. Also, once a high energy beam has been obtained, it may be difficult to remove it from the accelerator.

In view of these limitations and since potentials in the million electron volt (mev) range can be produced in cavity resonators with comparatively small scale equipment (already in a satisfactory design stage), a number of laboratories in this country and abroad have undertaken the development of high frequency linear accelerators for electrons and also for heavier particles. While the energies realized by existing linear accelerators do not yet compare with those attained in present day circular machines, the preliminary results are encouraging. As the particles travel in straight lines in a linear accelerator, electromagnetic radiation loss does not impose such limits on attainable energy as it does in some of the circular devices.

The linear accelerator (see Figure 1) being developed at the Sloane Physics Laboratory under a contract with the Office of Naval Research is specifically for electrons. The machine now nearing completion will provide electrons with energies up to 15 mev. Although this energy is not unusually high, the possibility of high beam current and good energy

homogeneity will allow considerable research on the interaction of fast electrons with matter.

Basically, the ideas of the various laboratories developing high frequency accelerators are similar insofar as the overall picture and ultimate results are concerned. However, specific techniques vary as to choice of wavelength and mode of operation. In a long accelerator consisting of a number of sections in cascade, some researchers favor standing-wave voltage distributions in the various sections; other workers choose to proportion the device so that a running wave is propagated throughout the length of the structure. In the latter case, particles ride the crest of a wave, so to speak. The velocity of the wave is adjusted at all points to coincide with that of the particle; hence, the particle continuously gains energy at the expense of energy in the wave. The choice of frequency is partly determined by the mass of the particle being accelerated - heavier particles require lower frequencies. With the exception of the Yale project, all other linear electron accelerators use wavelengths in the 10 cm range, power being obtained from cavity magnetrons and from power klystrons recently developed by the group at Stanford University. Finally, since a multiplicity of power sources is necessary to achieve high energies, a decision must be made regarding the method of synchronizing these separate sources. All of the above considerations are intimately related, and an optimum set of parameters may be difficult to choose until more information is derived from existing projects.

In many of the existing developments, self-excited oscillators are employed, magnetrons in the centimeter range and triode tubes at lower frequencies. While synchronization in phase of a number of such oscillators has now been successfully achieved, it was still a formidable problem when this project began. For this reason, as well as others, a scheme was adopted in which individual resonators are electrically isolated from each other. Each such resonator is supplied with power from a high frequency triode amplifier operated under pulsed conditions at a peak level of about a million watts. Each amplifier is, in turn, driven by a master oscillator system, the frequency of which is maintained constant to a high degree of accuracy. Oscillations in the individual cavity resonators are then phased relative to each other by a

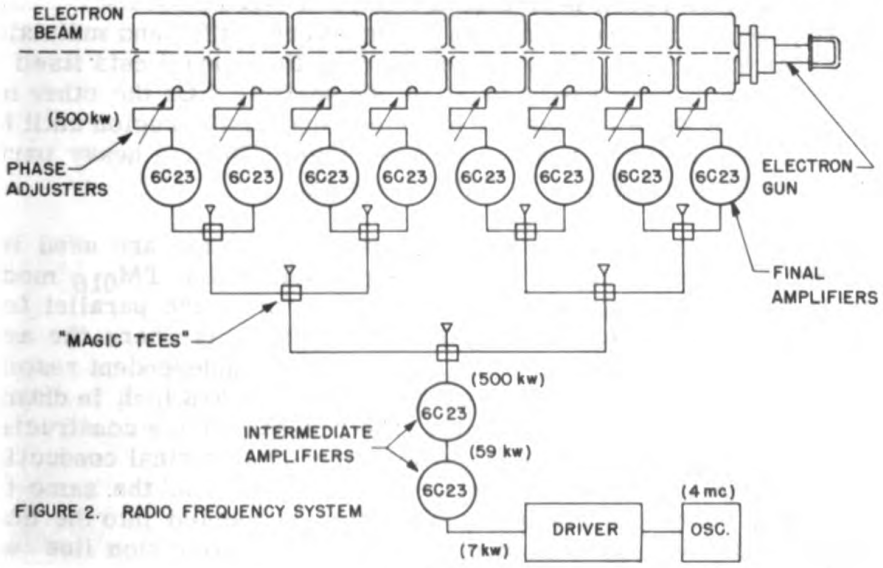

FIGURE 2. RADIO FREQUENCY SYSTEM

phase-shifting element between the amplifier and its associated resonator. In this way, phase relations are adjusted and maintained without the need of extremely precise machining tolerances. A frequency of 590 Mc has been chosen, since this was near the upper limit of operation for triodes available when the project was begun. Since each amplifier has a power gain of approximately 10, it is necessary to amplify the signal from the master oscillator after every nine sections.

In the Yale machine, electrons are injected into the first section at relatively low energies, namely at voltages in the range of five kilovolts. Although electrons are injected over a complete cycle of radio frequency, nevertheless in the first few sections they become bunched and move down the axis of the system as "slugs" of charge. Theory confirmed by experiment shows that, although alternating fields are involved, the energy spectrum of electrons after passing through the first few sections is surprisingly sharp. Also, in these early sections where the velocity is changing appreciably, lateral electromagnetic forces tend to focus the beam into a well defined pencil.

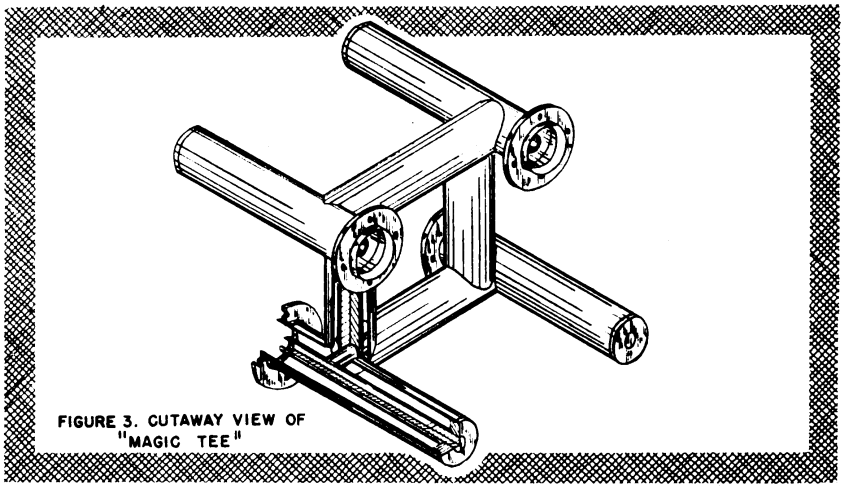

FIGURE 3. CUTAWAY VIEW OF "MAGIC TEE"

In the case of electrons, the first few sections of the accelerator are the most critical to adjust since they have an important bearing on the nature of the final beam obtained. Very shortly, however, the electrons attain a speed near that of light, and throughout the remainder of their journey the beam tends to become very "stiff" and maintain its initial characteristics. Increase of energy, then, manifests itself only in an increase of relativistic mass of the particle. On the other hand, heavy particles do not attain the extreme relativistic region until their energy is well in the hundreds of mev range. Thus, a heavy particle linear accelerator is more critical in design.

Cavity resonators of simple geometrical shape are used in the Yale linear accelerator. These are operated in the TM_{010} mode of oscillation, in which case electric lines of force are parallel to the axis. Electrons traverse the system along the axis where the accelerating forces are greatest. They pass from one independent resonator to the next through axial portholes approximately 3/8 inch in diameter in the flat end plates of each cavity. The resonators are constructed of steel, copper plated on the inside to insure good electrical conductivity, and they form the vacuum envelope of the system at the same time. Power from each high frequency amplifier is coupled into the corresponding resonator by means of a co-axial transmission line which

terminates in a small, properly oriented loop just inside of the cylindrical wall of the cavity. For the TM_{010} mode, the resonant frequency of any cavity is determined only by the cavity diameter. At 590 Mc, the diameter is approximately 15 inches. The first two sections of the accelerator are shorter than the later ones, which are seven inches long. A tuning adjustment is provided in each resonator so that all resonators can be adjusted to the same resonant frequency, thus minimizing the care necessary in machining.

A simplified diagram showing in detail the radio frequency power system is shown in Figure 2. There are eight cavity resonators. The fundamental control oscillator is one of the electron-coupled type operating at approximately four Mc. The final operating frequency of 590 Mc is obtained by frequency multiplier circuits. Eventually, the primary oscillator will be crystal controlled. One important feature of the system is the use of "magic tee" sections to insure proper division of driving power to each final amplifier. The "magic tee" also minimizes interaction between adjacent amplifiers. Figure 3 shows the "tee", the name being carried over from the corresponding device constructed of wave guide where the name is more appropriate. All phase adjusters are merely adjustable lengths of transmission line built in the form of a trombone.

At the present time, construction of the final accelerator, as depicted in Figure 1, is nearing completion. Preliminary experiments, with an operating two-cavity system in which electrons were accelerated to about one and one-half million electron volts, verified theoretical predictions and served to isolate faults in earlier designs of components. Should the present accelerator of eight sections prove satisfactory in operation, efforts will then be made to extend it to considerably higher energies.

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Neural Metabolism and Function

R. W. Gerard
University of Chicago

It has been recognized at least from the time of Lavoisier that the functioning of cells and organs depends on the maintained flow of energy. The more precise correlation of a particular metabolic step with a particular mechanism in the functional machine is still, however, largely before us. As this is achieved, in case after case, not only will a major problem of theoretical biology be illumined, but also practical problems of malfunction will be solved. The nervous system is a favorable focus for such combined studies of chemistry and performance, because electrical measures can give quantitative information of the state of activity.

Two methods have been widely used in this type of research. If function is suspended in the absence of a particular reactant, then the specific need for this substance can be tested by observing whether it alone, or other substances, can restore function. If a particular step in a metabolic sequence can be blocked by an appropriate inhibitor, especially when subsequent steps can be maintained as desired by supplying the product of the blocked reaction, then the changes or lack of changes in functional behavior may give critical information.

Thus, a nerve that has lost its ability to conduct during oxygen deprivation can be restored by other reducible molecules. A nerve, normally using up sugar in vitro, can maintain its full rate of oxygen consumption and its ability to conduct after its available sugar reserves are emptied. Clearly, although oxygen and carbohydrate normally support nerve function, neither is in itself irreplaceable. In the case of the brain, for which glucose is regarded as normally the exclusive fuel of rest and activity, the case seemed to be different. Yet conditions have been found under which a brain homogenate continued its full oxygen consumption when sugar was unavailable. It is now possible to extend this evidence with the aid of an in vitro perfusion technique using the rat spinal cord.

This preparation has proved surprisingly simple and satisfactory. The length of the cord is exposed by removing the vertebral arches. Then the animal is placed supine and, under artificial respiration, the chest and abdomen are opened. The aorta is ligated at the diaphragm and a cannula inserted at the arch. Perfusion through it is begun with a syringe and continued with a pump a few minutes later, when the length of spinal column has been cut out (using an electrocautery to seal the edges). Perfusion occurs under pulsatile pressure of the normal magnitude, at body temperature, and with an oxygenated salt solution of

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Ralph W. Gerard, professor of physiology at the University of Chicago, received his Ph.D. from the University in 1921 and his M.D. from the University of Chicago, Rush Medical School in 1924. Professor Gerard spent the year 1926-27 in Europe as a National Research Fellow. He has been teaching at the University of Chicago for the past 20 years. He is chairman of the Physiology Advisory Board of the Office of Naval Research.

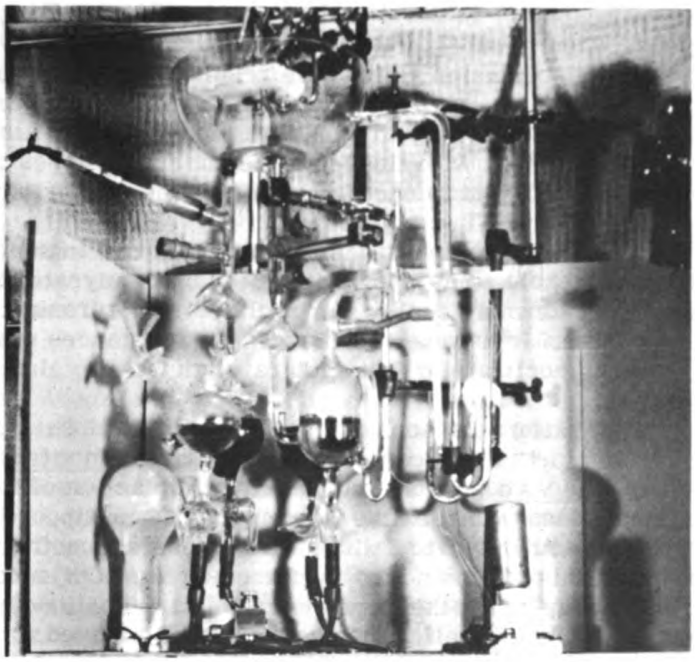

Figure 1. The perfusion apparatus consists of a hemispherical tissue chamber (upper left) in which the spinal cord preparation is placed. Three-way stop-cocks provide rapid reservoir change-overs, and rotary pumps on the base provide the perfusion pressure.

proper acidity, and salt ions, 100 mg percent of glucose, and a protein at proper osmotic pressure. A dorsal nerve root is placed on stimulating electrodes and a ventral root on recording ones connected via a push-pull amplifier to a cathode ray oscilloscope. The sharp two-neurone reflex response is seen as a standing wave about 30 mm high on the screen face. (The lucite trough which holds the segment of spinal cord, removed with blood supply intact, is shown in the upper left hand corner of Figure 1. Arterial supply and drainage communicate through the bottom.)

Flow rate (1.9 cc/min/g cord) is at the upper range of in vivo measurements on brain, and reflex responses remain full size over many hours. In sharp contrast to this maintained functioning, the reflex response is entirely lost in one to two minutes if oxygen is omitted from the perfusion fluid. If glucose is omitted, the response is lost in two to four minutes. Such anoxia or aglycemia has been maintained for more than 30 minutes and then full reflex activity restored in one to two minutes after re-adding the missing oxygen or glucose. It is clear that function is immediately dependent on the continued oxidation of foodstuff; and the utility of any substance can be tested simply by adding it, instead of glucose, to the aglycemic (non-sugar) preparation. One needs first, however, quantitative information about normal oxidations. This is easily obtained by analysis of the entering and leaving perfusion fluid and knowledge of the flow rate.

In passing through the cord, glucose loss is 7.6 mg/hr/g and would correspond to Q_{O_2} ($mm^3O_2/hr/g$) of 5700 - again in the upper range of in vivo measurements. The actual oxygen used, 4250 $mm^3/hr/g$, would account for the complete oxidation of only 73 percent of the glucose disappearing - a discrepancy which has also appeared several times during in vivo studies. Attempts to trace the "extra" glucose as such have not yet been made.

Of especial interest is the return or lack of return of reflex response when a substance other than glucose is added to the aglycemic oxygenated perfusion fluid. The results have been surprisingly sharp and unequivocal - a given substance has regularly been either entirely ineffective or able fully to substitute for glucose. This is subject to one partial exception - oxaloacetate regularly restores activity only half way to normal; and to one reservation - the matter of penetration.

The following substances were ineffective in supporting reflex activity: alcohol, acetate, lactate, β-hydroxybutyrate, fumarate, malate, succinate, adrenaline, dl-alanine, dl-lysine, l-tyrosine, dl-aspartic acid, dl-cysteine, l-cystine, l-serine. These substances were fully effective: pyruvate, isocitrate, α-ketoglutarate, glutamate, glutamine.

The failure of some of the substances is surprising. Succinate, for example, is oxidized with avidity by brain in vitro and has even been reported in vivo to counteract the narcotic action of barbiturates or the hallucinations of mescaline. Its inertness in supporting reflex activity might be attributed to failure of successful penetration into the cord. However this seems not to be the case, for both succinate and oxygen are taken up from the perfusion fluid at a continuous rate well above that for glucose itself. Succinate, though oxidized to yield a great sufficiency of energy, does not support reflex function. One might contend that succinate is burned by glia rather than neurones, and experiments to test such a possibility are in progress. Such an ad hoc assumption, however, would not account for its positive effects on neural function, noted above, and would indeed leave all past metabolic studies inconclusive - as perhaps they are. A more positive interpretation for the present, and one that is supported by successes, is that succinate enters into the metabolic chain beyond a critical link.

Every substance that can replace glucose is, or is easily deaminized into, a member of the tricarboxylic cycle above succinate. Substances in lower positions are ineffective. If, for example, the particular step from α-ketoglutarate to succinate (one unique in its energy yield in other metabolic relations) were critical for function of the two-neurone spinal reflex, these findings would all be in order. True, by continuing around the cycle, even succinate should eventually pass through this step; but at least this would be far less direct and presumably at a slower rate. Other possibilities exist, however, such as a conversion of substrate to glucose which is burned along an alternate path.

Obviously, much remains to be explained, but the technique now available seems quite adequate for this purpose. Its exploitation has just begun and there is no reason why all interesting metabolic intermediates should not be followed through their chemical changes and related continuously to their functional effectiveness. In addition, the action of a variety of inhibitors can be utilized in like manner and their mode of action even more precisely identified. Similarly, the metabolic basis of action of many neurotropic drugs can be analyzed and new clues obtained as to particular chemical changes associated with function. But this is for the future.

Nuclear Spectroscopy

Allan C. G. Mitchell
Indiana University

It is now common knowledge that a quick method of chemical analysis is possible with the help of a spectrograph. The material to be analyzed is placed in the core of an ordinary arc carbon, and the light from the arc is sent through a spectrograph. From the positions of the lines obtained, and their relative intensities, an analysis of the material may be made.

The development of atomic spectroscopy took place during the 70 years between 1860 and 1930. The main object was not to benefit chemical technicians but rather to aid physicists to develop, in a very fundamental way, nearly the entire knowledge of atomic structure. From a spectrographic study of the light given off by atoms, physicists were able to get a picture of the motion of the electrons around the central atomic core, the nucleus; as well as a conception of the forces between the electrons and the nucleus and of the forces between the electrons themselves. It was found that the force between an electron and the nucleus is far larger than the forces between electrons. That is why physicists can now obtain such a clear picture of what the electrons do in the atom.

Physicists now feel that they know all of the fundamental things about the exterior part of the atom (the electrons around the nucleus) and study is at present concentrated on the nature of the nucleus, the central core itself. Here the situation, at least in the present state of our knowledge, appears much more complicated. The nucleus consists of protons and neutrons as elementary particles and in any given atom the total number of protons and neutrons in the nucleus is approximately equal to the atomic weight. In gold, for example, there are 79 protons plus 118 neutrons in the nucleus, or 197 particles altogether. The main problem of nuclear physics is to study the forces between these particles. For this purpose methods of spectroscopy can be applied to the radiations from the nucleus in a manner similar to its application to radiations from the exterior of the atom.

Just as the normal atom gives off no radiation unless it is somehow excited—by an arc, spark, or some other kind of discharge, so a normal nucleus gives off no radiation unless it is excited. A nucleus which gives off radiation is called radioactive. In general it gets its excitation energy from bombardment by neutrons in a chain-reacting

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Allan C. G. Mitchell is head of the Department of Physics at Indiana University. He received his Ph.D. from the California Institute of Technology in 1927, was a Fellow of the Bartol Research Foundation 1928-31, assistant professor and associate professor of physics at New York University 1931-38, and has been at Indiana University since 1938. During the war he worked on the atomic energy project at the Metallurgical Laboratory, University of Chicago and at Indiana University. Dr. Mitchell then transferred to the Applied Physics Laboratory, The Johns Hopkins University, where he worked on anti-aircraft directors and guided missiles.

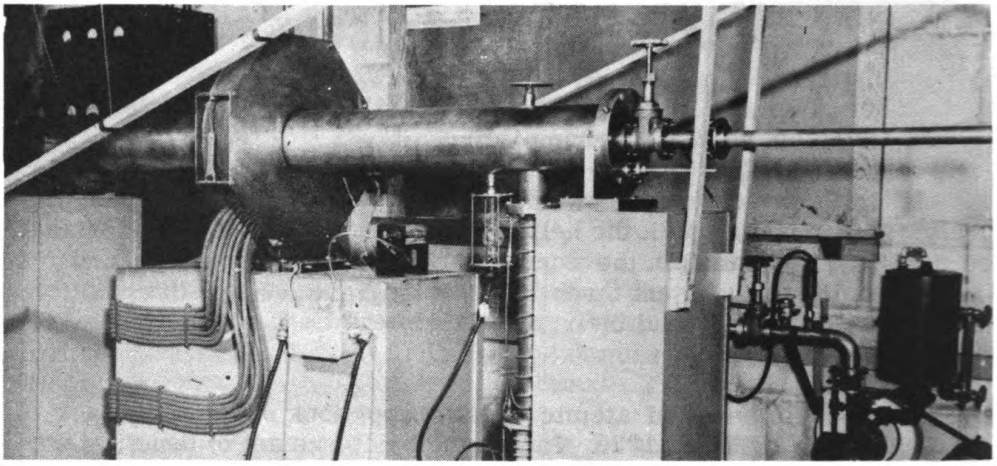


Figure 1. Magnetic Lens Spectrograph.

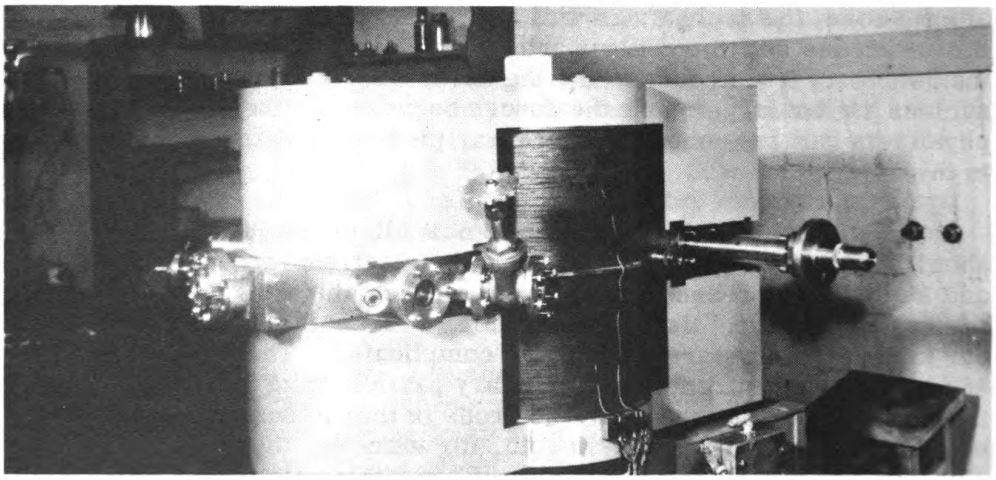


Figure 2. Large 180^0 Magnetic Spectrograph.

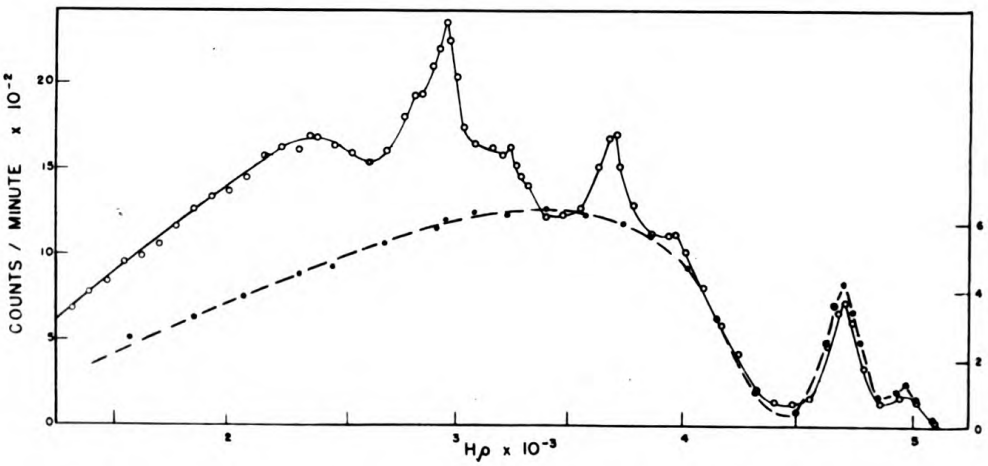


Figure 3. Solid line curve shows lines of Cs^{134} and Rb^{86}. After chemical purification, the pure Rb^{86} gave the spectrum shown in broken line curve.

pile or by high-energy particles in a cyclotron or other accelerator. A radioactive nucleus will radiate alpha particles, electrons (positive or negative), and gamma rays. In the particular application in which we are interested we shall consider only those nuclei giving off electrons (positive or negative) and gamma rays. Gamma rays are light rays, but of higher frequency (shorter wave length) than X-rays, which have shorter waves than ultraviolet rays, the light with waves just too short for the human eye.

The main program of the Physics Department at Indiana University, assisted by a contract with the Office of Naval Research, is devoted to spectroscopic investigations of radioactive nuclei. It is hoped that this program of nuclear spectroscopy will be as fruitful in gaining knowledge of the nature of the nucleus as the study of atomic spectroscopy was in gaining knowledge about the atom.

The energy of gamma rays (light from the nucleus) cannot be measured directly as in the case of the light from atoms. The physicist has to rely on secondary effects produced by the gamma ray. When gamma rays strike a metal, they release electrons and from a measurement of the energy of these electrons the energy of the gamma ray can be inferred. Thus, for these measurements, it is necessary to have a device which will measure the energy of electrons.

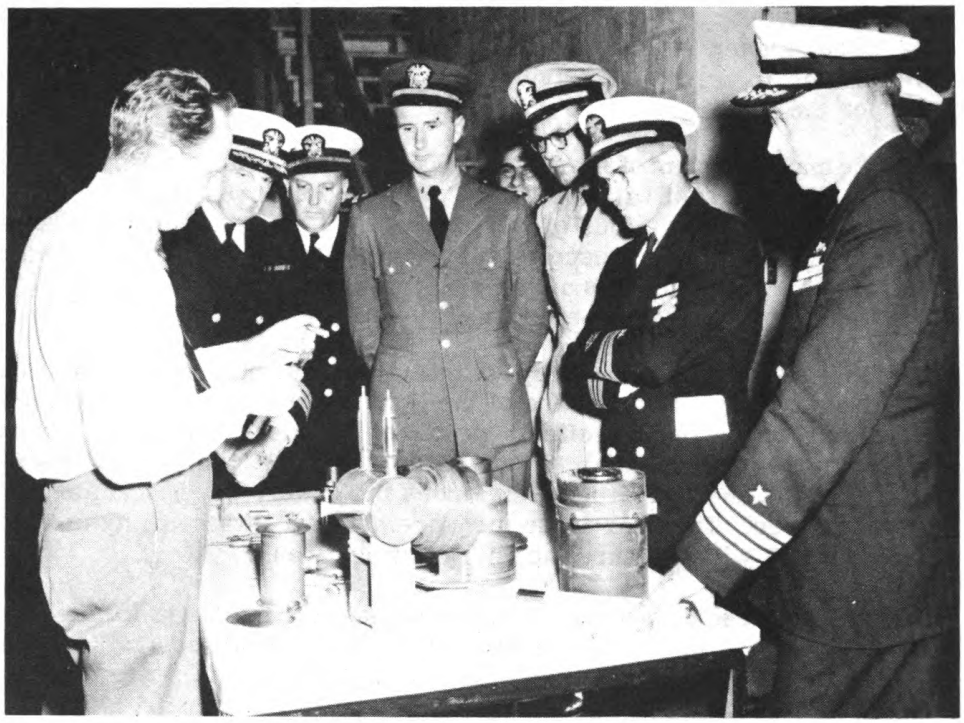
The most useful device for this purpose is a magnetic field. Two different types of magnetic spectrometers are used at Indiana University. In one type the electrons traverse a semicircular path at right angles to the magnetic field and come to a focus at an angle of 180° to the starting point. In the other type, a coil produces a magnetic field along the axis of an evacuated tube. Electrons leaving the source at a small angle with the axis, spiral around the axis and come back to it in a "focus" on the other side of the coil. In either instrument, for a given setting of the magnetic field, only electrons of a given energy are brought to a focus. The problem then resolves itself into counting the number of electrons which come through at a given magnetic field and observing the counting rate as the field is changed. In this way the energy of the gamma rays can be inferred.

Three 180°-type instruments and one magnetic lens type have been constructed at Indiana University and an additional magnetic lens is being built. Figure 1 shows a picture of a magnetic lens with the coil for producing the magnetic field visible in the center. Figure 2 shows one of the large 180°-type spectrometers used at the laboratory. One feature embodied in the University's instruments should be mentioned. A certain gain in the sharpness of the lines observed can be obtained by "shaping" the magnetic field. Thus, two coils, properly spaced, have been used in the magnetic lens to obtain sharper lines. Similarly, in the 180°-type instrument, the field is not uniform but falls off on either side of the central ray.

Identification of radioactive isotopes by their gamma ray spectra is an interesting by-product of this investigation. Figure 3 shows a spectrum of a sample of Rb^{86} before and after chemical purification. The spectra of 50 nuclear species scattered throughout the periodic table have been worked out in this and other laboratories. From study of these 50 nuclear species, some rather general rules are beginning to be apparent, but it is still too early to formulate any general theory of the nucleus.

On the Naval Research Reserve

Boston "Scientific Seminar"



Construction of high powered magnetrons for linear electron accelerator is demonstrated at the Massachusetts Institute of Technology Research Laboratory of Electronics for, reserve officers attending the scientific seminar in Boston in August.

A two-day "scientific seminar" for New England Naval Reserve officers was conducted in Boston, on August 29 and 30 under the sponsorship of the Commandant of the First Naval District.

The intensive two-day familiarization seminar included tours of various laboratories and other scientific installations at Harvard University and Massachusetts Institute of Technology.

The seminar was limited to Commanding Officers of Volunteer Naval Reserve units throughout the First Naval District. The purpose of the seminar was to acquaint the officers with the close cooperation which exists between the Navy and academic science. Approximately 80 Naval Reserve officers from the New England area attended.

Rear Admiral Hewlett Thebaud, USN, Commandant of the First Naval District, addressed the group at the Navy Building, Boston, on August 29. On a visit to Harvard University, the officers toured the Psychoacoustics Laboratory, the Acoustics Laboratory and the Electronics Laboratory.

On Tuesday August 30, the group visited M.I.T., where they inspected the synchrotron, cyclotron, and medical electrostatic generators. Vice Admiral Edward L. Cochrane, USN, (Retired), former Chief of the Bureau of Ships, Navy Department, and now Professor of Naval Archi-

tecture and Marine Engineering at Massachusetts Institute of Technology, addressed the group at noon, prior to a tour of the Design Section of the Massachusetts Institute of Technology.

The program was conducted under the direction of Captain Arthur L. Pleasants, USN, Director of the Boston Branch, Office of Naval Research.

Research Reserve Seminar at Oak Ridge

A 14-day scientific seminar for 50 Research Reserve officers will be held at the Oak Ridge National Laboratory at Oak Ridge, Tenn., beginning November 30, 1949. The seminar will be conducted under the sponsorship of the Office of Naval Research and as a project of Volunteer Research Reserve Unit 6-3. The Commanding Officer of this unit is LCDR David J. Mallon, USNR.

In general, the seminar will consist of lectures by the department heads at Oak Ridge and lecturers from ONR and other Offices and Bureaus of the Navy Department, and inspection of activities at Oak Ridge.

The Bureau of Naval Personnel is now in the process of establishing quotas for the Naval Districts involved. Applications will be considered from Research Reservists residing on and east of the Mississippi River including Com 8. Applications for the seminar will be received by the Chief of Naval Research, Code 104, Washington, D. C., and nominations will be made to the commandants of the Naval Districts concerned.

In approving quotas, preference will be given to members of Research Reserve units, particularly those with backgrounds in the field of physics.

Further particulars concerning the seminar will be sent to commanding officers of units as they become available.

MODIFICATION OF PUBLIC LAW 810

Prior to 1 July 1949, each year of Reserve service (not necessarily continuous) is considered to be a year of "satisfactory Federal service" for the purpose of establishing eligibility to receive retired pay under Public Law 810 whether or not this service included membership in an Organized Reserve unit or any training duty.

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 C. J. Fish, USNR Oceanographic Institute Woods Hole, Mass.
1-3	1900, 1st & 3rd Tues. University of Massachusetts Amherst, Mass.	LCDR E. D. Emerson, USNR Mechanical Eng. Department University of Massachusetts Amherst, Mass.
3-1	1930, Alt. Thurs., from 8 Sept. Auditorium Cornell University Medical College 1300 York Ave. New York, N.Y.	CDR J. D. Hardy, USNR Cornell University Medical College 1300 York Ave. New York 21, N.Y.
3-2	1930, 2nd & 4th Mon. Special Devices Center Engineering Bldg. Sands Point, Port Washington, Long Island, N.Y.	CDR L. E. Yoder, USNR Special Devices Center Sands Point, Port Washington, Long Island, N.Y.
3-3	2000, 1st & 3rd Mon. USNR & 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. USNR & MCRTC 900 East Main St. Rochester, N.Y.	CDR Henry C. Sheve, USNR USNR & 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. Rowell, USNR USNRTC Fort Nathan Hale Park New Haven 13, Conn.
3-6	2000, 2nd & 4th Mon. USNRTC Syracuse (Liverpool) N.Y.	LT A. O. Quinn, USNR USNRTC Syracuse (Liverpool) N.Y.
3-7	2000, 2nd & 4th Thurs. USNRTC Scotia, N.Y.	LCDR Robert P. Haviland, USNR USNRTC Scotia, N.Y.
4-1	2000, 1st Wed. Nassau Tavern Princeton, N.J.	LCDR Paul Busse, USNR Aeronautical Eng. Bldg. Princeton University Princeton, N.J.
4-2	1930, Alt. Thurs. Franklin Institute 20th St. & Parkway Philadelphia, Pa.	LCDR Wm. G. Amey, USNR Electronics Section Franklin Institute 20th St. & Parkway Philadelphia 3, Pa.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
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	2nd & 4th Tues. Pennsylvania State College College Station, Pa.	CDR E. R. Queer, USNR c/o English Experiment Station Pennsylvania State College College Station, Pa.
4-5	USNRTC Foot of Madison St. Wilmington, Del.	LCDR Donald MacCreary, USNR USNRTC Foot of Madison St. Wilmington, Del.
W-1	2000, 1st Thurs. Navy Dept. Bldg. T-3, Rm 1515 2000, 3rd Thurs. Auditorium, Interior Dept. Washington, D.C.	CDR W. M. Richardson, USNR ONR, Bldg. T-3, Rm 2602 Washington, D.C.
W-2	1900, 1st Thurs. NRL Auditorium, Bldg. 8 2000, 3rd Thurs. Auditorium, Interior Dept. Washington, D.C.	LCDR H. A. Tanner, USNR Naval Research Laboratory Bldg. 8, Rm 152 Washington 20, D.C.
W-4	2000, 2nd & 4th Wed. Navy Dept. Bldg. T-3, Rm 1803 2000, 3rd Thurs. Auditorium, Interior Dept. Washington, D.C.	LCDR Lawrence Gardiner, USNR Atomic Energy Commission Public Health Bldg., Rm 102 Washington, D.C.
5-1	1930, 1st and 3rd Wed. Rouss Physics Lab. University of Virginia Charlottesville, Va.	LTJG Gilmer T. Fitchett, USNR Cobb Chem. Laboratory University of Virginia Charlottesville, Va.
5-2	1915, 1st & 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.
6-1	2000, Alt. Thurs. 103 Physics Bldg. 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. 318 Ross Lab. Alabama Polytechnic Institute Auburn, Ala.	LTJG J. E. Land, USNR Chemistry Department Alabama Polytechnic Institute Auburn, Ala.
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.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
6-5	USNRTC Gulfport, Miss.	LT V. O. Smallwood, USNR 2412 East Ave. Gulfport, Miss.
6-6	1945, 2nd & 4th Thurs. USNROTC Armory University of North Carolina Chapel Hill, N.C.	LCDR R. F. Stainback, USNR 317 W. University Drive Chapel Hill, N.C.
6-7	2000, 1st & 3rd Thurs. Biology Bldg. Duke University Durham, N.C.	LCDR John H. Roberts, USNR 2813 Legion Ave. Durham, N.C.
8-1	1930, 1st & 3rd Tues. Chemistry Bldg., Rm 27 Tulane University New Orleans, La.	LCDR John M. Scott, USNR Chemistry Department Tulane University New Orleans, La.
8-2	1930, 2nd & 4th Wed. USNRTC Baton Rouge, La.	LCDR W. R. Edwards, Jr., USNR Chemistry Department Louisiana State University Baton Rouge, La.
8-3	1930, 2nd & 4th Mon. & 2nd Thurs. P & M A Bldg. Texas A & M College College Station, Tex.	LCDR Norman F. Rode, USNR Electrical Eng. Dept. Texas A & M College College Station, Tex.
8-4	1930, Alt. Wed. (14 Sept.) USNROTC Bldg. Rice Institute Houston, Tex.	LTJG John J. Banewicz, USNR 4811 Mt. Vernon St. Houston, Tex.
8-5	2000, Alt. Tues. & Wed. (14 Sept.) Physics Bldg., Rm 201 or Chemistry Bldg., Rm 15 University of Texas Austin, Tex.	LCDR G. H. Ayers, USNR Chemistry Department University of Texas Austin, Tex.
8-6	(Meetings irregular) USNRTC Galveston, Tex.	LTJG C. N. Sechrist, USNR 1235 3rd Ave. North Texas City, Tex.
9-1	1900, 2nd & 4th Tues. Navy Pier Campus University of Illinois Chicago, Ill.	CAPT George C. Lamb, USNR Technological Institute Northwestern University Evanston, Ill.
9-2	1930, 1st Wed. (Irregular) 319 Gregory Hall University of Illinois Urbana, Ill.	LCDR A. C. Williams, Jr., USNR Psychology Department University of Illinois Urbana, Ill.
9-3	1930 (Irregular) Angell Hall, Rm 18 University of Michigan Ann Arbor, Mich.	CDR C. M. Davis, USNR Geography Department University of Michigan Ann Arbor, Mich.
9-4	1930, 2nd & 4th Tues. Old Armory, Rm 107 Ohio State University Columbus, Ohio	LCDR Karl E. Krill, USNR Engineering Exp. Station Ohio State University Columbus, Ohio

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
9-5	1930, 1st & 3rd Wed. (Irregular) NROTC Bldg. Iowa State College Ames, Iowa	LCDR O. C. Kreider, USNR Mathmetics Department Iowa State College Ames, Iowa
9-6	1930, 1st Mon. & 3rd Tues. Murphy Hall Auditorium University of Minnesota Minneapolis, Minn.	LCDR J. A. Wise, USNR 220 Experimental Eng. Bldg. University of Minnesota Minneapolis, Minn.
9-7	1930, 2nd & 4th Thurs. (Irregular) 111 Stanley Coulter Hall Purdue University Lafayette, Ind.	LT L. M. Baker, USNR Psychology Department Purdue University Lafayette, Ind.
9-8	2000, 1st Wed. (Irregular) 101 Crew Hall Washington University St. Louis, Mo.	CDR R. M. Varney, USNR Physics Department Washington University St. Louis, Mo.
9-9	1930, 1st & 3rd Thurs. 204 Mechanics Hall Missouri School of Mines & Metallurgy Rolla, Mo.	CDR R. A. Cooley, USNR Missouri School of Mines & Metallurgy Rolla, Mo.
9-10	1930, 1st & 3rd Wed. USNRTC Peoria, Ill.	LCDR F. C. Albers, USNR 108 Devon Lane Peoria, Ill.
9-11	2000, 1st & 3rd Mon. (Irregular) USNRTC 1089 E. Ninth St. Cleveland, Ohio	LCDR Viktor Schreckengost, USNR 2366 Noble Road Cleveland 21, Ohio
9-12	(Time & Date Not Established) Botany Bldg. Annex Colorado A & M College Ft. Collins, Colo.	LTJG W. D. Thomas, USNR Botany & Plant Pathology Dept. Colorado A & M College Ft. Collins, Colo.
9-13	1930, Wed. USNRTC 9th & Pleasant Sts. Des Moines, Iowa	LCDR J. R. Maloney, USNR 2920 48th St. Des Moines 10, Iowa
9-14	(Time & Date Not Established) USN Armory University of Wisconsin Madison, Wis.	CDR W. B. Sarles, USNR University of Wisconsin Madison 6, Wis.
9-15	(Time & Date Not Established) Community Center Midland, Mich.	LTJG D. D. McCollister, USNR 1220 Michigan St. Midland, Mich.
9-16	(Time & Date Not Established) Michigan State College East Lansing, Mich.	LT Elbert S. Churchill, USNR Bacteriology Department Michigan State College East Lansing, Mich.
11-1	2000, 1st & 3rd Tues. 1030 E. Green St. Pasadena, Calif.	LCDR H. J. Pedersen, USNR 1030 E. Green St. Pasadena, Calif.
11-2	2000, Alt. Thurs. USNROTC Armory Pasadena, Calif.	LCDR J. H. Biggar, USNR 680 E. Colorado Dr. Pasadena, Calif.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
11-3	2000, 1st & 3rd 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	(Time & Date Not Established) Long Beach, Calif.	LCDR Myron S. Allen, USNR 3130 E. Second St. Long Beach, 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 Lab., 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 Engineering Dept. Stanford University Stanford, Calif.
12-4	2000, 2nd & 4th Thurs. McLane Hall, Rm M-103 Fresno State College Fresno, Calif.	CDR Ralph 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 Engineering Design Division University of California Berkeley, Calif.
12-6	1945, 2nd Mon. Animal Science Bldg., Tower Room University of California Davis, Calif.	LT Arthur H. Smith, USNR Animal Husbandry Division University of California Davis, Calif.
13-1	1930, 2nd & 4th Mon. Anatomy Bldg., Rm 108 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 General Electric Co. Richland, Wash.
13-3	1930, 2nd & 4th Mon. YMCA Pullman, Wash.	LCDR W. G. Gnaediger, USNR Community College Serv. State College of Washington Pullman, Wash.
13-4	1930, 1st & 3rd Mon. Swan Island Portland, Oreg.	LCDR Richard F. Stevens, USNR 811 N. E. Oregon St. Portland, Oreg.
13-5	(Time & Date Not Established) Oregon State College Corvallis, Oreg.	LCDR Albert V. Logan, USNR Chemistry Department Oregon State College Corvallis, Oreg.