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Univ California Radiation

It was, on motion, unanimously,

UNIVERSITY OF CALIFORNIA - CYCLOTRON

RESOLVED
RF 40036

that the sum of One million one hundred fifty thousand dollars ($1,150,000), or as much thereof as may be necessary, be, and it hereby is, appropriated to the UNIVERSITY OF CALIFORNIA toward the cost of construction, housing, and installation of a giant CYCLOTRON, upon condition that the University shall agree to provide a minimum of $250,000 toward capital costs, and shall further agree to provide not less than $85,000 annually as a maintenance budget for a period of not less than ten years following completion of the instrument; it being understood that any balance of this appropriation remaining unexpended as of June 30, 1944, shall revert to the Foundation; this appropriation to be charged to the Principal Fund.

The following were the considerations presented:

Natural Sciences - Exceptions to Program

Previous Interest: A total of $82,000 has been appropriated to the University of California for equipment and expenses in connection with the cyclotron research of Professor E. O. Lawrence during the period February 1, 1938, to June 30, 1942.

General Description: A cyclotron is a device for imparting enormous velocities to certain minute particles (such as the central core of hydrogen or helium atoms). In principle, it operates like a whirlpool in reverse. The particles are released in the center of the "pool", and powerful electric and magnetic forces, imposed by the cyclotron, cause the particles to circle in constantly enlarging orbits and at ever-increasing speeds, until they finally emerge from the machine in a steady beam moving at velocities that may exceed 100,000 miles a second. Moving with such high speeds, they constitute the most powerful concentrations of energy ever controlled by man. The essential parts of the cyclotron are: (1) a large electromagnet, containing hundreds of tons of steel and copper, which

generates the magnetic forces that bend the paths of the moving particles into circles; and (2) a huge oscillator, similar to but larger than the power installation of a radio broadcasting station, which furnishes the pulsating electrical force that accelerates the particles to ever higher speeds.

The Importance of Cyclotrons - From the time of Democritus, the natural philosopher has steadily tried to probe inside the matter of which our physical universe is built, has tried to learn the nature of its smallest parts and the laws which govern them. For centuries there could be nothing but vague speculation, for suitable experimental procedures were not available. But brilliant advances have been made since the turn of the present century. Indeed, the general public is now familiar with diagrams showing the atom as having a central core, or nucleus, around which electrons spin like planets around the sun.

To probe the tiny structure of the atom, one must have minute and yet powerful tools. Information is usually gained by shooting into the atom projectiles of such high speed that they disrupt the internal pattern. Then from a study of erupted fragments, the mutilated remainder, and the battered projectile, one gains knowledge of the atom's structure. Physicists have, therefore, used all their ingenuity in developing machines which would produce high speed particles which could be used in this way as tools in modern atomic researches. Thus the cyclotron's importance rests upon the fact that it is a device for producing these intense beams of super-speed particles which are essential to the modern student of atomic structure.

In the process of carrying out such atomic researches, moreover, various practical applications have appeared, and doubtless will continue to appear. Thus physicists have learned that it is possible artifically to produce radioactive matter. This new array of radioactive substances will almost surely have important applications to practical problems; but one broad field of application has already been clearly demonstrated; for these artifically radioactive atoms are the familiar "tagged atoms" which are now being used in chemical, biochemical, physiological, and other laboratories all over the world in a wide range of basic researches which would be quite impossible were it not for this unique new material.

The beam of exceedingly high speed particles produced can, furthermore, be applied, like X-rays, gamma rays, and other types of radiation, directly to living organisms; and the effects on the various organs and vital processes can be analyzed and ultimately utilized. It will require years to investigate the effect of beams of different composition and intensities on various vital processes; but experiments have already shown, for example, that beams of neutrons can penetrate deeply into living tissue and there release local radiations which can be (but need not be) intense enough to

kill cells. These further applications are now in their first tentative stages. An exact prediction is as difficult as it would have been for X-rays when they were first available.

Number and Distribution of Cyclotrons - The cyclotron was invented just ten years ago. If it is indeed the best tool for atomic research, then one may fairly expect that it would be taken up eagerly and developed at several places. What is the record?

There are now in operation or, in a few cases, under construction, four small cyclotrons, four moderate-sized ones, twenty-one of substantial size and power, and five very large cyclotrons. These installations represent a total capital cost of the order of two million dollars. In addition there are at least six more definitely planned. Of all these cyclotrons, 22 are in the United States; 3 each in England and Japan; 2 each in Russia, Belgium, and Germany; and 1 each in Canada, France, Denmark, Italy, Sweden, and Switzerland.

In 24 of these cases, including English, Japanese, Belgian, German, Canadian, French, Danish, Swedish, Italian, and Swiss laboratories, as well as 14 in the United States, the cyclotrons were either built by, or are now being operated by, men who were trained in Lawrence's laboratory. At these cyclotron laboratories there are now, in fact, over 40 experts who received specialized cyclotron training and experience with Lawrence. He has been as successful with men as he has been with machines.

The Case for the Proposed Cyclotron - Cyclotrons have been responsible for advances in our knowledge of the atom and in our power to modify matter in the laboratory so as to make it useful to man. But the most powerful cyclotrons now in existence produce particles whose speeds, when they are fired at atoms, only enable them to knock off the more loosely-bound and more external features of the atoms being studied.

It is just here that the ~~proposed~~ new giant cyclotron is of critical importance, for it would produce projectiles so powerful that they could penetrate and explore the nucleus itself.

It is essential to realize how important this point is. During the last forty years science has learned a good deal about atomic structure; but one principal mystery, however, remains, and in many senses it is the major mystery. We know very little about the nucleus, or central core. There is evidence that this nucleus possesses a discoverable structure - that it is formed out of certain elementary units in accordance with laws which we do not yet know; and physicists today consider its investigation the most important present problem in physical science. Why? Chiefly, one must agree, because the interior of the nucleus is the one essentially unexplored part of our universe. It is a world into which we have hitherto been powerless to enter; and the urge to penetrate, to explore, and to analyze is irresistible.

This urge, moreover, is heightened and justified by the conviction that this virgin territory will prove to be rich. Practically all of the energy of the atom, for instance, is stored within the nucleus; and it is the nucleus which essentially determines the character of an atom and is hence ultimately responsible for all the properties of matter. There is, furthermore, evidence that the essential forces which bind the nucleus together are due to an elementary particle called a "mesotron". These same mesotrons play an important role in cosmic rays; and if one could learn something more about mesotrons, he would at one stroke shed light on the problem of atomic structure and also on the problem of cosmic rays.

Exploration of the unknown is based not only upon the pure urge to know, but also on the practical urge to find useful knowledge. The evidence from present cyclotrons is offered as suggestive illustration of the sort of practical results which may be obtained. But the real case for building a great cyclotron rests upon its ability to make accessible a new infinitesimal world - the interior of atomic nuclei - and its corresponding ability to attack the basic problems of atomic structure.

<u>The Size of the Proposed Cyclotron</u> - There are various ways of stating the size of a cyclotron. One usually gives the diameter of the pole face of the great magnet, or states the tonnage of steel and copper in the magnet; for these quantities definitely limit the output of the machine. One can, alternatively, state the voltage of the emergent beam. Lawrence himself has built a sequence of cyclotrons of increasing size, whole pole face diameters were 4 inches, 9 inches, 11 inches, 27.5 inches, 37 inches, and 60 inches, these varying in weight from a few ounces to some 220 tons. The original 4-inch model produced a beam of 80,000 volts. Of the two cyclotrons he is now operating, the 37-inch produces a beam of 9 million volts, and the 60-inch a beam of 16 million volts.

Having solved the problems involved in expanding this device to its present size, Professor Lawrence and his group began over a year ago the design of a definitely large cyclotron, powerful enough to make a frontal attack on the remaining mysteries of atomic structure. This machine - the "giant cyclotron" - is designed to have pole pieces of 184" diameter, to have over 4,200 tons of steel and copper in its magnet, and to produce a beam whose voltage would be more than six times as powerful as any previously produced - which would indeed range from 100 million volts to 200, or even 300, million volts.

It is difficult to appreciate the power of such an instrument. The beam of the largest cyclotron now operating penetrates, in air, about five feet. The beam from this giant instrument would penetrate some 140 feet. The new giant would be hundreds,

or even thousands, of times more effective in producing radioactive substances. In a short run of a few hours, and with power costs of a few dollars, it could produce an amount of radioactive zinc equivalent (in gamma-ray activity) to some thousands of grams of radium.*

What is the justification for calling this a cyclotron of definitive size? Why not the bigger the better? Ordinarily one would not be in a position to indicate in advance how far it might be desirable to explore into an unexplored region. But the situation here is unexpectedly favorable; for evidence from cosmic rays indicates that a beam of voltage of about 150 million is almost surely intense enough to deal with mesotrons, and hence to meet all requirements which can now be foreseen or imagined.

Finances: The following table and notes offer detailed information in connection with three possible levels of support:

	Budget 1	Budget 2	Budget 3
Capital Expenditures			
Cyclotron Magnet, vacuum chamber, oscillator, cooling system	$ 666,000	$ 666,000	$ 646,000
Power supply & controls Primary line; oscillator, magnet, and low voltage power supply; controls	132,200	132,200	47,000
General equipment Shop equipment, crane, trucks, water tanks, lead screening, focussing magnets, general laboratory equipment	162,000	120,800	27,000
Building Including buried control house, roads, etc.	200,000	150,000	135,000
Salaries during construction Physicists, machinists, draftsmen, radio engineer, helpers, etc.	81,000	81,000	60,000
	$1,241,200	$1,150,000	$ 915,000
Contingencies	158,800	100,000	85,000
	$1,400,000	$1,250,000	$1,000,000

*There now exist about 850 grams of purified radium, whose present market price is about seventeen million dollars.

	Budget 1	Budget 2	Budget 3
Operating Program	$850,000	$850,000	$500,000
Salaries, stipends, & wages, cyclotron operation, research equipment & supplies, building maintenance: all for a 10-year period	(10 x $85,000)	(10 x $85,000)	(10 x $50,000)

(1) The first budget provides for the full project. If The Rockefeller Foundation were to contribute $1,150,000 toward the capital costs, the University of California is prepared to accept this, subject to the condition that they raise $250,000 additional for capital expense, and subject to the condition that the University also provide at least $85,000 annually for a minimum of ten years, following construction, as an operating budget.

(2) The second budget involves certain cuts which are undesirable, but which would still permit the instrument itself to be built full size. The general equipment would be reduced by $41,200, the building would be reduced in size and hence in usefulness, and the contingency item would be reduced by $58,800.

To adopt this budget, the Foundation would appropriate $1,000,000, the University of California raising $250,000 toward capital costs, and carrying the operating program.

(3) The third budget involves further serious cuts, and also involves postponement of certain necessary expenditures. The cooling system of the cyclotron would be reduced by $20,000; the power equipment and controls would be reduced by $85,000; the general equipment would be reduced by $93,000; and the provision for salaries of the construction staff would be reduced by $20,000. While the sum provided by this suggestion would make it possible to construct a cyclotron which would probably go up to one hundred million volts, it is only fair to say that the instrument thus built would definitely fall short of the desired goal.
