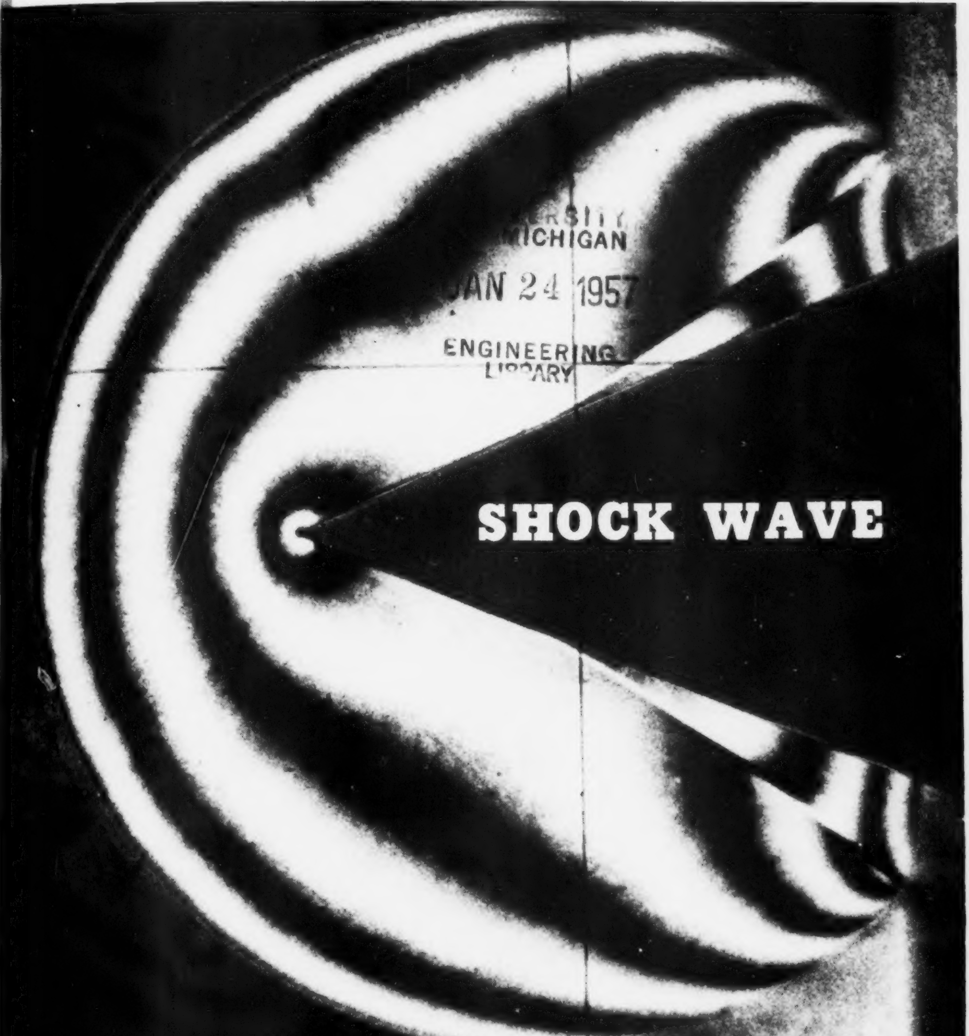
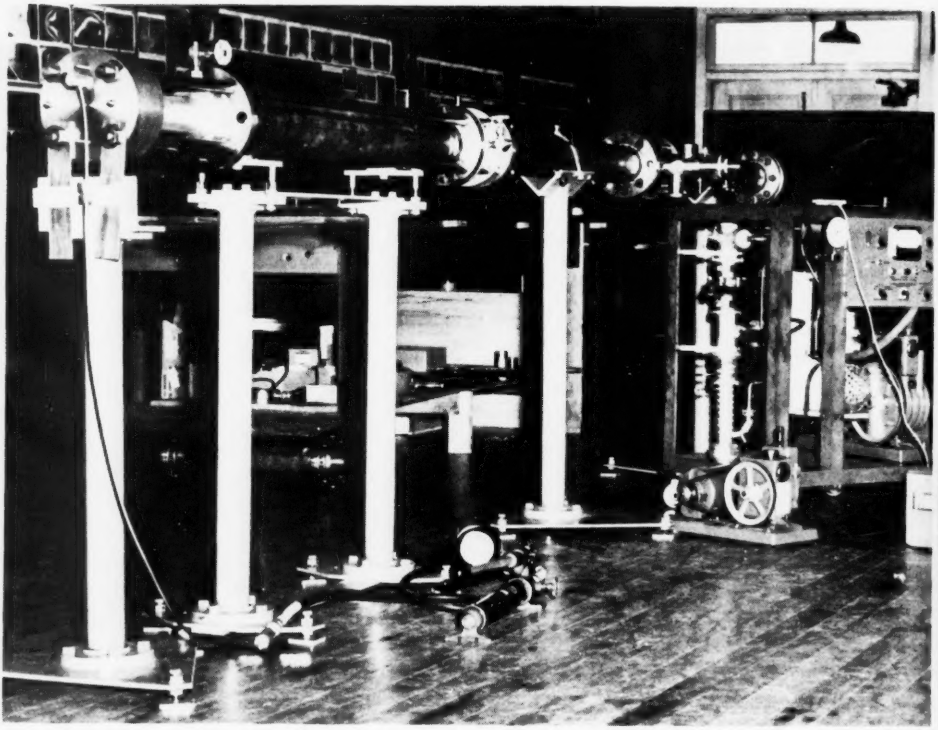
OFFICE OF NAVAL RESEARCH JANUARY 1957

RESEARCH REVIEWS



DEPARTMENT OF THE NAVY
WASHINGTON, D. C.



The Shock Tube

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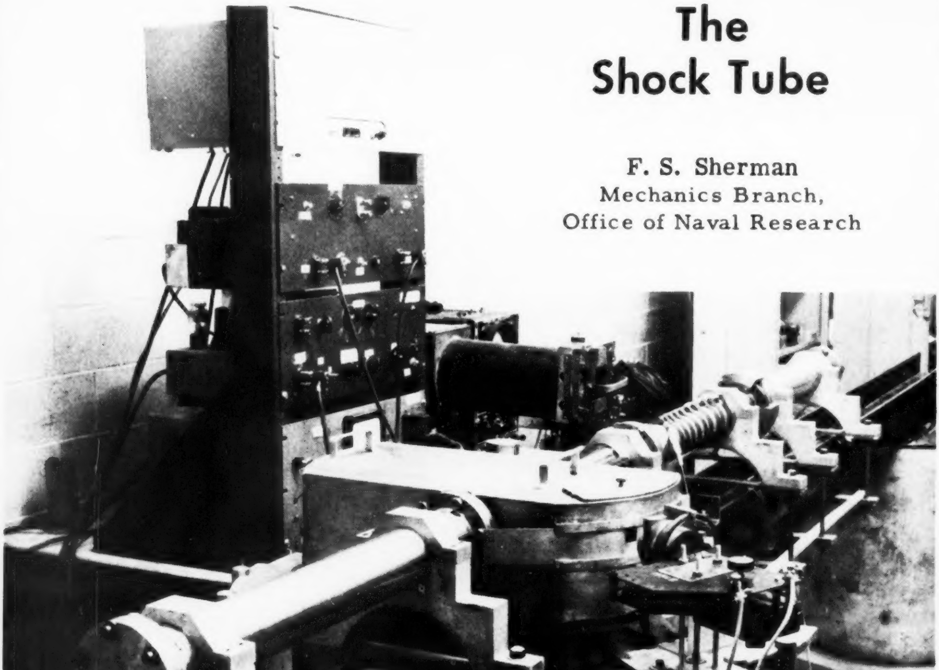
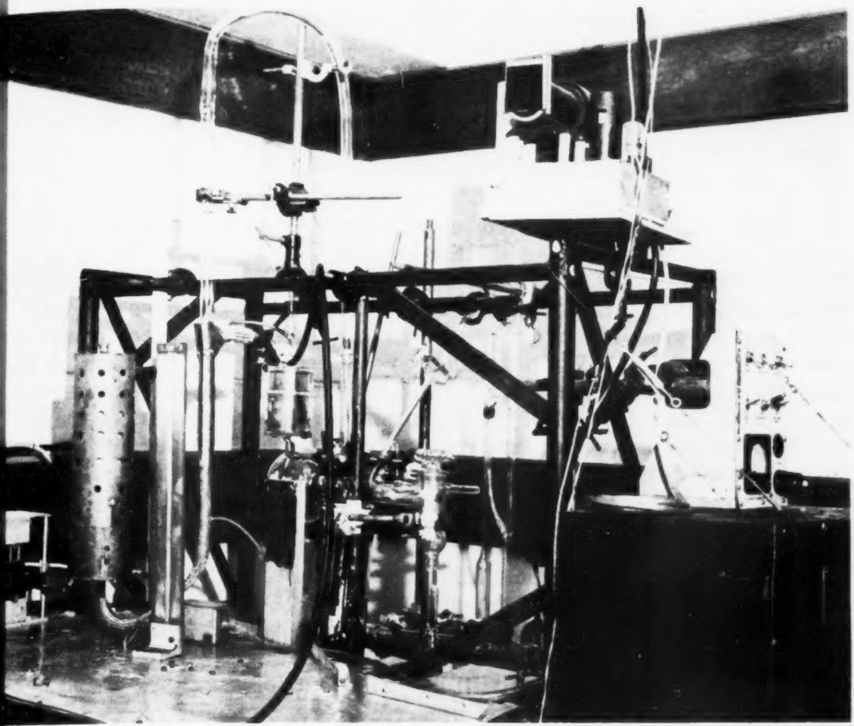




The shock tube is a tricky, versatile tool that is used for research in aerodynamics, heat transfer, thermodynamics, and physical chemistry. It got its start in this country under the Office of Scientific Research and Development, was nurtured by the Office of Naval Research through a period of suspicion and belittlement, and is now riding a high wave of popularity as a result of the role it is playing in research sponsored by the Navy, Air Force, Army, Atomic Energy Commission, and industry. Originally intended as a device for the calibration of pressure gages used in explosion tests, it was later vigorously employed in studies of the basic nature of blast loading of structures for the Armed Forces Special Weapons Project. Today it is a vital tool in research associated with very high speed flight and the production of extremely high temperatures.

WHAT IT LOOKS LIKE—HOW IT WORKS

Shock tubes may be found today in such variety that they are sometimes hard to recognize. The distinctive thing to look for is a piece of straight pipe, special tubing, or rectangular channel from a few inches to a hundred feet in length and from a fraction of an inch to several feet in diameter. The chances are that you will find the shock tube almost smothered under a bewildering array of cameras, oscilloscopes, spectroscopes, and intricate electronic timing gear. Unusual concentrations of gas bottles, vacuum pumps, pressure gages, and scattered thin sheets of cellophane, copper, or steel through which holes have been blown are likely to be a clue as to the shock tube's whereabouts. A few typical shock tubes set up for operation are shown on the title page. If the operator is particularly safety conscious or dramatically inclined, you may be asked to watch the proceedings from behind some sort of explosion shielding or to shield your eyes from a blinding flash of light.

Shock tubes are as varied in the way they work as they are in appearance, but all are alike in that they contain a gas which is to be suddenly compressed by the action of some sort of driver. When the driver rams into this gas at one end of the tube, a compression wave which rapidly steepens into a shock wave, is formedand races down the tube to the other end. When the shock wave reaches a given point in the tube, the gas which it overtakes is compressed, heated, and accelerated in the direction of travel of the shock wave. A good driver keeps this accelerated gas moving at constant velocity for a time long enough for the purposes of the experiment at hand.

FOUR TYPES

Shock tubes may be classified in terms of the type of driver used. Thus four types of tubes can be distinguished. On the surface they appear quite different from one another, but all accomplish the same general effect from the point of view of the gas through which the shock wave is to be driven. They will be called the piston type, diaphragm type, solid-explosive type, and electric type. Let us look at each in turn.

Piston type (Figure 1).—The piston is fired down the tube at finite speed in the gas to be driven. A shock wave forms in front of the piston, as it does in front of any projectile, and because the walls of the tube prevent the escape of the compressed gas around the sides of the piston, this gas accumulates between the piston and the shock wave, forcing the latter to move steadily farther and farther ahead of the former.

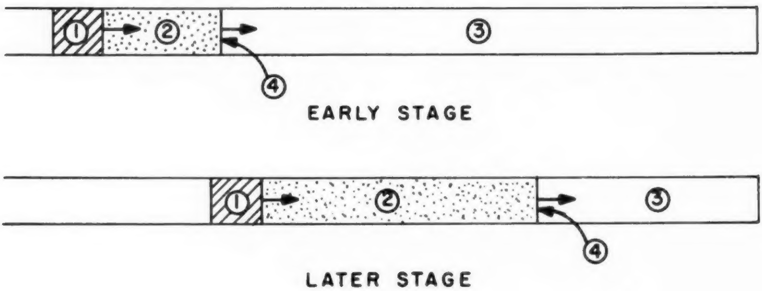


Figure 1 - The piston tube.

1 Piston (driver). 2 Driven ("shock processed") gas. 3 Undisturbed gas. 4 Shock wave.

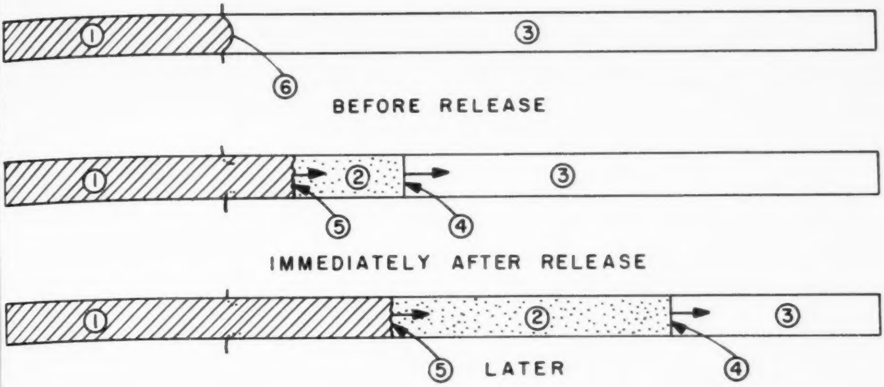


Figure 2 - The diaphragm tube.

1 Driver gas. 2 Driven gas. 3 Undisturbed gas.
4 Shock wave. 5 Contact surface. 6 Diaphragm.

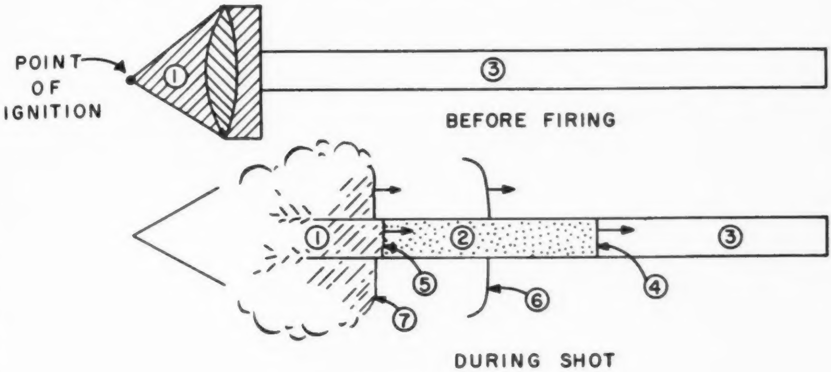


Figure 3 - The solid-explosive tube.

1 Driver. 2 Driven gas. 3 Undisturbed gas. 4 and 5 Shock wave and contact surface in test gas. 6 and 7 Shock wave and contact surface in outside air.

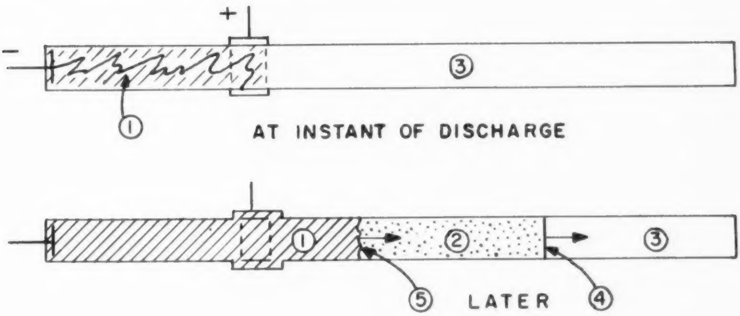
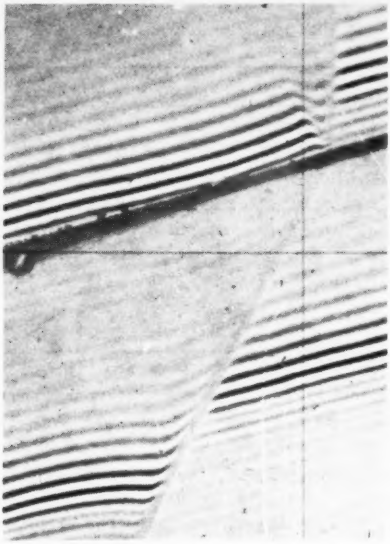


Figure 4 - The electric tube.

1 Driver. 2 Driven gas. 3 Undisturbed gas.
4 Shock wave. 5 Contact surface.



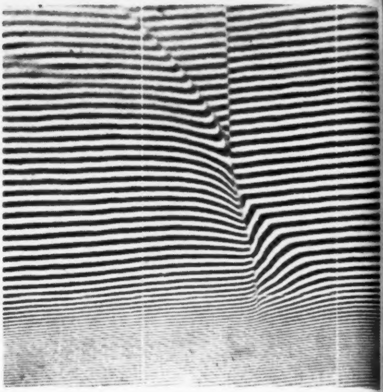
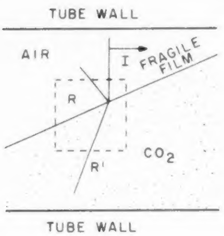


Figure 6 - Shock wave sweeping over a thermal boundary layer.

Figure 5 - Refraction of a shock wave at an interface between air and carbon dioxide.

KEY TO SYMBOLS

D	Diffracted wave
I	Incident wave
M	"Mach stem"
P	Plate
R	Reflected wave
R'	Refracted wave
S	Shock wave 1
S'	Shock wave 2
Sl	Slipstream
T	Thermal boundary layer
----	Photo limits



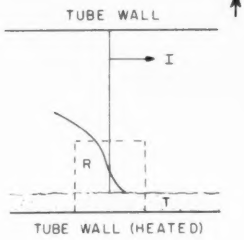
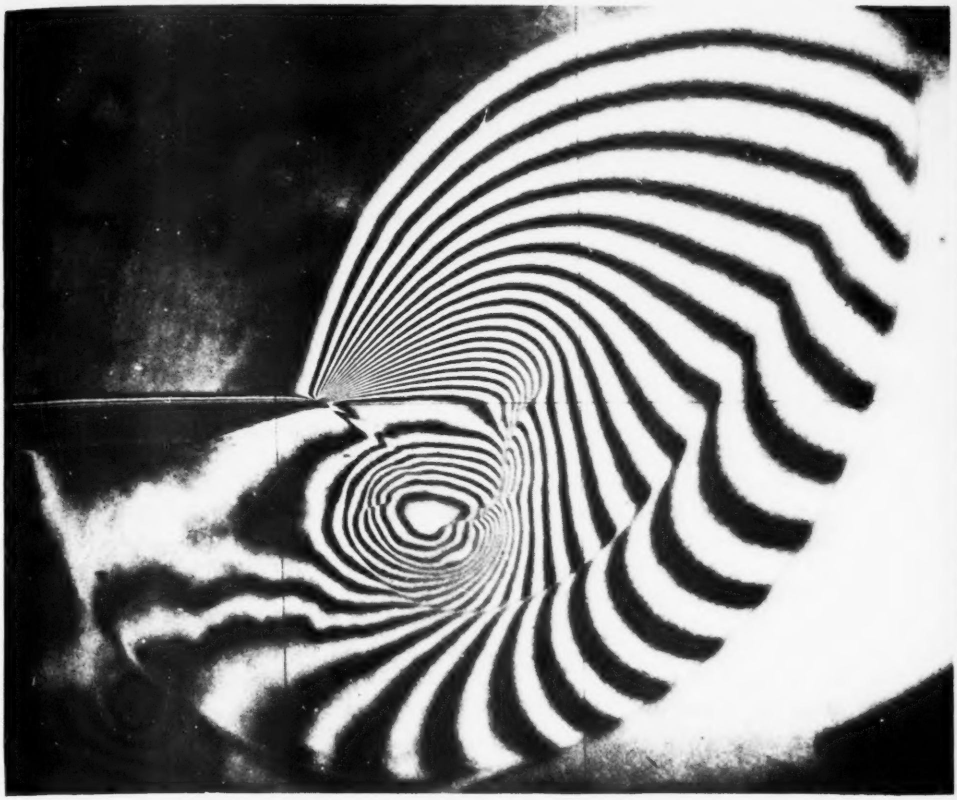


Figure 7 - Two shock waves intersecting obliquely.



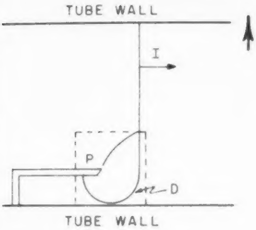
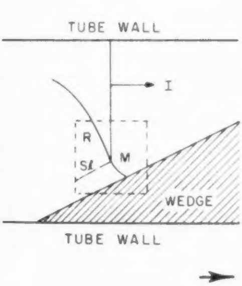
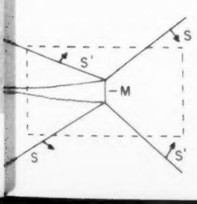


Figure 8 - Shock wave being diffracted around the rear end of a plate.

Figure 9 - Reflection of a shock wave from the surface of a wedge.





Diaphragm type (Figure 2).—Here the driver is high pressure gas, frequently hotter and of a molecular type different from the gas to be driven. The driver gas, which is released by the rupture of a diaphragm, mixes with the driven gas only throughout a very narrow zone, called a contact surface, which is analogous to the driving face of a piston. Note that the shock outruns the contact surface, just as it outruns the piston in the piston-driven tube.

Solid-explosive type (Figure 3).—The development of shaped-charge demolition technology has made it possible to construct explosive "lenses" which can produce an extremely plane explosion front in solid explosives. Such a lens may be placed at one end of a shock tube and detonated. The driver in this case will be the vaporized products of explosive combustion, which act on the driven gas in the same manner as the driver gas of the diaphragm type tube, mixing only slightly with the driven gas in a carefully prepared experiment. This experiment is obviously of an all-out type, a shock tube being destroyed with each shot. Its success depends on the shock wave transmitted through the gas in the tube outracing the elastic waves transmitted through the tube walls, so that the desired observations on the shock-processed gas can be made before the walls disintegrate. In the experiment illustrated by Figure 3, the test gas used is one such as helium, which has a sound speed higher than that of air; therefore, the shock wave and contact surface inside the tube outrun those outside it.

Electric type (Figure 4).—This type of tube is originally filled with one gas. Part of this gas is suddenly converted to driver status by heating it locally by an electric discharge. This electrically energized slug of gas then expands, just as does the driver gas of the diaphragm type tube after the bursting of the diaphragm. The contact surface is very sharp and clean. This operation may quite properly be thought of as channeling a thunderbolt, the discharge being the lightning, and the shock wave the thunder.

RESEARCH USES

Research uses of shock tubes may be divided roughly into three categories, as follows:

Investigations of the properties and behavior of shock waves themselves.—In a sense, shock waves are the big brothers of sound waves, which have long been quite well understood. But the mere strength or violence of shock waves makes their behavior essentially less easy to product by theory. Thus we have had to conduct experiments to learn how shock waves are refracted at a contact surface between two gases (Figure 5), how they interact with a layer of hot gas along a sidewall (Figure 6), how they intersect one another (Figure 7), how they are diffracted around corners (Figure 8), and how they are reflected from rigid walls (Figure 9). Shock-tube experiments tell us how shock waves tend to be thick in complicated gases and thin in simple gases; thus they teach us things about the actual physical structure of the gas molecules.

Investigations of the properties of the driven, or shock-processed gas; particularly of high-temperature gases and their interactions with their environment.—Very hot gases, such as are found behind the shock waves associated with very high speed projectiles (see Figure 10), have a number of properties which have never been accurately determined because such gases are so difficult to handle in the laboratory. In the first place, it is unreasonable to expect that we may study an extremely energetic (hot) gas in equilibrium with its laboratory surroundings, because the gas temperatures of interest (which are perhaps higher than the surface temperature of the sun) lie above the melting or boiling points of all conceivable container materials. Consequently, one naturally looks for some scheme of heating the gas very rapidly and then making very quick observations of its properties before the heat can leak out into the container, trusting that the total amount of energy involved will be too little to damage the container or that the container is expendable. Furthermore, it is frequently very hard to determine (but very desirable to know) just how much energy has been put into a gas to raise it to an observed state of hotness. In a shock tube, the driven gas is heated practically instantaneously by the passage of the shock wave, and the amount of energy

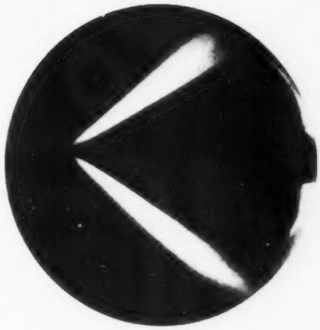
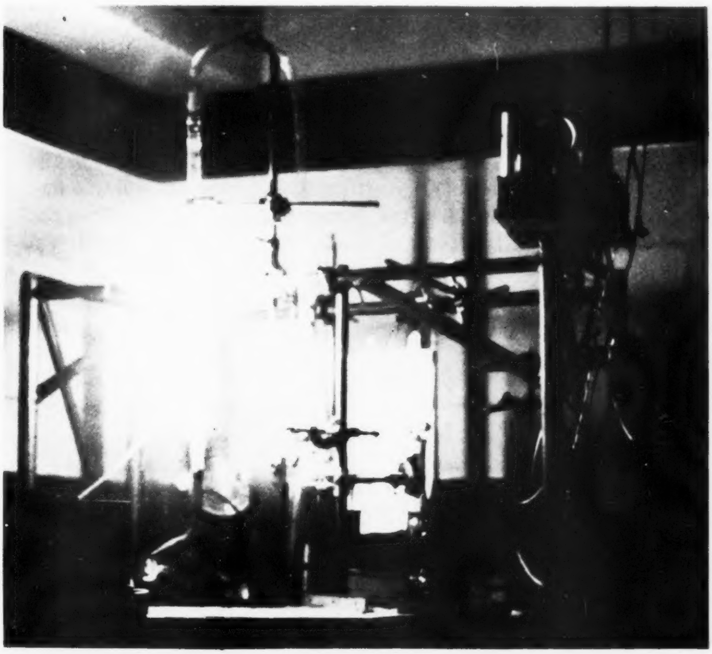


Figure 10 - Luminous flow of xenon over a model wedge viewed through window of tube.

Figure 11 - Light emitted by helium in an electric shock tube.



put into the heating can be accurately estimated from a measurement of the speed with which the shock wave travels. It is true that the energy may start to leak away again almost immediately by radiation, but this loss has been judged to be a minor one in a wide class of important experiments.

Just how one best goes about studying a very hot gas once he has control of it is still open to question and considerable further research. So far, investigators have concentrated largely on observations of two very noticeable characteristics of hot gases, namely their emission of light and their relatively high electrical conductivity. Figure 11 shows the light emitted by helium during the "flashing" of an electric shock tube. High-temperature chemical reactions between gases which don't react at room temperature (such as O_2 and N_2) can be produced and studied by slamming a strong shock wave into a mixture of these gases.

As mentioned before, the energy of the hot gas must eventually leak out into the wall of the shock tube. The mechanisms by which it does this, and the corresponding rates of heat transfer, are current targets of intensive research in connection with high-speed aerodynamics. Conduction, convection, and radiation of heat, and chemical or electrical interactions with the walls may all play a role.

Aerodynamic model testing in the driven gas.—When the shock wave has run far enough down the tube to get well ahead of the slower moving contact surface (Figures 1-4) we may think of placing in the center of the tube a small model over which the shock, and then the constant velocity flow of driven gas, will move. If we are lucky, the steady flow of driven gas will continue long enough for the establishment of a stationary flow pattern about the model, with time left over for some photographic or other measurements, before the contact surface arrives to change conditions. We have then, in the shock tube, an extremely fast-acting and hard to handle, but versatile, competitor of the wind tunnel. The versatility is particularly important with regard to the temperature attainable in the gas being blown over the model.

The Mach numbers reached in the driven gas may be either greater or less than 1 (supersonic or subsonic flow), and although they are limited to values less than about 3 in air in a simple, straight shock tube, they can be increased greatly by attaching an expanding section to the end of the tube, as shown in Figure 12. The added section acts like the expanding part of a supersonic wind tunnel nozzle. The photograph of Figure 10 was actually taken of a model in the test section of such a hypersonic shock tunnel, at a Mach number of about 8.

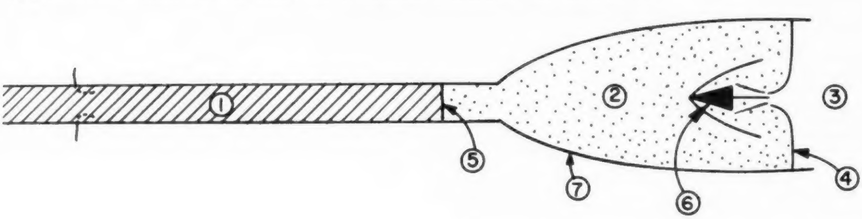


Figure 12 - Shock tube to which an expanding section has been attached. 1 Driver, 2 Driven gas, 3 Undisturbed gas, 4 Shock wave, 5 Contact surface, 6 Model, 7 Nozzle.

It can doubtless be appreciated, even from the little that has been written here, that shock-tube research is not easy to perform. The requirements for precise timing of the rapid sequence of events and observations which make up a typical experiment are hard to comprehend unless one has had experience with similar work. Timing errors must be kept as low as a few ten-millionths of a second in some tests, typical photographic exposure times are a microsecond or less, and the entire experiment usually lasts less than a hundredth of a second. Obviously, the well-rounded shock tube researcher must be at least some part electronic wizard. In addition, if he is to make sense of what he sees in the shock tube, he may have to be a very competent aerodynamicist and molecular physicist. If, on the side, he happens to be particularly clever with photography, or perhaps an expert in spectroscopy, he'll find that these abilities facilitate his work. The shock-tube investigator is a very good example of the combination engineer-physicist who is so much in demand in today's research laboratories.

ONR may well be proud of the success of its shock-tube contractors in training people of this sort. Many of the faculty and students who were among the first to enter this field have spread out to start their own shock-tube projects in other universities or in government or industrial laboratories, so that now, only 13 years after the first American tube was fired at Princeton, there are probably more than 50 separate groups working with this tool.

An excellent technical survey of shock tubes and an introduction to the literature on the subject is presented in a paper entitled "Shock Waves in Gases," by W. C. Griffith and Walker Bleakney, which appears in the American Journal of Physics, December 1954, vol. 22, no. 9, pages 597-612.

NRL Develops a Long-Lived Glowing Paint for Aircraft

In 1953, the Assistant Secretary of the Navy (also an Active Reserve pilot) for Air, asked the Naval Research Laboratory to tackle the problem of increasing the effective life of the highly visible, luminescent paint used to mark Naval aircraft. Commercially available paints were bright enough when first applied, but they stayed bright for only about 6 weeks. What was needed was a paint that would stay bright for as many months.

In answer to the request, a new orange-red paint that includes ultraviolet light absorbers was formulated by NRL chemists. The paint is of high visibility and remains luminescent for about the length of time desired--6 months. NRL's Flying Laboratory (a converted DC-4) has tested it in murky Arctic weather and has found that it is as conspicuous as a bonfire. Members of Expedition DEEPFREEZE I, out looking for two planes downed in the Antarctic, made the same discovery. The brilliant orange-red paint on the upper wing surfaces of the downed planes was quickly spotted by the searchers, thus making possible the early rescues of the crews.

H-Bomb Fission Products Collected in Equatorial Pacific

Within weeks after the last United States H-bomb tests were made in the equatorial Pacific, 11 ships of 3 nations moved in concert into the region to study the waters affected by the blasts. Two of the ships that participated belong to the Scripps Institution of Oceanography, whose role in the investigations was supported by the Office of Naval Research. Other ships participating were provided by the U. S. Fish and Wildlife Service (2), Japan (6), and France (1). Never before have so many ships worked together in the equatorial Pacific at the same time.

One of the purposes of the undertaking—called EQUAPAC (EQUAtorial PACific) Expedition—was to study, by means of the increased radioactivity, the movements of the ocean waters. In reporting on the radioactivity studies, Roger Revelle, director of the Scripps Institution of Oceanography, pointed out that oceanographers were interested in the problem not primarily to learn more about radioactivity, but to learn more about the ocean.

"You can hardly find a better method of determining horizontal diffusion in the ocean and the rate of mixing in the upper layers than to

The Scripps Institution of Oceanography's STRANGER, one of 11 ships which studied waters affected by the last H-bomb blast in the equatorial Pacific.

collect fission products," he said. "From these studies, we will learn a great deal about how fast substances are moved from one place to another in the ocean and how long they stay in the upper layers before sinking to the deep sea. Such studies are essential if we ever plan, as has been suggested, to dump radioactive wastes from peacetime reactors in the ocean.

"All oceanic waters are radioactive to a slight degree. Since these values are known, the introduction of fresh fission products can be readily determined. The explosion of an H-bomb for the first time introduces into the water enough fission products to permit very detailed and accurate studies of the oceanic circulation over a very wide area. It is a wonderfully useful method of studying the ocean."

The area covered by the ships participating in EQUAPAC lies between the latitudes of 20°N. and 5°S. and extends from the United States to the Philippine Islands and Formosa. The Japanese worked in the area west of the Marshall Islands where most of the fission products from the H-bomb were expected to be carried by currents. Ships of the United States and France collected samples in other parts of the equatorial Pacific to fill out the picture of the distribution of radioactivity.

In addition to making radioactivity studies, oceanographers aboard the ships investigated the water temperatures and currents and took samples of plankton organisms and fishes, much as was done on NORPAC, the United States-Canadian-Japanese expedition carried out in the northern Pacific in 1955.

Studies of Radioactivity in the Air to be Expanded

Plans are now underway to expand the program for the study of the distribution of natural and man-made radioactivity in the air that was begun by the Naval Research Laboratory in 1949. The expanded program will be conducted by NRL in cooperation with the Atomic Energy Commission, the Weather Bureau, and the meteorological services of Ecuador, Peru, and Chile. According to the plans, a network of ten to twelve monitoring stations will be set up along the 80th meridian West from Greenland to Antarctica and will be operated during the International Geophysical Year 1957-1958. Seven of the stations are already in operation. The network will supplement a series of stations which have been operated by NRL in Washington, D. C., and at several Naval establishments since 1949.

Two general methods of collecting and analyzing data will be used. In one, samples of airborne particulate matter will be collected on gummed film, cloth screen, and filter paper and returned to NRL for analysis. In the other, naturally occurring radon and thoron decay products and gross fission products will be collected and their radioactivity measured at the collection site.

When coordinated with meteorological data, the information obtained at these stations will give scientists a better knowledge of the distribution of both natural and fission-product radioactivity, the rate of its removal from the atmosphere and the factors responsible for the removal, and the movement of air masses. This information will also be of help to biophysicists in evaluating the possible hazards associated with the fallout of fission products.

Portable Aerosol Generator

To most of us the word "aerosol" means getting rid of mosquitoes and other insects and spraying new paint on old kitchen chairs. We don't often think of aerosols as being useful in other ways. But to scientists in the Protective Chemistry Branch at the Naval Research Laboratory, the word has a much broader meaning. By means of aerosols they are able to carry on their research to better advantage in many fields, including, even, meteorology.

Aerosols are dispersions of small liquid or solid particles in a gaseous medium. To dispense them most effectively for scientific purposes, a number of special generators have been built. One of these—a special portable generator (Figure 1)—has been developed by the Protective Chemistry Branch at NRL to facilitate its investigations of ventilation and air-cleaning systems. This generator operates on compressed air at 5 pounds pressure and provides a polydisperse aerosol at a rate of 40 liters per minute from either liquids or suspensions.

One of the better known aerosols is that of dioctyl phthalate (DOP). As dispensed by the NRL portable generator, this aerosol has a most-frequent particle size of 1 micron, a maximum particle size of 3 microns, and a mass concentration of 180 micrograms per liter; the light-scattering power is sufficient to give a reading of 100 percent on the

Figure 1 - The portable aerosol generator.

NRL Light Scattering Meter. This light-scattering power is equivalent to that of a monodisperse DOP aerosol (the aerosol usually used for filter-paper testing) whose particles are 0.3 microns in diameter, whose mass concentration is 100 micrograms per liter, and whose number concentration is 10^9 particles per liter.

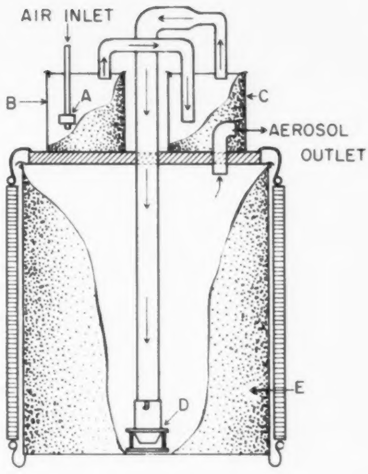


Figure 2 - Sketch of generator, showing component parts.

Details of the generator are shown in Figure 2. It consists of an atomizer nozzle (A) immersed in a liquid reservoir (B), and a spray trap (C), a jet impactor (D), and a surge tank (E). The atomizer nozzle and jet impactor are fabricated from brass. The liquid reservoir and the spray trap are 1-pint metal cans; the surge tank is a 5-gallon can. Connecting pieces are made of copper.

The generator weighs 10 pounds and occupies 3 cubic feet of space. Because all that is needed to operate it is a source of compressed air, it is especially suitable for use away from the laboratory where it might be impractical to use more elaborate equipment. The generator has been used both in the laboratory and in the field for such purposes as studying the performance of certain types of air filters, tracing air currents, and locating and measuring very small air leaks.

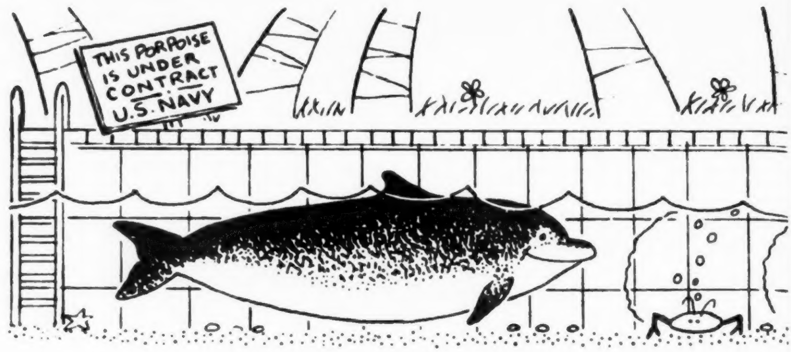
ONR Symposium Rescheduled for March 19th and 20th

"A Decade of Basic and Applied Science in the Navy," the symposium to be held by the Office of Naval Research as part of its Decennial Year, was originally scheduled for March 26 and 27 and was so announced in Research Reviews, December 1956. However, because a convention that is being held in Washington on those days will take over all available facilities, the symposium has been moved up one week--to the 19th and 20th. The new dates are firm.

French Award Given to ONR Contractor

The French Metallurgical Society has awarded its Grande Medaille Le Chatalier to Dr. Robert F. Mehl, Metallurgist of Carnegie Institute of Technology. Much of Dr. Mehl's research in metals has been under contract with the Office of Naval Research. He has been associated with ONR's metals research programs ever since ONR was established, 10 years ago. Among the investigations under ONR contracts in which Dr. Mehl has played a vital part are those concerning the properties of metals and alloys and the corrosion of metals.

Drawn by
Ken Duggen,
All Hands
Magazine



Research in Hydrobiology

So that the presence of enemy mines, submarines, and surface ships can be detected in time to take protective measures, the Navy uses modern electronic equipment. The efficiency of this equipment can be materially reduced by the presence of marine organisms. Early in World War II, "false bottoms" were recorded by our echo sounding gear used to measure the depth of water. It was learned that these "false bottoms" were echoes returned by great communities of organisms which live at varying depths in the sea, depending on the time of day. They were dubbed the "deep scattering layer." The communities of organisms were studied, and now the Navy knows when to expect their equipment to record this echo and how to recognize it.

If our Navy is to do its job at peak effectiveness, its equipment must be in peak condition. The accumulation of barnacles and other fouling organisms on a ship's hull reduces her speed, causes additional engine wear and fuel consumption, and changes her handling characteristics. She makes more noise as she goes through the water, making detection by the enemy easier. The ship must, therefore, be put into drydock periodically so that her hull can be cleaned. Time spent in drydock is expensive, and the ship is kept from her job. All shipboard equipment exposed to the sea, plus harbor defense nets and buoys, are subjected to severe environmental conditions, with resultant expensive maintenance necessary. The development of special anti-fouling, anti-corrosion, and protective coatings is aimed at reducing overhaul time. Damage to wooden structures like pilings and small boats by marine borers costs American shipping half a billion dollars annually. The Navy must strive, through basic research, to improve the protective agents used against marine biological deteioration.

The use of sonar by submarines and in anti-submarine warfare has increased with the growth of the submarine as a defense tool. Sonar has become the submarine's chief means of locating enemy surface vessels and submarines. During World War II, sonar operators often received sonar "contacts" that later proved false. Often, the sonar echo had bounced off a whale, shark, or other large animal, and was

misinterpreted as a ship echo. The resulting loss of time in tracking a non-existent opponent, as well as the psychological impact associated with false alarms, proved to be a serious problem for the Navy.

A wide variety of undersea organisms make noises of various sorts. Some of these noises can be confused with those a ship makes. Even small fish, which, singly, make barely audible noises, create sufficient interference, when they travel in schools, to drown out the sounds of a large ship. Continuing research in identifying and characterizing marine sounds is aimed at helping sonarmen know when and where they can expect such noises, and how they can differentiate between them and the sounds of ships.

Much information has been gathered concerning the characteristics of poisonous and venomous fish by the Biology Branch of ONR. Familiarity with this subject is vital to fliers downed at sea, survivors of sinkings, and underwater demolition teams. These men must be able to recognize the marine life which is dangerous and know how to avoid it. Survivors must know what marine life they can eat, how to protect themselves against sharks, barracuda, and other flesh-eating fish. It has been found that some fish are poisonous at one time and in one area, while under other conditions they are edible. Fish poisons are tasteless and odorless; sight recognition of a harmful species must be relied upon for survival.

Some marine organisms exhibit biological luminescence. This phenomenon can aid in detection of a darkened ship at night—especially from the air. As she steams along, the vessel's wake is alive with glowing marine life. Even submarine snorkels and periscopes cause sufficiently luminescent wakes to give an enemy an advantage on a dark night. Investigations of this phenomenon, like the studies of the makeup of fish poisons, and like the basic research that is being conducted in many other subjects, promises to contribute information that is of value, not only to the military, but to the general fund of scientific knowledge.

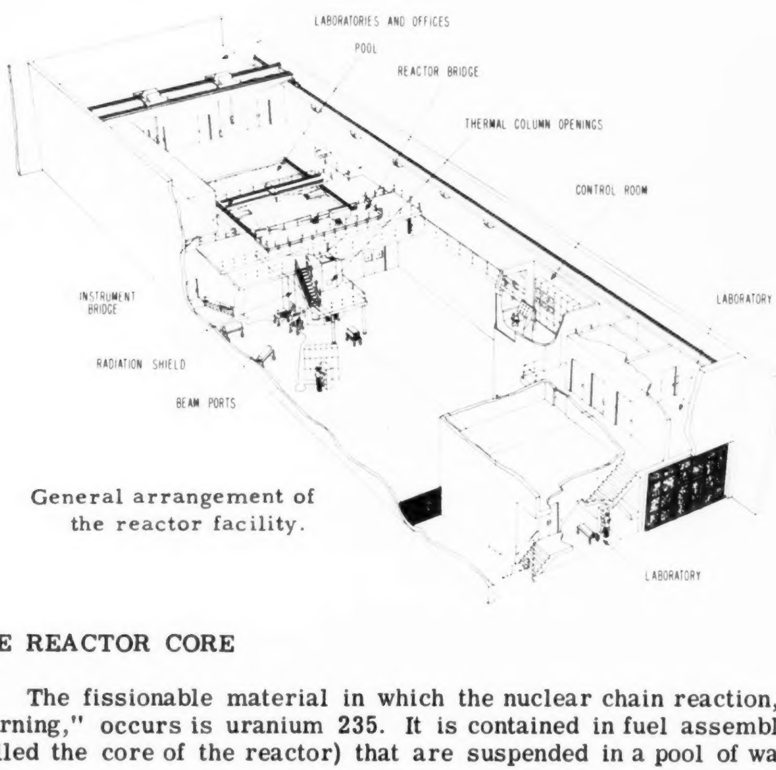
In evaluating the worth of marine biological research in terms of its usefulness to the Navy, no single project by the Office of Naval Research can be considered alone. It is all the investigations taken together that prove the worth of the efforts. In combination, this work is helping achieve the goal of the entire Naval establishment: to keep our Navy abreast of the most modern scientific, technological and operational developments for the fulfillment of its mission in the defense of the United States.

NRL's Nuclear Reactor

E. N. Stirewalt
Reactor Supervisor, Naval Research Laboratory

One of the most unusual buildings both inside and out at the Naval Research Laboratory is the 60-foot by 210-foot structure that houses NRL's nuclear reactor. The building has no windows, all of its exterior doors are a heavy, refrigerator type that close on gaskets, the air ducts of its ventilation system are hooked up in such a way that all can be shut instantly by pushing a button and its walls are sealed with a layer of aluminum foil. These containment measures have been incorporated in the design of the building for the protection of personnel in the vicinity in the unlikely event radioactive materials should be released in the building.

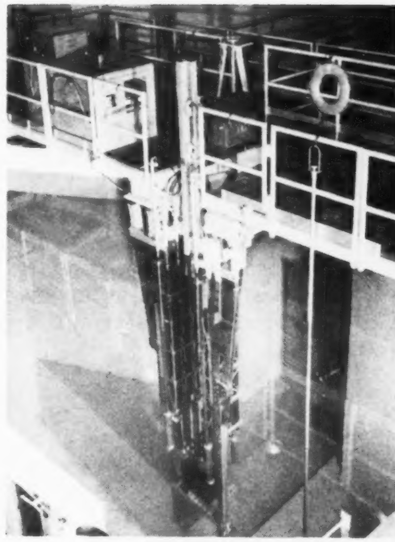
The reactor's primary function is to produce a powerful supply of neutrons. The neutrons are usedfor research in such fields as nuclear physics, solid-state physics, metallurgy, chemistry, mechanics, electronics, and reactor technology. By means of these subatomic particles, studies are made of the structure of matter; new substances are created; chemicals are made radioactive in order that they and their decay products can be analyzed; and chemical and biological changes are effected.



General arrangement of the reactor facility.

THE REACTOR CORE

The fissionable material in which the nuclear chain reaction, or "burning," occurs is uranium 235. It is contained in fuel assemblies (called the core of the reactor) that are suspended in a pool of water from a movable bridge that spans the pool. A single fuel plate (A) (see illustration below) contains about 8 grams of uranium 235. It consists of a sandwich 60-thousandths of an inch thick. The filling of this sandwich is uranium-aluminum alloy 20-thousandths of an inch thick and the two outer layers are aluminum cladding, each 20-thousandths of an inch thick. The cladding seals in the radioactive products formed by the splitting of uranium 235 atoms, preventing them from contaminating the pool and the air.

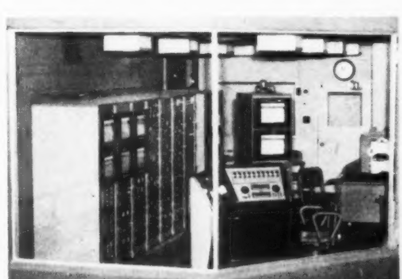


The reactor core assembly suspended in the pool.

A fuel assembly consisting of 18 fuel plates containing a total of 140 grams of uranium 235 is shown in (B). Half of the plates have been removed from the assembly shown in (C) to permit the insertion of control and safety devices. To regulate

Uranium-bearing fuel components. (A) Single fuel plate. (B) Fuel element assembly of 18 plates. (C) Special assembly for insertion of control or safety rod. (D) Stainless steel control rod.

The reactor control room.



the power of the reactor, a stainless steel rod (D) is placed in the core and moved up and down. To provide for rapid quenching of the reaction, if such is needed, several other rods containing boron, a good neutron absorber, are inserted in the core. Each safety rod is coupled to its drive rod by an electromagnet. If an undesirable condition should arise, the current to the magnet is interrupted and the rod falls by gravity into the core, stopping the reaction.

Radiation detectors—the eyes and ears of the system—are located on each side of the core. The remainder of the system consists of motors that drive the rods up and down, instruments that display and record the signals from the detectors, a control console, and a complex electrical and electronic system that coordinates all phases of the activity.

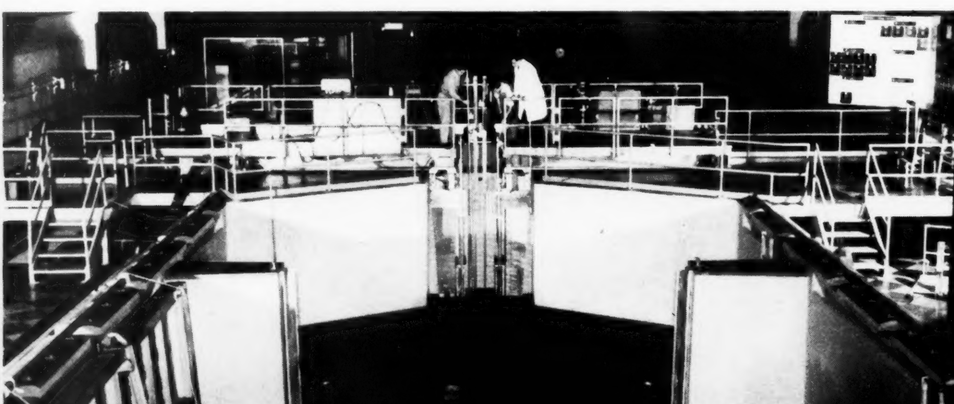
THE POOL

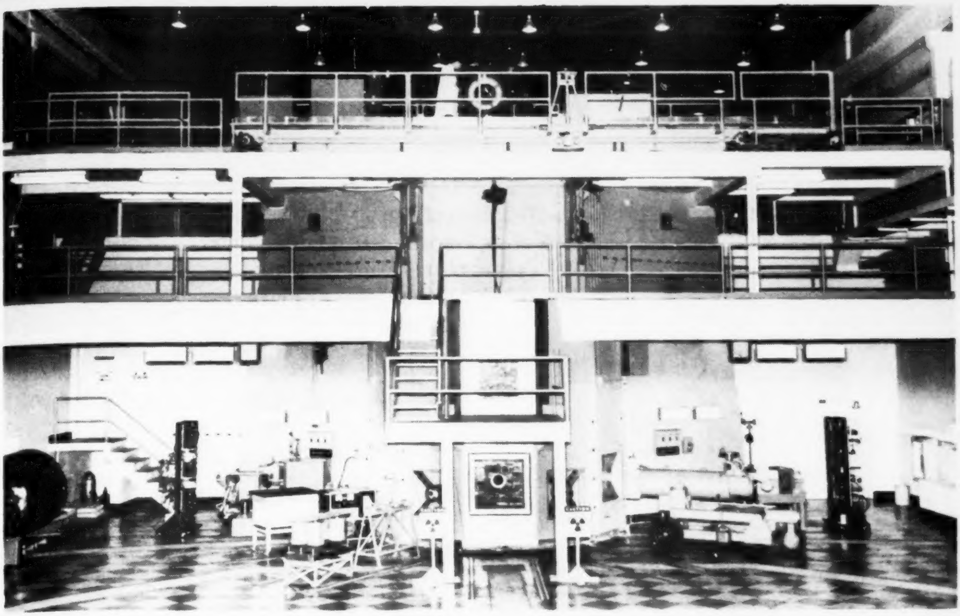
The pool is 40 feet long, 26 feet wide, 20-1/2 feet deep, and holds 150,000 gallons of water. It may be divided in half by positioning a movable water gate across its center, a provision which increases the flexibility of operation by making it possible to drain part of the pool while the reactor is being operated or the radioactive core is being stored in the other half. The portion of the pool farthest from the main shield may be used as a shielding facility for investigations aimed at improving methods of calculating radiation shielding requirements. It may also be used as a gamma-ray irradiation facility.

The water serves three purposes. First, it slows down the fast-moving neutrons which are released when a uranium 235 atom breaks in half. Fast-moving neutrons are less effective in causing the fission of other uranium 235 atoms than slower moving neutrons are. Therefore, the presence of water reduces the amount of uranium 235 necessary to sustain a nuclear chain reaction. Second, the water serves as a coolant to remove the heat formed in the uranium by the reaction. And third, it forms a radiation shield which protects personnel from the harmful neutrons and gamma rays generated in the core of the reactor.

The water drains from the pool into a 170,000-gallon tank, where it is carefully analyzed by health physicists to assure that permissible biological tolerances are not exceeded before it is discharged into the Potomac River.

View of the pool, showing the control room in left background and core loading board at the right. A fuel element is being loaded into the core.

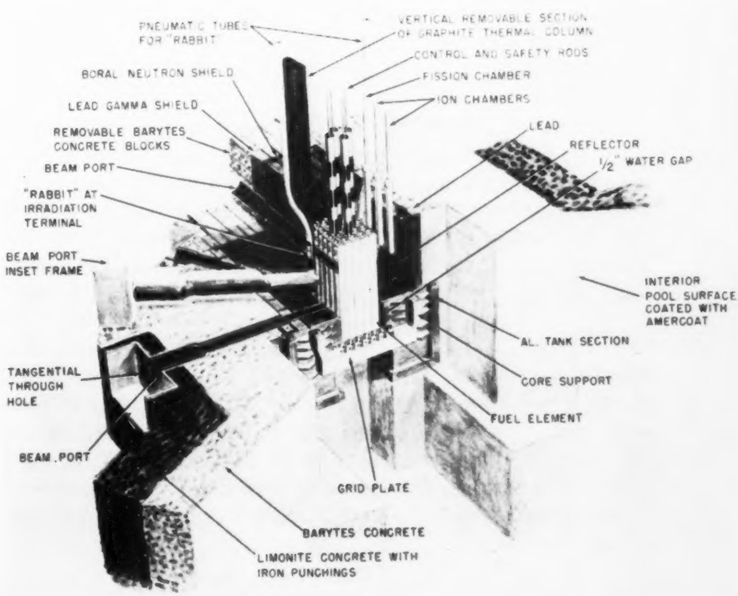




The east face of the reactor pool, showing the main shield and beam ports.

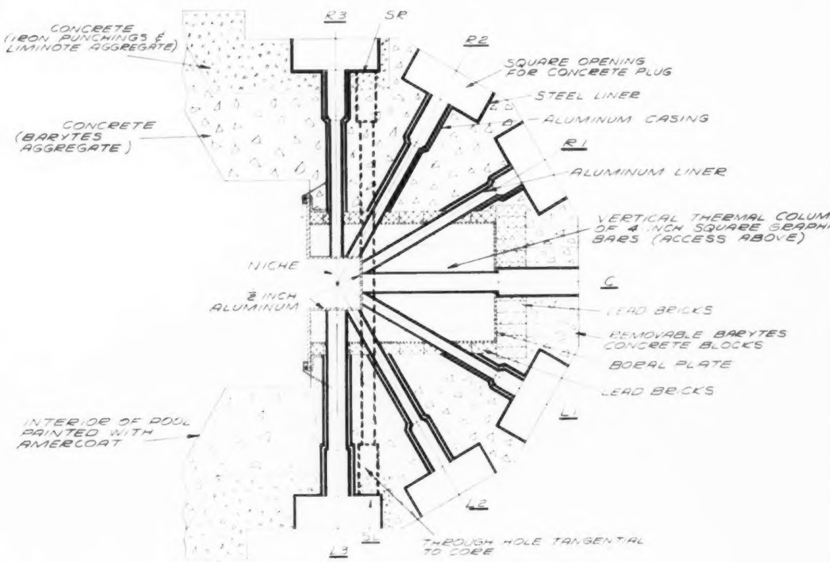
THE MAIN SHIELD

The pool is walled off at one end by a heavy concrete radiation shield. This barrier is penetrated by a number of openings, or "beam ports," that provide access to the core. Special concrete was used to build the shield. The heavy aggregate on the side toward the core is barytes, a barium sulfate rock, which is a good neutron absorber. In sections of the shield behind the barytes portion, the heavy aggregate is iron ore and iron punchings, which serve as a shield to stop the gamma rays.



Cutaway drawing of the main shield.

In the center of the shield just behind the reactor core recess is a stack of graphite blocks, called a thermal column. Graphite is a dense form of the element carbon, which is a good medium for slowing down neutrons to thermal velocities. The graphite extends out on each side of the core recess, or niche. The graphite immediately surrounding the core is sometimes called the reflector because many of the neutrons which are slowed down in this region diffuse back into the core. When the core is in the niche it is graphite-reflected on three of the surfaces that surround it and water-reflected on the other three. Because graphite is a better reflector than water, less fuel is required to constitute a critical mass in the niche than is required out in the pool.



Plan drawing of the main shield.

THE HOT CELL

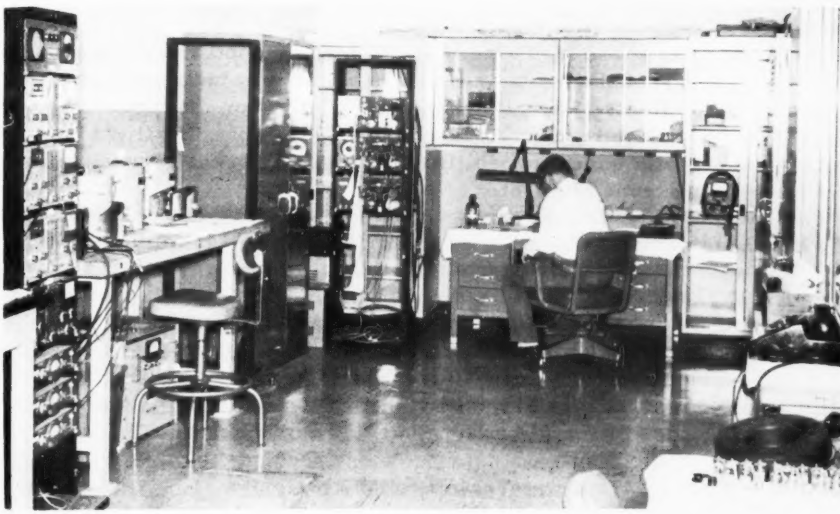
A room heavily shielded by concrete, called a hot cell, adjoins the pool at the end opposite the main shield. Many metallurgical, chemical, and mechanical operations can be conducted on highly radioactive specimens in the kilocurie range in this room by scientists working with special manipulators from an adjoining room. Objects made radioactive by exposure to the reactor core may be transferred directly to the hot cell through one of three underwater transfer chambers.

The cell is equipped with special windows, 3 feet thick, through which operations can be viewed. The windows consist of two sheets of plate glass, each 1-inch thick. Spaces between these sheets are filled with a saturated solution of zinc bromide, a dense liquid that has good optical properties and that is an excellent attenuating medium for radiation. The hot cell is equipped with a pair of master-slave hand manipulators and a heavy-duty manipulator operated electrically from a console.

SHIELDED RADIATION MEASUREMENT LABORATORY

Samples that have been made radioactive by exposure to the reactor are measured, or "counted," in a laboratory whose walls and ceiling consist of concrete 2 feet thick. This shielding reduces the amount of background radiation reaching the room, thereby allowing more accurate measurements to be taken.

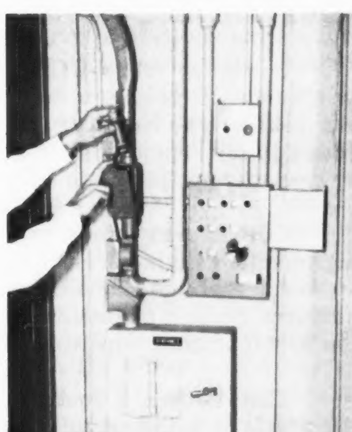
An operator checks a pair of master-slave remote manipulators in the hot cell.



The shielded radiation measurement laboratory.

The "RABBIT" SYSTEM

Small quantities of materials to be irradiated are placed in carriers, called rabbits, which are transferred by compressed air through a system of tubes to terminals near the core. After irradiation, the containers are returned to lead-walled receiving boxes outside the main shield or to remote receivers near laboratories in the building.



"Rabbit" being inserted in penumatic tube system for irradiation.

CDR G. W. Hoover: "Pioneer in Modern Aeronautics"

The American Astronautical Society has presented its first spaceflight award to CDR G. W. Hoover, Instrumentation and Special Projects Officer of the Air Branch of the Office of Naval Research. The presentation climaxed the Association's third annual meeting, held in New York City on December 6-7, 1956. The citation given to CDR Hoover reads as follows:

Pioneer in Modern Aeronautics—

The man whose driving spirit, organizing genius, imagination, and foresight set in motion the mighty effort toward the first man-made earth satellite, man's first step toward space flight.

Pioneer in high altitude research, a necessary step toward space flight, he added immeasurably to our knowledge of the threshold of space by means of high altitude plastic balloons.

Pioneer in space medicine, he was instrumental in the conception and development of the human centrifuge which was instrumental in establishing the effects of large accelerative forces on the human system.

Pioneer in instrumentation, his concept of equating flight control requirements with human capabilities is resulting in the simplifications requisite to all types of flight.

Given in recognition of his achievements and unselfish labors in the advancement of the science of space flight.

CDR Hoover's greatest contribution to space flight has been in recognizing the potentialities of the satellite as a research tool and in fighting for its adoption as one. In 1954, he brought together a number of qualified people interested in space operation to determine the feasibility of launching a satellite. This meeting did much to catalyze the belief that a satellite could be launched successfully.

Ten years ago at the Training Device Center, CDR Hoover was actively engaged in Project HELIOS, a program of high altitude research from a manned space laboratory carried aloft by balloons. Recently, as part of Project STRATOLAB, a successor to HELIOS, three manned flights were made, one to a record altitude of 76,000 feet.

For many years CDR Hoover has been working on an aircraft instrumentation program that has safe, all-weather flying as its goal. For example, he has urged the use of simplified instrumentation that will result in the replacement of many of the instruments in today's cockpit by transparent flat-plate television tubes.

CDR Hoover's interest in the upper atmosphere and in high-speed, high-altitude flight also includes aeromedical research. When it became apparent that the human centrifuge at Pensacola was not adequate to perform certain phases of aeromedical research, CDR Hoover pushed the development of one that would be.

CDR Hoover's contribution to space flight can be summed up in the words of a colleague: "Let's do it. Let's do it now."

Heat Transfer in the North Atlantic Ocean

Glenn H. Jung
Department of Oceanography and Meteorology
Texas A and M College

For several centuries scientists have recognized that the earth and its fluid envelope receive a surplus of heat by solar radiation in equatorial regions. The polar regions in turn lose more heat than they receive from the sun. As there has been no significant progressive heating in equatorial regions nor cooling in polar regions within recent times, it must follow that a transfer of heat takes place from the equator to the poles.

The solid earth presumably does not conduct heat or other forms of energy in measurable amounts; consequently, the fluid envelope must act as the exchange medium. How such energy transfer is divided between atmosphere and oceans within the envelope has been a question of interest to meteorologists and oceanographers throughout the years. It has been assumed that most of the transfer occurs in the atmosphere and that relatively little takes place in the ocean. But is this assumption justified? A study of heat transfer in the North Atlantic Ocean indicates that it is not.

The transfer of energy horizontally in an ocean can be accomplished by several processes, the most important of which is advection. To determine the amount of energy transported by advection, one needs to know the temperature and salinity at various depths throughout the ocean. Temperature and salinity measurements used in the recent study of the North Atlantic Ocean were obtained primarily from atlases prepared by the METEOR Expedition; these atlases are based on all data collected in the North Atlantic Ocean before 1927, the year of the expedition. Temperature and salinity measurements obtained recently by the Navy Hydrographic Office were also used in the study. These data were plotted on a series of eight cross sections of the North Atlantic Ocean spaced about 9 degrees of latitude apart from the equator to 63° N.

From the bathymetric chart prepared by the METEOR Expedition, depth contours of the ocean were drawn for each cross section. By reference to these contours the areas of the cross sections were calculated. Estimates were then made of the depth below which the water does not move. The advective flows of mass, salt, and heat were then determined for all ocean levels. Estimates were also made of the vertical mass transfer between the deep, intermediate, and upper layers.

As a result of the studies of these ocean data and of radiation data compiled recently by competent investigators, new values of atmospheric and ocean heat transport have been computed. These values indicate that less heat is transported by the atmosphere and more by the ocean than had previously been assumed, especially in the subtropical latitudes. The amount of heat released to the atmosphere from the North Atlantic Ocean was also estimated from the ocean heat-transport data. This exchange may be great enough to have a pronounced effect on atmospheric cyclogenesis and, therefore, on weather conditions.

The simplest concept of effective horizontal heat transfer in the ocean involves poleward flow of water in the surface layers (which are of relatively high temperature) and equatorward flow of water in the deep layers (which are of relatively low temperature). A modification of this simple picture would permit a large portion of the surface water to return equatorward within the surface layers. Such a system of heat transfer appears to exist in the North Atlantic Ocean. Thus the concentrated northward flow of the Gulf Stream is partly compensated for by the broad southward current on the eastern side of the Atlantic Ocean and partly by the equatorward flow of the deep water.

Laminated Woods, Ahoy!

Laminated woods not only make better bows for archers and skis for skiers, but they also make better spars and masts for ships. Natural solid wood that is long enough to serve as spars and masts is difficult and expensive to obtain and often contains hidden defects and characteristics that lead to early checking, splitting, or decay. Therefore, the Bureau of Ships is examining the possibility of stocking laminated wood-turning squares as much as 60 feet in length instead of stocking masts and spars of natural solid wood.

Laminated material, when properly fabricated, does not have many of the inherent defects and limitations that the solid wood has. It has been used successfully in the construction of many minesweepers, providing structural members that are dry throughout, free of incipient decay infections, checking, splitting, and sapwood.

New Executive Officer at Training Device Center


CDR Hudgins

CDR William D. Hudgins, USN, relieved CDR Charles R. Gebhardt, USN, last month as Executive Officer at the U. S. Naval Training Device Center, Sands Point. The new Executive Officer will also serve as Administrative Director of many of the Center's key departments.

CDR Hudgins reported from duty at the Tenth Naval District Headquarters, San Juan, Puerto Rico, where he served for 2 years as Commanding Officer of the Bureau of Ships Industrial Manager Organization and staff officer to the Commandant, RADM G. B. H. Hall, USN. Before going to Puerto Rico, CDR Hudgins was Executive Officer for the Supervising Inspector of Naval Materiel in Chicago. During World War II, he served as Radio Materiel Officer at the Naval Operating Base, Trinidad, British West Indies, where he was responsible for construction of major communications stations used to relay radio messages between Washington, D. C., and northern Ireland during the European invasion. While he was in Trinidad, CDR Hudgins also organized and directed the Electronics Ship Repair Activity for convoy escort vessels running from Trinidad to ports in Brazil, Africa, and Cuba.

On the Naval Research Reserve

Naval Reserve Research Panel 9-13 Assists in Strato-Lab Launching

An important behind-the-scenes figure in the launching of the STRATO-LAB on 8 November 1956 from the "Strato Bowl" near Rapid City, S. Dak., was LCDR Willard J. Martin, USNR, Officer-in-Charge, Naval Reserve Research Panel 9-13, Rapid City, S. Dak. LCDR Martin, known in civilian life as Dr. Martin of the faculty of the South Dakota School of Mines and Technology, was assisted by LCDR Clyde Harbison, LT Donald Macken, LTJG Robert Sandvig, and LT Danti Santi—all Reserve officers associated with Panel 9-13. Some of the ways the panel assisted in the launching are as follows:

- Provided information and advice on the local available facilities.
- Provided services, such as duplicating services and the facilities of the School of Mines.
- Assisted the observation groups at the time of the launching; one group was stationed on the rim of the "Strato Bowl" and the other in the bowl.
- Cared for invited guests and made arrangements for reporters and photographers.

These details could have been accomplished without too much strain if the exact time of the launching could have been established in advance. However, because the success of the flight depended on the weather, only a tentative schedule could be drawn up. This schedule called for the launching to take place at sunrise on 5 November. But as the weather was not favorable at that time, the launching was postponed. During the following 2 days the flight was scheduled and cancelled several times. It was not until shortly after midnight on Thursday, 8 November, that conditions were favorable, final arrangements were made, and the launching effected.

LCDR Martin and his associates gave freely of their time and energy. Their assistance aided greatly in the smooth operation of the project.

Nuclear Sciences Seminar at Oak Ridge, Tennessee

The Eighth Annual Nuclear Sciences Seminar, under the sponsorship of the Office of Naval Research in cooperation with the Atomic Energy Commission, was held 26 November through 8 December at Oak Ridge, Tenn. CDR Richard B. Martin, USNR, was the chairman of the Seminar, which was attended by 36 Naval Research Reserve Officers, 32 members of the Air Force, 14 members of the Army, and 5 members of the Marine Corps.

Navy, Air Force, Army, and Marine Corps officers attending the Nuclear Sciences Seminar at Oak Ridge, Tenn.

The principal emphasis during the Seminar was placed on nuclear reactors. However, the object of this seminar was also to refresh the Reservists' knowledge of the fundamentals of nuclear science. The study of reactors is of value to Reservists both in their civilian scientific capacities and in their naval careers, because the development of nuclear powered ships and planes is now proceeding at a rapid rate.

Some of the nation's leading research scientists and authorities on nuclear science and reactor technology addressed the group. They presented a discussion of the fundamentals of reactors and the fundamentals of nuclear science in general, isotope production, and some of the various nuclear research programs now underway at Oak Ridge. Among the speakers were Mr. Ned Williams, AEC Deputy Assistant Manager for Operations, Oak Ridge Operations Office; Dr. J. A. Swartout, Deputy Director, Oak Ridge National Laboratory; Dr. W. G. Pollard, Executive Director, Oak Ridge Institute of Nuclear Studies; Dr. R. T. Overman, Chairman, Special Training Division, ORINS; and Dr. G. A. Garrett, Superintendent, Operations Analysis Division, Union Carbide Nuclear Company. Interesting and timely presentations were made by the following Naval personnel: CAPT A. B. Metsger, USN, Deputy and Assistant Chief of Naval Research; CAPT A. B. Cook, USNR, Assistant Chief of Staff for Naval Reserve and Training, Sixth Naval District; CAPT N. R. Richardson, USN, Director, Aircraft Nuclear Propulsion Program, Bureau of Aeronautics; COL J. B. Lampert, USA, Special Assistant for Nuclear Power, Office of the Chief of Engineers; CDR G. B. Cattermole, USN, Executive Officer, Weapons Development Division, Armed Forces Special Weapons Project; CDR H. F. Burr, USNR, Special Assistant to the Chief of Naval Research (Research Reserve); and LCDR Edward Biddle, USN, Development and Production Branch, Atomic Energy Division, Office of the Chief of Naval Operations.

Tours of several installations in the area were made. Among the places visited were the American Museum of Atomic Energy, Abbott Laboratories, Kingston Steam Plant (TVA), Loudoun Dam (TVA), and the Oak Ridge National Laboratory.

IGY Seminar of NRRC 11-4

The Scientific Seminar on the International Geophysical Year 1957-1958, which is being conducted by NRRC 11-4, Compton, Calif. (Research Reviews, December 1956), has had two more interesting sessions. In addition to members of NRRC 11-4 attending the sessions were representatives from the ONR Branch Office, Pasadena, and

Dr. Joseph Kaplan addressing th IGY Seminar

members of other Naval Reserve companies. The sessions had capacity audiences.

On 27 November 1956, Dr. Joseph Kaplan, chairman of the U. S. National Committee of the IGY, discussed the Earth Satellite Program in its relationship to the entire IGY. Using as his theme "Around the World in Ninety-Four Minutes," Dr. Kaplan described the plan of providing the Earth with an auxiliary moon. Dr. Kaplan explained that information broadcast by the satellite while it travels outside the Earth's atmosphere for a year or two will result in advances in communications, weather prediction, and knowledge of surface densities. However, he emphasized that although the Earth Satellite Program is perhaps one of the most spectacular undertakings of the IGY Program, it is still an integral part of the larger program; thus the results obtained by use of the satellite gain their real significance when coordinated with the complete research findings of the IGY Program.

On 11 December 1956, Mr. James M. Bridger, a commander in the Naval Reserve and a member of NRRC 5-9, addressed the group on "The Development of a Three-Stage Rocket for Launching the Earth Satellite." Mr. Bridger is Head of the Vehicles Branch of Project Vanguard at the Naval Research Laboratory, Washington, D. C. He discussed the satellite's orbital requirements, which must be met by the launching vehicle; he outlined the way in which the design for the launching vehicle was determined; and he discussed the specific requirements for various power plants, the design and requirements for the control system, and phases of the test program.

ONR Research Reserve Seminar

The Ninth Annual Research Reserve Seminar, sponsored by the Office of Naval Research, will be held 28 January through 9 February in Washington, D. C. CDR H. F. Burr, USNR, Special Assistant to the Chief of Naval Research (Research Reserve), will serve as chairman. About 100 officers who hold Reserve commissions in the Navy, Army, Air Force, and Marine Corps are scheduled to attend.

A deviation from the conventional pattern of past ONR Research Reserve seminars is planned. After the first 4 days, the officers will form into 5 groups, each of which will study a particular phase of research and development. Each group will consist of 20 Reservists and be led by a member of the staff of ONR. By means of this arrangement the participants will be able to study a particular line of research more thoroughly than they would be able to if they remained in one large group. To the extent that it will be feasible to do so, members of the Seminar will be allowed to join the group in which they have the most interest.

RADM Rawson Bennett, USN, Chief of Naval Research, will address the Seminar and introduce the Honorable C. C. Furnas, Assistant Secretary of Defense (Research and Development), and VADM T. S. Combs, USN, Deputy Chief of Naval Operations (Fleet Operations and Readiness). Reserve matters of the Navy will be discussed by RADM J. McN. Taylor, USN, Assistant Chief of Naval Operations (Naval Reserve); RADM E. H. von Heimburg, Commander, U. S. Naval Reserve Training Command; CAPT A. Jackson, Jr., Assistant Chief of Naval Personnel for Naval Reserve; and other representatives from the Bureau of Naval Personnel and ONR. A picture of the reserve program of the other services will be presented by MAJ GEN William E. Hall, USAF, Assistant Chief of Staff for Air Reserve Forces; MAJ GEN P. F. Lindeman, USA, Chief of Army Reserve and ROTC Affairs; and BRIG GEN W. W. Stickney, USMCR, Deputy Director, Marine Corps Reserve. Other subjects of interest to Reservists will be presented by Mr. Ray A. Crosby, Director, Training Division, Office of Industrial Relations; and CAPT J. D. Lamade, USN, Deputy Chief of Information.

One day will be devoted to presentations by representatives of ONR and its direct research activities. Speakers will include CAPT A. B. Metsger, USN, Deputy and Assistant Chief of Naval Research; CAPT P. H. Horn, USN, Director, U. S. Naval Research Laboratory; CDR J. I. Leonard, USNR, Head of Requirements Department of the U. S. Naval Training Device Center, Port Washington, Long Island; Dr. T. J. Killian, Deputy Chief and Chief Scientist; CAPT George W. Robillard, USN, Assistant Chief for Patents and Patent Counsel for the Navy; CDR J. J. Shea, USN, Director, Contract Division; Dr. R. M. Robertson Science Director; and Dr. R. O. Burns, Development Coordinator.

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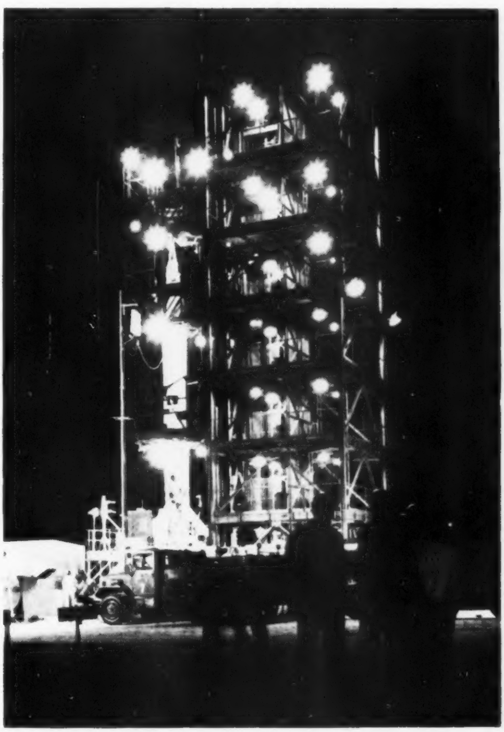
LAST MONTH WITH "VANGUARD"

On 8 December at 1:03 in the morning, Viking XIII arose majestically, shot straight into the sky, thence in a long arc seaward, and dropped into the Atlantic 180 miles from its launching pad at the Air Force Missile Test Center, Patrick Air Force Base, Florida. In its flight it achieved an altitude of 125 miles and a maximum velocity of 4,000 miles per hour.

The rocket was launched as a test preliminary to the satellite firings. Although the Viking is not a prototype of the larger Vanguard rocket, the first stage of the latter will be a modification of the Viking. Hence, launching operations will be similar in many respects. Also, the Viking carried aloft some of the same kind of instruments that will be used in the satellite—for instance, the "Minitrack" radio transmitter. In the recent firing, the transmitter was ejected from the rocket at an altitude of 50 miles and then tracked by scientists stationed at AFMTC. The telemetering equipment and tracking beacons were also similar to those planned for the satellite rockets.

For the sake of comparison, the 45-foot Viking XIII weighed about 15,000 pounds and developed 21,000 pounds of thrust; the 72-foot three-stage satellite vehicle, at takeoff, will weigh about 22,000 pounds, and the calculated thrust of the first stage will be 27,000 pounds.



Viking XIII shortly before launching. The gantry is the same one used at White Sands, moved piece by piece to Florida.

In This Issue

COVER PHOTO: A shock-wave reflection similar to that of an atomic-bomb burst, photographed in a shock tube at Princeton University.

NAVEXOS P-51

RESEARCH REVIEWS endeavors to report briefly highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C. . . . Research Reviews is listed for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Subscription price: $1.50 per year in U. S. and Canada; $2.00 per year, foreign; $.15 per individual copy.

Approved by Bureau of the Budget, 28 February 1955