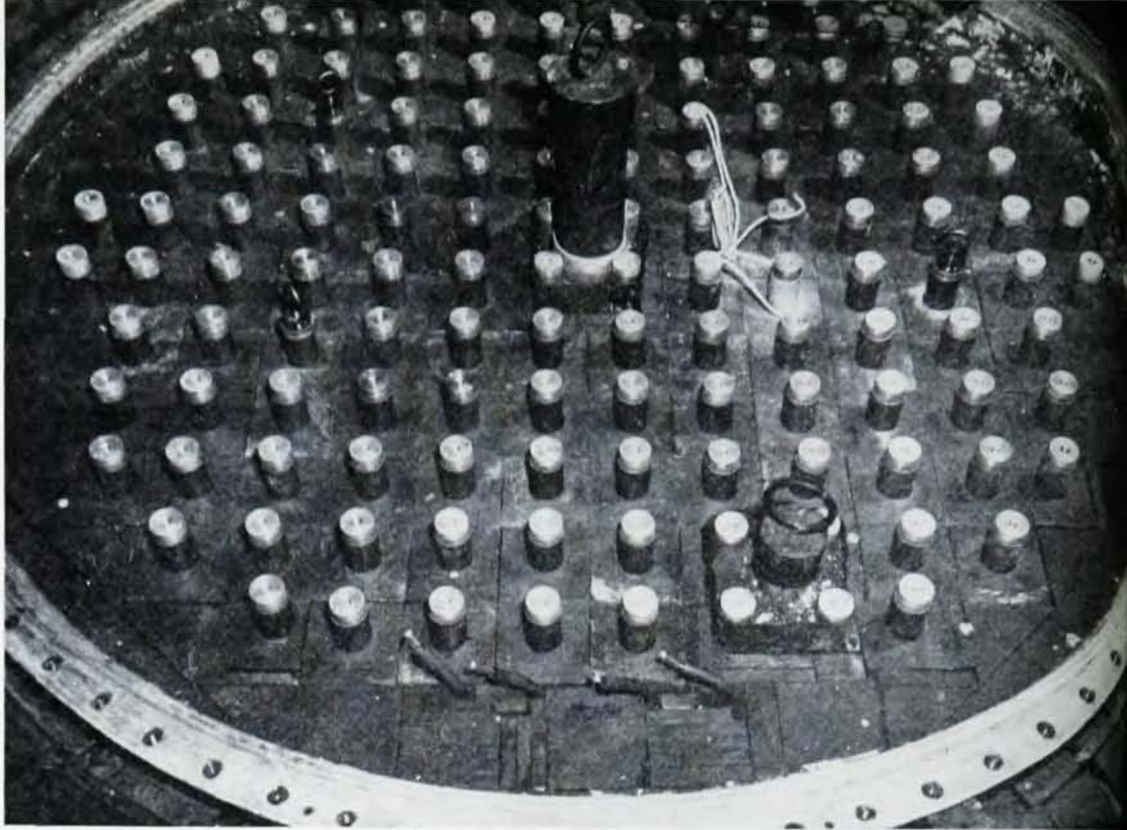


Top of reactor core of Argonne National Laboratory's heavy water reactor. Shield has been removed to show ends of uranium rods which are suspended in tank of heavy water. Materials to be made radioactive are lowered into large hole in center, extending nearly to bottom.

Argonne National Laboratory photo

transmutation. Thus the experiments one does with cyclotrons and Van de Graaff accelerators, and even the problems of design and operation of the machines themselves, are of related interest.

In attempting to understand the forces of interaction between two nuclear particles, theorists have found it necessary to assume the existence of a new particle about one-tenth as heavy as a proton. Shortly after this concept was introduced, mesons were discovered in the cosmic radiation and now it has been possible to produce these particles by bombarding nuclei with protons at energies in excess of 300 Mev in the largest cyclotrons. It is evident that a thorough comprehension of the forces between nuclear particles must wait upon extensive experimental studies with mesons. It is equally evident that this problem is complex, for ten different kinds of mesons have already been identified in the cosmic radiation, some of which will require, for their artificial production, machines capable of accelerating protons to energies of a billion electron volts or more. For the purpose of carrying on these studies, the Commission has four machines under construction, two for protons and two for electrons.

In all of the studies aimed at a better understanding of the nucleus, the most basic questions relate to the kinds of assumptions that are appropriate to make and the methods one must use to calculate the observable effects. Studies of the fundamental concepts of quantum mechanics thus have a direct bearing upon the program. The need for clearly understanding fundamentals is so obvious that one does not have to belabor a justification for listing it as an objective. Furthermore, all phases of instrumentation and the development of experimental methods for nuclear physics are of interest.

ONE OF THE MOST USEFUL facilities for studies in nuclear physics is a reactor or pile. It provides an intense and steady source of neutrons which can be collimated into a beam for many kinds of studies, including those of diffraction and the structure of crystals, the interaction of neutrons with nuclei or with the elastic modes of a crystal. Neutron beams are also useful for investigating the properties of the neutron itself, namely, its magnetic moment, and its interaction with electrons and protons. The neutrons in a pile are also used for producing new nuclear species. Moreover a reactor makes an ideal facility for training graduate students since it provides many locations where independent experimenters can work without mutual interference or the need for scheduling. Through the atomic energy program, reactors have been made available for general studies in neutron physics at Brookhaven, Oak Ridge, and Argonne. Soon a reactor will be operating at the University of North Carolina, and some other university laboratories have expressed an interest. The Commission has developed several designs for reactors which are suitable for university purposes.

Problems in applied physics arise in connection with the production program. The present production of fissionable material involves two different processes. In the first a fissionable isotope of uranium is separated by gaseous diffusion from the more abundant nonfissionable isotopes in natural uranium. In the other method a fissionable isotope of plutonium, which does not occur in nature, is manufactured by a process involving the capture of a neutron by the uranium nucleus when it is exposed in a reactor. Both of these processes are based upon physical principals which must be understood thoroughly and in detail, if the production plants are to be designed for efficient operation. The isotope separation method involves the kinetics of gaseous diffusion and chemical reactions; separation may also be accomplished by the differential deflection of a beam of ionized gas in a magnetic field. The phenomena of gaseous discharges and ion sources are thus of related interest. The interest of the Commission in isotope separation is not limited to uranium but extends to a number of other elements. In fact, whenever two isotopes differ substantially in nuclear properties, there is a real or a potential interest in their separation. Thus the heavy isotope of hydrogen has proven to be a useful material for moderating neutrons in a reactor. The two lithium isotopes are entirely different substances as regards their reactions with neutrons so that while Li^6 is a good thermal neutron absorber, Li^7 is sufficiently inert to neutrons to be of interest for reactor applications. Separated boron ten has a high cross section for capture and is useful as a neutron detector. Boron eleven on the other hand is almost entirely inert to neutrons, and for that reason might be of interest as a moderator.

There are other stable isotopes such as N^{15}, O^{18}, and A^{38}, which are useful as tracers in biological, chemical, and metallurgical research but are not of special significance in the atomic energy program. The concentration of these, in several instances, is a straightforward, well-understood process open to development by private enterprise as the demand warrants, and there should be no fear that the AEC will invade the field with taxpayers' money to undersell anyone who ventures into it.

Brookhaven National Laboratory photo of a Navy balloon taken at dawn on a morning when balloon flights were made cooperatively by the Navy and the Laboratory in cosmic-ray research.

Reactors are useful not only as producers of plutonium and of other nonoccurring isotopes, but also as sources of neutrons and potentially of power; their operation involves physical phenomena which need to be better understood. Among the problems needing study are those relating to the nuclear capture of neutrons, the diffusion and energy losses of neutrons in the process of slowing down, and the nuclear radiations emitted by the new nuclei that are formed. The cross sections for capture of neutrons by nuclei, and those for scattering, both as functions of neutron energy, are data of direct practical application and of basic theoretical significance. Much work in this field remains to be done. Another important field bearing upon reactor design and operation is the study of the effects of radiation and high temperatures upon the materials one wishes to use in their construction. In order to understand and predict these effects, one is led into the whole field of solid state physics, which attempts to relate the elastic, the thermal, and the electrical properties of materials to atomic structure.

THERE ARE OTHER fields of physics which have been opened up by the availability through the program of new materials. For example: studies of liquid He^3 have led to a better understanding of superfluidity and the general theory of quantum statistics; tritium is useful as a target material in deuteron accelerators for producing 14 Mev neutrons; reactor-produced Hg^{198} is used as a better wave length standard in spectroscopy, and so on.

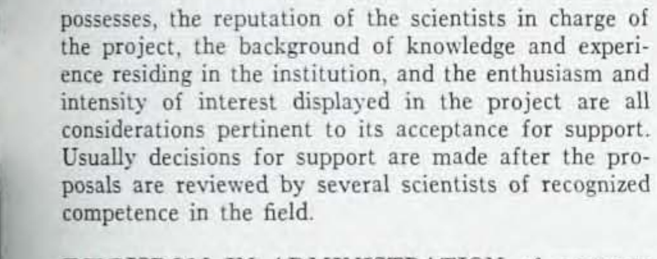
In carrying forward its research program, the Commission has established the great National Laboratories, and it has supported research projects in the university and industrial laboratories. In planning and administering its research program, the Commission has sought to follow policies which would advance the level of our basic knowledge, increase the supply of trained men for future work, and provide answers to the immediate problems having application to the operation of facilities and the design of devices. Although, in most instances, the National Laboratories carry the prime responsibility for applied work, there has been no sharp line of demarcation between the kind of work undertaken in those laboratories and that done in the university laboratories. Very excellent basic work has been done, and is now going on, in the National Laboratories. On the other hand, university groups have supplied a great deal of the data most urgently needed in the design of reactors and weapons.

This intermingling on the one hand of basic research with the applied work of the National Laboratories and on the other of applied work with the basic studies in the university laboratories, has been both expedient and productive. In many cases, the unique facilities of the National Laboratories have opened new possibilities for certain basic studies. On the other hand, university groups have often had the equipment and the experience needed to make measurements much needed by the Commission. The encouragement of basic work in the National Laboratories has given the Commission access to some of the best minds for consultation and advice on its practical problems. The basic work has also promoted an extensive interchange of personnel between the universities and National Laboratories which has brought university groups into close touch with the Commission's problems and has greatly increased the effectiveness of their cooperation in the work of the Commission. The recognition that basic work can be done in the National Laboratories is also an attraction to the best of the recent graduates who are seeking employment. There may be some tendency on the part of students to feel that if they go to work for a National Laboratory they will be told more specifically what to work on, than if they sign up with a university. Actually the National Laboratories give many of their younger staff members enough latitude so that the individual can develop his own ideas under his own initiative for a few years, and can establish his appropriate place in basic or applied work according to his desires and his abilities; however, there should be more of this. So rarely does an individual emerge who can make substantial progress in basic physics, and so valuable are the contributions of those who can, that every promising young physicist should be encouraged and given the opportunity to prove his worth. In promulgating this policy, it must be recognized that physics is getting to be so difficult and involved that a period of several years may be required before an able man can raise his head above the crowd. Now in particular, when there is such a serious shortage of scientific manpower, the need for every individual to achieve his maximum growth is pressing, but the danger is also imminent that he will not get the opportunity.

At the present time, the Commission's program in physics under the Research Division is at an annual cost level of seventeen and one-half million dollars, and there is other work in physics carried as a part of the reactor, the weapons, and the production programs. Thirty-six percent or six million dollars of the Research Division's money is spent outside of Commission laboratories where it is divided among fifty-nine projects in university and other private laboratories under direct contract with the Commission, forty-four projects under the joint program with the ONR and nine projects contracted through other government agencies. Sixty-four percent, or eleven and one-half million dollars, is in support of physics in the National Laboratories, i.e., Argonne, Oak Ridge, Brookhaven, Ames, and Berkeley. Directly negotiated contracts with the university laboratories are of two types: those involving basic work in fields of interest to the Commission for which the proposal is usually initiated by the university group, and those applicable to the solution of a specific problem which are usually proposed by the Commission. All degrees of support are given to both

University of California Radiation Laboratories at Berkeley. *University of California photo* types of projects, depending upon the particular circumstances; but under the first type of contract, it is customary for the university to carry about half of the costs, including most of the overhead, while in the second type of contract, the Commission frequently carries the entire cost. It is not possible for the Commission, under its present budget limitations, to accept all of the proposals that are submitted to it. It would not be wise for it to accept all of the proposals if there were no budget limitations. Decision to support a project is usually based upon consideration of the probable benefits that will accrue to the program of the Commission. These benefits are considered to include increase of *basic* knowledge in a field of interest, development of *particular* knowledge which can be applied to one of the Commission's problems, and enlargement of the supply of trained men who will be available for work in the program or will otherwise relieve the shortage of manpower available for such work. Obviously, the nature of the work that is proposed and the experience that will be gained are prime considerations, but just as important a consideration is the confidence the Commission can feel that the program will be well managed, that the research will be carried on with vigor, imagination, and skill, and that it will react to the future advantage of the institution and its relations with the Commission. The facilities that the institution possesses, the reputation of the scientists in charge of the project, the background of knowledge and experience residing in the institution, and the enthusiasm and intensity of interest displayed in the project are all considerations pertinent to its acceptance for support. Usually decisions for support are made after the proposals are reviewed by several scientists of recognized competence in the field.

WISDOM IN ADMINISTRATION of contracts for research is as important as in their selection. In the field of basic research, the Commission has widely recognized that its policy should be to encourage its most competent contractors to pursue those investigations which, in their opinion and those of their colleagues, hold the best promise of fundamental discovery. Many of these projects are given titles as general as "Experimental Research in the Field of Nuclear Physics." I do not believe there are many contracts of this nature where scientists of recognized ability feel, because of the source of their support, any lack of freedom to choose and pursue their investigations without pressure to produce quick results or fear of failure. I think they do and should feel obligated to pursue their programs with vigor and efficiency.



U. S. Atomic Energy Commission Headquarters Building, Washington, D. C.

It is perhaps somewhat unsatisfactory to the universities to tie the support of basic work to any development program or to subject it to government financing procedures, which require funding on a year-to-year basis with no positive guarantee of continuity. With regard to the latter complaint, there are many examples where continuity has been established over a period of years, and I hope that future experience will strengthen confidence that worthwhile basic work, once begun, will not be arbitrarily or abruptly cut for budgetary reasons.

In administering *applied* work, the criteria for effective direction are quite different. Here it is essential that the research match the requirements. Projects in applied research cannot be undertaken or maintained because of the enthusiasm of someone not in position to see or to judge the whole picture. The Commission itself must formulate its objectives and judge the merits of applied work on the basis of its relation to other parts of the program. Applied work which does not apply is all too likely to be wholly lacking in significance.

Figures indicating the extent of the physics activities in the atomic energy program have already been quoted. They represent a sizable fraction of the whole activity in these fields in the U.S.A. The purpose of these activities is to advance the development of atomic energy; the demands of the program are great and they are affecting our educational institutions, our physicists as individuals, and our physics as a growing science. There are some who fear the consequences when our science receives such a large measure of its support from an agency with a specific job to do. They say that physics should be free to develop in any direction that the quest for knowledge takes it. However, this situation in physics is not new. From the time of Archimedes, physicists have responded to the needs of the times, and who is there to say that physics has been debased, or undesirably distorted in its growth because of these pressures? In the present situation, the sound policies developed by the Office of Naval Research have been an influence against subjection of basic work in favor of that which advances the immediate needs of the program. Furthermore, the National Science Foundation holds forth hope that those who wish to follow independent lines of investigation need not feel the constraints implicit in their being associated with the atomic energy program. In the meantime, while so much of physics is under the support of the Commission, much confidence can be derived from the foresight of those who wrote the law and from the broad and liberal interpretations of those in charge of its administration.