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C.I.C.

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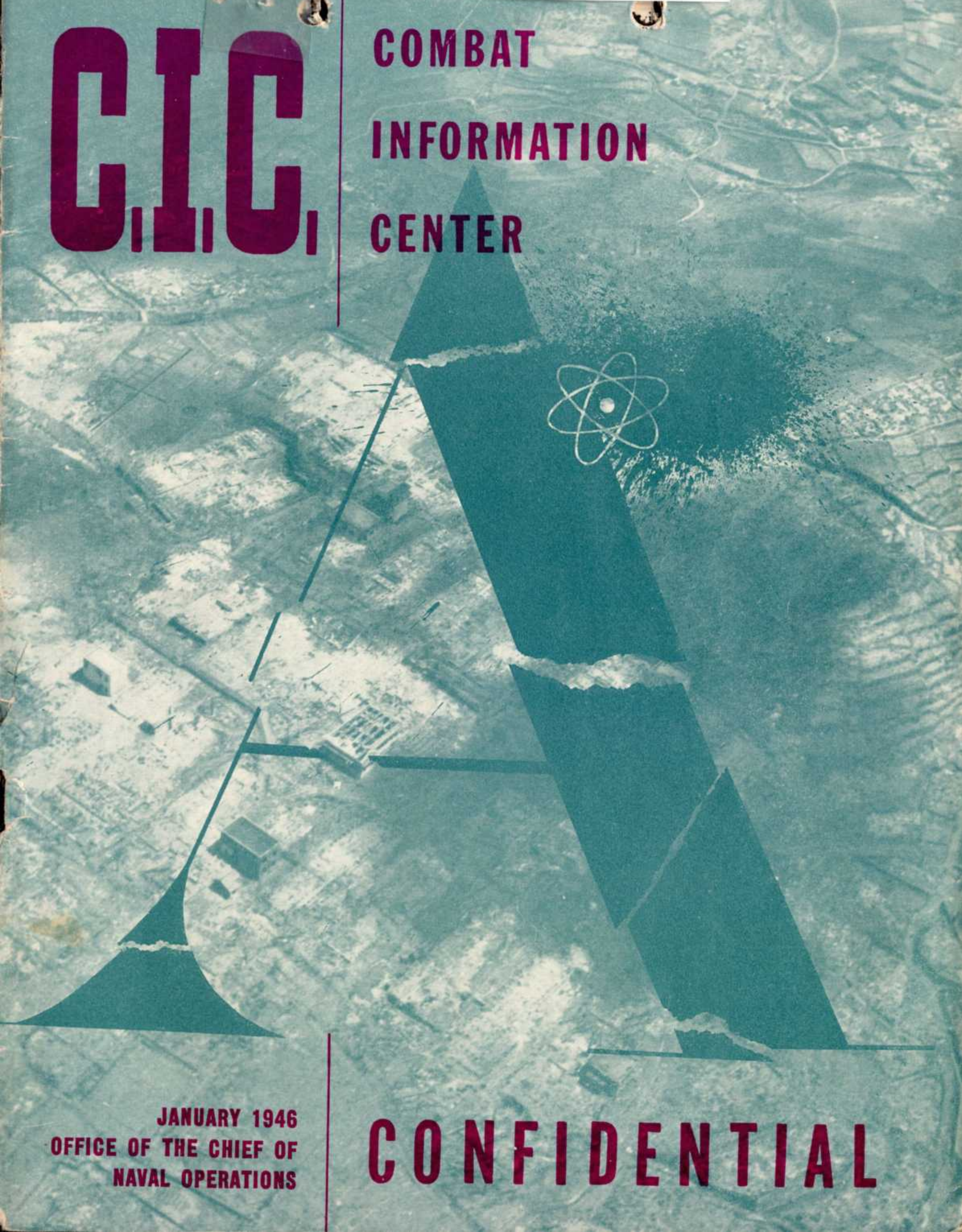

JANUARY 1946
OFFICE OF THE CHIEF OF
NAVAL OPERATIONS

CONFIDENTIAL

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C.I.C.

the tactical use and operation of electronic and associated equipment.

VOL. III, No. 1 **JANUARY 1946**

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digest of facts on the Atomic bomb

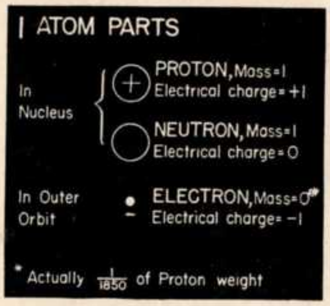
The Atomic Bomb, the most formidable weapon in the history of mankind, will undoubtedly bring major changes in the strategy and tactics of Naval and all other modes of warfare. No one, as yet, can do more than conjecture as to what these changes will be. One thing is clear, however: It is imperative that Navy personnel have some understanding of what atomic fission is and, roughly, how it is utilized in a bomb. This article (printed originally in the Westinghouse Engineer) is a masterful condensation of H. D. Smyth's official report. It may take three readings for the picture to take shape for you, but the effort is decidedly worth making.

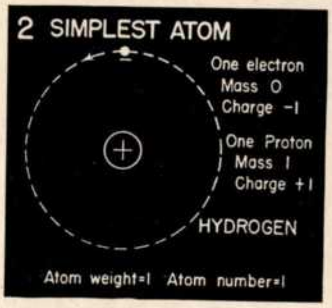
by E. U. Condon, Director, National Bureau of Standards, formerly Associate Research Director, Westinghouse Electric Corporation.

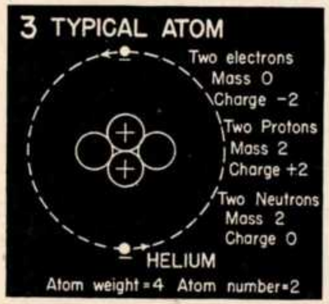
To the familiar subjects of civil, mechanical, electrical, electronic, and chemical engineering, a new field has been given us by the physicists—nuclear engineering. This can be defined as the art of applying nuclear transmutations of matter to useful purposes. The subject of nuclear engineering, which has gradually been developing over the past 15 years, is very much in everybody's mind because of its application to the making of a military weapon whose first use was followed by the end of the war 8 days later.

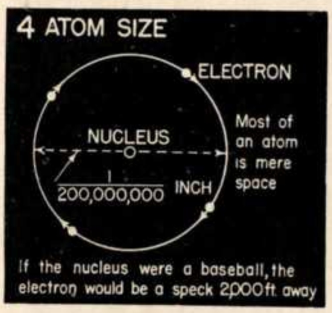
It was considered in many official quarters that the war with Japan might have continued for another year. This might easily have meant the loss of another million American and British lives, probably the lives of even more Japanese, and a cost to us of upwards of 200 billion dollars. Instead, peace was restored at the cost of the lives of fewer Japanese and of none of the American lives that would have been lost and at a cost of only 2 billion dollars to ourselves. And moreover it has put us in possession of the means of assuring peace through world organization if the knowledge of the new weapon is used properly.

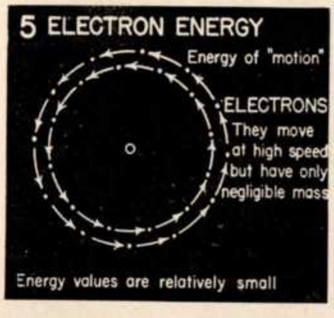
Before the atomic bomb, nuclear physics had provided a host of new ideas having peaceful uses—neutrons for cancer therapy, artificial radioactive materials for treatment of leukemia and of cancer, and for











use in fundamental chemical studies both in biology and in chemical industry. So important had this field of work become just before the war that several large companies were considering the manufacture and sale of these radioactive materials. Although the war interrupted this activity and placed over all nuclear research a tight secrecy restriction, it enormously accelerated the research that ended so dramatically in three atomic bombs, one exploded experimentally and two dropped on Japan.

With the war ended we can now devote our energies to active cultivation of the applications of nuclear engineering to peaceful purposes—to better ways of producing neutrons and high-energy electrons for therapy and of artificial radioactive materials for all kinds of uses. Moreover we are standing on the threshold of the era in which atomic power will be developed, surely to be the most important engineering achievement of the next generation.

All sorts of prognostications are being voiced about the future of atomic power. Some say it will come only in the very distant future and may not then be practical; others are rashly predicting automotive power from U^{235} in a very few years. The wide variance in predictions comes about largely, of course, from the fact that most of the prophets have little but a crystal ball to guide them.

First let us get the main points of the story in terms of answers to some questions that occur at once.

WHAT IS ATOMIC ENERGY?

All energy used industrially comes either from the work done by falling water or from the combustion of fuels—coal and petroleum products principally. In combustion of coal the atoms of carbon combine with oxygen of the air to form carbon dioxide with release of energy. The characteristic thing is that the atoms involved in the combustion process are not changed intrinsically—the carbon atom from coal is still a carbon atom in the CO_2 of the flue gas. The energy used is that made available with the formation of CO_2 molecules from C from coal and O_2 molecules from the air. This is called chemical energy.

What is being called atomic energy is the energy associated with changes in the basic chemical nature of the atoms. In a chemical reaction, atoms of the same kind are present before and after, as in the familiar combustion process

$$C + O_2 \rightarrow CO_2$$

But in nuclear reactions, atoms are made to react in such a fundamental way that the product atoms are not the same as those we start with. For example, the nuclear

$$H^1 + Li^7 \rightarrow 2He^4$$

reaction is a process that actually occurs in the laboratory, an English discovery in 1932. Hydrogen reacts with lithium to give helium. This is atomic transmutation and quite outside the scope of the classical science of chemistry.

From 1932 to 1939 we were in the position of knowing that large energy releases were possible from many different nuclear reactions—but these could be produced only in laboratory apparatus that required more energy for their operation than was liberated by the nuclear reactions.

HOW DID URANIUM FISSION CHANGE THIS PICTURE?

However, as soon as the word of discovery of uranium fission reached this country from Germany in January 1939, it was at once realized by physicists that the possibility of getting atomic power in useful form was within reach. But first let us say what uranium fission is. Uranium is the heaviest atom occurring in nature. The nucleus of uranium contains 92 protons surrounded by 92 electrons. One kind of uranium nucleus, U^{235} contains, in addition to the 92 protons, 143 neutrons, giving a total weight (i. e., atomic weight) of 235.[1]

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[1] For convenience, the approximate weight of an element is given as a superscript to the chemical symbol. The atomic number, when given, is a subscript preceding the symbol. Thus ${}_{92}U^{238}$ is uranium of atomic number 92 and atomic weight 238 approximately.

Another and predominating kind, U^{238}, contains 146 neutrons raising the weight to 238. When a neutron strikes a uranium nucleus in the right way, the nucleus breaks up by falling apart in two approximately equal fragments with the release of about 200 million electron volts per atom split. Great as this is it is no better, weight for weight, than the reaction that forms helium from hydrogen and lithium; in fact it is only about half as good from an energy release standpoint.

The essential thing about uranium fission is that the uranium atom falls apart in such a way as to produce two more or less equal fragments—*and to liberate several more free neutrons.* It is this neutron liberation that makes a self-maintaining process possible. The splitting requires a neutron to make it go—and the splitting process itself acts as a source of neutrons which can cause more uranium atoms to split. Here is the basis of a self-maintaining process, technically known as a chain reaction, such as is ordinary combustion.

WHY DOES NOT ORDINARY URANIUM EXPLODE?

There are complications. Because several neutrons are released at every fission, a chain reaction is possible. But to make it an actuality, one of the several neutrons released must actually produce another fission to keep the process going. Otherwise, the nuclear "fire" goes out.

If all the neutrons released produced more fissions the material would explode violently. But because neutrons move rather freely through matter (like X-rays) many are lost by escaping through the surface. Remedy: use a big enough lump to get a smaller surface-to-volume ratio. In other words unless the lump of fissionable material exceeds a certain critical size the chain reaction cannot proceed.

Another complication is that impurities in the uranium have a powerful effect on neutron absorption. This is very difficult to remedy for appreciable losses result from the presence of only one part per million of some materials, and it is no easy matter to manufacture anything of that purity on an industrial scale.

The worst complication of all was that uranium itself absorbs neutrons in other ways than those that produce fission. This phenomenon was both a blessing and a curse to the aims of the military project. It turns out that the over-all effect of this nonfission absorption of neutrons by uranium is sufficiently great to prevent the explosion of perfectly pure uranium even in so large a lump that escape of neutrons through the surface is negligible.

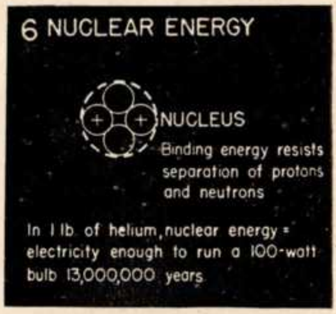
Neutrons given out in the fission process are "fast," i. e., have speeds corresponding to several million electron volts of kinetic energy. Such fast neutrons colliding with uranium atoms have a rather great chance of losing energy without being caught and without producing fission.

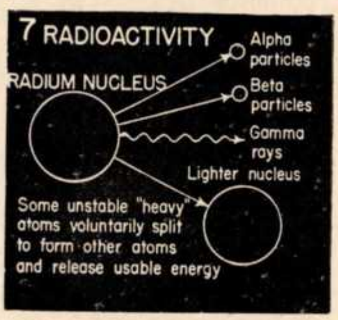
Neutrons of intermediate speed produced this way are unable to produce fission in U^{238}. They can do so only in U^{235}, which forms only 1/140 part of natural uranium.

Neutrons of a particularly low energy (about 10 electron volts) are very likely to be captured by U^{238} to form U^{239}. This is very important. More on this later. This happens so readily that so many neutrons are used up this way that a chain reaction cannot be maintained in ordinary uranium.

An uncaptured neutron continually loses energy by colliding with atoms as it diffuses throughout any material, until its average energy is that of the heat motion of the atoms of the material. Neutrons of certain extremely low energies are strongly captured by U^{235} to produce fission.

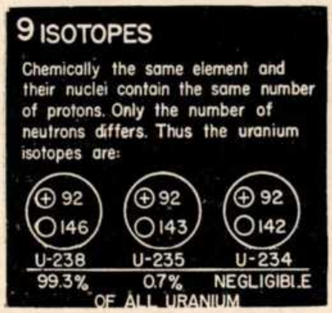
The clue to possibly making the chain reaction go with ordinary pure metallic uranium, which contains all kinds of uranium atoms but is predominently U^{238} was to arrange the uranium in a lattice of small lumps so that many of the fast-moving neutrons would diffuse out of the uranium into some surrounding material. Here many of them would be slowed down before diffusing back into the uranium. The idea was that most neutrons would thus escape being caught by U^{238} until they had lost so much energy that capture by U^{238} was unlikely. Ultimately,






8 NATURE'S HEAVIEST ATOM

Basic Source of Atomic Energy


9 ISOTOPES

Chemically the same element and their nuclei contain the same number of protons. Only the number of neutrons differs. Thus the uranium isotopes are:

through, they would return to the uranium lumps and be of sufficiently reduced speed to cause fission in U^{235}.

In the technical vocabulary of nuclear engineering this other material that keeps neutrons in custody and helps them lose energy until they are safe from capture by U^{238} is called the moderator. Evidently the moderator material must not absorb too many neutrons or the reaction will be stopped by this circumstance. Besides the quality of not absorbing neutrons, it is desirable to use material of low atomic weight. This is because the neutrons to be slowed collide elastically with the nuclei of the moderator material and so give up more energy at each impact if the two partners of the collision have nearly the same mass. The hydrogen content of ordinary water would be ideal from this viewpoint but absorbs too many neutrons. Heavy water is satisfactory from a neutron-absorption standpoint but previously had not been available in sufficient quantity. Metallic beryllium is a possibility but proved too expensive so that graphite was finally adopted, although not until processes were developed for manufacturing it to much higher standards of purity than is usual in ordinary industrial practice.

As this qualitative picture evolved prior to January 1942 the question of whether a chain reaction would go remained unanswered because of lack of exact quantitative knowledge of the various absorptions involved. But as knowledge accumulated, it became more and more probable that such a lattice of uranium lumps and moderator—now called a pile—would go, i. e., a chain reaction continuously releasing atomic energy by fission of the U^{235} in it would be self-maintaining.

HOW CAN THE PILE BE KEPT FROM BLOWING UP?

If a pile is so arranged that, on the average, more than one fission results from the neutrons produced by each fission, then clearly the number of neutrons present, and the amount of heat generated, increases by the compound-interest law. If a great multiplication happens rapidly—say in a small fraction of a second—then the phenomenon becomes an explosion. In short, we have an atomic bomb. Even if the reaction occurs slowly the pile would soon be destroyed by melting if the multiplication were allowed to proceed.

One way to control the pile is to provide passageways through it into which rods of material that strongly absorb neutrons can be placed. When these rods are in they absorb so many neutrons that the chain reaction is stopped. As these are slowly withdrawn a point is reached at which the reaction is just able to proceed. If pulled out farther the neutrons are able to multiply more rapidly and the pile operates at a higher power level. To stop the pile the absorbing rods are simply pushed back in farther. Cadmium and boron-containing steel are suitable materials for the control rods.

The language of the preceding paragraph implies that the time scale is slow enough for an operator to maintain control by manual operation of the rods or by use of a similar slow-acting control mechanism. That is in fact the case owing to another phenomenon in the fundamental physics of fission—delayed neutrons.

It was discovered in May 1942, that most but not all neutrons emitted in the fission process come out instantly. The uranium nucleus in splitting apart spills out some neutrons immediately. But the atomic fragments formed are also in a highly unstable condition and some of them throw out additional neutrons after a short time delay, amounting on the average to half a minute. It is the delayed ones that set the time scale on which the neutron multiplication in the pile builds up and set it for such a long time that slow-acting controls are easily able to regulate the activity of the pile.

The first pile was built on the University of Chicago campus during the fall of 1942. It contained 12,400 pounds of uranium, together with a graphite moderator. It was intended to be spherical in shape but as the critical dimensions proved to be smaller than the original calculations indicated, the sphere was left incomplete, giving the actual pile the shape of a large inverted doorknob.

It was first operated on December 2, 1942, at a power level of ½ watt and on December 12 the power level was stepped up to 200 watts but it was not allowed to go higher because of inadequate provision for shielding personnel from dangerous radiations. Further studies on piles were made by the construction of one in Tennessee designed for 1,000-kw. level of operation. Later a pile using heavy water instead of graphite as moderator was built.

In summary, it should be remembered that although a pile is built with ordinary uranium, it is only the 0.7 percent of the metal that is U^{235} that is active. The U^{238} that forms most of the metal actually tends to stop the process. Only by ingenious lattice arrangement for slowing neutrons in a moderator is the pile able to operate in spite of the presence of the more prevalent U^{238}.

This means that, regarded as a fuel, only 1/140 of the total weight of uranium is being directly used; the rest is an inert material that remains largely untransformed by the pile.

HOW DOES THE BOMB CHAIN REACTION DIFFER FROM THAT IN THE PILE?

The atomic bomb explodes, whereas the reaction in the pile proceeds in a slow way easily controlled by manual operation of absorbing rods. The big, fundamental distinction is that the bomb (one type) is made of essentially pure U^{235} and without the use of moderator. The chain action in the bomb is carried on by fast neutrons directly released by fission. As already remarked, this cannot happen with ordinary uranium because the U^{238} slows the neutrons to the point where they cannot produce fission in U^{235} and also absorbs many of them. With essentially pure U^{235} these competing absorption processes do not occur and the reaction is carried by the fast neutrons directly emitted from a U^{235} fission. These are utilized at once to produce fission in other U^{235} atoms. Here the main factors tending to stop the reaction are the loss of neutrons through the surface (which sets a minimum size to the bomb) and losses by absorption by impurities including any remaining U^{238}.

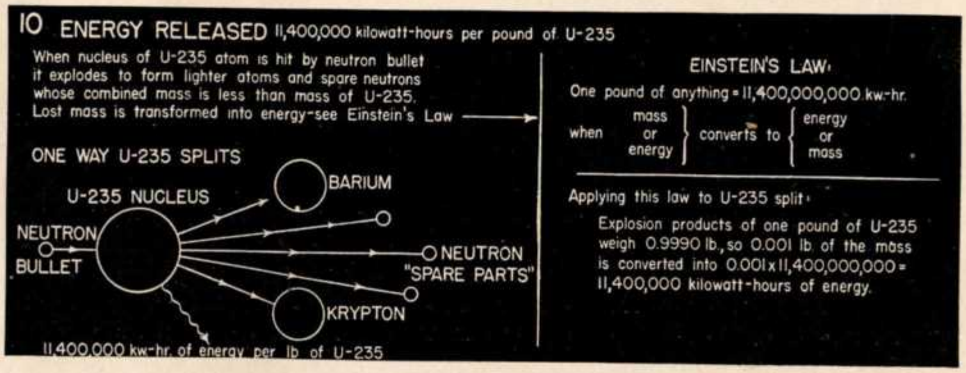
WHAT IS PLUTONIUM?

This is a newly discovered chemical element not known to exist in nature but which is made from uranium by atomic transmutation. Plutonium is important because it, like U^{235}, is a material from which atomic bombs can be made.

That U^{238} can capture neutrons has already been mentioned as a phenomenon detrimental to the operation of a pile. When U^{238} captures a neutron it becomes U^{239} and emits gamma radiation as does radium. This U^{239} is not stable but emits high-speed electrons by a process of spontaneous radioactivity. The mean life of the U^{239} atoms is only about 20 minutes. By this activity they are transformed into atoms having essentially the same mass but one greater positive charge, 93, on the nucleus, and hence a new chemical element. It is called neptunium and written Np^{239}. Neptunium 239 is also spontaneously radioactive and emits another high-speed electron becoming thereby an atom having 94 positive charges on the nucleus but still essentially of mass 239. This process is slower; the mean life of the neptunium atoms is about 2 days. The resulting atom of charge 94 and mass 239 is another new element that does not occur in nature. It is called plutonium and written Pu^{239}.

Actually the purpose of piles in the military project was not to get atomic power but to produce the new element plutonium, which provides a second bomb material. It is, in short, a competitor to U^{235}. The process by which plutonium is formed—capture of neutrons by U^{238}—has already been mentioned as one that tends to stop the chain reaction in a pile. Nevertheless the uranium lumps in the pile are exposed to a dense atmosphere of neutrons, and so the means is at hand for changing a part of the U^{238} into Pu^{239}.

The several large piles put in operation generated many hundreds of thousands of kilowatts as heat. This heat was, however, not utilized, as the main purpose of the operation was the production of plutonium for use in the atomic bomb. To utilize the heat would have required additional engineering to operate the pile at a high temperature and there was not time for that.



10 ENERGY RELEASED 11,400,000 kilowatt-hours per pound of U-235

When nucleus of U-235 atom is hit by neutron bullet it explodes to form lighter atoms and spare neutrons whose combined mass is less than mass of U-235. Lost mass is transformed into energy–see Einstein's Law

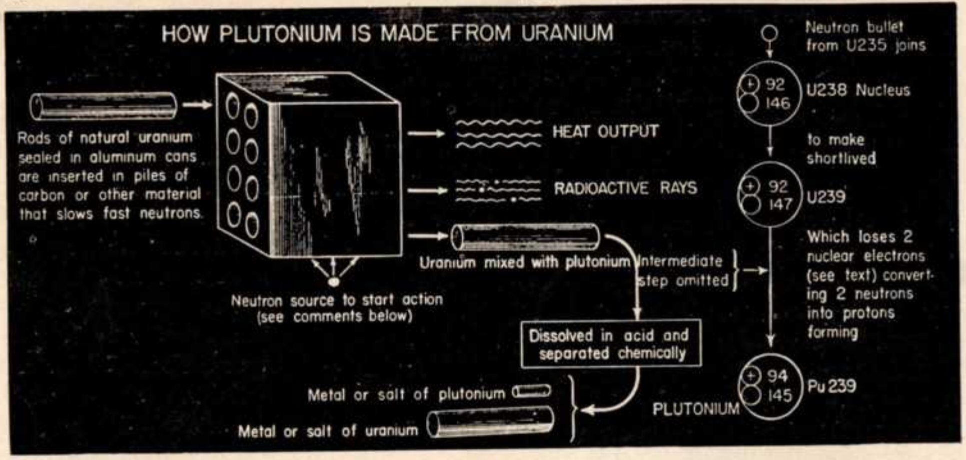
EINSTEIN'S LAW:

One pound of anything = 11,400,000,000 kw.-hr.

when mass or energy converts to energy or mass.

Applying this law to U-235 split:

Explosion products of one pound of U-235 weigh 0.9990 lb., so 0.001 lb. of the mass is converted into 0.001 x 11,400,000,000 = 11,400,000 kilowatt-hours of energy.



The pile when run at a high power level also generates an enormous amount of radioactive material, far more potent than all radium ever mined. This greatly complicates the problem of operation of the large piles, requiring a high standard of reliable operation that must depend entirely on remote controls.

The plutonium is formed in the blocks of uranium in the pile. These have to be removed from the pile and the plutonium extracted by fairly simple chemical methods, because plutonium and uranium, being completely different elements, are dissimilar chemically. This process, however, is greatly complicated by the intense radioactivity of the materials.

HOW IS U^{235} SEPARATED FROM ORDINARY URANIUM?

The makers of the atomic bomb had plutonium at their disposal. An alternative material is U^{235}. It was felt desirable, in view of all the uncertainties involved, to develop several methods and provide production facilities for extracting in almost pure form the 0.7 percent of U^{235} contained in ordinary uranium. (The third isotope of uranium, U^{234}, is present in so minute proportion as to be wholly insignificant.)

Because of the almost complete identity of all physical and chemical properties of two isotopes of the same element—in this case U^{235} and U^{238}—this is an extraordinarily difficult problem. Several methods were tried, some of which were abandoned as not operative, or as requiring too great an effort, or as being too uncertain of success. These are mentioned in Smyth's report. Three methods were carried from the research stage into production plants. These are:

a—the mass-spectrographic method
b—the gaseous-diffusion method
c—the thermal-diffusion method.

In addition to these three methods a fourth, that of separation of gas in large high-speed centrifuges, was successfully carried to the pilot-plant stage. The centrifuges work on the same principle as the cream separator on the dairy farm, operating on the very slight difference in mass of the two uranium isotopes.

Huge, elaborate installations were required to do this work. The processes are too technical to be understandably described to nontechnical people. It is sufficient to say that separation of U^{235} from natural uranium is being done by production plants based on the three entirely different methods at the Manhattan District's reservation at Oak Ridge, Tenn.

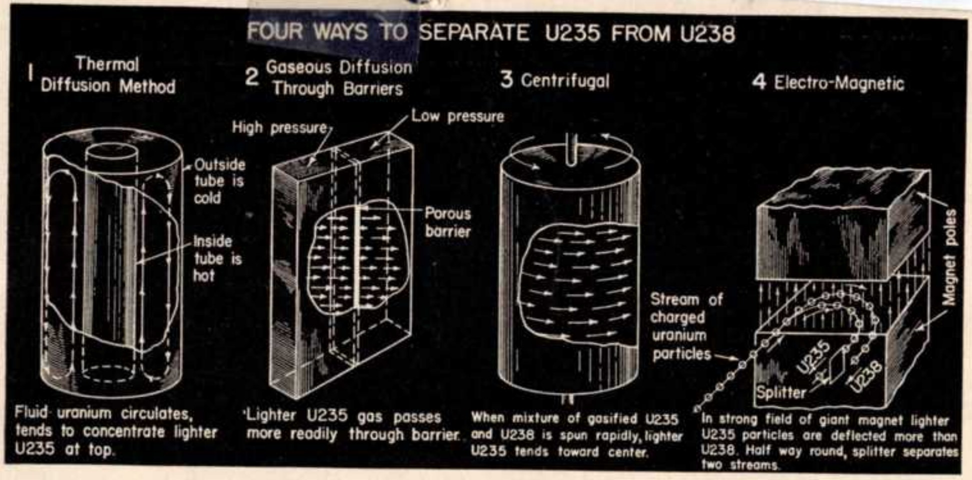
AND NOW THE BOMB!

Very little of this part of the story can be told as yet. Preliminary studies on this problem were made in 1941 and early 1942. At the end of the summer it was decided to concentrate all this work on a greatly expanded scale at a specially constructed laboratory at Los Alamos, N. Mex., about 40 miles northwest of Santa Fe. The first group of laboratory buildings, administrative buildings, homes for the personnel and barracks for the soldier guards were built during the winter of 1942–43 and the scientific staff began to arrive and start work in April 1943. What these people achieved, starting with empty buildings on a remote mesa with only an old Diesel-driven mine generator as the laboratory power supply thousands of miles from major industrial facilities and supplies, is an epic in the annals of science. The story of this group, continually growing in numbers, and communicating with outside suppliers only by devious channels, because of requirements of military security, will be most fascinating when properly told.

Although discussion of the bomb's details is not permitted, these essential points can be enumerated:

a—The active material is either Pu^{239} from the piles at Hanford, Wash., or U^{235} from the three different separation plants at Oak Ridge, Tenn.

b—A bomb less than the critical size will not explode


FOUR WAYS TO SEPARATE U235 FROM U238

Fluid uranium circulates, tends to concentrate lighter U235 at top.

Lighter U235 gas passes more readily through barrier.

When mixture of gasified U235 and U238 is spun rapidly, lighter U235 tends toward center.

In strong field of giant magnet lighter U235 particles are deflected more than U238. Half way round, splitter separates two streams.

at all so it is not possible to experiment with little ones to learn how to make a big one.

c—Before firing, the active material must be kept separated into two or more lumps each of subcritical size. The act of firing consists of assembling these rapidly into a mass that is above critical size for that shape.

d—This has to be done with great rapidity, using a firing mechanism, which was itself a difficult problem. The need for rapidity arises from the fact that if the parts come together slowly an explosive reaction begins before the parts are completely together. This would blow them apart again and stop the fission chain reaction with only an insignificant release of the atomic energy.

e—Even with the best design possible, the stopping of the reaction due to the bomb's blowing itself apart was expected to prevent the effective conversion by fission of all the material in the bomb. Some estimates placed this conversion efficiency as low as a few percent. What was actually attained at the Alamogordo, N. Mex., tests has not been disclosed to date.

f—The fission products are extremely radioactive and if all of them were to remain in a relatively small area (say a square mile) the radiations would be too intense to permit the existence of any living matter in the region for probably several weeks after the explosion.

g—To get maximum destructive effect from the blast the bomb is fired while at a considerable height above ground, which also favors the dispersal over a wide area of the radioactive products so that the contamination of the area is not thought to be an important attribute of the weapon.

WHAT OF THE FUTURE?

While no reputable scientist ever makes definite promises about anything that lies in the future, still it is possible to venture an opinion that the following significant developments are highly likely to be made within the coming decade:

a—More effective ways of producing U^{235} and Pu^{239} will be developed, permitting greater production at lower cost.

b—These materials in combination with ordinary uranium will make possible power-producing piles of smaller size than those thus far developed.

c—Piles will have important peacetime uses as special-purpose energy sources, and as sources of neutrons and radioactive materials for medical and other scientific work.

d—Piles will probably not be developed into small power units for automobiles or airplanes because of their overall weight including that of the material needed to shield the passengers from the dangerous radiations.

e—Also because of shielding difficulties, piles will probably not provide the driving power for railroad locomotives. However, it is reasonable to suppose that within a decade some ships may derive their power from piles.

Besides uranium it is known also that fission may be produced in thorium, which is much more abundant in nature than uranium and therefore may be the fuel in piles of the future. Whether release of atomic energy from other materials can be achieved is a question which can be decided only by future research. At present no means of doing this is in sight—but it should be remembered that the atomic bomb would have seemed fantastic to the best nuclear physicists in 1938.

LOOKING AHEAD

In conclusion, it is conducive to serious thought to reflect on these sobering paragraphs from H. D. Smyth's report:

"A weapon has been developed that is potentially destructive beyond the wildest nightmares of the imagination; a weapon so ideally suited to unannounced attack that a country's major cities might be destroyed overnight by an ostensibly friendly power. This weapon has been created not by the devilish inspiration of some warped genius but by the arduous labor of thousands of normal men and women working for the safety of their country. Many of the principles that have been used were well known to the international scientific world in 1940. To develop the necessary industrial processes from these principles has been costly in time, effort, and money, but the processes which we selected for serious effort have worked and several that we have not chosen could probably be made to work. We have an initial advantage in time because, so far as we know, other countries have not been able to carry out parallel developments during the war period. We also have a general advantage in scientific and particularly in industrial strength, but such an advantage can easily be thrown away.

"As to the future, one may guess that technical developments will take place along two lines. From the military point of view it is reasonably certain that there will be improvements both in the processes of producing fissionable material and in its uses. It is conceivable that totally different methods may be discovered for converting matter into energy since it is to be remembered that the energy released in uranium fission corresponds to the utilization of only about one-tenth of 1 percent of its mass. Should a scheme be devised for converting to energy even as such as a few percent of the matter of some common material, civilization would have the means to commit suicide at will.

"We find ourselves with an explosive which is far from completely perfected. Yet the future possibilities of such explosives are appalling, and their effects on future wars and international affairs are of fundamental importance. Here is a new tool for mankind, a tool of unimaginable destructive power. Its development raises many questions that must be answered in the near future."

∴ chronological highlights of the

1896—Bocquerel discovers radioactivity of uranium.

1898—Curies separate radium from pitchblende.

1905—Einstein enunciates equivalence of mass and energy.

1911—Rutherford initiates theory of nuclear atom.

1919—Rutherford discovers transmutation of nitrogen by alpha particles from radium.

1928—Quantum mechanics applied to understanding of radioactive disintegration by Gurney, Condon, and Gamow.

1932—First transformation of lithium nuclei by artificially accelerated protons by Cockcroft and Walton of England. Discovery of heavy hydrogen by Urey, Brickwedde, and Murphy. Discovery of the neutron by Chadwick. Discovery of positron by Anderson.

1939–40—Period of rapid development in many laboratories including discovery of artificial radioactivity by Irene Curie and F. Joliot; development of the cyclotron by E. O. Lawrence; development of electrostatic high-voltage atom smashers by van de Graaff (Massachusetts Institute of Technology), by Tuve (Carnegie Institute of Washington), by Herb (University of Wisconsin) and by the research physicists at Westinghouse. Extensive study of many nuclear reactions and parallel development of fundamental theory of nuclear structure. Much was learned about the special forces which bind together the constituent protons and neutrons in the nucleus. Fermi (in Italy) bombarded uranium with neutrons in 1934, but did not reach proper interpretation of fission.

1939—Discovery of uranium fission by Hahn and Strassman in Germany. First reported in this country by Niels Bohr of Denmark on January 16, 1939, and immediately confirmed and further studied in many laboratories in America and Europe. Possible military applications were recognized at once by a group of physicists, among whom were E. Fermi (Columbia), E. Wigner (Princeton), and E. Teller (George Washington).

1939, March—Pegram and Fermi (Columbia) made first approach to Navy Department to advise them of possibilities in fission. Navy expressed interest and asked to be kept informed.

1939, July—Einstein, Wigner, and Szilard enlisted aid of Alexander Sachs of New York in getting the facts on military possibilities before President Roosevelt. Roosevelt referred matter to "Advisory Committee on Uranium" headed by L. J.

∴ glossary of important terms in nuclear physics

Atom—Smallest unit of matter remaining unchanged in chemical reactions. All atoms are about 10^{-8} cm. in diameter. They consist of a central positively charged nucleus, about 10^{-12} cm. in diameter, surrounded by enough electrons to make the atom electrically neutral.

Neutron—A basic constituent particle of atomic nuclei having no electric charge and having a mass of about 1.67×10^{-24} gram.

Proton—A basic constituent particle of atomic nuclei having a positive charge numerically equal to that of the negatively charged electron, 1.60×10^{-19} coulomb and a mass about the same as that of the neutron. The proton itself is the nucleus of ordinary hydrogen atoms.

Electron—Smallest atomic particle. Unit of negative electricity.

Deuteron—This is the nucleus of heavy hydrogen atoms which occur in nature as about one part in 5,000 of ordinary hydrogen. It is the simplest composite nucleus known, consisting of a combination of one proton and one neutron.

Alpha-particle—This is the nucleus of helium atoms and is a composite nucleus of two protons and two neutrons. The name originally referred to the alpha radiation from naturally radioactive substances like uranium and radium, later recognized to be fast-moving nuclei of ordinary helium gas.

Atomic number—An integer characteristic of each chem-

Briggs, director of the National Bureau of Standards, and with members from both Army Ord. and BuOrd. First meeting of this committee on October 21, 1939. Voluntary secrecy policy in this field began to be set up by physicists about this time.

1940, April 28—Committee meeting to plan a larger research program. First definite reports on German activity on this subject having to do with military aims.

1940, Summer—Radiation Laboratory, University of California discovered possible use of plutonium for explosive chain reaction.

1940, Summer—Sachs active in urging more effort on this subject by contacts with President Roosevelt through his aide, Gen. E. M. Watson. Uranium Committee under Briggs constituted as a part of the National Defense Research Committee by President Roosevelt on formation of latter body. Various small research contracts let to Columbia University, Princeton University and others for fundamental studies bearing on the problem.

1940–1942—Gaseous-diffusion method of separating uranium isotopes developed by a research group at Columbia University headed by Profs. H. C. Urey and J. R. Dunning.

1940–1944—Investigation of thermal-diffusion method of isotope separation (on basis of research in Germany in 1938) by P. H. Abelson, first at the National Bureau of Standards and later at the Naval Research Laboratory. Pilot plant built at Philadelphia Navy Yard.

1941, Summer—Uranium Committee enlarged by addition of several new members. National Academy of Sciences Committee made an independent study of the situation. This study involved consideration of engineering problems as well as scientific problems.

1941—Development of centrifuge isotope separation initiated by Prof. J. W. Beams, University of Virginia.

1941, Fall—Previous cooperation and exchange of data with British scientists greatly extended especially by trip of Oliphant (Birmingham) to America and of Pegram and Urey to England.

1941, Fall—Preliminary studies of atomic bomb begun by Prof. G. Breit of University of Wisconsin. Work continued in summer of 1942 under Prof. J. R. Oppenheimer of University of California.

1941, December 16—Top Policy Group consisting of Vice President Henry A. Wallace, Secretary of War Henry L. Stimson and Dr. V. Bush, recommended reorganization of program outside N. D. R. C. with greatly enlarged activity and Army jurisdiction.

1942, August 13—The "Manhattan District" was officially established for this purpose.

1942—Government sponsored research at Columbia University indicated that a nuclear chain reaction was of possible accomplishment.

1942, May—Discovery by Snell, Nedzel, and Ibser of delayed-fission neutrons.

1942—Mass-spectrographic method of separating uranium isotopes developed by Radiation Laboratory, University of California.

1942, Fall—First pile built at University of Chicago (later moved to Argonne Laboratory, near Chicago) under direction of E. Fermi, W. H. Zinn, and H. L. Anderson. First operated on December 2.

1942, Sept.—Military Policy Committee appointed: Dr. V. Bush, chairman, Dr. J. B. Conant, alternate, Maj. Gen. W. D. Styer, and Rear Adm. W. R. Purnell. Gen. Groves named to sit with committee and act as executive officer to carry out policies.

1942, Fall—Construction begun at Los Alamos, N. Mex., of atomic-bomb laboratory, under direction of Oppenheimer.

1942, Fall—Design begun of large-scale diffusion plant built at Oak Ridge.

1943, Spring—One thousand-kw. pile constructed at Oak Ridge, Tenn., for production of plutonium.

1943—Plant at Hanford, Wash. for production of plutonium designed on the basis of research work at Metallurgical Laboratory, University of Chicago.

1943, January—Large-scale mass-spectograph separation plant at Oak Ridge designed and built.

1944, Summer—Large-scale, thermal-diffusion plant built at Oak Ridge, Tenn.

1945, July 16—First experimental bomb statically detonated on desert near Alamogordo, N. Mex.

1945, August 6—First military atomic bomb dropped on Hiroshima, Japan.

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ical element which tells how many protons there are in the atomic nucleus and also how many electrons there are in the atom, outside the nucleus. Usually denoted by Z. Examples: hydrogen, $Z=1$; helium, $Z=2$; neon, $Z=10$; uranium, $Z=92$.

Isotope—A particular variety of atom or nucleus characterized by a particular atomic weight as well as a particular atomic number. Example: all uranium atoms have a nuclear charge $Z=92$, those of the light isotope have an atomic weight of about 235 while those of the heavy isotope have an atomic weight of about 238. There is also a very rare isotope having an atomic weight of 234.

Neptunium—A new chemical element not known to occur in nature having $Z=93$ and an atomic weight of 239. This is formed by radioactive decay of U^{239} which emits a B-particle (high energy electron) to become Np^{239}.

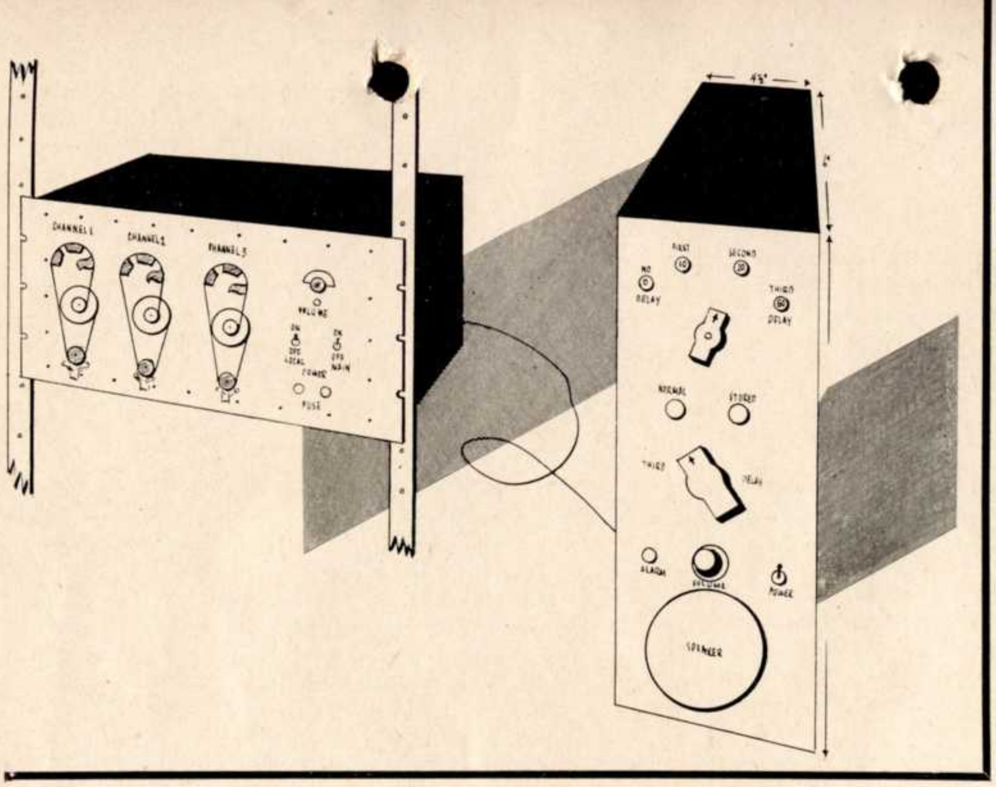
Plutonium—A new chemical element not known to occur in nature, having $Z=94$ and an atomic weight of 239, formed by radioactive emission of a B-particle from Np^{239}.

Moderator—A substance (carbon, heavy water, or beryllium) used as a means of slowing down neutrons by means of elastic impacts of the neutrons with the atoms of the moderator.

Heavy water—A kind of water whose molecules consist of the heavy hydrogen isotope, deuterium, in combination with oxygen, written D_2O instead of H_2O.

Chain reaction—Any reaction, chemical or nuclear, in which the process continues by virtue of the action of one of the products to cause the reaction to continue. Example: uranium fission is caused by a neutron and the fission process releases more neutrons which can cause more fissions.

Pile—Any arrangement involving lumps of fissionable matter, e. g., uranium, together with moderator, so arranged as to utilize the neutrons well enough to result in a chain reaction.



recorder eliminates radio repeats

A poll among CIC personnel to select the two words that give them more headaches, cause more confusion, and play more general hell with R/T procedure than any other transmission would undoubtedly bring forth an overwhelming vote for:

"Say again!"

Requested repeats have loaded down the air channels in the past. Information that should have been understood and acknowledged on the first transmission was often times repeated two, three, and even more times which was a serious bottle-neck in successfully carrying out tactical operations. The problem was to find a method of eliminating all "on the air" repeats. A partial solution to the problem is the introduction of the radio repeat unit, or the short memory recorder as it is called, which is an application of magnetic recording. The Chief of Naval Operations has authorized procurement of 100 models of this unit for extensive operational tests at sea.

The principle of this short memory recorder can be easily understood by those familiar with the "mirrophone." It is simply a recording device that automatically records all transmissions making it possible to play back the information in CIC without using overtaxed radio channels to "say again."

THE RECORDING UNIT

The basic part of this equipment is the recording unit itself consisting of an endless magnetic tape, a recording head, an erasing head, and a play-back head. This recording unit can be located in any available, unattended space either in CIC or elsewhere. In this rack-mounted recorder unit are three continuous recording tapes or loops which makes it possible to have three different "delay times" and also to "store" a message on one while still recording on the other two.

The "delay time" is the time interval between the recording and the play-back of any given message. This delay time is determined by the tape speed and the length of the tape in the loop. It is proposed that the three tapes will have delay or "running" times of 10, 20, and 60 seconds. Any incoming message is recorded simultaneously on all three tapes if the switches are set for normal operation.

REMOTE CONTROL STATION IN CIC

What CIC personnel are primarily concerned with is the remote station or control panel which will be located in CIC. There may be one to three of these remote control stations, all connected to the recording units by regular power lines. This remote control station or panel is a box-like affair approximately 11 inches high, 5 inches wide, and 6 inches deep, or equivalent to the size of two cigar boxes placed back to back.

In this remote control station in CIC is a speaker, a selector switch for selecting which of the three recordings is to be played back, another selector switch for storing information for future use instead of immediate play-back, a volume control button, an alarm light that glows if trouble occurs at the recording unit and an indicator light that glows when a message is being received.

In normal operation, all three tapes are recording simultaneously. The 10-second tape has a 10-second running time which means that 10 seconds of conversation is recorded, then automatically "wiped off" the magnetic tape and 10 new seconds of conversation is recorded. "Hello Ginger this is Pepper, interrogatory bogey zero nine zero fifty-two" is an example of a short transmission that may come over the radio channels. If you did not understand this short transmission, you would turn the selector switch to the "first delay" position and in a few seconds the message would be repeated through the speaker on the remote control station.

FOR LONGER MESSAGES

If the message were longer than 10 seconds, such as: "Hello Ginger this is Pepper, interrogatory bogey zero nine zero, fifty-two, closing, estimate four planes, angels eight, Pepper one two on interceptor vector," you would switch to "second delay" which would play back the longer tape that records 20 seconds of any message before being "wiped off." For exceptionally long tactical messages, the selector switch would be turned to the "third delay" position which gives you a 60-second recording. By using three recording tapes the repeat of the entire message, no matter how short or long, would be only 3 to 5 seconds behind the actual time of transmission in most cases. This is actually faster than the time required to go out on the network with a "say again" transmission.

It should be noted that the delay time of 10, 20, and 60 seconds are not exact established values, and that magazines for introducing any delay between 10 and 90 seconds are provided with the equipment. These, of course, will be worked out with use of the unit. It may be necessary, for instance, to have a 90-second delay rather than the 60-second delay, or a 30-second delay rather than the proposed 20-second timing. The magazines can be easily changed as desired.

MESSAGES CAN BE "STORED"

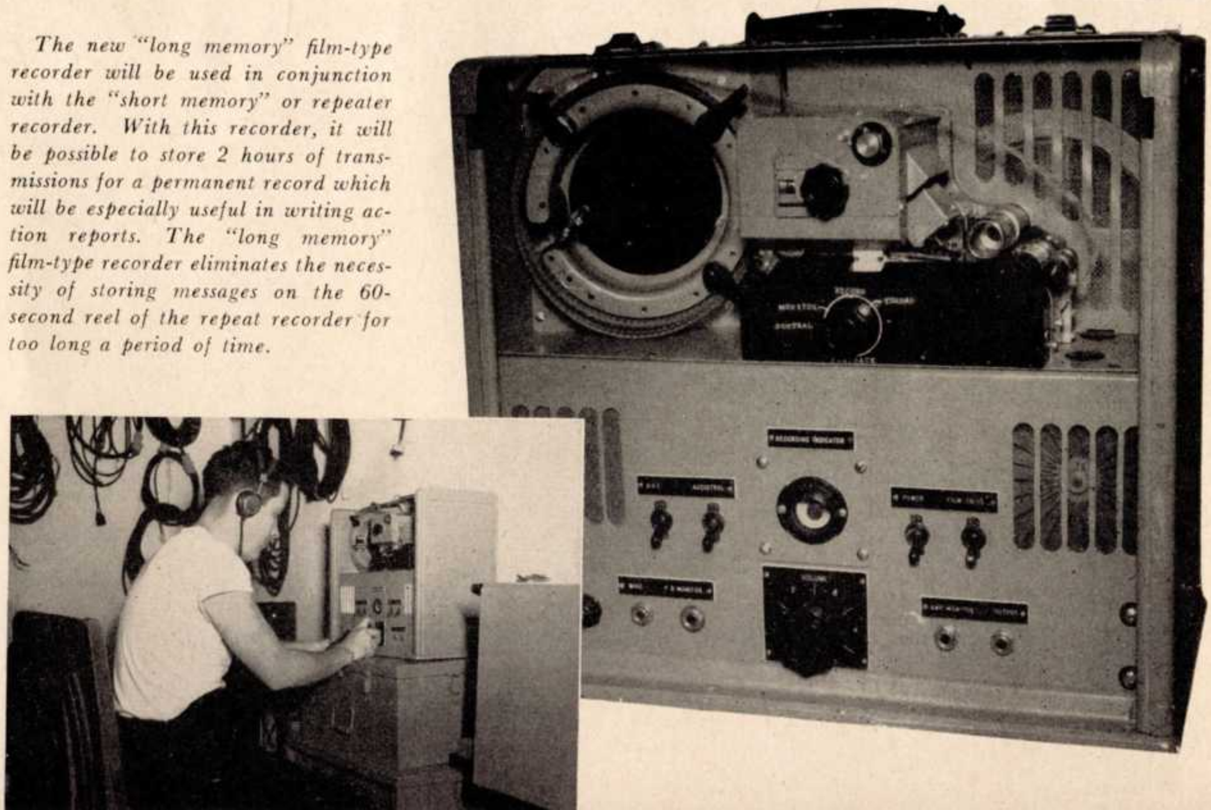
On the "third delay" or the proposed 10-second position, it will be possible to "store" messages. Transmissions that may be needed later on, such as cruising disposition information, can be recorded for later use by switching the "third delay" special switch from "normal" to "stored." Although this tape will not automatically record future transmissions while on the "stored" position, this represents no serious handicap as the other two tapes, one and two, are constantly recording incoming signals for quick repeats.

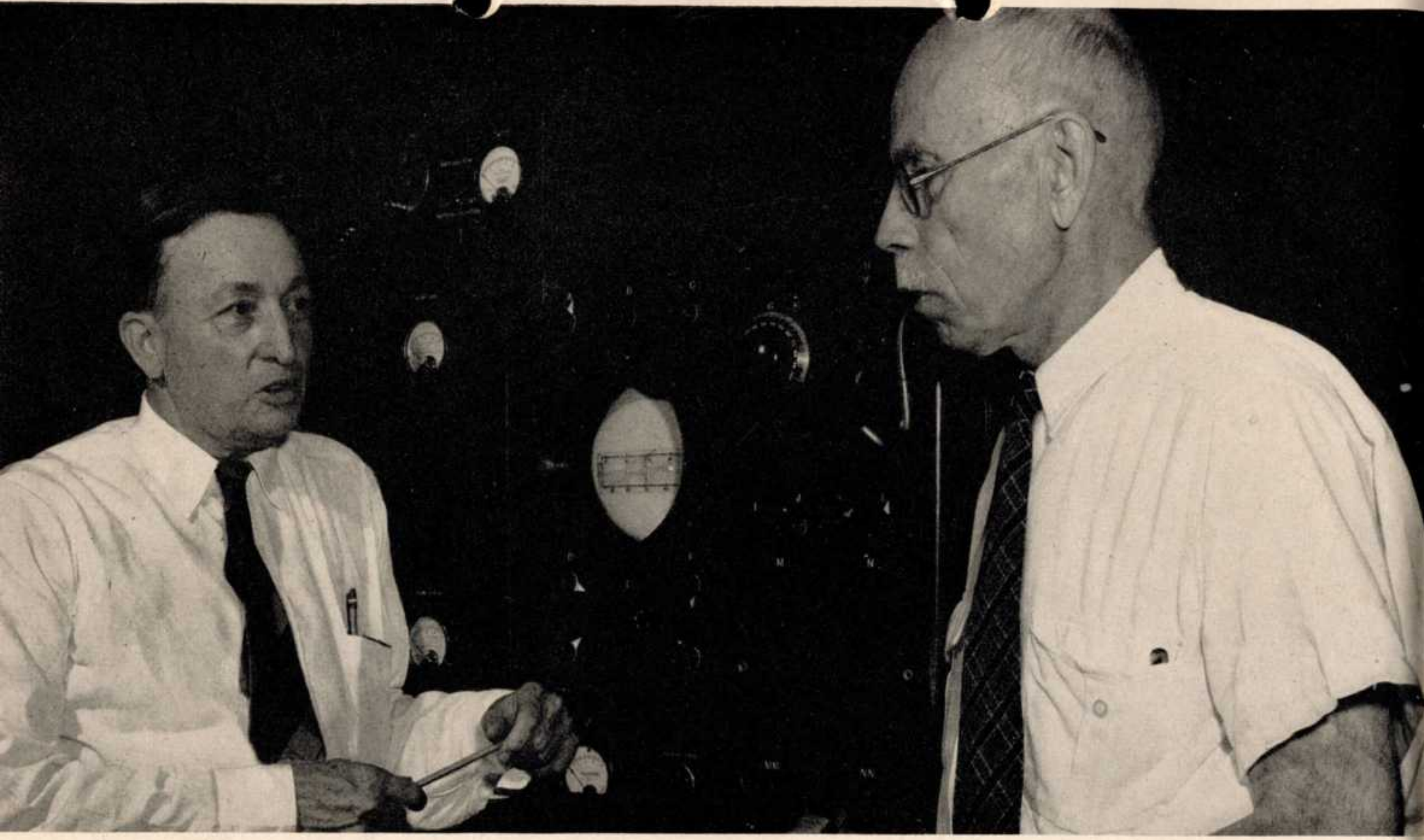
OTHER USES FOR THE REPEAT UNIT

Although the primary purpose in developing the short memory unit has been to eliminate the repeats of part or all of a message, other possible applications are quickly discernible. The "storing" feature is especially convenient for the evaluator. Errors in repeating messages to the bridge are eliminated by playing back the recording to the captain. On condition watches, the radio repeat unit enables one man to guard two or more channels which is a special boon to small ships where personnel is not sufficient to guard all channels simultaneously. It is also of great assistance to monitoring personnel in keeping a more complete log, and to CIC officers for writing up action reports, although a long-memory film-type recorder (see illustrations) has been perfected for these purposes. The long-memory recorder will be used in conjunction with the repeat unit.

These few examples represent the most obvious applications of the device. Experienced personnel understanding the flexibility of the unit undoubtedly will visualize many more circumstances where such an instrument would be of assistance in improving the flow of communication.

The new "long memory" film-type recorder will be used in conjunction with the "short memory" or repeater recorder. With this recorder, it will be possible to store 2 hours of transmissions for a permanent record which will be especially useful in writing action reports. The "long memory" film-type recorder eliminates the necessity of storing messages on the 60-second reel of the repeat recorder for too long a period of time.





Mr. Leo C. Young and Dr. A. Hoyt Taylor, Chief Coordinator for Electronics and NRL staff member since its founding in 1923, discuss test runs on an early radar, the console of which can be seen in the background.

origin of radar

Radar (that means ranging and detection by radio waves) is not a single invention. It's made up of hundreds of inventions and ideas which have been contributed by a great many people both in this country and in England. Even our enemies have contributed, certainly in the later phases of the war, a few ideas.

It has been known for many, many years that radio waves, similar to all other electro-magnetic disturbances, could be reflected from various objects, particularly from large objects, so that echoes of radio waves have been in a way known for a long time indeed, practically since the birth of radio waves in 1886. The idea that these disturbances from moderate-sized objects could be made to reveal the presence of such objects, particularly moving objects, at a considerable distance from the observer, perhaps entirely beyond the range of sight, is, however, new but not so new as most people might imagine.

In 1922, working near the Naval Air Station at Anacostia and assisted by Mr. Leo C. Young, I was conducting experiments on the transmission of radio waves which were, for that day, of very high frequency. Of course, our equipment was very crude, receivers were insensitive, the transmitter of very low power; but we conducted experiments across the branch of the Anacostia River and in the course of those experiments, we noticed that the signals received were affected, in a very marked degree, by the passage of even relatively small moving ships or boats anywhere near the region in which we were working.

This led us to the idea that it might be possible for our ships to detect enemy ships under conditions of extremely bad visibility, as at night or in a smoke screen or during a storm when visible methods were worthless. And in September of the year 1922, I wrote a letter to the proper authorities in the Navy Department suggesting that we equip a squadron of destroyers with some equipment of this nature and try them out at night in an experiment to see if an enemy could filter in between our destroyer lines when the destroyer lines were separated far beyond the ordinary distances then used on night patrol. However, this permission was not granted and the experiment was not made at that time. This may not be as unfortunate as it may at first seem because the successful development of radar depended on the production of certain new technical devices, new tubes, and new procedures which were not available to us at that time and while I have no doubt that, had our experiments at sea been permitted in 1922, we would have had interesting and useful results, it is doubtful that they would have been regarded as highly practical.

RESEARCH ACTIVITIES CONSOLIDATED

About 1923, in the month of May to be exact, the Navy Department consolidated all of its radio research and development activities in the Naval Research Laboratory which was formally opened on the first day of July 1923. For some little time we were busy adjusting ourselves to a new and partially equipped laboratory, and no more work was done which had a direct bearing on the development of radar. However, in the latter part of 1923 and from then on for a long period of years, we were very much interested in short-wave communication problems and in the course of these problems and studies, we found it necessary to measure the height in various hours of the day and various seasons of the year of the Kennelly-Heaviside layer or portion of the atmosphere which permits long distance, high frequency communications.

In 1924 a suggestion was made by Drs. Breit and Tuve of the Carnegie Institution that if we could produce a high-power, high-frequency pulse we might be able to send it the 100 to 150 miles necessary to reach the Heaviside layer, bounce it back and by measuring the time of transit, get at the height of the layer. We promptly stated that we believed that we could produce such a pulse transmitter and we built the first high-powered, high-frequency pulse transmitter in 1924 and continued working on it into 1925 and 1926. Of course, we were shooting at a target a considerable distance away from us but it was a very large and very excellently reflecting target.

It did not occur to us at that time that the technique could be advanced to the point where we could hope to locate very much smaller targets at reasonably long ranges. However, we did continue during this period and up into the very early 1930's, the study of the perturbation methods, which we had originated in 1922. Mr. Carlos B. Mirick had a hand in these experiments as well as Mr. Young and myself and also Mr. Ray Gordon, now assistant superintendent of the airborne division at NRL and Mr. Lawrence A. Hyland now with the Bendix Corp. They were all attached to the laboratory and with the exception of Mr. Hyland, they are still attached to it today.

In the early 1930's then, Mr. Hyland reported on the return from certain field experiments that the device was detecting the presence of airplanes at a very considerable distance. This was immediately realized as an extension of the 1922 discoveries to air-borne targets and the work was vigorously prosecuted with the idea of getting assistance that would work on air-borne targets for a reasonable distance. This we succeeded in doing, in getting ranges of a good many miles. However, it appeared to us that this system was inherently unsuitable for naval ships. The reason for that is that the system required the coordination of several stations transmitting and receiving and while well enough adapted for protection of the land area where your stations were not moving about, it would have been an impossible thing to handle at sea.

At this point, about 1932, I prepared a letter addressed to the Secretary of War via the Secretary of the Navy, which was signed by the Director of the Laboratory at NRL, calling to the atention of the Army the fact that we had an area-protection system which would detect the presence of aircraft out to 35 to 50 miles and that we thought would be of more interest to the Army than it would be to us.

Now this early system had a number of difficulties. It required a considerable complexity of apparatus, the job couldn't be done all in one place and the range indication was determined by rather indirect calculations and not given immediately by instruments, so that we continued our search for perfection of this method.

Early in '33 Mr. Young came to me one day and said, "Why don't we try the pulse method that we used on the Heaviside layer shots in '24, '25, and '26?"

"Well," I said, "We've got targets which may be nearer than the Heaviside layer but they're very poor and very small reflectors compared to that immense area and I imagine we will have difficulty in doing such a job, but let's try it anyway."

Mr. Young then went at it and after a few months of very arduous work, succeeded in getting pulsed re-

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Dr. A. Hoyt Taylor, who is the chief consultant and chief coordinator of electronics at the Naval Research Laboratory, dictated informally this story of some of the highlights in the origin and development of radar. Dr. Taylor, one of the pioneers, tells in simple language the work done by the Naval Research Laboratory, describes the important, full exchange of technical information with the British, and appraises the Japanese and German radars. This story was put down for the archives of the Office of Naval Records and Library by whose permission it appears in "C. I. C."

*

flections from airplanes at a few miles distance. He then called for more help and Mr. Robert Page was put on the job with the express purpose of expediting this work and he was assisted by Mr. Philipott. Mr. Page has been in radar work of one form or another ever since and I believe has contributed more original ideas to the field of radar and perhaps more inventions, than any other one man.

LIKE THE OLD-TIME ECHO SYSTEM

Perhaps a word as to the nature and necessity of the pulse system should be put in here. You see this whole system of radar ranging reminds one very much of the methods of navigation used by a lot of our old-time coastal skippers, particularly in places like the inside passage to Alaska. If they're in a fog and they can't see the shore, the cliffs, they give a short, abrupt toot of the whistle and time the echo coming back from the surfaces ashore. This system works most effectively, of course, when there are rather abrupt cliffs or pronounced targets to reflect the echo back. Many of you have probably tried it by firing a pistol or making a shout and listening to the echo coming back across the mountain valley.

Well, now that's what you're doing in radar, except that instead of traveling around a thousand feet a second, the radar echo travels fast enough so that if it could keep on going it would travel eight times all around the world in one second. In other words, instead of measuring time in seconds with our radar echoes, we have to measure them in micro-seconds or millionths of a second.

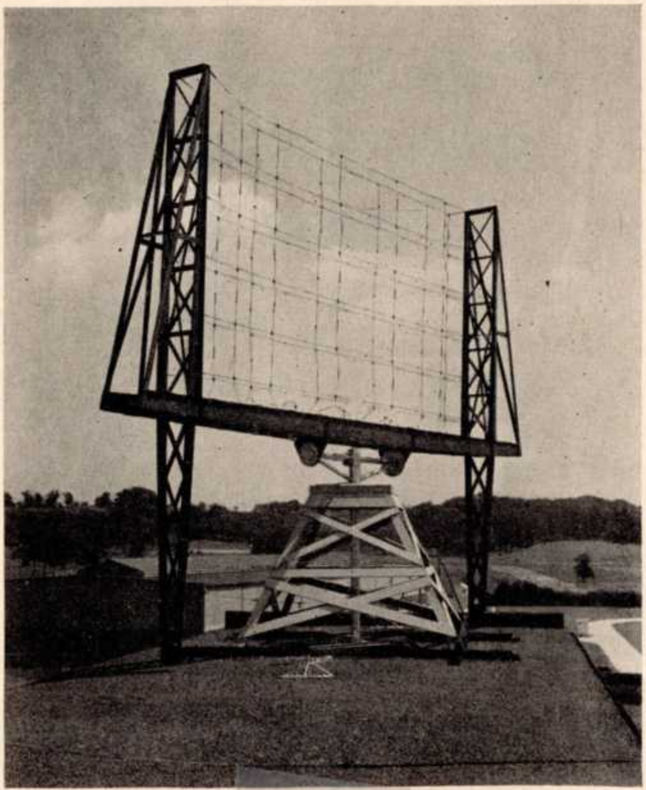
Now it means that our outgoing energy must be cut off extremely abruptly or else an echo from a relatively nearby object even a few miles away will come back so soon that you won't be able to distinguish it from the outgoing signal. So we have to have very high-power pulses. We have to put a tremendous energy out for a very brief interval of time. And then that is repeated a good many times a second but actually our radar transmitters are idle, many of them, 99 percent of the actual time of operation. They put out perhaps a thousand pulses a second but each pulse is so short compared with the time between the pulses that the transmitter is not working very hard, so it is that we can have pulses of many kilowatts at peak power put out by extraordinary small and compact radar equipment.

Now these pulses going out strike various objects and will reflect. But, of course, the harder the strike, the more energy the pulse has when it hits, the better. And so in addition to putting a lot of power in the pulses we put a directive antenna on the transmitter so that the energy is concentrated in the particular direction wherever you are searching for a target. This has an added advantage because when you strike a target, you know it's in that particular direction and by turning your radar antenna so that you get the maximum echo strength, you measure very accurately just what the bearing of the target is.

The average uninformed person would consider that the problem of measuring time in millionths of a second, would be one of the worst parts of the problem. Actually that's ridiculously easy with modern equipment. It probably would have been difficult, if not impossible in 1922, but by 1932 and on, it was easy. It is relatively easy to set up equipment that will give you visual indications, clear and sharp, down to fractions of a micro-second. So that, that part of the problem was relatively simple to solve and didn't hold us up. The formation of sufficiently high power pulses of sufficiently short duration did take a great deal of research and a great deal of time to finally solve.

A factor in this matter of getting a sharp beam or high concentration of energy in one direction, is the frequency of the radio wave which is used for propulsion. Now if you use a long wave length or a low frequency, it requires directive equipment of tremendous size which you couldn't possibly get on board ship. So we have to use relatively high frequencies and we have explored and made available for radar, before and during the war, a very large gamut of frequencies and all of them have given us valuable equipment for various purposes, both for Army and Navy work and both for ships and for air-borne equipment.

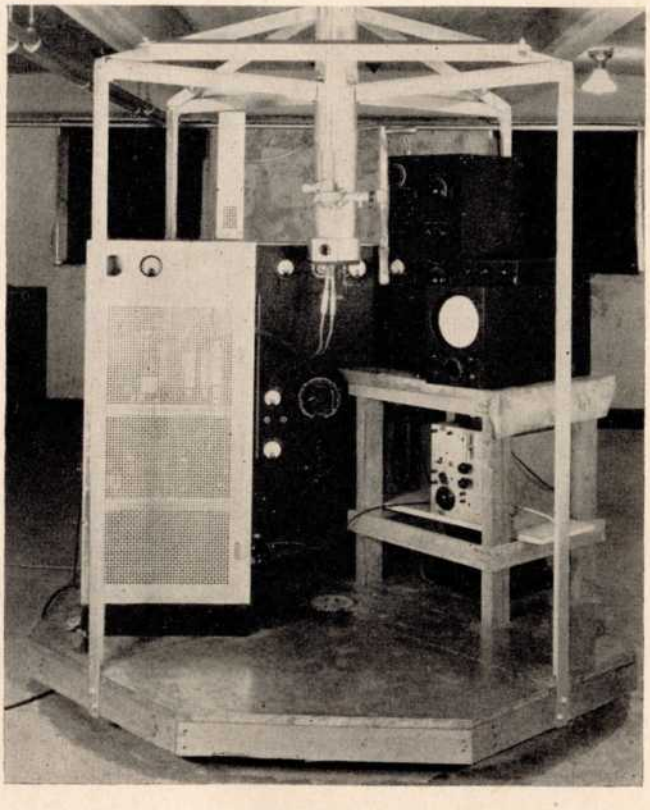
An early search radar antenna 1937.



RADAR SAVED BRITAIN

It's interesting to see what the situation was when the full exchange of technical information with the British began to take place about 1940, as I remember it. It seems that both countries had been working on radar without either knowing with any certainty that the other was working on it. Our dates were a bit earlier here but Britain was working under the pressure of imminent war and they put a tremendous effort on their development at an earlier date than we did and they had good reason to be thankful for that because by the time the German blitz hit them, they had established a set of long-range warning stations around the English coast which permitted a small but efficient British fighter force to cope with very large numbers of German bombers.

As for our use of it in the air, this may be said as preliminary that the British made the first use of radar in the air except for a pulse altimeter which we had developed at this laboratory but which had not gone into production. The British, however, were in limited production and were equipping their coastal command planes with search radar for hunting down German submarines before we had any equipment of that sort on our planes. However, although we bought a few hundred of their sets and immediately put them to work on similar labors, we couldn't use their equipment on carrier-borne planes; it was too large, too clumsy, too heavy, it took too many knots off of the speed of the plane. You had to carry so many and so elaborate antennas.



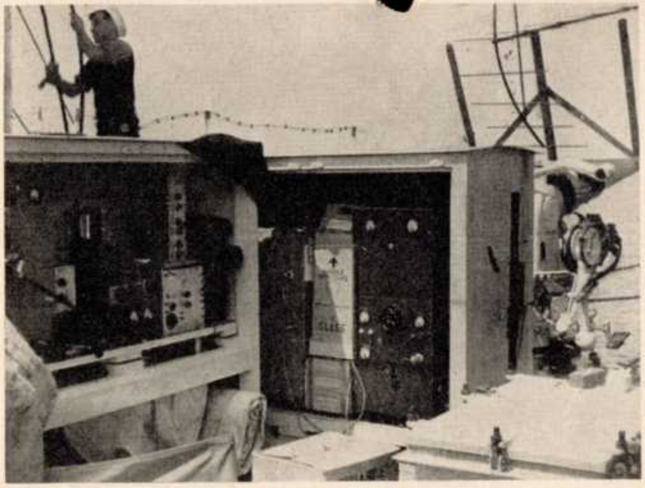
An early search radar 1937, which with antenna shown on opposite page makes a complete early radar installation.

So this laboratory went to work to produce as quickly as possible an air-borne search set, particularly for submarine hunting, which would be lighter, much smaller, smaller antenna that wouldn't hamper the planes and could be put on carrier-based planes. That resulted in the development of what we call the AS Baker and it went into production to the tune of over 26,000 sets and I judge that quite a few of them are still in commission although they're really now an obsolete model. So we see that it's interesting to note that as far as our installations are concerned, the British were ahead of us when the exchange of information began, and also in point of numbers and coordination of shore installations; but both the Army and the Navy had long-range search installations which were much more convenient to use in many ways, easier to install and equal in performance, if not superior, to the British equipment. We had not gone as far in quantity production and installation as they had.

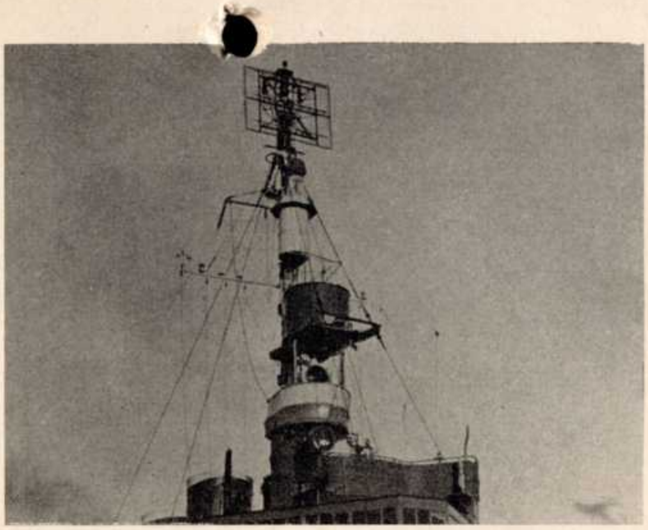
THE WORK WAS DIVIDED

When the Office of Scientific Research and Development was formed, the question came as to what would be the most effective field of radar for them to get into. Since this laboratory, and the Army also, I believe, had been practically committed to pushing the relatively low-frequency radar, although we had both of us done extensive research in the very high-frequency field, we felt that the high-frequency field, namely the micro-waves, 10 centimeters, and under, should be pushed by the National Defense Research Committee working under the Office of Scientific Research and Development. That was about the way it divided up and since that time there has been very close cooperation between the Army, the Navy, and the NDRC organization. And I want to take this opportunity to say that the OSRD organizations have done a magnificent job in microwave radar. But if we had waited for that organization to produce the first ship-borne sets, we would have gone into battle with the Japanese in the Pacific without any radar. We, therefore, don't have any remorse in our having stuck to the long waves and got something on the ships to fight with.

Radar besides being one of the premier weapons of World War II has served another and extremely useful purpose. More than anything else, I think it has sold the whole country and particularly the high command, on the absolute necessity of the continuation of scientific research and development if a nation is to remain safe. We made more friends at this laboratory through our work in radar than we had made through the preceding 20 years with less spectacular, although perhaps almost as valuable, accomplishments. I have always said that radar still appealed even to me as the nearest thing to a miracle that I had ever experi-



View of the first radar installation on the old U. S. S. "Leary" (DD158) in 1937 at Chesapeake Bay. Mounted on a five-inch gun, the Yagi-type antenna was swung about by moving the gun.



In May 1941 the U. S. S. "Semmes" (DD189) became a radar experimental ship marking the advent of microwave equipment.

mented with. So naturally it always affects people who have no deep technical interest in much the same way, as something of a minor miracle.

It is interesting, but perhaps fruitless, to speculate what would have happened if we had had adequate support, adequate funds, adequate personnel, to advance the radar program by a period of 5 or 10 years, which would certainly have been perfectly possible if the proper push could have been put behind it. I hope that similar mistakes will never be made again in the future because I believe that the whole world is aware that from now on science is very definitely in warfare.

For peacetime radar should have a number of very important and interesting applications. Although I don't believe that the time has come when you're going to have one in every car to see whether another fellow is coming around the next bend. For one thing radar rays go straight and don't curl around bends, anyway. But as an aid to navigation for sea and air it has been a perfectly wonderful thing and should prevent collisions both at sea and in the air, permit constantly blind navigation as the Navy has used it all through the war and as the Army B–29s have used it bombing Japan in pin point locating of targets.

It ought to be practically impossible for collisions to occur in the air or at sea, or for people to get lost if the planes and ships are properly equipped with radar.

There may be other applications. There probably are a good many of them but certainly as aids to navigation there can be no question about the value. The application of radar to the Merchant Marine is already under very lively discussion and the time will probably come when it will be just as compulsory for a big ship to carry radar as it is to carry life preservers.

Our earliest sets in the Navy were search sets. We knew, of course, that we needed far more precise instruments for fire control. But our main worry at the beginning was the detection of enemy planes at sufficient distance to get our fighters up and cope with them and, on the other hand, to get something immediately that would aid us in navigation and finally to get something on our planes that would cope with the submarine menace and keep them underwater at night and at all times if possible.

FIRE CONTROL CAME EARLY

The development of the fire-control radar came rather early, however, both in the Army and Navy and also rather early in England in connection with anti-aircraft fire. That is a long story of itself and I don't think I can go into detail of it here but the earliest fire-control sets in the Navy were produced by the Bell Telephone System. We called down some of their leading engineers and said we had something very secret but we wanted to take them in on it and we showed them our search radar which was then able to pick up planes at around 40 or 45 miles. They were quite unable to believe the evidence of their own eyes but finally accepted it. We then asked them if they wouldn't consider taking a contract from one of the material bureaus for a developmental set along these lines. But they said that we were so far in advance of what they knew that they had better not take any contract immediately, but would rather work on their own for a while and when they were ready, they would come and ask for a contract.

A few years later they asked the Navy Department for a contract and then they proposed to try a fire-control set. That resulted in the development of the Mark 4, which, of course, has long been outmoded but nevertheless served an excellent purpose and was responsible for many a Jap ship being on the bottom of the ocean and many a plane being shot down.

Very early in the radar picture we considered the needs of submarines. Admiral Bowen, now chief of ORI, then director of this laboratory, called me into his office one day and said, "Can't we give the submariners something that they can stick up out of the water and tell whether there is a plane around before they fully surface?" He said, "They're very much afraid of these Japanese planes," and I said, "Well, that's going to be a tough proposition because we can't use any directive equipment. We need a low frequency for long-range search radar and haven't any very high frequency developed now anyway. We'll have to use quite an antenna. We can't make a beam mount. But if you're satisfied with a limited range of 15, 20, or 25 miles, I'll see what I can do."

But I didn't give him very much encouragement. However, in a few months we had the preliminary model of the Sail Dog equipment going and that went on board many of the submarines as a warning set. Its range was in truth limited but it isn't any exaggeration to say that it undoubtedly saved quite a few submarines. It is interesting to note, however, later, that the set became somewhat of a menace to us because the Japs had learned about it and they had learned also to put a countermeasure receiver on board their planes to pick up these signals and to home on them.

It's the old story, whenever a good weapon comes out, a countermeasure is sooner or later involved in the picture and radar is certainly no exception. We've had a great battle of countermeasures, especially in the latter part of the war, and the Germans, of course, tried countermeasures against radar, English radar, very early and then the English, of course, tried to counter countermeasures. It is a question of a never-ending battle and each person out-thinking the other as well as he can.

MUST ANTICIPATE COUNTERMEASURES

It should be pointed out here, I think, that while in some ways a nation has to go to work with the weapons it possesses at the time war opens, I won't say declared, because nations don't seem to declare wars anymore, it is also true that you can't go on through the war with the same weapons. That has been most extraordinarily true in this war. There are a great many other weapons than radar that could be used as an illustration of this same thing, such as the bazookas, the mine, constantly improved and then countermeasures produced for it and different kinds of weapons, radar, mines, etc., used and again the enemy has to catch up with us. So you have just to keep right on out-thinking the enemy scientifically even beforehand. It isn't sufficient to just prepare beforehand, you must keep on with it. That was undoubtedly one of our biggest headaches, especially during the last 2 years of this war, to anticipate the enemy's countermeasures and have remedies on hand for them. I think we succeeded fairly well in doing so.

The enemy did not use radar when they started the war, neither the Germans nor the Japs. The Germans had been making experiments and some minor developments leading up to it but they didn't have anything in production. And I think the English radar was a considerable surprise to them and it was quite a long time before they had any adequate countermeasures or answers to it. They got to be very good, however, both at searchlight-control radars and fire-control radars in the last $2\frac{1}{2}$ years of the war. And they also got very clever at jamming and various other countermeasures, especially as against some of our guidance methods, navigating methods, long-range navigating methods, and blind bombing radars, etc.

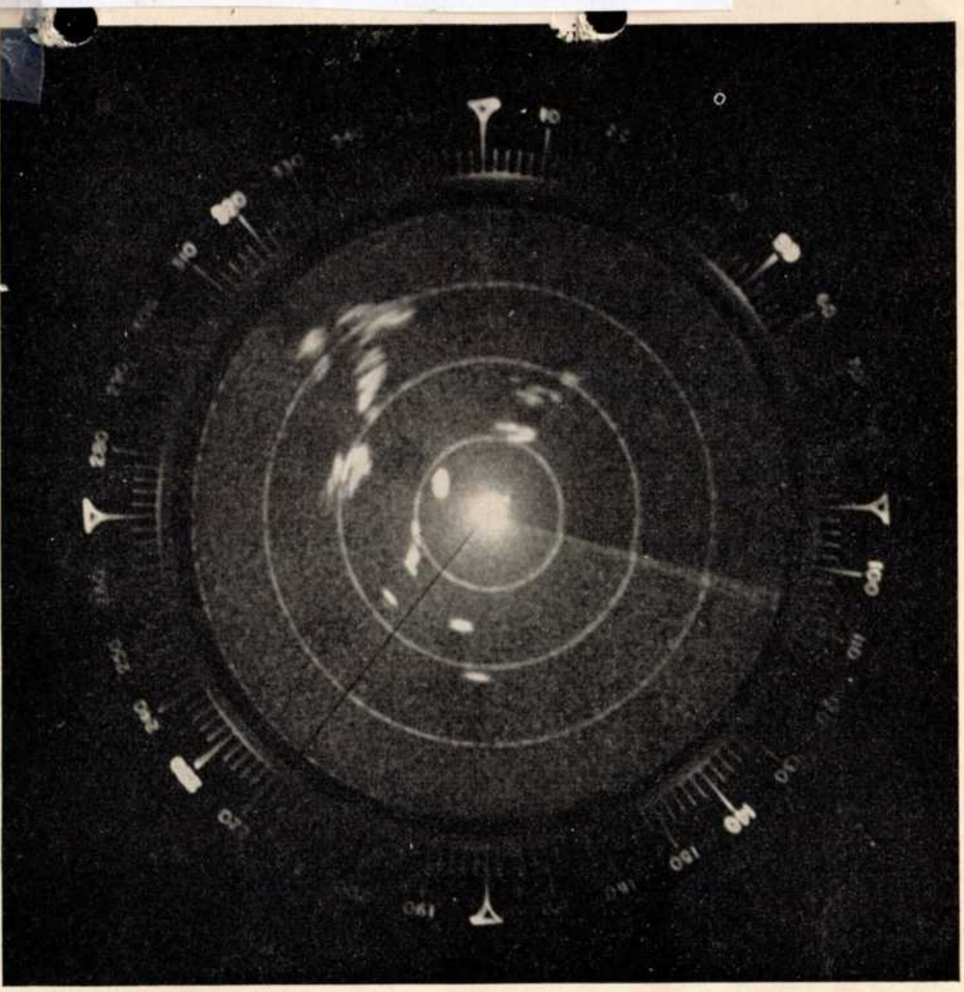
The Japanese were distinctly behind the Germans as might have been expected. They also showed some traces of German influence but it should be remembered that the Japanese captured a good United States Army radar in the Philippines when they took the Philippines and they also captured some British equipment at Singapore, which equipment was very badly smashed up but unfortunately they got an instruction book with complete wiring diagrams and pictures. They apparently made an attempt to construct Jap radar on the British plan and something went wrong and they didn't succeed. They finally turned out the model which is similar to the one we captured on Guadalcanal at first and another one, that hasn't yet been set up and operated, at Attu.

These radars were in the hundred megacycle band and they were supposed to be long-range search. They were only reasonably good and not very accurate in bearing. They also had very poor transmitting tubes in these radars and their whole technique was a number of years behind ours. And I think up to the end of the war we had consistently kept several years ahead of them on the whole radar program. The same thing again can be said of the Germans only to a lesser extent, the Germans being much better both at technique and mass production.

I think this story shows clearly enough that in the future, if we have to economize, it had better not be on military research.

First operational radar installation on a Navy plane adds a spiked appearance to the otherwise smooth skin of the fuselage on this consolidated PBY patrol bomber. The antenna of the radar is strung between the spikes on the port bow.

PPI view of Fujiyama



Fujiyama, sacred mountain of the Japanese and long the objective of holy pilgrimages for the Mikado's subjects, now forms a different kind of "objective" for Uncle Sam's armed forces. Its 13,000-foot mass, towering above the surrounding Tokyo plain, provides an excellent radar fix. CIC personnel of the USS DAYTON identified the peak on both SK and SG radar scopes during the night of 18–19 July when TG 35.4, under command of Rear Adm. C. F. Holden, USN, conducted a sweep against shipping and shore installations in the lower Tokyo Bay areas.

In this photograph of a remote PPI (SG radar on 80-mile scale), Fujiyama is the bright pip at 315° (T)—68 miles. Other features shown include Nojima Saki, 022° (T)—20 miles; O Shima, 295° (T)—17 miles; and Miyake Shima, 195° (T)—29 miles. Tokyo lies in radar shadow at 001° (T)—67 miles. When the photograph was made USS DAYTON was at latitude 34°—33′15″ N., longitude 139°—42′15″ E. Other technical data: Antenna height, 111 ft. 2 in.; frequency, middle "A" band; scale, 80 miles.

The DAYTON reports that Fujiyama was first picked up on the SK at 295° (T)—115 miles at 2145 the evening of 18 July. It showed continuously on the scope until the formation retired, disappearing at 310° (T)—138 miles at 0315 19 July.

Zig Zag plan at a glan

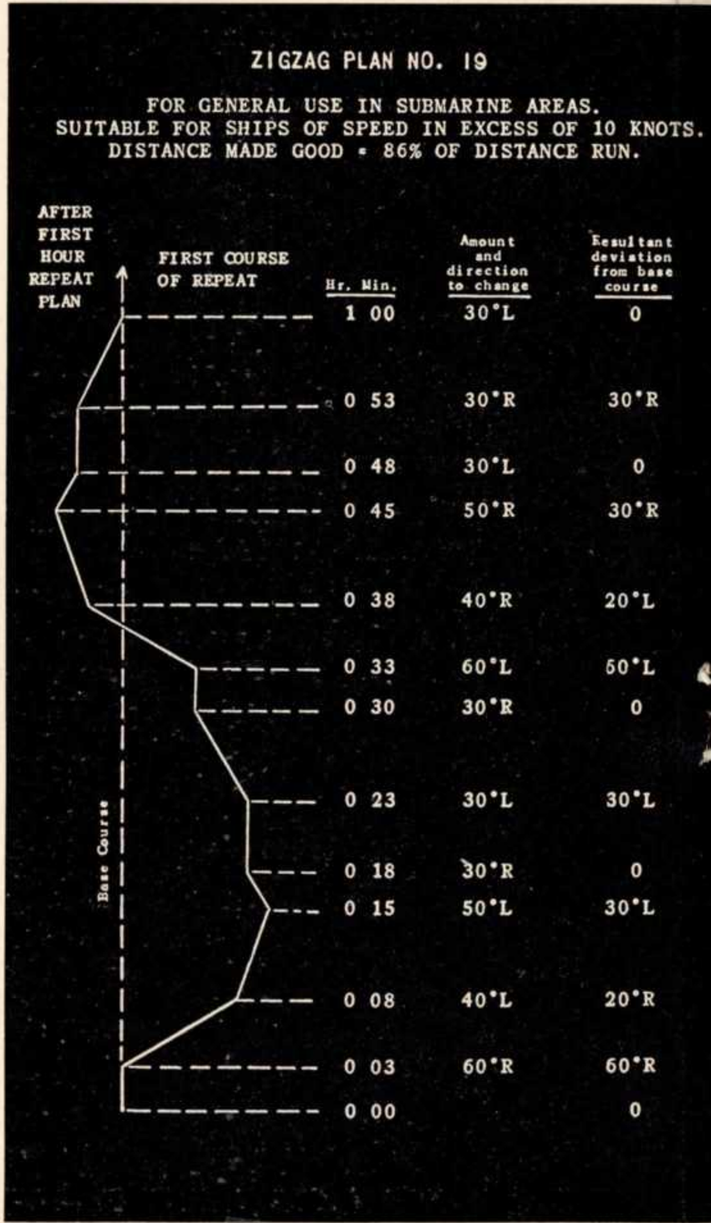
A new device for simplifying the execution of zigzag plans has been developed by Lt. John W. Peirce of the USS PRINCE WILLIAM. The "Peirce Zigzag Gizmo," as it has been tagged by officers-of-the-deck aboard the USS ATTU (CVE 102) where it was first put into practical use, can be made aboard ship from any standard plexiglass compass rose or bearing circle. Under this are used diagrams for each of the zigzag plans, drawn on heavy paper.

The gizmo illustrated is a 9-inch plexiglass bearing circle mounted on a plexiglass base and secured to the base with a wing screw in the center for easy rotation of the circle. The diagram of the zigzag plan to be used is placed under the bearing circle and secured to the base with scotch tape.

HOW TO DRAW THE DIAGRAMS FOR THE ZIGZAG PLANS

The zigzag plans are all illustrated in USF 10B, appendix II, with all course changes expressed in terms of turns of so many degrees to right or left at stipulated times. The purpose of the "Peirce Zigzag" device is to give the OOD the correct headings for all turns, worked out in advance. This enormously simplifies the task of the OOD in the execution of any zigzag.

As a guide to preparing the diagrams for use in the device, Zigzag Plan No. 19 (from USF 10B) is reproduced here, together with the same plan "translated" for use in the Peirce device. The diagram was made as follows: First, a circular piece of heavy paper, of the same size as the plexiglass bearing circle, was marked at the top with a short heavy line to indicate base course (and so labelled). Next, short radial lines were drawn to right and left of the base course line, representing the turns in degrees transposed into the resultant headings as they fall on the compass rose. Next, vertical lines were drawn, parallel to the "base course" line, towards the bottom of the circle, these lines leading from the inner ends of the radial "bearing" lines. On these vertical lines, the correct time for each turn (or change to new heading) was marked, working down from 1 00 to 0 00, the latter indicating zero time or the beginning of the zigzag plan. Finally, these "times for turning" were connected by blue pencil or dotted lines, starting at 0 00, going [illegible] to 0 03, to 0 08, and so forth up to 1 00. It must be understood that this blue or dotted line is NOT the pattern of the zigzag but the guide line leading from one "time of course change" to the next. However, if the course change is to the right, this line also goes to the right, and vice versa.



ZIGZAG PLAN NO. 19

FOR GENERAL USE IN SUBMARINE AREAS.
SUITABLE FOR SHIPS OF SPEED IN EXCESS OF 10 KNOTS.
DISTANCE MADE GOOD = 86% OF DISTANCE RUN.

Hr. Min.	Amount and direction to change	Resultant deviation from base course
1 00	30°L	0
0 53	30°R	30°R
0 48	30°L	0
0 45	50°R	30°R
0 38	40°R	20°L
0 33	60°L	60°L
0 30	30°R	0
0 23	30°L	30°L
0 18	30°R	0
0 15	50°L	30°L
0 08	40°L	20°R
0 03	60°R	60°R
0 00		0

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HOW TO USE PEIRCE ZIGZAG GIZMO

In using the Peirce Zigzag Gizmo, as each course change is effected, a check can be made with grease pencil on the surface of the bearing circle so that OOD can note at a glance his position in the zigzag plan. At the end of the plan these checks can be removed before starting over.

When the base course is changed, it is necessary only to loosen the bearing circle and rotate to the new base course, and this automatically establishes the correct new headings for executing the zigzag.

The original device was developed by Lieutenant Peirce at the Pre Commissioning Detail at Astoria, and was first placed in use aboard the USS ATTU in July 1944. The present improved version was first used on the USS PRINCE WILLIAM in June 1945 and since that time has proved more satisfactory than any other known method of helping the OOD to maintain a zigzag plan. Its use has greatly decreased the chances of the OOD coming to the wrong heading after a change of course and also has provided a quick method of determining the new heading.

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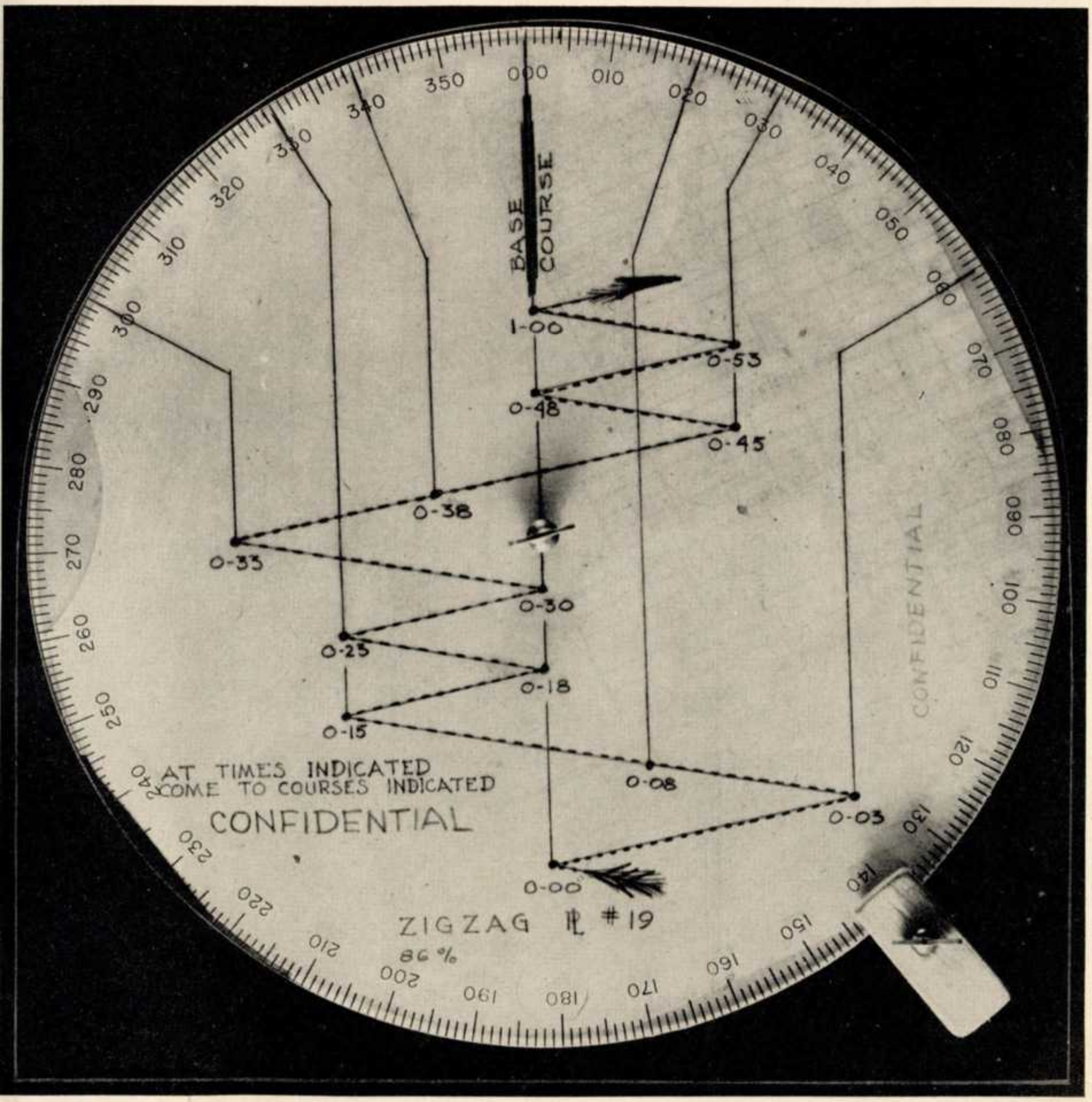

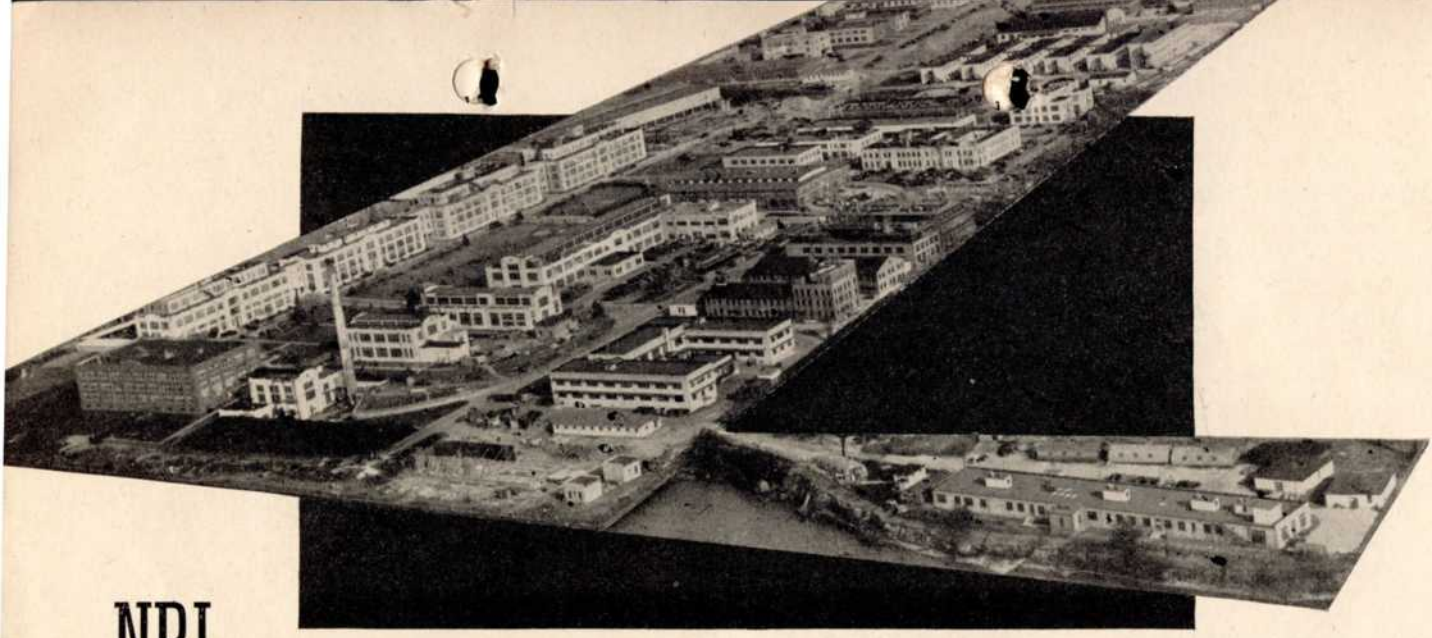

NRL...

... backbone of Navy's scientific research

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PERSONNEL

Top man at NRL is the director, a commodore, or rear admiral, selected because of proved technical and administrative ability. The director has a staff of civilians and naval officers.

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Reporting to the director are the civilian scientific superintendents. These men are:

Airborne Radio	—Mr. R. A. Gordon, Acting
Aircraft Electrical	—Dr. Ross Gunn
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Chemistry	—Dr. P. Borgstrom
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Sound	—Dr. N. C. Hayes

During its 22-year career, NRL has been variously under the offices of the Assistant Secretary of the Navy, the Chief of the Bureau of Engineering, the Chief of the Bureau of Ships. Today it is a division of the Office of Research and Inventions which, in turn, is in the Office of SecNav.

NRL FACILITIES

Although the number of employees at NRL has varied throughout the war, at their peak they numbered well over 5,000. To house this number and provide the facilities for carrying on their work has required the addition of literally dozens of new buildings. The main Lab at Bellevue now stretches over 50 acres and includes machine and pattern shops, foundries, drafting rooms, storage warehouses, and a cafeteria serving 2,000 meals daily.

Perhaps the most important facility is the astonishingly large NRL library which consists of 14,000 bound volumes, 150 100-foot microfilm rolls, and copies of the 300 technical journals to which the library subscribes. Employing 25 workers, the NRL library performs a unique and highly valuable service by classifying, analyzing, and abstracting articles in technical periodicals for the research workers and is believed to be one of the best technical libraries in the world.

Many of NRL's scientists, like scientists everywhere, donned uniforms during the war. Many of them carried on their work at the same desks and laboratory benches and despite gold braid and buttons concentrated on the same projects as when they were civilian employees. Others found their way to combatant units and the Laboratory looks forward to welcoming them home.

NRL'S JOB

In the bewildering maze of bureaus, divisions, subdivisions, subcenters, projects, and other facilities in which Navy research was carried forward during the war, NRL occupied a highly significant if often unspectacular place. As the principal center of Navy "know-how" in applied scientific research, NRL was charged, among other things, with the job of scientific

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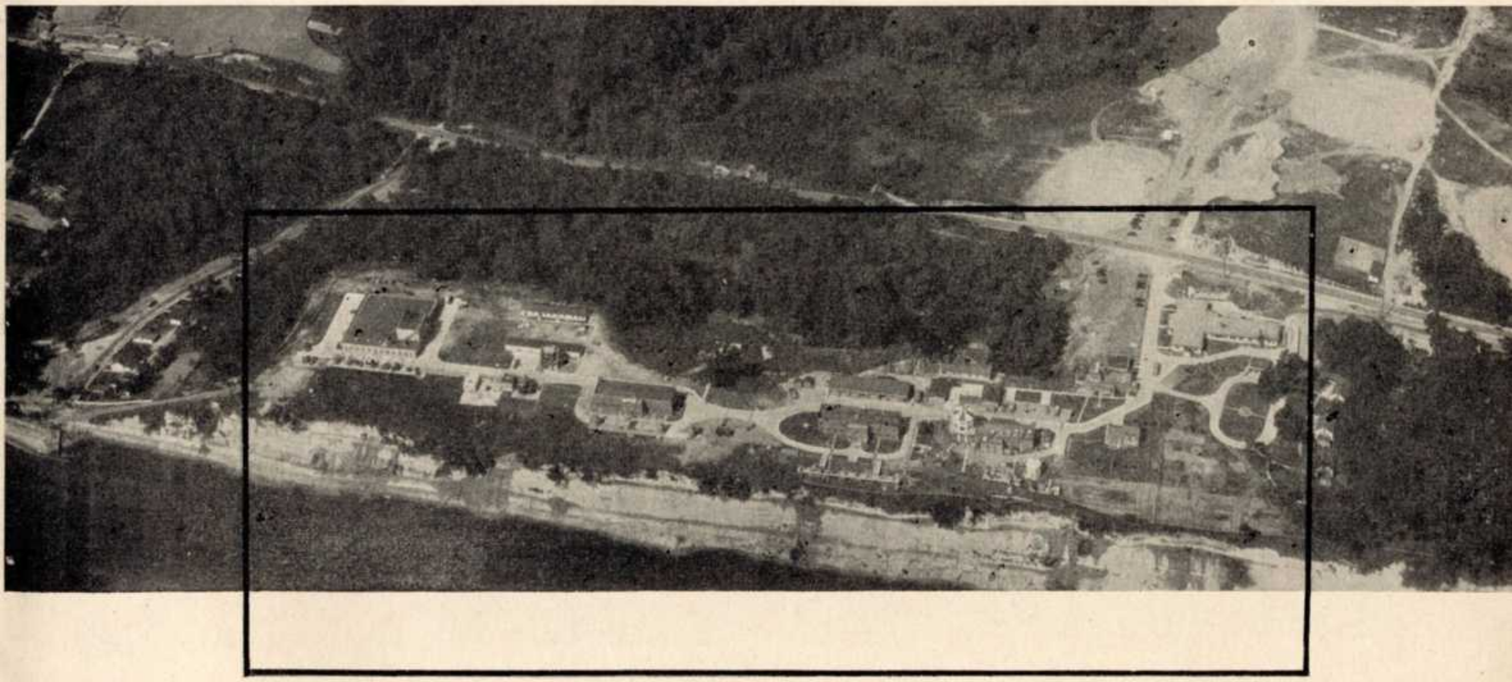

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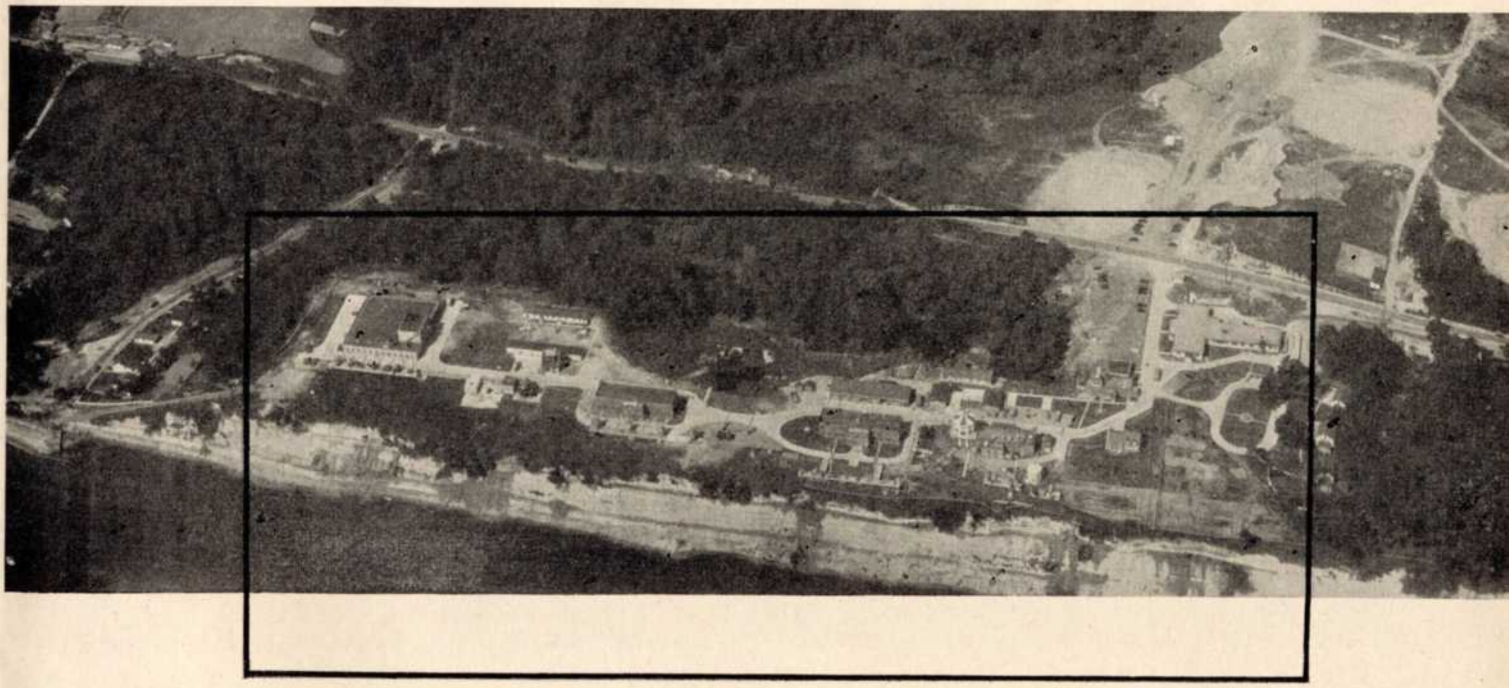

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watch dog. Manufacturers faced time and again with the problem of devising instruments that would work as well for ships at sea as in their laboratories turned to NRL's physicists and experienced engineers for practical advice. The MIT RadLab, which did much of the pioneering in centimeter wave electronic development, also learned that NRL was a sound, deep mine of information on such vitally important matters as the feasibility of a suggested piece of equipment for ship or air-borne use. Throughout the war relations betwen the two labs as well as between NRL and industry remained close and harmonious, with NRL providing the "Navy element." Production models of radars now standard were thus most frequently submitted to NRL for analysis and rigorous testing before the jump into big production was made.

NRL, however, did not confine its activities to the role of watchdog. Typical of the type of original research carried on in NRL's workshops and drawing rooms was the development of the familiar pulse analyzer for countermeasures. Early in 1943 two members of BuShips countermeasures section were making a routine visit to NRL. In the course of conversation with the head of the Radio Receiver Section, one of the visitors suggested that a useful piece of equipment would be gear that would measure the pulse width, record the pulse repetition rate, and provide other data for the study of enemy radar emanations. When the visitors had left, the head of the section called in one of his assistants and said: "How about thinking about a gadget to measure pulse width and frequency. Can it be done?" It could. Within a week the practicality of such a device had been demonstrated. On April 4, 1943, the first model was constructed, and within 3 months tests were being conducted in the fog-bound Aleutians. The final results—with AN/SP Pulse Analyzers installed on all capital ships—are well known to CIC personnel. Other illustrations of NRL applied research include the development of instrumentation essential to the eventual refinement and mass production of centimeter wave radar. Other momentous projects under way at NRL include extensive work on missile control links, standard signal generators, portable direction finders, jamming and monitoring systems, in addition to the initial developments giving rise to new early-warning and air-borne radars.

During the war NRL, like many other research organizations, was unable to keep fully abreast of the flood of problems which swept in from the field, through the bureaus and agencies of the Navy, and into the doors of the Lab. In order to help put "first things first," the advice of a board of officers representing the Navy Department's principal operational offices and material bureaus was secured. This board met monthly and reviewed the most urgent items of work. It was a life-saver in the electronics research field.

Though the electronics field used a substantial portion of the laboratory effort, there were also major programs in chemistry and other fields of physics.

Research in homing devices and in engineering processes, corrosion, fouling, fuels, chemical warfare, underwater explosions, metallurgy, and sound gear would, if fully reported, fill many volumes. One of the most satisfactory programs, for example, solved the problem of precipitation static in aircraft.

NRL FUTURE

It is evident that the Navy feels that it is necessary to continue a strong program of research within its own organization, guided by men who are experts in their own fields and yet have intimate knowledge of the special needs of the Navy and who maintain frequent contacts with all branches of the armed services. Relying on science and industry not only for the ultimate production of our equipment but for invaluable assistance in various fields of research, the Navy values NRL as a reservoir of naval and scientific information available to industry in both peace and war. The Navy, as well as NRL, derives great satisfaction when industry is able to convert to peacetime usage important nonmilitary byproducts of the laboratory work.

A clue to what NRL physicists and scientists hope will be their future is contained in a paper by Dr. E. H. Krause, a young NRL physicist working on guided missiles, who hopes for a return to pure research.

"One of the greatest lessons we have to learn from the past," says Dr. Krause, "is the wrong philosophy that pervades a nation from a scientific point of view during the periods between wars. During a war, there is usually little basic research done. All pure science is stopped so that a tremendous effort can be put into marshalling all of the technical forces of the nation to applying the scientific facts at hand to instruments of war. The result is that revolutionary advances are made in military machines and techniques. At the conclusion of the war, the policy is usually to spend the peace in perfecting the instruments and machines of the past war. This will, for example, find a nation beginning the next war with tanks that go faster and planes that go higher than those in the previous war. The latter is certainly desirable, but we must be very careful that we do not fall into thinking that it is either most urgent or sufficient. A reasonable amount of the nation's scientific effort must go into pure research."

Taking an illustration from NRL's own history, he goes on to say: "In reviewing the history of the Naval Research Laboratory, we find that this laboratory was less guilty than most of the 'Spend most of your time applying what you already know' philosophy. If we go back to the twenties, we find a group of men at NRL, notably Dr. Taylor, Dr. Gunn, and Dr. Hulbert, working in a basic research field in company with several people outside NRL, such as Dr. Breit, Dr. Tuve, and others. These people were concerned with

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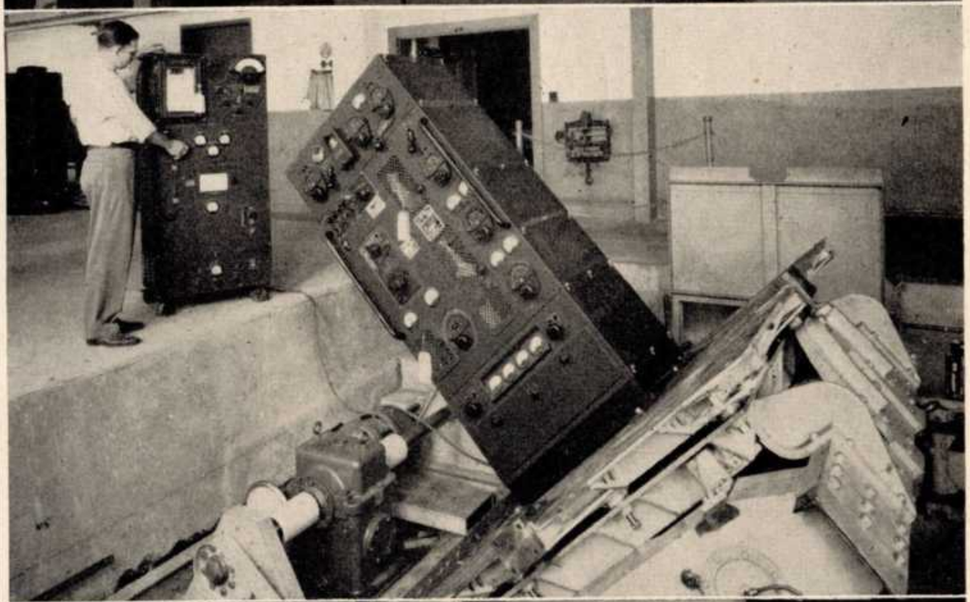
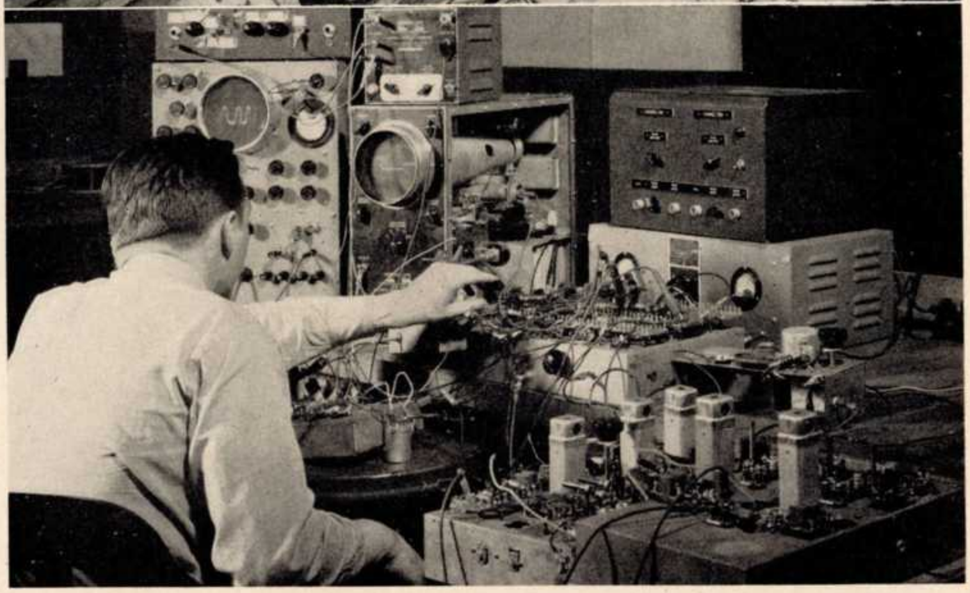
Experimental facsimile studies are carried on in a dark-room laboratory.



As scientific watchdogs for the Navy NRL scientists conduct tests to determine seaworthiness. Here a radio transmitter is being tested on a vibration, shock, and roll table which simulates shipboard conditions.



NRL research worker is here pictured working with an experimental range calibrator.

the investigation of a phenomenon, the existence of which was first predicted by Kennelly and Heaviside. I would venture to say that these people were buffeted by many critics who felt that an investigation of the electromagnetic reflective properties of the ionosphere was hardly a field for naval scientists to be engaged in. And yet, today, in retrospect, we find (1) that most of the detailed knowledge we have of long-distance communication and (2) the emergence of one of the most powerful military tools of World War II are a result of the research and vision of this small group of men working in a field which at that time must have seemed very impractical indeed. So we find that radar is the byproduct of an investigation into the ionosphere. Now, it should be pointed out that these men did not go to work one sunny afternoon and find a CXAF radar hidden behind an ion cloud. It was simply that, at some time during the investigation (and at this late date it is hard to say just when or where), the techniques and phenomenon at hand gave birth to an idea for a military tool. There then followed the long and exceedingly difficult period during which Dr. Taylor and notably Dr. Page built this idea into a practical device.

"Now, no one can say that the basic research from which the idea sprung was more important than the applied research which made it practical. No, rather, one is impressed with the great importance of both, particularly the manner in which one aspect complements the other. But, here again, a warning note is in order. Once the radar idea had been conceived, the potentialities of such a device could easily have diverted all the effort from the field which gave it birth, into the field which looked as though it would definitely 'pay off.' This is a practical illustration of how applied research drives out pure research, and why they should be organizationally separated.

"Another historic example should really drive this point home. In 1919 Rutherford bombarded nitrogen with alpha particles and produced oxygen plus protons. This was the first demonstration of artificial nuclear disintegration. Rutherford, so the story goes, was describing this work and the work that led up to it, to a friend. The friend remarked that this was a nice piece of academic work but what had he (Rutherford) contributed to winning the war? Whereupon, Rutherford replied that this work would be remembered long after World War I was forgotten. It took just 26 years to demonstrate what prophetic words these were, prophetic beyond the vision of even Rutherford!"

Stating the case for both pure and applied research, Dr. Krause goes on to say:

"It is my belief that basic research and applied research should be independently pursued.

"The reason for this has perhaps best been stated by Bush in his report to the President, 'Science: The Endless Frontier,' in which it is brought out very clearly that 'applied research drives out basic research.' It should be pointed out that this does not imply that one type of research is more important or difficult than the other, but merely that the two cannot exist together. This conclusion is, I believe, inescapable.

"In analyzing the organizational structure of NRL, as it is today, we find that there are very clear signs of its being, or at any rate, of once having been, in agreement with this tenet, but the pressure of war has in many instances allowed the applied to drive out the pure research. This was to be expected. However, I feel that right now is the time to make a vigorous effort to return those groups originally concerned with pure research back to that field.

"By basic research I mean the investigation into the fundamental composition and properties of the material which constitutes the universe and the study of the phenomena which surrounds and relates these materials. This type of research underlies all others and obviously has as little to do with guided missiles as it has with any field that can be named. Basic research cannot be pointed at any target but must develop from within itself into any channel that may present itself. Thus it cannot be directed except for the direction which exists in the mind of each individual engaged in it.

"As the name implies, applied research attempts to apply the facts and phenomena which result from basic research. Also, it differs from basic research in that it has a specific aim or target, and to be fruitful, some mechanism must be provided to maintain the aim on the target. A good example of applied research is the application of the basic research of Maxwell, Ampere, Faraday, and others to the development of the electric motor. A typical applied research target in guided missiles might be a homing system or a gyro stabilization device."

One certainty is that Navy research both pure and applied will continue—and at a higher level—than in the past. United States radar supremacy, to cite but one example, illustrates the abiding value of the long haul in research. It might well serve as a testimonial, too, to Navy's NRL. For it was there it all began.

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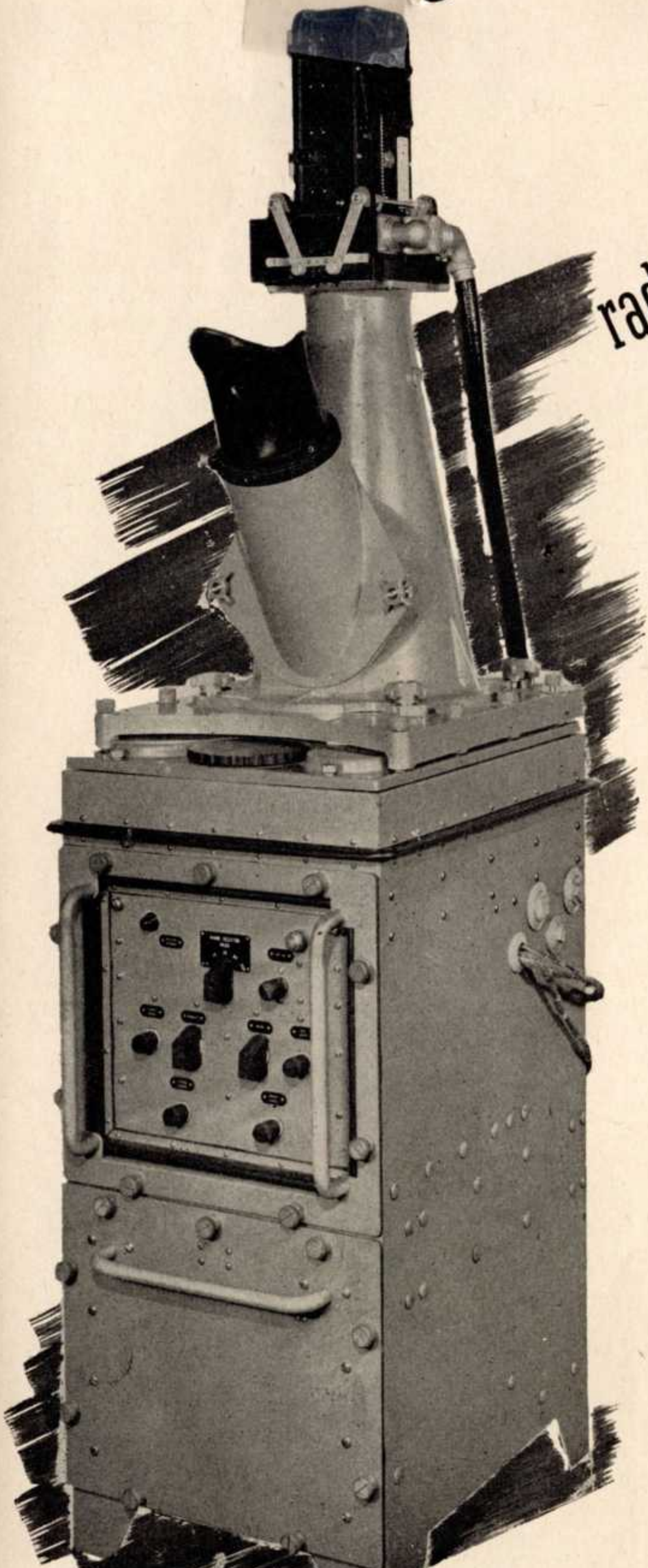
radar camera for shipboard use



A new 35 mm. camera designed especially for shipboard use in photographing PPI scopes will be available for a limited number of designated ships as soon as final tests, now being conducted at the Naval Research Laboratory in Washington, are completed.

This radar camera is expected to fill the long-felt need in the fleet for a camera that could record PPI pictures without involving an elaborate preliminary set-up of the photographing apparatus. It has fully automatic operation, a data-recording chamber, a selective-scan control and a detachable magazine of 100-foot capacity. The camera is always in place ready to photograph any scope situation by the simple expedient of turning on the switch; yet the camera does not in any way handicap the operator or CIC officer watching the actual face of the scope.

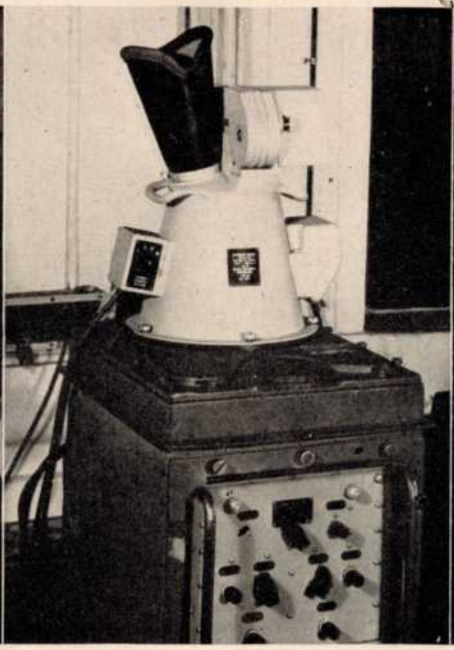
HOW IT OPERATES

At the present time, there are 4 positions on the small control panel. With the switch on the first position, the camera automatically photographs every sweep, on the second position every other sweep is recorded. The third position, designated on the camera by the numeral "12," photographs 3 consecutive sweeps out of every 12, while the fourth position, or numeral "60" on the panel, records 5 consecutive sweeps out of every 60. The 300-foot roll of film takes 1,600 separate photographs.

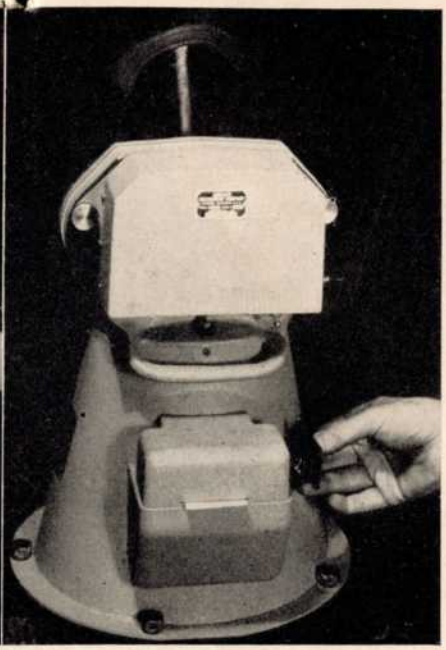
Incorporated into the base or camera mount is a clock, a frame counter, and a data-recording chamber. Every picture made by this camera shows not only the scope itself but the time the photograph was taken, the number of photographs and any pertinent information that may be necessary to identify the photograph, such as "Disposition of ships enroute to Guam" which can be written or typed and inserted in the data-recording chamber.

Although this camera was not perfected in time for wartime needs, the peacetime applications are numerous, especially in navigation. With this camera, it will be possible to make actual radar-navigation charts,

The mounting of the camera on a PPI scope is a simple process, accomplished in slightly less than jig time.



When the camera is mounted, normal operation of the scope is possible through the use of the hood shown above.



The camera is placed in operation by throwing a switch built into the unit.

similar to simulated charts made during the war by radar planning-device methods. On designated sea lanes, when approaching land, for instance, photographs of the PPI scope giving exact location and speed of the ship at all times could be reproduced for all ships as navigational aids. Along this same line, these photographs can be utilized in the training of new CIC personnel by showing what type of images can be expected on the radar screen in almost any given situation. The 35 mm. motion picture-type film makes it possible to project these pictures either as individual frames or as a motion picture.

OTHER USES

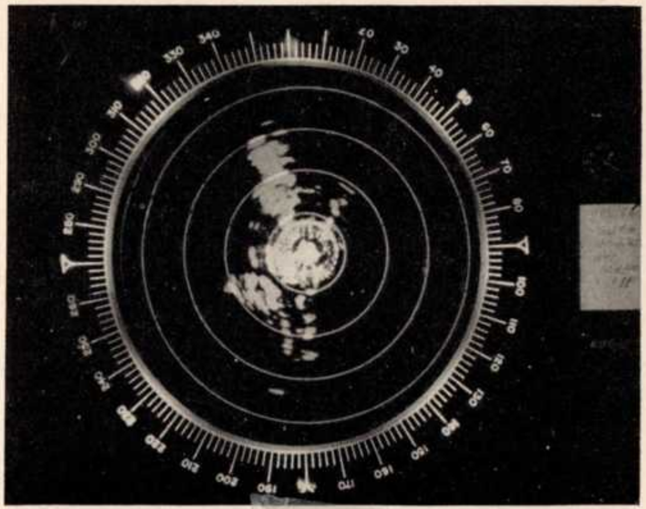
Routine CIC reports as well as action reports will be more accurate in the future when supplemented by positive prints made up from these 35 mm. negatives. This new camera opens up the field of weather observations with radar by giving aerologists more tangible information on how the scope actually looks for each kind of weather. Responsibilities for collisions at sea may be more accurately fixed. Some collisions may even be avoided by the use of photographs made of ideal cruising dispositions which can be overlaid on the scope at any time.

On maneuvers, photographs can be made of "projectile splashes" which will be used in post mortem pep talks to gunnery and for determining scores of individual gun crews.

For training potential fighter directors, mistakes can be quickly pointed out and suggested methods of improvement be made by projecting the entire raid and intercept or attempted intercept on an ordinary movie screen.

The radar cameras shown in the photographs illustrating this article are experimental models. They were developed by the Development Branch, Bureau of Aeronautics Photography Division. It is highly probable that the production model will differ somewhat from the ones shown here.

A typical photograph made with the radar camera is shown below.



Declass, Declass in Full, March 1998, Per OPNAVIST 5513 16-02

—*By Fleet Training Center, Oahu*

they're still using fade charts

Altitude determination is still a tough problem for CIC personnel, despite the advent of altitude determining radars such as SM and SP. Many ships in the Fleet are not equipped with SM and SP radars and for altitude determination must depend on fade charts [1] or intership reports.

Fade charts have their limitations. They are reliable only when the bogey is flying at a constant altitude. Japanese aircraft in the late stages of the war flew erratic courses and at constantly varying altitudes, except when still at considerable distance from the target. In such instances the only reliable sources of information on bogey's angels must be the altitude determining radar. But for early warning and intercept work beyond the operational sphere of lookouts and the Visual Fighter Director, fade charts are still useful aids.

A representative of the Fleet Training Center, Oahu, through personal interviews aboard ship and research in action reports, found the following attitudes current with regard to fade charts and altitude determination:

USS Natoma Bay (CVE–62) . . . "The use of fade charts in altitude determination was impossible due to the fact that raids were not detected beyond 32 miles. It was necessary to vector the CAP stacked at various altitudes against incoming raids. This method appeared to work satisfactorily inasmuch as all raids detected by radar were 'tallyhoed'."

C. O. Task Group 58.8 . . . "In the absence of radars designed to determine altitude at effective ranges, destroyers should be given numerous opportunities to check fade charts on calibration runs. This technique is not to be depended upon because of late detection of high or very low flying aircraft."

USS Monssen (DD–798) . . . "The longest range at which bogey was detected by our SC–3 was 105 miles. It was noted with interest that altitudes derived from fade charts checked accurately with those reported as derived from radar in about 75 percent of all cases."

C. O., 2d Carrier Task Force, Pacific . . . "The present tendency of the Task Groups to rely on the SM alone for altitude must be changed. Altitude from any information from the SK–SC radars, when carefully calculated, is more accurate than from any one SM which may or may not be properly calibrated. All ships must use their fade charts on every target. All reports to the Group CIC officer should include estimated or 'Jeep' Angels whenever possible."

USS Auburn (AGC–10) . . . "The composition of targets was read with a reasonable amount of accuracy. The fade chart developed at Pearl Harbor portrayed the threshold beam very accurately and was frequently within 1,000 feet of accurate; it is not dependable enough, however, to carry out night intercepts. An SP is urgently required to direct night fighters in repelling raids during darkness."

USS Isherwood (DD–520) . . . "In two instances merged plots were obtained, but lack of altitude information spoiled what might have been a good job. For example, one raid was reported by various ships as being at various altitudes between 500 and 30,000 feet. This vessel's fade chart proved of no value. The fire control radar continues to be the only means of altitude determination, and it is valueless at ranges greater than 35,000 yards, a fact not too well recognized by some authorities."

USS Mount McKinley (AGC–7) . . . "The CIC team has turned in an excellent performance in three assault areas: Palau, Leyte, and Lingayen Gulf. In the land locked San Pedro Bay in upper Leyte Gulf this team frequently tracked enemy planes from 80 miles over land and vectored friendly planes out 30 miles to successful interceptions. The fade charts developed from frequent calibrations have proved to be dependable."

USS North Carolina (BB–55) . . . "Fade charts have been used very successfully in conjunction with the SK radar. Results are found to check accurately with theoretical expectations (after the customary corrections). Upon comparison with SM results of other ships, the determination of altitude was found to check very closely."

USS Boston (CA–68) . . . "We don't use fade charts as we have an SP for altitude determination. However, we have calibrated our radars for fade charts and found them to be satisfactory; we haven't had to depend on them."

USS Sigsbee (DD–502) . . . "We have used fade charts at all times, having no other means of altitude determination. We have served as a picket destroyer and have never missed an interception."

These reports indicate that fade charts are not infallible. They also show that fade charts are being used and used successfully even in this day of altitude determining radars. Until such time as SM's and SP's, or the information therefrom, become available to all ships, fade charts will continue to play an important role as a source of altitude determination or as a supplementary source.

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[1] For aid in making them, see "Fade Charts Without Mathematics," "C. I. C." of 25 October 1944, Vol. I, No. 8, page 30.

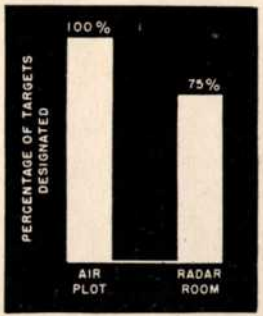
TARGET INFORMATION SKULL PRACTICE

As in "between the halves" chalk talks, the objective of this discussion is to graph various methods of passing target information from CIC to the gun-director operators. CIC operations must stress the study of fundamental procedures in much the same way that any winning football team must master the details of basic plays. Since "canned" problems have proved helpful for testing CIC fundamentals, the following graphic illustrations emphasizing results of time motion studies of certain AA target indication procedures may help in designing useful practice exercises. These thoughts may assist CIC and gunnery personnel in their effort to reduce the number of seconds it takes a director to acquire a target indicated from CIC's radar facilities.

To obtain the data shown here a Shipboard Research Group from the Systems Research Laboratory (see "C. I. C." October 1945, p. 36) made an action analysis of antiaircraft target indication and designation procedures of a heavy cruiser of the Baltimore class. The purpose of the study was to obtain quantitative measurements of several aspects of AA target designation during multiple enemy air attacks against the ship. The VF, the VG, and the Mark 10 Mechanical Designator were not used, nor were lookout reports and visual searching or sighting. All coaching was done with radar information exclusively in order to isolate the CIC-to-director information channel for study. Here are the time-motion study results.

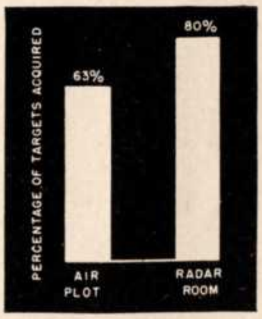
Graph A

More targets were indicated when coaching originated at the Air Plot than when coaching originated at the radar. Furthermore, target indication was successfully completed with 16 directors when the GLO was at the Air Plot, whereas only 11 directors received necessary information when the coaching was done from the radar. This difference can be attributed to the comprehensive picture presented on the Air Plot—the GLO can see each target in relation to all other targets, and can distinguish more readily between different targets.



Graph B

Although more targets were indicated to the directors from the Air Plot, it was found that target acquisition was more successful in radar control coaching. Eight of 10 targets were acquired during radar control coaching while a lower percentage—10 of 16—were successfully acquired with the GLO sitting at the Air Plot. This difference can be attributed to time lag necessitated by the additional sound power transmission from search radar operator to plotter, plus the plotting time.



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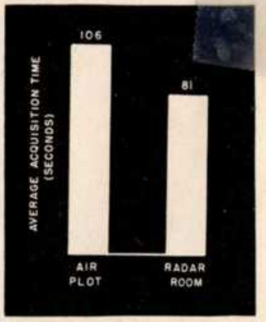
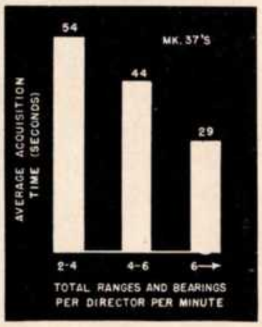


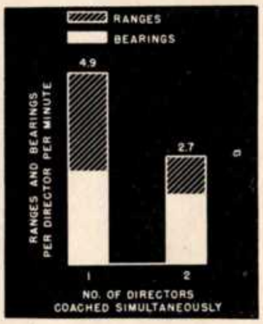
Graph C

It took less time to acquire targets that were indicated directly from the air search radar. On the average 106 seconds were consumed from the time the director received range-bearing-altitude information from the Air Plot until it was "on" the target. The same procedure averaged 81 seconds when range-bearing information direct from the SK was supplemented by altitude information from the SP. In addition, the latter targets were acquired at a slightly greater range than when coaching was done at the Air Plot—8,600 yard average for Air Plot, 10,000 yard average from radar control.



Graph D

The average acquisition time decreased as the amount of coaching information increased. This proved true for Mark 57 and Mark 63 directors as well as the Mark 37's, even though the latter acquired more targets (97 percent of targets assigned to Mk. 37's were acquired in average time of 37 seconds as compared to 72 percent of the assigned targets which were acquired by the Mk. 57 and 63 directors with an average acquisition time of 77 seconds). It is evident that improvement in acquisition time can be expected when the coaching rates can be increased to 6 or more ranges or bearings reported per minute.



Graph E

The more directors being coached simultaneously, the lower the coaching rate. The graph shows the difference in the number of range-bearing reports from one officer coaching from the radar over one circuit when two directors were being coached as compared with one director. In another exercise all 40 mm. directors were being coached on the same circuit by two officers. Though they were dividing work, indication information fell from 5.5 bearings per minute for one director to 2.5 bearings per minute (per director) when four directors were receiving his information. Range information decreased proportionately.

Development of means of transferring information from CIC to director and gun-control stations has progressed from the early practice of stopping the radar antenna with each indication up to a system that utilizes new equipment, now being furnished the Fleet, that makes possible rapid designation from remote PPI indicators directly to gun directors. Regardless of equipment development, target information will depend to a great extent upon the CIC-gunnery team and its knowledge of fundamental facts. These "lessons learned," from the Research Group's scientific study of isolated operations, may contribute to a better understanding of such fundamental facts.

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RADNINE coming soon

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RADNINE, the "Tactical Use of Radar in Small Vessels," will be distributed to the fleet sometime during March. Initial distribution will be to those who are considered to be primarily concerned with the material contained within this publication. Additional copies should be requested from CNO (Operational Readiness).

This publication was prepared for use aboard small vessels, minor combatant vessels, and larger auxiliaries which are equipped with radar but do not have authorized CICs. Material included covers plotting procedures and equipment, relative motion and the maneuvering board, radar piloting with the VPR, the use of radar in connection with gun, rocket, and mortar fire, the organization and conduct of radar plot and certain pertinent parts of the Radar Operator's Manual on defense against enemy radar countermeasures.

post mortem CIC notes

As the officers and men who made up the vast majority of the Navy's CIC personnel move back into civilian life, it is inevitable that much valuable battle experience will go with them. Much of what they learned has been preserved in the RAD series of publications and in articles in "C. I. C.," "Electron," "Airborne Radar Digest," and similar publications. In culling the action reports of the last battles of World War II and the summary statements prepared by some officers now moving out of the Navy's CIC's into law chambers, advertising offices, university classrooms and a hundred other civilian haunts, the editors of "C. I. C." have come across much material which belongs in the written record of CIC lore. Following are excerpts from such a report, prepared by the CIC Officer of the Third Fleet during its last few months of operation.

PERSONNEL

"The responsibilities and duties of Force and Group CIC Officers as presently set up are greatly beyond the capacities of one man to administer over a period of active operations involving weeks or months. It has not been unusual for Force and Group CIC Officers to have to be up on IFD circuits for days at a time without interruption except for the absolute necessities of life. Night air and surface responsibilities often are far more demanding than 15 hours of full day strike operations. At times, fueling days have been as trying as strike days. To this must be added the burden of action reports, preparation of Op Plans, continual meetings to keep pace with new equipment, operational requirements, and changes in tactical organization, personnel and matériel responsibilities, and professional reading. The need for at least one assistant, on duty in a permanent staff capacity, is crying.

"Though excellent in theory, practice has not borne out the belief that the CIC Officer of the flagship can stand-in for the staff CIC officer. A carrier or AGC CIC officer has equally great commitments upon his time, and has responsibilities nearly as great as has the staff CIC officer.

"The principle of constant rotation of radar (technical) officers and CIC officers between the operating forces and training activities is important to the maintenance of high standards in both respects. If technical developments do not go hand in hand with tactical employment and requirements thereof, wasted efforts is the invariable result.

TRAINING

"Aside from the more important factors of rotation and refresher which have already been touched upon, specific recommendation is made that all officers, and unquestionably those who handle fighter direction circuits, be more thoroughly grounded in the technique of R/T procedure. Situations should be studied rather than just vocabulary. Development of abbreviated procedure is recommended as a worthwhile project.

DISSEMINATION OF INFORMATION

"For CIC to put out 'the dope,' sufficient information has to come in to make the dope 'good dope.' Whether or not it was so intended, CIC has developed into an evaluating activity, and it has been in this instance that CIC personnel has received its most fragrant bouquets from commanding officers. But to be effective all information of an operational and background nature must get to CIC. There must be meaning and associated understanding if the chaff and wheat are to be distinguished when seconds hold lives at stake. Such dissemination is of the utmost importance in the case of the force and group CIC officer.

"The needs of the training activities should never be forgotten. Operation plans and action reports, timely in hand, are the fuel for their lamps of knowledge. During this war fighter direction and training schools have been a minimum of 6 months behind the operating forces in keeping up with new fighter direction and CIC procedure and techniques.

"It would seem that much is to be gained by the inclusion of Force and Group CIC staff specialists in planning conferences prior to the preparation of the Op. Plans, if for no other reason than utilizing the radar equipment of the force to the best advantage. But more important is the understanding gained of the objective involved, and the intent and wishes of the officers in tactical command.

UTILIZING EXPERIENCE

"Force and Group CIC officers, and to a lesser extent ship CIC officers, have not possessed the rank commensurate with the responsibilities of their jobs. This not only has proved a handicap in an operational way, in that such officers participate on a level of command not often realized, but it has deprived those key officers of information needed in the fulfillment of their duty, and of contact with officers who, alone, can provide, the needed information. It has not been infrequent that CIC officers have bewailed the fact that their juniority has put them last on the routing and dissemination list, even though they were expected to be able to take action based on said subject matter.

"It is recommended that all possible advantage be taken of the operational experience of senior CIC officers, who will, in the majority of cases, return to inactive duty in the not too far distant future. The 'ultimate' in CIC design and installations is yet to be conceived. There are only a very few regular (USN) officers in the navy who have had meaningful experience on the GCICO level. There are no more than six who have had modern fast carrier-force experience as carrier CIC officers, most of whom have since been assigned to other duty."

AIR-SHORE COORDINATION

"Fighter direction units of fast carrier forces were in varying degrees uninformed on the fighter defense and facilities of the shore establishments at Okinawa and Leyte—such information as the following:

a—Available day and night fighters, and types of patrols flown.

b—Type aircraft and calls used for fighter direction and radar reporting.

c—H/F and VHF frequencies available and how assigned; type equipment and frequencies in aircraft.

d—Fighter direction procedure used at Leyte.

e—Tactical organization for air warning; area authorities and jurisdiction of relative to radar warning and air defense.

f—Type radar equipment available; quantity of; coverage of

g—Reference points and special (local) procedure.

"Land-based radar and fighter-direction activities at Leyte possessed little or no information on TF 38 procedure and equipment, such as: tactical organization in respect to air defense and operations; voice calls and system relative thereto; aircraft control procedure; IFD procedure; frequencies and radio equipment available and used; day and night fighters available in emergency; patrols and air operations; radar guards; effective radar coverage, etc.

"Force and Group CICO's must have access to information on all air operations which will have any effect on his own area.

"Information of the whereabouts of nearby surface units; particular emphasis on subposits, subzones, communication with units of other forces etc., is a necessary factor in insuring immediate identification and action upon receipt of radar reports or reports from aircraft requesting instructions relative thereto, and the like."

COMMUNICATIONS

"Operations of the fast carrier forces of recent months have demonstrated the need for two force IFD circuits—tactical and administrative.

"The Coordination of air operations and air defense at such times as large-scale operations are in progress, necessitates a circuit between task groups (IFD) on which the background information important to the tactical situation may be disseminated (administrative), such as: posits of groups and pickets; fleet center from point option and other information necessary for station keeping; launch-land operations; deck conditions of carriers; flash reports from aircraft received by another group and which must reach the force without delay; changes in air plans; and the intergroup coordination of air-sea rescue.

"It was not seldom that such traffic interfered with such vital transmissions as the state of interceptions in progress; identification of possible bogies; assignment of action and backing-up groups on interceptions; contacts picked up by one task group high over an adjacent group and unidentified.

"The operational advantages of the AN/ARC–1 radio for CIC installations were demonstrated time and again by those ships which had several such units installed.

"It is recommended that such automatic tuning features be incorporated in all CIC radio equipment so that the necessary flexibility of communications on all fighter-direction channels is available in CIC, without reliance upon a remote station for selective tuning.

"So-called VHF 'tactical' or 'OP-AD' circuits required use of one of the transmitters (and in some cases, receivers) needed by a fighter direction ship. As standard CIC radio equipment allowances were not predicated upon the existence of such a circuit, CIC communications in several ships assigned fighter direction duties were handicapped in terms of flexibility.

DIRECTION-FINDING EQUIPMENT

"Installation of such equipment for use in VHF bands on all fighter direction ships could have been utilized to great advantage."

REPORTS AND RECORDS

"It is almost impossible for anyone but the trained yeoman to log the traffic typical of high-speed IFD circuits. The importance of complete logs on such circuits has been established. Reconstruction of engagements and countless action reports are based on the information derived from IFD logs.

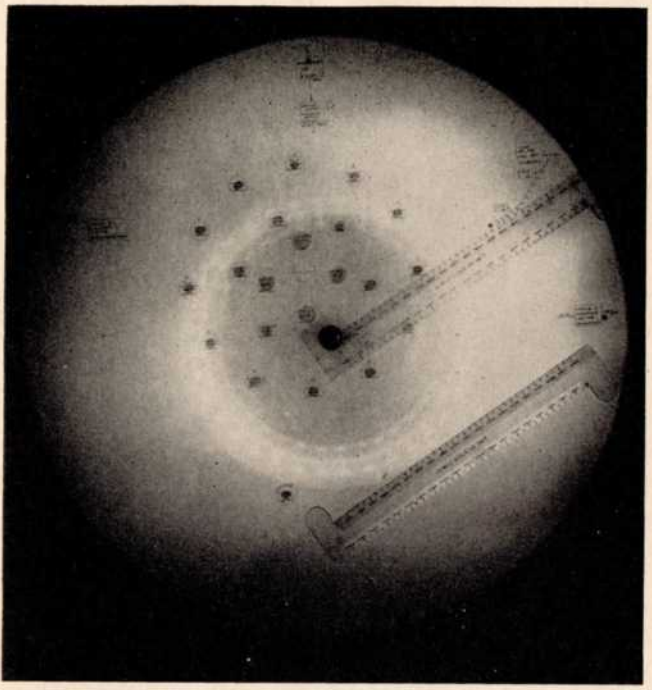
"Several carriers have found that banks of Arma-type wire recorders, with patch-panel control boards, have proven most satisfactory for this purpose. Detailed air operation reports, air-borne 'situation reports,' etc., may be transmitted rapidly, same being played back for write-ups and status-board display. Eliminated is the 'Repeat all after'."

IDEAS OF THE MONTH

cursor scales for the VG

—by Lt. Ralph F. Whannel, USNR
CIC Officer, USS DULUTH (CL–87)

Accurate reading of ranges and bearings directly from the VG unit has been facilitated by cursor scales designed by CIC personnel of the USS DULUTH. The scales are designed to rotate about a fixed pivot in the center of the VG plotting surface. The fixed pivot, fabricated of brass by ship's machine shop, consists of a disk 1 inch in diameter with a peg of 1/8-inch diameter and 1/8-inch high in the center. The disk is 3/32-inch thick at the base of the peg and tapers to a feather edge. A very small hole is drilled in the top of the peg to receive a compass point when concentric circles are drawn on the plotting surface. The disk is cemented at the center of the plotting surface as determined from the true north bearing circle. A thin coat of liquid plastic (plexiglas scraps cut with solvent) has proved the most satisfactory cementing material for holding the brass disk on the polished glass top.



The scales, fabricated from 1/4-inch plexiglas, are 14 inches long. The zero marks start 1 inch from the ends. The linear graduations are made on basis of 3 inches equals the distance between two of the electronic range circles. The sweep length on each range scale of the VG unit can be adjusted to meet this condition. This results in reasonably accurate ranges over the entire range at which the unit is normally operated. A 1-inch projection normal to the axis of the scale at the zero marking permits the scale to be rapidly engaged on the fixed pivot. A hole (1/4-inch diameter) at the zero mark engages the fixed pivot so the scale can be rotated freely by the slight pressure against the pivot. Slight pressure away from the pivot disengages the scale. The fixed pivot projecting above the plotting surface causes interference with the rolling rule but this interference is overcome by simply bringing ruler up to pivot, making small mark at the outer end of ruler, lifting ruler to other side of pivot and lining it up with the mark (making due allowance for thickness of peg)—then proceed with operation.

The use of these scales also permits rapid determination of course (relative) and speed of surface contacts being tracked. With own ship on steady course a skilled operator can easily track 10 contacts simultaneously and determine their relative course, speed, point of closest approach, and time thereof. The scales have also proved satisfactory for tracking of air contacts.

When steaming in formation the VG is normally operated on the 10-mile range. The entire task-group formation is very carefully laid out with our own ship at center. Circles are drawn at each assigned station and these circles carefully identified with ship's true name and her voice call. As long as the pips show under the assigned circles the ships are on station. If all pips start to move out of assigned circles own ship is getting off station. The ranges and bearings to all pickets and other task groups in the area are also shown on the plotting surface. This system has proved very satisfactory on board this vessel.

The scales were designed aboard this vessel and were fabricated by the RMO at the Norfolk Navy Yard. Although this vessel has a separate scale calibrated on both edges for each range setting of VG it is believed feasible to combine two range markings on same scale. e. g., 10- and 20-mile scales on same unit.

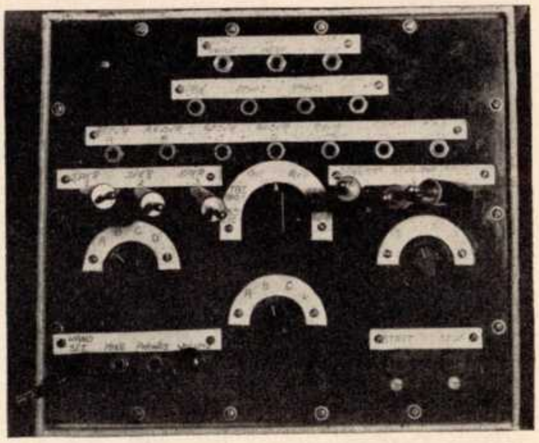
A Centralized Radio Transmitter-Receiver Panel in CIC

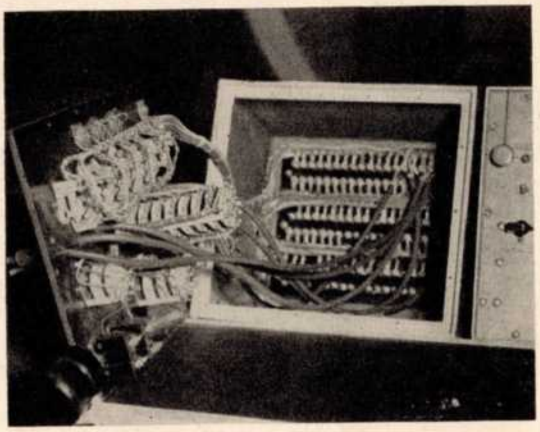
—by Lt. E. C. Huster, USNR
CIC Officer, USS Sitkoh Bay (CVE–86)

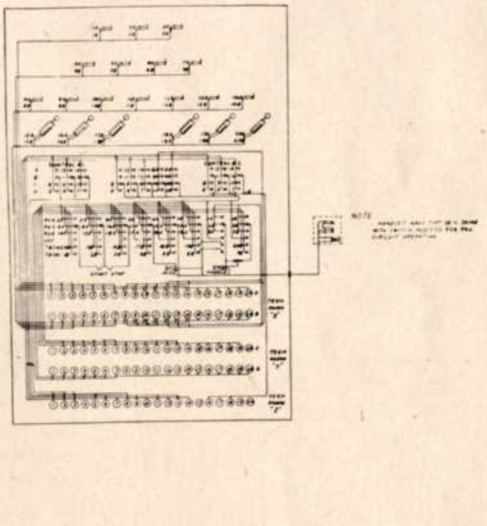
The increase in available VHF circuits has improved communications, but in so doing, has complicated the problem of controlling various radio circuits. The ship's force of the Sitkoh Bay designed and built a control panel for the multichanneled radio transmitters and receivers in their CIC to overcome these growing complications. This control panel (pictured here) has been of tremendous help to CIC personnel in the Sitkoh Bay in the efficient handling of ship-to-ship and ship-to-plane communications.

This control panel, designed for space conservation and simplicity, concentrates the radio communications control in CIC. It eliminates the necessity of CIC personnel running from one dispersed control unit to the other in order to transmit or receive on any particular channel. CIC officers can plug either headset phones or speakers into any selected channel outlet indicated on the control panel, and can quickly shift the transmitting mike from one channel to another with little effort or movement. The installation is made on the plotting table in CIC, adjacent to the 21MC, within easy sight and reach of the CIC watch officer. The space required for the unit is small and no additional personnel is required for its operation. The panel is not considered as a replacement for any of the rotary radiophone selector switches, but merely supplements these switches to permit the patching of receiver circuits from Radio 1 to locations in CIC. A "receiver watch" is maintained in Radio 1 to guarantee that all channels are tuned to maximum reception.

Some of the modifications proposed by the Sitkoh Bay have already been incorporated in a centralized CIC communication unit now under development by the Bureau of Ships. The idea presented here may be of use to other ship combat information centers as an interim measure.







Training Film "Radar Weather—Parts 1 and 2"

* * *

Two 20-minute R. A. F. training films entitled "Radar weather—Parts 1 and 2" are now available at Training Aids Section libraries, Ser. Nos. MB6005A and MB MB6005B.

These films show how the weather produces conditions which lead to trapping of the waves emitted by a radar transmitter, extending their range beyond the geometrical horizon.

* * *

Action

EXCERPTS FROM RECENT REPORTS

CIC

RAPID CONVERSION OF CONTACT REPORTS

COMDESRON 55: "No disposition is fully effective unless each ship in the disposition maintains a correct summary plot. All screening ships have to do this, otherwise they cannot perform their duties. Some heavy combatant ships do not keep a plot of the stations occupied by the screening ships. The screen commander, when executing a signal to the screen, invariably makes the group or unit an information addressee. When an accurate summary plot is kept by all ships, a contact report is clearer when located with respect to the station occupied by the reporting ship of the screen, than it is when the location of the contact is given with respect to the guide or to the center of the disposition. On one occasion at night, based on previous reporting-of-contact instructions, and while my flagship was without an air-search radar, I reported 'Blank, in station three, has a low flying plane on Fox Dog. Range twelve thousand and coming in fast. Unless informed otherwise Blank will assume plane is enemy and open fire.' Two nearby destroyers immediately advised that the plane was a bogey and it was driven off. A short time later instructions were issued that all contacts would be reported with respect to the center of the disposition. When a contact is located with respect to the screening ship making the report, the adjacent screening ships are alerted much faster than if the contact is located with respect to the guide or the center. The whole picture is clarified quicker and with certainty, from my point of view."

◆

TRUE VS. RELATIVE REPORTS

A PICKET DESTROYER: "One of the big problems in CIC has been to exchange information with control, lookouts, machine gunners, and the bridge in such a way that it can be done quickly and without any possibility of confusing relative and true bearings. A system has been devised on this ship which is worthy of mention. All bearings given plot, control, combat, or the bridge are three figure true bearings; thus any three figure bearing is immediately recognized as true. For the lookouts and machine gunners, the port and starboard sides are divided into seventeen 10° sectors numbered consecutively from the bow aft. Planes dead ahead or astern are so reported. A plane bearing 90° relative would be reported as 'Starboard 9.' Position angles are reported as 'up' so many degrees. A complete preliminary report on a plane bearing 300° relative at a position angle of 17 degrees would be: 'Plane port 6, up 17.' This system has proved completely successful in coordinating lookout reports with the air plot and in designating targets to machine gunners. True bearings are always used with Control.

"Against the type of attack which usually occurs on radar picket stations, the SG radar was frequently more useful than the SC. The need for an SG plotter in addition to the SC plotter, on the air plot, was found in our first engagement. Accordingly this additional plotter was located next to the air plotter, and the problem was then handled with ease when the bogies were few and were out beyond 5 miles.

"When a coordinated attack occurred and there were many bogies all within 5 miles, the air plot became a mass of spots which could not be accurately located or evaluated. The answer was to have both plotters write down on the plotting table the bearing and range. The evaluator read the range and bearing, glanced at the ship's head indicator on the air plot, and called out to control."

◆

CONTROLLING SEA RETURN

USS WALKER (DD–517): "The Hamamatsu bombardment mission presented another familiar recurrent operational difficulty in the case of the SGa. Because the ships were operating during darkness in a tight formation and there was considerable sea return which blotted out ship signals on the bridge remote PPI scope, it was necessary to keep the receiver gain turned down a portion of the time for station keeping purposes. At the same time the SGa was being depended upon to give warning of low-flying aircraft, motor-torpedo boats and other small craft. This unit was also used for navigational purposes. While there was difficulty in combining and coordinating the three functions of station-keeping, small craft detection, and navigation with a single SGa unit, it was accomplished with fair success by judicious use of the push-button signal operating from the bridge. The conning officer signaled by light when he desired the gain turned down and the remainder of the time the unit could be used for detection and navigation."

Editor's Note: The STC Circuit described in the October 1944 "C. I. C.", page 20, will be of interest as an interim ship's force installation.

◆

POLYCONIC GRID USED FOR STATION KEEPING

USS WILLIAM C. COLE (DE–641): "The air search radar SA–2 was limited in effectiveness by (1) The proximity of the land. (2) Concentration of shipping in vicinity, and (3) enemy use of window. Plotting air targets over land mass background has been extremely difficult to accomplish.

"The surface search radar SL–1 has been found to be extremely reliable for navigational purposes. Radar center bearings and ranges on three or four landmarks and visual bearings have been taken simultaneously with a resultant error in the vicinity of three and four hundred yards, which, when the problem is considered, is satisfactory. This ship maintained her screen sector station at night by means of radar fixes, utilizing a grid chart of the H. O. Misc. 11,557 series, superimposed on the DRT. All sector screen assignments were placed on this chart, enabling the Combat Watch Officer to maintain an accurate estimate of the tactical as well as the navigational situation at all times. The grid used was a polyconic projection, but error introduced was negligible when considering the problem of radar navigation. When used in station keeping, the SL–1 has been a decided advantage to the Officer-of-the-Deck."

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CIC—FLAG RELATIONSHIP

CTG 50.8: "Flag Plot and CIC on the flagship (USS DETROIT), were directly adjacent so that the Flag Duty Officer had ready access to CIC, though the two organizations functioned separately, with combat supplying radar information as necessary or requested over the voice tube. Bogies were handled in CIC as in an independent ship CIC, with Flag Plot being kept informed. Usually the bogey track was kept plotted in Flag Plot on the Air Plot table.

"The VD–1 unit in Flag Plot located directly beside the vertical 36-inch plexiglas polar plot of the formation proved to be excellent and indispensable. The SG forward, with maximum gain setting, was employed for long-range search and the SG aft with reduced gain was used for ranges to the guide for the flagship and for close work. Simply by shifting the selector switch at the VD a clear picture of the entire formation or a picture of contacts outside the formation, was immediately available to the Flag Duty Officer.

"An up-to-date continuous plot of the entire formation, usually consisting of 40 to 50 ships, was maintained on the 36-inch plexiglas vertical polar plot by Flag personnel using a scale of 1,000 yards to the inch, and plotting the formation center at the center of the board. The maintenance of the plot was usually complicated by almost continual shifting of stations due to forming fueling lines, consolidating of tankers, transfers of personnel, etc. Also, enough escorts were seldom present to form a circular screen so that screen rotation was required for every course change."

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POSITIONING SHIP FOR BOMBARDMENT

USS BOSTON (CA–69): "Land was first contacted by the SK radar at 134 miles, believed to be Mt. Fuji. The SP picked up land soon thereafter, bearing 300 (T), distant 124 miles. The next land was picked up on the SP bearing 358 (T) at 96 miles. The first radar plots checked well with the DRT position and no correction was made to the DRT until the ship was plotted within 25 miles of the beach. Here the Mark 13 radar was used in conjunction with the SP radar and VF, to establish the ship's position. This arrangement was continued throughout the action.

"The rangekeepers were given their first setup on our target at 34,000 yards. The solution was checked frequently, always after a radar fix which differed from the DRT position. The SP was used to check the nearest land and distant points such as Point Omai Saki, while the fire-control radars were trained on specific points at short range, such as Kakezuka Light and the Bentenjima Bridge. The SG was used in keeping the surface summary plot (on the VG), surface search, and in station keeping. The Mark 12 radars were also used in surface search.

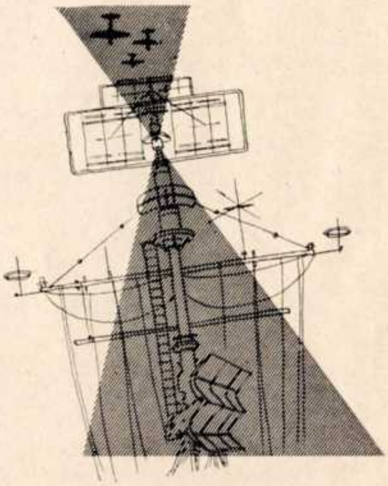
"Night bombardment of an unfamiliar enemy coastal area, without assistance from spotting aircraft or shore fire control party, presents a very special problem in radar identification, both for navigational purposes and for control of fire. Fire-control personnel experienced in shore bombardment, recognize at the outset that success in getting on assigned targets depends almost wholly upon the ability of radar operators and associated tracking personnel to identify correctly preselected landmarks. Study of excellent aerial photographs of the target area together with appropriate charts by radar operators and other fire-control personnel is necessary. However, in spite of this study, much difficulty was experienced in coaching radar operators on to selected landmarks, and in reconciling the radar presentations with the charts and aerial photographs. It is believed that the assistance of RPD (radar planning device), described in "C. I. C." issues for January and May 1945, would prove invaluable in preparation of radar, tracking, and fire-control personnel for their roles in the control of effective shore bombardment—particularly night bombardment."

◆

TRACKING BOGIES AT CLOSE RANGE

USS UHLMANN (DD–687): "The performance of the Mark 12 radar was especially gratifying and picking up of air targets at range scale limit was not unusual. The SC was kept on a medium speed automatic rotation as much as possible and bearings and ranges taken 'on-the-fly.' Though, because of our station in the radar picket line, one of whose main functions is that of identifying returning planes, many unavoidable interruptions in the sweep were necessary for determining if tarkets were friendly. Marked improvement in the tracking of 'bogies' at close range was accomplished by having an officer wearing air-plot-circuit phones reporting on contacts within 20 miles as read from the 12-inch RPI on 20-mile scale and also by keeping a grease pencil plot on the plastic overlay. Better bearing accuracy of plots helped to put the Mark 12 'on target' in less time. Recognition of window and other deceptive devices, and separation of actual air targets from them, is quickly accomplished by drawing in the exact outline in grease pencil and noting any changes in pattern with elapsed time as well as the speed and direction of movement.

"Fire control radar was the only accurate source of altitude determination inasmuch as the fade chart was almost useless. When operating with-



in 30 miles of land, the fast-moving planes seldom passed through any fades and lookouts were useless until too late for anything but ships' AA fire because the approach was made with the benefit of a low ceiling of clouds."

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ANOTHER "CLOSE-UP" METHOD

USS RANDOLPH (CV–15): "A special operational technique was employed while enemy night hecklers were in the immediate vicinity and during daylight attacks. One VC unit was set up on the 20-mile scale and the SC4 was kept on continuous sweep. This gave an excellent picture of plane movements in the immediate area and proved invaluable to gunnery in coaching on fire control radar and warning lookouts of sectors of anticipated attack. Flag Plot also reported that this information was employed in maneuvering the Task Group. Even when a considerable amount of enemy 'window' showed up on the PPI, there was no difficulty in detecting and tracking planes on the 20-mile scale."

◆

SPEEDY TARGET INDICATION

USS CHEVALIER (DD–805): "During CIC exercises to evaluate time studies of the target indication function of CIC we found the VF in conjunction with verbal communications from the SP was able to put the director on the target in times varying from 20 to 100 seconds. Average time was 45 seconds.

"The following system of target designation was used. The Gunnery Liaison Officer gave the Control Officer the initial range and bearing over the 5JW. While the director was being slewed to the target, the VF transmitted range and bearing 'marks' to the director using the buzzers provided. VF designation was given until control was on target. Elevation of target was transmitted verbally from SP radar via the 41JS circuit.

"It is believed that the system has great merit, but more practice is necessary."

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COMMUNICATIONS

A REQUEST

USS ENGLISH (DD–696): "Continuous effort is being made toward the end of efficiently guarding required circuits, of improving the general efficiency of the combat team, and of reducing the noise level. Outstanding accomplishment in this vein should be promulgated for the information of those of us who are still 'slightly con-confused.' We get the job done but at an awful cost!"

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AN ANSWER

USS ST. LOUIS (CL–49): "During early campaigns the handling of external communications and the rapid dissemination of information to proper and all interested stations within the ship had frequently not been too satisfactory. Prior to the Okinawa campaign a 6- x 10-foot space adjacent to the main CIC was converted to what is now known as Combat Radio. This was accomplished by the installation of four monitoring stations with plug-in connections to all radiophone circuits, typewriters, etc., along the long axis, and a communication center with radio telephones, JX outlet, and a selector switch to the JA, JO, JC, 1JS, and 21JS circuits in the rear of the space behind the monitoring stations. This station was manned by communication personnel and operated as an adjunct of CIC directly under the Evaluator (the Executive Officer). Watches were maintained and circuits monitored according to the situation and readiness condition.

"The Communication Officer is stationed in Combat Radio at General Quarters and a duty CWO at all other times except during routine Condition III. The set-up as established was immediately found to be the most satisfactory this ship has had or observed and as operations progressed this conviction was increased. Among the numerous advantages are the following:

"a—Communications are centralized permitting rapid evaluation, action, and follow-up by CIC evaluator.

"b—A continuous up-to-date log of all communications is available for ready reference. The advantage to the Evaluator, Radar Officer, or Watch Officer, of being able to check with the Communication Officer, or look on the log sheet to verify or check on incoming message received during busy moments is incalculable. Work can continue on whatever has attention at the moment without worrying about missing something important. Furthermore the whole story is recorded, i. e., the transmissions to other units, etc., are available so the entire situation can be evaluated.

"c—The burden of tactical communications is relieved for CIC yet the information is in CIC for proper use and/or evaluation.

"d—The noise level in CIC is reduced to normal, resulting in much more efficient operation.

"e—By the installation of a selector switch communications requiring fast action can be phoned direct to the action officers."

◆

PEACETIME COMMUNICATIONS TRAINING

CTG 38.4: "The operations incident to the cessation of hostilities complicated the communication problem. Traffic was extremely heavy and as Task Groups separated, high frequency became a necessity for efficient communications. Extra voice circuits increased the load on scarce voice circuit operators, and CW circuits became suddenly very active. The situation was handled by 'brute force' with many deficiencies very evident. Poor operating and incorrect procedure on CW circuits emphasized the results of neglect in that phase of training. Radiomen in the Fleet today are proficient in reception but not in procedure and sending, a result of wartime radio operating where the emphasis has been on reception. The inevitable differences between our war and peacetime radio operating conditions were very evident, and our future training programs for radiomen must take into account these differences.

"In the transition to peacetime operations the importance of voice radio communications must not be forgotten. Voice radio has been the backbone of tactical communications in wartime. It presents many difficult problems. The problems of obtaining good operators, efficient recording, and rapid dissemination of information are unsolved. It may be that teletype or some other device with a visual presentation of information may offer a better answer, but voice radio will still be second best and must be fully exploited. In future training we must consider the fact that good voice operators require careful selection and intensive training, and are not made overnight. Training and other communication problems must not be sidetracked, with Communications cursed as a necessary evil as it has been in the past."

INTERFERENCE BETWEEN FREQUENCIES

CTG 38.4: "The problem of interference between VHF channels in carriers is serious and must be eliminated. The efficiency of VHF communications is reduced and, in certain combinations, communication is impossible. The necessity for careful study of antenna locations, standing waves in transmission lines, and location of equipment is indicated. If interference cannot be eliminated for all frequency combinations, limitations as to which frequencies can be used simultaneously must be determined, and the restrictions considered in preparing frequency plans."

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VHF LIMITATIONS

USS MARCUS ISLAND (CVE–77): "Atmospheric conditions appear to greatly affect VHF communications, often adversely. However, there is a general lack of knowledge concerning the nature of such effects. Further information concerning atmospherics is urgently desired and, it is believed, could be used toward greatly improving VHF performance, or toward better understanding of its limitations.

"VHF communications in general were improved and performance of electronic gear was above average. The troubles in order of importance seemed to be (a) Atmospheric, (b) Equipment failure, (c) Pilot error, (d) Lack of procedure, (e) Shop mistakes. There is a general lack of knowledge about the effect of the atmosphere on VHF. Twelve planes west of Okinawa on TCAP remained in a communication black-out for one-half hour. Similar instances of temporary failure were consistent. Fighters above a cloud layer at 12,000 feet had a communication black-out which cleared up below the clouds. Such effects occur in certain sectors of LCAP while not in others. Similar instances occur with TBM's especially on missions over irregular terrain. This situation might be improved through greater use, wherever possible, of MHF gear."

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EXPERIENCED TALKERS ELIMINATED

COMCORTDIV 63: "It is felt that particular mention should be made of the use of the TBS within the task force and task units. Its use has been uniformly highly satisfactory, due principally, it is felt, to the employment by each ship in the unit of an experienced TBS talker, and absolutely correct procedure. No confusion existed at any time within the unit, and message repetitions were almost nonexistent. The value of using correct procedure and experienced talkers was particularly noticeable when at various times the task unit or small detachments thereof approached within TBS range of a unit that was not using them. In spite of a cluttered air, our own communications never broke down, or suffered in any other manner."

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VHF ANTENNA LOCATION

COMDESRON 25: "The operations of the TDQ-RCK transmitter receiver units themselves is beyond reproach. Unfortunately, however, the reliability of the equipment, especially in surface communications, is dependent almost entirely upon the location of the antenna and the relative bearing of the station communicated with. Aboard the JOHN ROGERS, TDQ-RCK No. 1 was installed with the antenna located halfway out on the starboard yardarm. In communicating with ships 4 to 6 miles away, signal strength invariably changed with changes in course and occasionally communication was lost entirely. Antenna location was changed slightly and the situation improved but operation is still not satisfactory. TDQ-RCK No. 2 was installed by ship's force in a forward area. The antenna is home made and located on a gaff aft of the SC antenna platform. Operation of No. 2 has generally been above average. This situation is typical of the experience of other ships in the squadron. It is recommended that possibilities of antenna redesign and the problem of antenna location be investigated and results passed to installing activities.

"All ships of the squadron have two AN/ARC–1's installed. Operation of the equipment is excellent but again performance is limited by antenna location. AN/ARC–1 sensitivity and power for aircraft control is almost on a par with TDQ-RCK operation. This, plus the fact that the gear itself is small and light and channels may be switched so conveniently, makes the gear ideal for destroyer use.

"When radio silence conditions permitted, MAN or SCR 608 was used in Task Group IFD frequency. Unfortunately, these units had been installed on the bridge during recent overhaul and it was necessary for ship's force to move the whole unit down to CIC, already seriously overcrowded. Several ships using MAN removed the control panel from the unit and installed it in CIC, the rest of the gear being installed in radio central. This procedure is recommended as being the most convenient.

"The installation of AN/ARC–1, AN/ARC–4, AN/APX–2, gears has presented a serious problem of power supply. It is virtually impossible for ships in forward areas to manufacture power packs with equipment available making it necessary to rely on batteries and the 28 volt D. C. output ABK motor-generator set. AN/ARC–1 may be operated on one M. G. set but continued transmissions over a period of 2 to 4 hours result in overheating. When sufficient ABK generators were available, two were paralleled and equalized to give satisfactory operation. Battery operation is inconvenient and unreliable. Two solutions to the power supply problem are suggested. One is to provide a standard power pack with a variety of plate, bias, and heater voltage outputs and sufficient power output to allow it to be adapted for use with any of the smaller radio and IFF gears in use at the present time. A second solution is to provide a standard 28-volt D. C. distribution throughout the ship with sufficient output to supply all ABK's, aircraft VHF's, etc."

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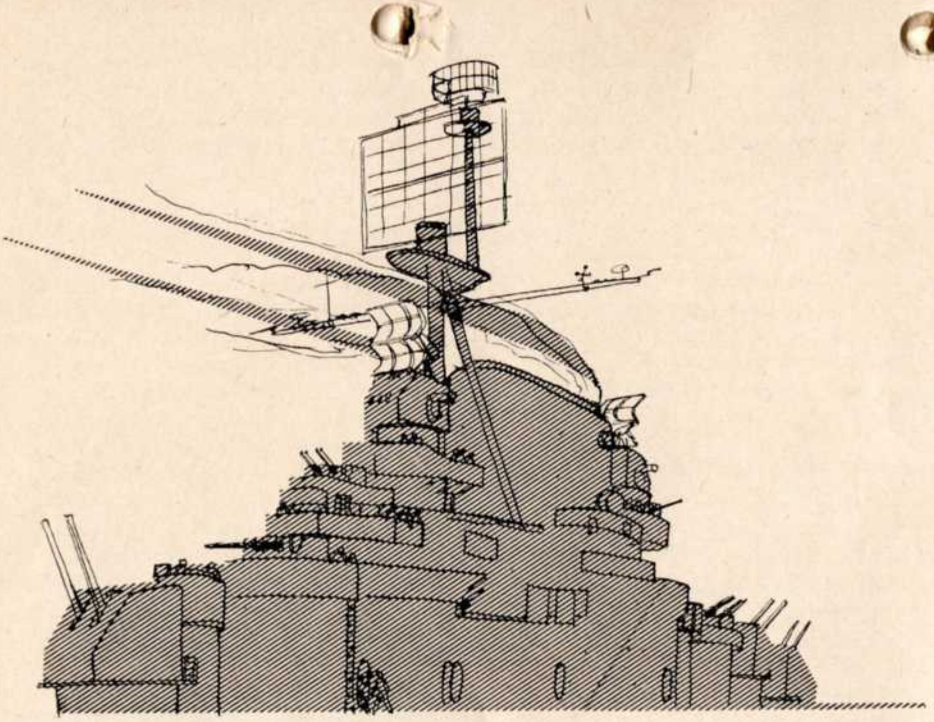
VHF ANTENNA FAILURES

CTG 38.4: "The Task Group flagship experienced a serious communication failure when all VHF transmitters except emergency AN/ARC–1's were put out of commission by failure of antenna transmission lines as a result of excessive heat from stack gases. A steady down-wind course placed stack gases directly on the cables which resulted in melting the prepolyethylene dielectric, collapsing the coaxial cable, and short circuting all VHF antenna lines. Fortunately, there was sufficient time to splice and renew the lines and put all VHF in commission between strikes. However, had this happened on a night before a strike day, the ship would have been seriously handicapped and a shift of flagships would have been necessary.

"If the cable is run up the forward side of the SM platform the danger will be greatly decreased. However, inspection of all cables, including power leads, revealed evidence of heat damage to insulation, indicating that



heat resistant material throughout, as well as better location and protection, will be necessary to completely eliminate this trouble. It is not known to what extent other carriers have experienced this difficulty, but it is believed that loss of efficiency of VHF has been experienced although complete failure may not have occurred."

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NAVIGATION

CONNING FROM CHART HOUSE VF

USS NEW ORLEANS (CA–32): "The VF RPPI in the chart house has proved to be an outstanding success for navigation during darkness and low visibility. Several small islands offshore and distinct points to which radar ranges could be obtained made good radar fixes by cutting in range arcs. These cuts combined with fathometer readings to give positions which were, in general, less than 200 yards in error as determined by visual cuts. Radar buoys were helpful in making the original approach to Okinawa during morning twilight when the island was obscured by haze. The buoys are definitely hard to pick up on the radar, however, and it is believed that with better visibility, they would have been picked up first visually."

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A RADAR BEACON DRILL

USS SALT LAKE CITY (CA–25): "While lying-to off west coast of Okinawa, a drill was carried out between this vessel and Naval Liaison Officer 10 in the use of the radar beacon. In addition to the fire-control use of the set-up, it is believed valuable as an aid to navigation particularly during low visibility near large land masses with relatively smooth coast lines affording few good points for radar bearings. NLO 10 gave the ship his grid coordinates and a range and bearing was taken on his beacon. At the same time radar ranges and bearings were taken on Kezu Saki, one from forward SG and one from after SG, and the ship's position plotted on the grid charts. Ranges and bearings taken from the resulting positions to NLO 10's location compared as follows with the direct range and bearing taken from the Mk 4 radar:

Fwd. SG., 144° (T)	6,175 yards
Aft. SG., 143° (T)	6,100 yards
Mk 4, 145° (T)	6,250 yards

"With little more experience and internal communication set-up it is believed the radar beacon would prove valuable as an aid to navigation.

"Our original entrance to the western Okinawa area was made through a swept channel in a minefield using radar buoys as an aid to navigation. The buoys were picked up about 5,000 yards distance. Six were visible at one time, providing a good channel. The line of buoys between Keise Jima and Rukan Sho were readily discernible at 4–5,000 yards and aided in navigation during flycatcher operations. However, no information was received in the SALT LAKE CITY as to the establishment of the buoys and they were mistaken for small craft the first night."

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RADAR PERFORMANCE

A RECOMMENDED SWEEP SPEED

USS SALT LAKE CITY (CA–25): "On several occasions there arose opportunities to track low-flying bogies on the SG short-scale scan. It was found, and is so recommended, that much better results are obtained by keeping the sweep power driven through 360° at the second sweep speed of the SGa. This speed corresponds nicely with the director's requirements of ranges and bearings, read direct from the PPI scope, for coaching the fire-control radar to the target. Experience proved that the operator had a difficult time staying with a fast target particuarly when the bearing rate was high and in one or two instances lost the target. Using power-driven rotation one low flyer was tracked crossing astern of the formation, up the starboard side between the screen and the heavy units and finally out on the port side where it was lost at 9,000 yards amongst a group of ships.

"The operation of the Mk 28 radar was entirely reliable for picking up targets and tracking continuously under ranges of 24,000 yards in open sky areas, if target designation in bearing and altitude was accurate. Planes could be followed out to greater ranges, generally 30,000 yards. Search results were negative on targets reported from a reference point by other ships. In areas surrounded by land and ships the only satisfactory designation was AA fire from other ships or visual sighting. Targets flying over land with sufficient range rate and angle of elevation (10° to 15°) could be tracked through land interference if it was picked up before it entered the land interference. However, the pointer had to disregard the elevation indicator which was usually low in the scope. If the antenna was depressed enough to center the elevation indicator the plane pip would be lost in land interference. Five-inch bursts could be observed, but the number of ships firing usually made spots unreliable."

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GETTING THE MOST OUT OF THE MARK 28

USS WICHITA (CA–45): "As a surface ranging device the Mk 28 Mod 0 is outstanding. On large targets the only limitation seems to be the range scale. It is commonplace to pick up destroyers at 35,000 yards. Range spotting is also highly accurate, four-gun 5-inch salvos can be followed while in flight and the fall of shot spotted. The limitation of having only an 'A' scope, of course, eliminates any deflection-spotting possibilities. Likewise navigational possibilities are limited.

"As an antiaircraft radar much of the difficulty in trying to increase our maximum range of this equipment is due to the problem involved in transferring a target from the search equipment to this set for full radar control. The narrow beam emitted requires precise positioning. The bearing and elevation accuracy limits of the search radar and the lack of a rapid and accurate designation system combine to make a most formidable obstacle in the path to successful AA performance. The best method employed thus far of directing this radar on an aerial target is to have an officer stationed at the control unit of the SK who verbally coaches the director pointers and trainers over the sound-powered circuit, 1JS. Once on a target, the latter is seldom lost, and tracking accuracy is much improved over the Mk 4, particularly at low-position angles.

"When employing partial radar control, ranging only, performance has been satisfactory. Targets located optically are usually picked up between 20,000 and 15,000 yards and accurate ranges speed up and improve solutions. One item of extreme importance in approaching the 'Mk 28 problem' is the matter of choosing personnel for director pointers and trainers and for operators. Maximum harmony and cooperation among these stations is essential.

"Experience has indicated that it is advisable to set the 'auto level' adjustment in the train and elevation indicator control unit for a grass height of at least one-half inch. The 'adjust zero' operation of centering all the indicating scopes must be checked at the start of each watch. On one occasion these centerings were noticed to drift appreciably during 10-minute intervals and it was found that the regulator rectifier output had dropped some 20 volts due to an unstable condition in the V803, V804, V805, and V806 tubes despite the fact they were still functioning."

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HANCOCK SR EQUALS SK PERFORMANCE

USS HANCOCK (CV–19): "After a short operational experience it appears that SR performance on 20 microseconds pulse length at 14½ k.v. is equal to or exceeds the SK radar. This performance is obtained only upon the unobstructed bearings of the SR. Fades appear in about the same place (difference in frequency is compensated for by difference in antenna height) but appears to be somewhat narrower than those on the SK. No trouble has been experienced in operating 527's in SR and the first pair were changed at 206 hours due to failure of one tube. Of this period 67 hours were at 10 kv. and remainder at 14.5 kv. The 20 microsecond pulse definitely appears to increase range as would be expected and 12-inch VC–1 repeater functions fairly well on the 60 PRF used with 20 microsecond pulse length. On the higher PRF's there is a double trace on the 12-inch repeaters which is very undesirable. This has also been noted on other high PRF radars.

"The SM directional array installed by ship's force seems to be functioning as hoped. (See CV–19 Monthly Performance and Operational Report for May.) This beam appears to be about 35° to 40° in width. This was estimated by training and a plane showing good IFF and training aft until IFF was lost. Reliability appears to have been somewhat increased in any case, is certainly as good as ranges obtained with nondirectional 'Stovepipe' antenna. Coming operations will really determine value of the modification but so far it shows promise."

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A VF MODIFICATION

USS WICHITA (CA–45): "The VF is a very valuable equipment. The Pilot House VF is the usual station keeping device; the CIC VF is the chief surface tracking unit. During a prolonged repair job on the SK master PPI, normal air search was continued with a combined use of the SK range scope and the CIC VF. The ship's trigger delay lines have been set so that the VF gives correct range when the B scope spot is on the closer edge of the target, rather than when on the center of the target (as directed by the instruction book). This change was made to allow the use of the VF in ranging to a beach line, one of its chief uses during this operation.

"The VD is located on the Open Bridge, Air Defense Forward, and in Flag Plot. Once experience was gained in proper adjustment and routine maintenance measures, no difficulty was encountered in their upkeep. The VD has proven to be an excellent RPPI and superior to its predecessor, the VC, for tracking, conducting intercepts, and observing safe firing bearings during night AA actions. The bearing courser and illuminated outside bearing circle are particularly valuable."

REQUESTS FOR "C. I. C." *should be addressed:* NAVY—*The Chief of Naval Operations, Editor of "C. I. C.", Washington 25, D. C.*
(issues prior to July 1944 are no longer available)
ARMY—*Adjutant General's Office, Operations Branch, Room 2B939, Pentagon Building, Washington 25, D. C.*

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Underneath that service cap, brother, is plenty of dope the Navy can use. Before you trade it for a new fedora, pass on what you know! Those who will replace you in CIC and other departments need to study the lessons you learned in combat. Put them down on paper and mail (via your C. O.) to CNO, attention Editor of "C. I. C." Rough notes will be sufficient—and welcome.

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