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ORNL-1383

ELECTROMAGNETIC RESEARCH DIVISION

QUARTERLY PROGRESS REPORT

For Period Ending September 30, 1952

OAK RIDGE NATIONAL LABORATORY
U.S. ATOMIC ENERGY COMMISSION

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
CARBIDE AND CARBON CHEMICALS COMPANY
A DIVISION OF UNION CARBIDE AND CARBON CORPORATION
OAK RIDGE, TENNESSEE

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This document contains 33 pages
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Category Particle Accelerators and High Voltage Machines

ELECTROMAGNETIC RESEARCH DIVISION
Robert S Livingston, Director

QUARTERLY PROGRESS REPORT
for period ending September 30, 1952

Edited by F T Howard

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OAK RIDGE NATIONAL LABORATORY
Operated by
Carbide and Carbon Chemicals Company
A Division of Union Carbide and Carbon Corporation
Oak Ridge, Tennessee

Contract No W-7405-eng-26

[redacted]

[redacted]

Index No ORNL-1383
Particle Accelerators and
High-Voltage Machines

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ABSTRACT

The development of techniques for measuring angular distributions from internal targets in the 86-inch cyclotron was completed, data have been obtained for elastic scattering of protons from Be, C, Al, Ni, Cb, Rh, Ta, and Th, for deuterons from Be and Mo, and for tritons from Be

The 86-inch cyclotron has been operated steadily, for a record three-week period it was in operation 75% of the available time with an average proton current of 767 μa A system for deflecting the beam to an external target is being designed

A number of reactions induced by bombardment of D, Be, C, N, and O with 25 Mev N^{+++} ions in the 63-inch cyclotron have been identified, nuclear fusion of nitrogen with carbon and with oxygen has been observed Photographic emulsions are being used in an attempt to measure the range and the energy of nitrogen nuclei

In the 22-inch cyclotron the effects of the shape of the accelerating electrode (for dc injection of ions) and its spacing from the arc chamber are being investigated

Thorium residue from a previous isotope separation run was recycled to produce 2/3 gram of 88% Th 230 (ionium) The first plutonium isotope separation run was terminated because of a broken electrode

A small but reproducible amount of radiation-induced increase in intergranular corrosion was produced in the Inconel of reactor fuel tubes (ANP) by proton-irradiation in the 86-inch cyclotron at >3000 watts/cc

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PREVIOUS QUARTERLY REPORTS

Quarterly reports have been issued by the Electromagnetic Research Division for the periods ending

September 30, 1949	Y-495
December 31, 1949	Y-548
March 31, 1950	Y-584
June 30, 1950	Y-637
September 30, 1950	Y-676
December 31, 1950	Y-722
March 31, 1951	Y-767
June 30, 1951	Y-795
September 30, 1951, Part I	ORNL-1173
December 31, 1951, Part I	ORNL-1269
March 31, 1952, Part I	ORNL-1339
June 30, 1952, Part I	ORNL-1345

REPORTS PREPARED DURING THE PRESENT QUARTER

Cohen, B L , Measurement of Beam Energy and Energy Distribution on an Internal Cyclotron Target, ORNL-1347

Cohen, B L , Spatial Distribution of Current on an Internal Cyclotron Target, ORNL-1348

Cohen, B L and Handley, T H , An Experimental Search for the DiNeutron, Part I, ORNL-1382

Stetson, N and Winton, M L , Thermal Cycling of Uranium, ORNL-1386

Livingston, R S and Martin, J A , Production of Polonium 208 - August 1952, ORNL-1392

Livingston, R S , "The Oak Ridge 86-Inch Cyclotron", Nature 170, 221 (1952)

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NUCLEAR PHYSICS RESEARCH

The development of the techniques for measuring angular distributions from internal targets in the 86-inch cyclotron was completed and data are being accumulated Two or more satisfactory sets of data have now been obtained for the following angular distributions

Elastic Proton Scattering

- Beryllium
- Carbon
- Aluminum
- Nickel
- Columbium
- Rhodium
- Tantalum
- Thorium

Deuterons from (p,d) Reactions

- Beryllium (ground state group)
- Molybdenum

Tritons from (p,t) Reactions

- Beryllium (ground and first excited state groups)

In an experimental search for a stable dineutron it was concluded that it is extremely unlikely that a dineutron can exist as a stable entity, the work has been reported in ORNL-1382 The tentative identification of boron 13 mentioned in the last report was investigated further and is now believed to be in error The activity in question could result from silicon impurity Work is progressing on the identification of other new activities

The scintillation spectrometer was developed further and is now yielding satisfactory Kurie plots A project on measurement of short half lives was initiated and necessary equipment constructed The project for measurement of the yield distribution from proton-induced fission of U 238 was completed except for the determination of some long half lives A similar project was begun for U 235

[redacted]

THE 86-INCH CYCLOTRON

Performance of the 86-inch cyclotron has continued to improve, there was only one shutdown during the quarter, to permit correction of a sparking condition During a three-week period in July the machine was in operation (innage) 75% of the available time with a total bombardment of over 288,000 microampere-hours, the target current averaged 767 μa during the 376 hours of actual operation Since July a reduced interest in isotope production has resulted in a shortened operating schedule and greater emphasis on research programs

Cyclotron Operation Schedule

At the end of July the operating schedule was changed from 21 to 15 shifts per week Under this new schedule the cyclotron is operated from 11 00 PM Sunday to 11 00 PM Friday During the extended work week (6 days) the cyclotron is operated 18 shifts, or from 11 00 PM Sunday to 11 00 PM Saturday This reduction in operating schedule resulted from a curtailment of funds available for isotope production, more time is thus made available for research activities Operating time is now divided among four programs nuclear physics, radiation damage, cyclotron development, including experiments preliminary to deflection of the beam, and isotope production for outside customers, including neutron irradiations for the Biology Division

Cyclotron Performance

The longest and most productive isotope production runs ever obtained on the machine were made during July, as listed below

Average Beam Current (μa)	Total μa - hrs	Bombardment Time (hrs)
790	53,038	67 1
800	69,113	86 4
875	166,922	191 0

The total microampere-hours of operation for this maximum production period (July 6 through July 26) was 288,607, the beam current averaged 572 μa for the 504 total elapsed hours The actual beam innage time for this 21-day period, which included some short runs for physics research and radiation damage studies, was 376 hours or 74 6% of the available time, the average beam current based on innage hours was 767 μa

The cyclotron is operating very satisfactorily under the present program of short bombardments, although the beam innage time is reduced because of the numerous target changes involved No detrimental effects have resulted from the weekly shutdown and startup of the cyclotron An average of six hours is required to get the machine back in satisfactory operation after being down for the weekend The innage for the past three months, exclusive of the shutdown period for changing the carbon lips, was 54 9% The innage for the best week was 85 1% A time summary for a typical week of short-run operation is shown below

	Hours	Percent of Available Time
Bakeout and attempted innage	10 7	8 9
Innage (beam on target)	65 9	54 9
Routine change & adjustment of filament	4 0	3 3
Routine change & inspection of targets	29 3	24 4
Electrical troubles	3 0	2 5
Utilities troubles	0 7	0 6
Weekly shutdown and startup	6 4	5 4
Total time scheduled	120 0	100 0

The following bombardments were made on the 86-inch cyclotron The length of bombardment time varied from a few seconds to 190 hours

Nuclear physics	113
Radiation damage	30
Isotope production	13
Experimental	21
Biology Division	6
	183

The six bombardments for the Biology Division were on a beryllium target at various proton beam currents for calibration of the neutron flux outside the tank An external neutron flux as high as $10^9/cm^2$-sec has been measured Upon completion of these preliminary studies, a program for the irradiation of plants, and perhaps animals, will be undertaken

Revisions

The cyclotron was shut down for changes only once during the quarter Inspection of conditions inside the vacuum tank when the radio frequency voltage was on the dees, and the ion source was turned off, disclosed that severe sparking was occuring between the carbon lips of the dees and the liner walls Upon closer inspection, with the tank open, it was found that holes were burned in the carbon strips on the liner walls opposite the dee gap The holes were exactly in line (in the magnetic field direction) with the butt joints in the dee lip carbons A possible explanation is that oscillations taking place just inside the dee lips generate large quantities of charged particles which find an escape route, in line with the magnetic field, through the gaps in the butt joints and induce sparking to the liner wall To correct this, new dee lip carbons with the butt joints cut at a 45° angle were installed, thus eliminating the path along the magnetic field It was then found that the sparking was markedly reduced and operational stability improved

An interlock was connected with the radiation damage target temperature recorder to help prevent accidental overshooting of predetermined maximum target temperatures The interlock de-energizes the cyclotron plate voltage when a certain target temperature is exceeded This addition has resulted in the elimination of burnouts from excessive temperatures

Preliminary Deflector Design

A general program for the deflection of the beam of the 86-inch cyclotron has been formulated In preliminary experiments a satisfactory voltage gradient for design purposes was determined and was then compared with the gradients used in the deflector systems of several cyclotrons now in operation It was concluded that 100 kv/cm is a conservative design choice According to present plans the beam will be deflected with combined rf and dc potentials and will then be directed through a magnetic channel which will permit the beam to pass through the low-gradient fringing field of the cyclotron magnet In order to determine the proper location of such a specially weakened field region it is necessary to calculate the orbits for various angles and energies It is known from other measurements on the cyclotron that the positions of the center of rotation of the last undeflected orbit may move about under different operating conditions Tests will be made of a new plan which, it is hoped, will provide a control of the position of the beam center

A design for a deflector support and adjustment mechanism has been made, as well as a design for a grounding capacitor and a quarter-wave line for use in lieu of the grounding capacitor A full scale model magnet for use in determining the shape of the magnetic shims, necessary for forming the magnetic field for beam deflection, has also been designed

THE 63-INCH CYCLOTRON

Nuclear physics experiments represent the major portion of the work conducted with the 63-inch cyclotron The internal beam has been used to bombard various light elements, and preliminary results have been obtained in an effort to determine the range-energy relations for nitrogen

Cyclotron Operation

Initially, a hollow-anode type ion source was used for the production of triply-charged nitrogen ions but, since serious mechanical difficulties necessitated a redesign of this source, the cyclotron has been operated most of the time with a hot-cathode ion source The hollow-anode source produces two to four times as many ions as the hot-cathode source, but ease of manipulation and adjustment more than makes up for the poorer performance of the latter There has been an increase in ion current in the cyclotron, monitoring now indicates 10^8 neutrons per second from the target

Activation Experiments

A number of activities resulting from the bombardment of deuterium, beryllium, carbon, nitrogen, and oxygen targets have been observed, Table I The targets are mounted on a water-cooled brass probe which is inserted into the upper dee Upon termination of bombardment the probe is immediately removed through a vacuum lock, and the target is inserted in a lead-shielded Geiger counter Since the transfer usually requires only two or three minutes, it is estimated that any activities longer than one-minute half life can be observed After the target is counted for an hour or so, it is transferred to a lead-shielded recording counter to detect any long half lives It is obvious that this method does not detect all reactions produced, but only

TABLE I OBSERVED ACTIVITIES

Isotope Bombarded	Half Lives Observed	Reaction-Products Observed	Reaction-Products Remaining
Deuterium	124^{s}	O 15	n
Beryllium	110^{m}	F 18	He 5
Carbon	15^{h}	Na 24	2H 1
	110^{m}	F 18	Be 8
	long	Na 22	He 4
Nitrogen	10^{m}	N 13	N 15
	2^{m}	O 15	C 13
Oxygen	113^{m}	F 18	C 12
	$2\ 4^{m}$	Al 28	2H 1

those which lead to radioactive products with half lives between one minute and a few days

The deuterium target was prepared by evaporating a zirconium film on a platinum backing and heating it in an atmosphere of deuterium The only activity observed on this target had a measured half life of 124 seconds, which is ascribed to the 118-second O 15 This is just what one would expect from the corresponding N 14(d,n)O 15 reaction From the fact that no other activity is observed we conclude that our target is sufficiently pure We also conclude that our cyclotron beam does indeed contain N^{+++} ions, since the N^{+} ions, accelerated by the third harmonic of the rf, would have insufficient energy to produce reactions with deuterium Due to the energy carried by the center of mass, 25 Mev nitrogen ions correspond to 3 6 Mev deuterons on a stationary nitrogen target

The beryllium target was a 5-mil foil, obtained commercially The one activity observed had a half life of 110 minutes and is ascribed to the 112-minute F 18 It is not likely that the observed half life was due to any other isotope, the nearest longer activity observable would be 52 9-day Be 7, and the shorter one, 20-minute C 11

The carbon targets were graphite plates 1/32' thick In this instance three activities were found the 110-minute half life, assigned to F 18, a 15-hour half life, assigned to Na 24, and a long half life Again there seems little doubt that the 15-hour half life is due to Na 24, but the assignment of the long activity to Na 22 must be regarded as tentative and subject to further investigation

Oxygen was bombarded in two forms, as oxidized copper and as TiO_2 powder pressed into a zirconium backing Identical activities of 113 minutes and 2 4 minutes were found in both targets The long activity is again assigned to F 18 and the short half life to 2 3-minute Al 28 Since no 15-hour activity was found in oxygen targets we may conclude that there is no carbon contamination and, conversely, since there was no short half life in the carbon we may assume it to be oxygen free The assignment of the 2 4-minute activity to Al 28 is not unquestionable, P 30, however, would be a radiative capture of nitrogen on oxygen, a reaction which is not as probable as one involving emission of two protons

Nitrogen was bombarded in the form of tantalum nitride, prepared by passing nitrogen over clean tantalum at 1000°C Upon bombardment, the target showed 2-minute, 10-minute, and 112-minute activities The possibility that the TaN target contains oxygen contamination cannot be ruled out The 2-minute activity may be a mixture of O 15 produced from the nitrogen in the target, and of Al 28 produced in the oxygen contaminant The 10-minute half life can be assigned to N 13 and is clearly a nitrogen-nitrogen reaction The 110-minute half life is assigned to F 18, which may be due entirely to oxygen contamination in the target

It is of interest to compare the activities observed with those having half lives in the observable range Table II lists the observable activities in the order of decreasing Q values The Q values were computed from the mass values of Mattauch and Flamersfeld * It is to be noted that in general the reactions observed are the most exoergic ones For this reason we are inclined to attribute the F 18 found in the nitrogen target to oxygen contamination

* Mattauch, J and Flamersfeld, A , Isotopic Report, Verlag der Zeits f Naturforschung, Tubingen (1949)

TABLE II OBSERVABLE ACTIVITIES

Reaction	Q(Mev)	M_3	M_4	$T_{\frac{1}{2}}(M_3)$
$N\ 14 + Be\ 9 \longrightarrow M_3 + M_4$	+ 1 8	F 18	He 5	112^m
E_{av} = 9 78 Mev	- 3 8	N 13	Be 10	$10\ 1^m$
E_B = 6 4 Mev	- 5 3	F 17	He 6	72^s
	- 9 6	O 15	Li 8	118^s
	-10 0	C 11	B 12	$20\ 5^m$
$N\ 14 + C\ 12 \longrightarrow M_3 + M_4$	- 3 0	F 18	Be 8	112^m
E_{av} = 11 5 Mev	- 3 1	Na 24	2H 1	15^h
E_B = 9 2 Mev	- 5 7	N 13	C 13	$10\ 1^m$
	- 7 9	C 11	N 15	$20\ 5^m$
	- 8 6	O 15	B 11	118^s
$N\ 14 + N\ 14 \longrightarrow M_3 + M_4$	+ 0 2	N 13	N 15	$10\ 1^m$
E_{av} = 12 5 Mev	- 0 3	O 15	C 13	118^s
E_B = 10 5 Mev	- 4 1	C 11	O 17	$20\ 5^m$
	- 4 9	F 17	B 11	72^s
	- 5 4	O 14	C 14	76^s
	- 6 5	Na 25	3H 1	60^s
	- 7 2	F 18	B 10	112^m
$N\ 14 + O\ 16 \longrightarrow M_3 + M_4$	+18	P 30	γ	$2\ 5^m$
E_{av} = 13 3 Mev	+ 0 73	Al 28	2H 1	$2\ 3^m$
E_B = 11 7 Mev	- 2 9	F 18	C 12	112^m
	- 4 8	O 15	N 15	118^s
	- 6 4	N 13	O 17	$10\ 1^m$
	- 7 0	F 17	C 13	72^s
	- 8 8	Mg 27	3H 1	$9\ 6^m$
	-11	C 11	F 19	20^m
	-23	Na 24	2He 3	15^h

E_{av} is the energy available in the center-of-mass system, assuming 25 Mev beam

E_B is the coulomb barrier $\dfrac{z_1\ z_2\ e^2}{r_1 + r_2}$, where $r = 1\ 4 \times 10^{-13}\ A_1^{1/3}$ cm

If the beam center is far removed from the center of the magnet the beam energy may be less than the 25 Mev equivalent to the $H\rho$ of the magnetic field The present energy determination from the range in nuclear emulsions may also be subject to doubt If we assume, however, that a penetration of the coulomb barrier is necessary for the observed reactions, there should be enough energy available in the center-of-mass system to produce activities which we have not observed In the case of the carbon target, for example, there should be approximately 9 Mev available in the COM system for the barrier to be penetrated We did not find a 10 1-minute, 20 5-minute, or 118-second activity in any of the carbon targets, even though the formation of the respective isotopes is energetically possible, and easily observable

Photographic Emulsion Experiments

Photographic emulsions have been used in an attempt to measure the energy of the nitrogen ions and to determine the feasibility of studying reactions with light nuclei in the emulsion A room has been equipped with two microscopes and necessary associated equipment

The determination of the proper exposure of the emulsions in the internal beam of the cyclotron proved to be quite difficult In the first attempts, uncovered emulsions were exposed but they were charred by arcing from the rf system Successful exposures are now made by placing the emulsion in a small brass box which has a slit, in the beam direction, covered by 0 2 mg/cm^2 aluminum foil The beam current may be reduced to the required level, either by reducing the intensity of the arc in the ion source or by reducing the rf voltage to its lowest level In either case an exposure of less than one second is required It has been found that reducing the rf voltage results in less fogging of the emulsion, presumably since fewer or less-energetic X-rays are produced

The emulsions are developed in the usual manner in dilute D-19 developer Since the emulsion thickness is only 50 microns, temperature development is not required Ilford C-2 emulsions have been used so that dense tracks with a clear-cut range would be obtained Probably a less sensitive emulsion, such as the E-1, would be preferable for the study of reactions

The range-energy relations for particles with more than two charges are not well known, since ions pick up charges as they slow down The theory of Knipp and Teller* has agreed fairly well with some older measurements of ranges in gases, but cosmic ray investigators have used range-energy values for heavy ions which are at considerable variance with these calculations Therefore, we have begun a program to determine the proper range-energy curves for nitrogen ions in emulsions This can be accomplished by observing proton recoils in the emulsion If θ is the angle between the proton and nitrogen ion, the energy of the nitrogen ion and the proton can be related by

$$E_N = \frac{3\, E_p}{\cos^2 \theta}$$

The energy of the proton can be determined from its well-known range-energy relations in emulsions Approximately ten events have now been located and they appear to agree quite well with the Knipp and Teller calculations, where the relative stopping power ratio between emulsion and air is 1700 The statistics are poor, however, and many more events will be required before a good curve is obtained

The energy distribution of N^{+++} ions in the beam has been investigated Ranges of these ions in emulsions were measured with a calibrated filar eyepiece The maximum range is approximately 15 microns, with the mean range

* Knipp and Teller, Phys Rev 59, 659 (1941)

at about 10 microns This corresponds to a maximum energy of 26 Mev and a mean of 21 Mev, it must be emphasized that these measurements are still preliminary

A number of events have been located in the emulsion that can definitely be identified as nuclear reactions Because of the difficulty of identifying the short, heavy tracks and because of the presence of a variety of light nuclei in the emulsion, it has not been possible to analyze any of these events Perhaps, with less sensitive emulsions, progress will be made in this directions A new type of Ilford emulsion which is diluted eight times with gelatin may prove valuable in this work

In the reactions, $N^{14} + N^{14} \rightarrow Al^{27} + H^{1}$ and $N^{14} + N^{14} \rightarrow Mg^{24} + He^{4}$, the protons and alpha particles may leave in the forward direction with energies greater than 30 Mev, due to the large positive Q of the reactions We have placed emulsions behind nitrogen targets, along with appropriate absorbers to reduce the proton and alpha energies so that they could be observed in the emulsions After bombardment of the target with 25 Mev nitrogen ions we have found protons and alphas in the emulsion which must have had more than 30 Mev at their source, showing that these reactions do occur Quantitative work has not been done by this method, primarily due to a lack of scanners

Scintillation Spectrometer

A scintillation spectrometer is now being used to aid in the identification of reactions that are produced in the 63-inch cyclotron The spectrometer is a conventional instrument consisting of detecting crystal, photomultiplier tube, A-1 preamplifier and amplifier, single channel differential analyzer, and scaling unit The instrument was originally set up as a beta-ray spectrometer with an anthracene crystal Later, it was decided that a gamma ray spectrometer would be more useful for the intended purpose, a sodium iodide crystal was then substituted for the anthracene crystal

The assembly and testing of the spectrometer has been completed, and the instrument is now ready for use The resolution, as measured in the usual manner with a Cs 137 source, is approximately ten percent This is with no shielding, no cooling, no collimation of the gamma rays, no selection of crystal, and with a choice of only three phototubes While this is not considered exceptional resolution for a gamma-ray scintillation spectrometer, it is adequate for this type of work

ELECTRO-NUCLEAR MACHINES

The 22-Inch Cyclotron

Tests are being made with the 22-inch cyclotron to determine the conditions necessary for increasing the proton beam current

Ion Source Length The output of the ion source was found to be approximately proportional to the effective length In the experimental arrangement a constant potential was applied to the accelerating slit and to the dees of the cyclotron, and an ion collector was placed to intercept the proton beam at the end of a 180° orbit Two sizes of arc chamber apertures were tested In both, the aperture through which ions pass was 3/32" wide but the lengths were 1/2" and 2 5/8" With arc conditions held constant at 150 volts and 2 amperes and with 10 kv accelerating potential the measured ion outputs were 35 and 170 ma, respectively

DC Injection of Ions The effect of applying a constant potential to the accelerating electrode is being investigated Potentials up to 10 kv are applied to this electrode while the rf potential on the dees may be varied from 10 to 25 kv The optimum accelerating potential, as indicated by the proton current measured at the maximum cyclotron radius, 10 5", varies from 1 to 3 kv and appears to depend upon the intensity of the arc, for the following data the cyclotron dee-to-dee potential was 22 5 kv and the arc was operated at 150 volts

Accelerating Potential (kv, dc)	Beam Current (μa) for 1-amp arc	Beam Current (μa) for 2-amp arc
1	-	530
2	330	640
3	450	560
4	410	540
5	380	510

When the beam is collected on a probe only 1 5" from the ion source the current increases linearly with the accelerating potential, from 1 5 ma at 35 kv to 3 5 ma at 8 5 kv The arc current was 2 amperes at 150 volts With 22 kv dee-to-dee the accelerating potential was limited to 8 5 kv by excessive sparking

Since the current measured at 1 5" continues to increase with accelerating potential while the beam measured at 10 5" is optimized at 3 kv or less, changes in ion focus are indicated The effects of the shape of the accelerating electrode, its spacing from the arc chamber, and of the applied potential gradient are still to be determined

Magnetic Field Orientation The floating wire loop method* has been used to locate the median plane of the magnetic field of the cyclotron and for locating the center of the shimmed field A single loop of #32 enameled copper wire is suspended, nearly friction free, approximately in the median plane When a current, ~ 5 amp dc, is passed through the loop, as it is shifted about, the position of unstable equilibrium at the median plane can be found The current-carrying loop also tends to center itself with respect to the magnetic center of the field Loops of various sizes are used to survey the whole field

Observations indicate that the median plane of the 22-inch cyclotron, at 6", 11", and 22" diameter, coincides with the geometric median plane within ± 0 125" and that the magnetic center coincides within ± 0 25" with the geometric center of the system

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* Anderson, H L and Marshall, J , The University of Chicago 170-Inch Synchrocyclotron, Progress Report No 3, July 1930, p 18

Cyclotron Ion Source Testing Unit

The experimental unit built for investigating dc injection of ions into the rf system of a cyclotron (originally described in ORNL-1173) has been revised to obtain higher dee potentials and more stable operation The revised oscillator arrangement uses a type 5771 triode and a self-excited grounded-cathode circuit, a direct coupling to the dee stems is made possible by making the oscillator portable The resonant frequency of the system has a nominal value of 9 67 mc/sec and can be varied from approximately 9 5 to 10 mc/sec by means of variable capacitors on the dees

Several tests have been completed on the unit at atmospheric pressure These tests indicate that the revised rf system is capable of producing the desired potential The dee voltage will undoubtedly be limited, though, by the spacing between the dee stems outside the vacuum tank, which is only 1 5" at one point A dee-to-dee voltage of 20 to 40 kv is anticipated when the system is completed

SPECIAL SEPARATIONS

Enrichment of Plutonium Isotopes

Facilities for the electromagnetic separation of gram quantities of plutonium isotopes have been completed and the initial run attempted A stable ionizing arc was obtained but a broken accelerating electrode interferred with normal operation Three-fourths of the plutonium trichloride charge material was vaporized While this material is being recovered, further test runs are scheduled to optimize performance of the equipment and operational techniques

Enrichment of Thorium 230

The objectives of the thorium separation program has been twofold to prepare gram quantities of high-purity Th 230 (ionium) and to use moderately radioactive material as a tracer to test the effectiveness of new equipment and techniques for safely processing alpha-active materials Thorium residue from a previous separation run was recycled and processed to produce 2/3 gram of 88% Th 230 The 10% residue from this run is now in process of recovery, chemical purification, and re-chlorination in preparation for an additional run Airborne alpha activity did not exceed permissible limits during continuous operation at the 0 6 curie level

Shipments of Enriched Classified Isotopes

Distribution of electromagnetically separated classified isotopes to Atomic Energy Commission laboratories during July, August, and September is tabulated below

Los Alamos Scientific Laboratory	2 mg U	51 7%	U 234
Oak Ridge National Laboratory, X-10	5 mg U	95 99%	U 234
California Institute of Technology	20 mg U	51 7%	U 234
Oak Ridge National Laboratory, Y-12	633 mg U	46 0%	U 234
Dow Chemical Company	328 mg U	33 23%	U 234
Dow Chemical Company	1,002 mg U	10 57%	U 234
California Institute of Technology	100 mg U	99 94%	U 235
Dow Chemical Company	388 mg U	99 79%	U 235
Dow Chemical Company	1,612 mg U	99 74%	U 235
Columbia University	293 mg U	42 38%	U 236
Dow Chemical Company	500 mg U	17 83%	U 236
Dow Chemical Company	1,000 mg U	99 994%	U 238
Brookhaven National Laboratory	10,747 mg U	99 9993%	U 238
Oak Ridge Institute of Nuclear Studies	3 mg U	99 988%	U 238
Argonne National Laboratory	209 mg Th	90 61%	Th 230
Los Alamos Scientific Laboratory	11 mg Th	90 61%	Th 230
University of California Radiation Laboratory	1,490 mg Th	90 61%	Th 230

RADIATION DAMAGE

A series of bombardments of fluoride eutectic fuels in Inconel containers has been completed Two zirconium-containing fuels were studied, eutectic #21 (sodium, potassium, zirconium, and uranium fluorides), and eutectic #27 (sodium, zirconium, and uranium fluorides), each in 0 010" Inconel tubing and under 22 Mev proton bombardment in the 86-inch cyclotron The irradiated targets were examined by the Metallurgy Division for radiation-induced effects on fuel stability, and on the rate of corrosion of the Inconel container

To decrease the probability of target destruction by any sudden increase in proton beam, two thermocouples were mounted on the target face The outputs of these thermocouples were monitored continuously on recording instruments, and were interlocked with the cyclotron dee voltage in such a way that if the temperature of either thermocouple exceeded 860°C the proton beam would be interrupted instantly In this manner it was possible to extend the practical duration of these irradiations from 8 to nearly 100 hours

Results with the eutectic #21 are shown in Table III The controls were subjected to the same thermal treatment without proton bombardment A fairly reproducible, but small, amount of radiation-induced increase in intergranular corrosion is found only in targets bombarded for periods in excess of about four hours And what is perhaps more significant, radiation corrosion is apparently induced by proton bombardment only when power dissipation exceeds 3000 watts/cc

The results of a completed series of tests with the newer #27 eutectic (NaF, 46 mole percent, ZrF, 50 mole percent, and UF_4, 4 mole percent) are shown in Table III This series, regulated with the interlocked thermocouple circuits, was extended to longer periods without undue loss of targets from overheating

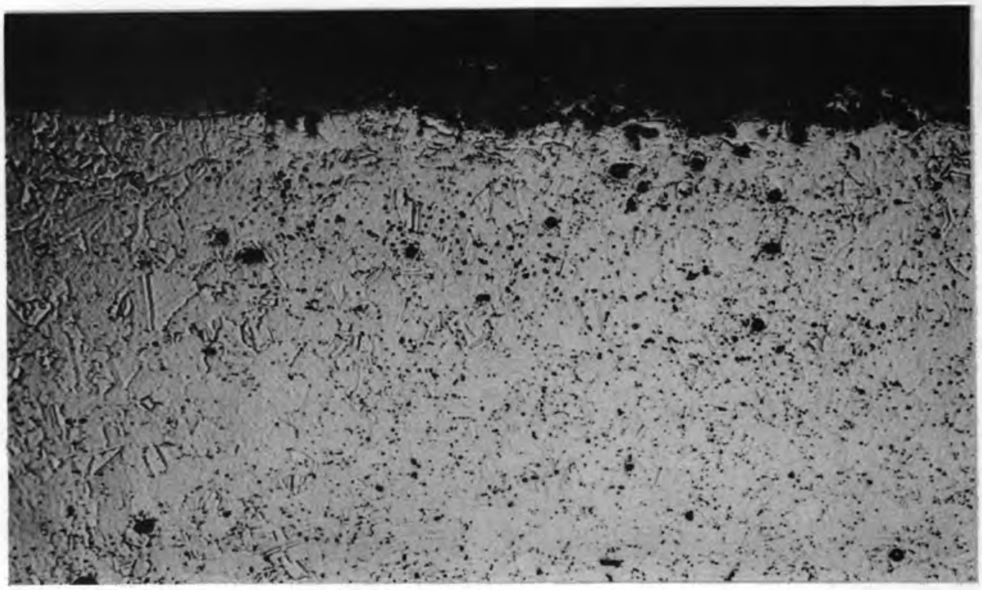
Sample Number	Bombardment Time (hours)	Power Density (watts/cc)	Fuel Analysis					Capsule Corrosion** (inches)
			Fe	Ni	Cr	U	F	
Eutectic #21								
910	3	2400	440	410	520	6 45	39 0	0 0005
907	3	Control	270	300	110	6 96	38 4	0 0005
1107	4 5	2300	450	90	590	6 7	37 8	0 0005
1101	4 5	Control	110	75	1100	6 5	35 2	0 0005
911	77	4100	510	185	670	5 5	38 1	0 0015
905	77	Control	140	29	1100	6 87	38 9	0 0005
1109	88	1150	610	105	670	7 7	36 7	0 0005
1102	88	Control	110	25	1090	7 4	34 6	0 0005
Eutectic #27								
1220	5 6	2800	1650	280	1730	785	41 7	0 0005
1205	5 6	Control	980	40	3000	*	*	0 0005
1214	10 6	2200	1780	55	1730	794	40 8	0 0005
1203	10 6	Control	150	510		744	*	0 0005
1217	14 3	2000	2100	30	1310	734	*	0 0005
104	14 3	Control	150	510		744	*	0 0005
15	15 4	2900	1530	65	1640	753	41 3	0 0005
6	15 4	Control	460	75	3400	*	*	0 0005
21	46 4	3300	3500	230	2100	728	40 2	0 002
1	46 4	Control	1250	180	2700	*	*	0 0005
19	92	1700	1950	50	1660	770	40 6	0 0005
2	92	Control	125	70		806	*	0 0005

** 0 0005" limit of detectability
 * Insufficient sample

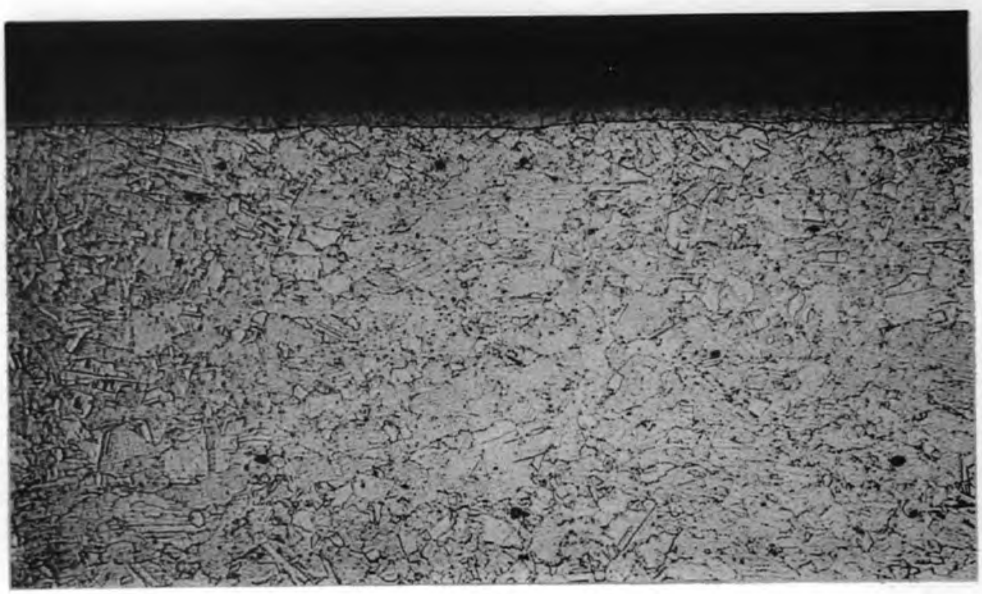
TABLE III CHEMICAL ANALYSES

Again, results in this series show no radiation corrosion for power levels below 3000 watts/cc for irradiations as long as 92 hours The most corrosion in this group was found in the fuel element irradiated at 3300 watts/cc for 46 hours, results of metallographic examination are shown in Figure 1 In addition to an intergranular corrosion of about 0 002" there appears, for the first time in a proton-bombarded fuel element, a 0 0015" layer inside the tube over the bombarded area of the Inconel This layer was shown to be depleted in chromium by testing its magnetic properties with a colloidal iron solution There is some indication of a double banding in the layer, but the colloidal iron test showed no difference in magnetic properties across the layer In these properties this phenomenon resembles closely the effects observed in static and circulating fuel experiments done on this fuel in independent metallurgical studies, and probably is not associated with the proton irradiation Results of this specimen serve as an indication of the sensitivity of the trace element analyses, for, despite the corrosion and chromium leaching seen metallurgically, little increase in chromium content over that of other bombarded samples was found

The 92-hour irradiation results serve to indicate a strong dependence of radiation corrosion upon power density The dissipation rate for this bombardment was about 1700 watts/cc, and both chemical and metallurgical examination showed no corrosion due to the proton beam If the effects of this particular variation of eutectic composition is not such as to alter radiation corrosion rates significantly, which, from previous experience, is probably true, one is again led to believe that the corrosion rate depends strongly upon power density It might be added that since the depth of corrosion in all cases observed is but a few thousandths of an inch, regardless of the length of irradiation, it appears that the corrosion rate quickly decreases from its initial high value



Intergranular Corrosion



Chromium-Depleted Layer

FIGURE 1. CORROSION OF INCONEL FUEL TUBE

ELECTROMAGNETIC FUNDAMENTALS

Plasma Control Studies

An ion source for isotope separation has been developed which has a peak output of over two amperes of ions, as measured both calorimetrically and electrically, on a flat plate collector placed 180° from the source The focus of the ions on the collector plate has been observed to be very good but when the beam is directed into collector pockets there is very marked deterioration of focus, "blow-up" At low beam currents the beam focus into collector pockets is good but as the current is increased a blow-up point is reached, this loss of focus does not appear on the flat collector During the past quarter this phenomenon has been studied

Conditions in and adjacent to the ion source appear to contribute to this blow-up, any oscillating condition lowers the beam current value at which loss of focus occurs When an insulated anode is used in the ion source electrons are forced to oscillate in the arc chamber, in some way, not now understood, these oscillations seem to be communicated through the beam and, combined with the conditions created by collector pockets, produce a blow-up of the beam at relatively low currents With the anode grounded to the arc chamber such oscillations are greatly reduced and larger ion beams can be focused in the collector pockets Unfortunately, there is a less efficient use of electrons when the grounded anode is used and filament life is greatly reduced Other oscillating regions in the vicinity of the accelerating electrodes also appear to affect the current value at which the focus deteriorates Attempts to eliminate these regions have not proved very satisfactory as yet

A new ion source, with supplies, capable of sustained output of at least 2000 milliamperes at 20 kv from 3 5 square inches of arc has been installed A new water-cooled collector with a flow rate of $\sim$30 gpm has been completed and the collector water supply has been enlarged to assure adequate flow Initial tests of the equipment have been started

OPERATION SUMMARY

A summary of operations in Buildings 9201-2 and 9204-3 for the months of July, August, and September include the following experimental runs

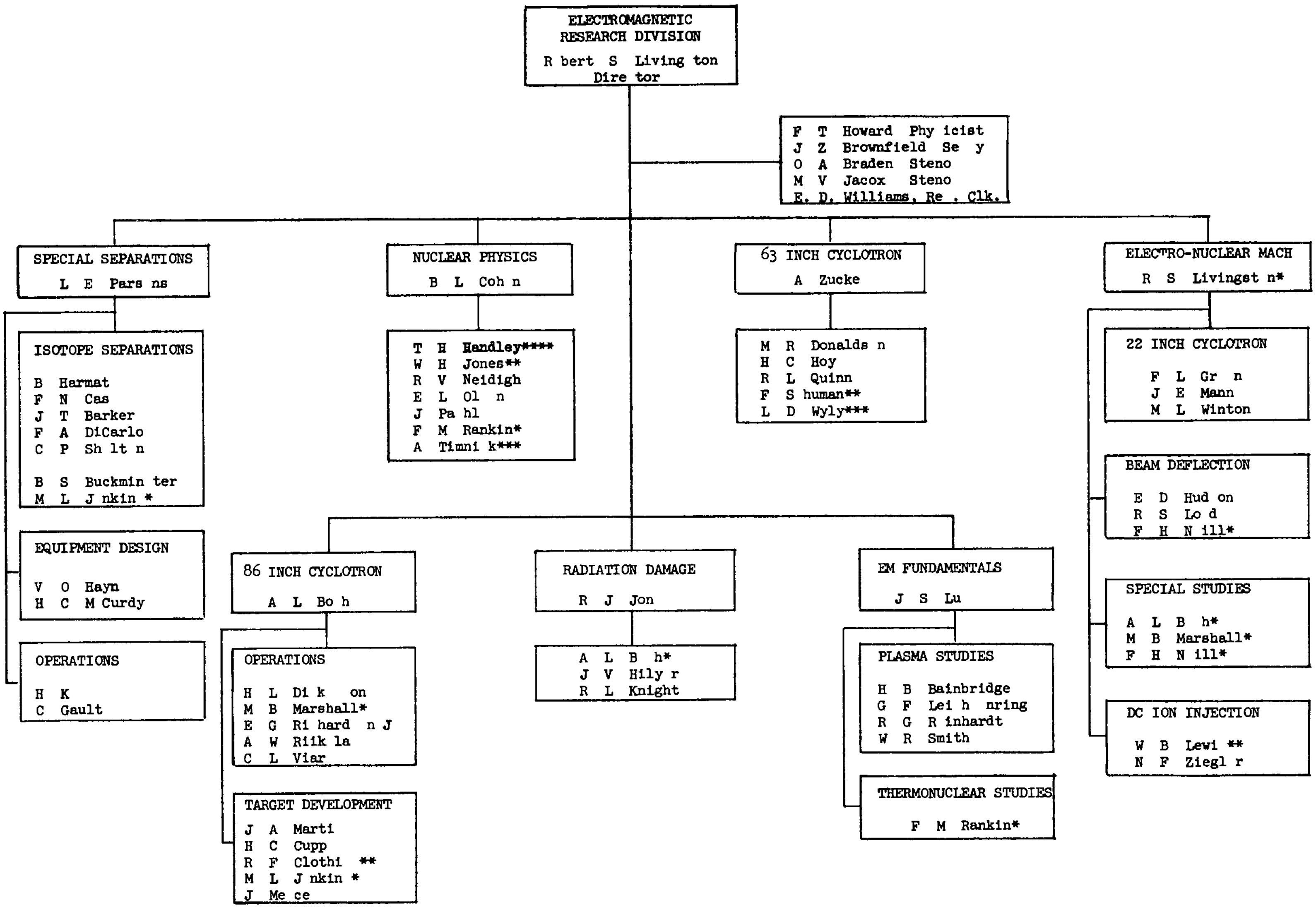
Special Separations	10
Electromagnetic Fundamentals	56
Electro-Nuclear Machines	27
The 63-Inch Cyclotron	32
The 86-Inch Cyclotron	183

Distribution of shop time charged to each of the various projects is given in Table IV

Assignment of personnel to the various projects is indicated by the personnel chart on page 33

	Project	Mechanical Service Hours	Mechanical Service % Used	Machine Shop - Carbon Hours	Machine Shop - Carbon % Used	Machine Shop - Metal Hours	Machine Shop - Metal % Used
33	Special Separations	2193 9	26 4	194	25 1	334	15 1
34-595	86-Inch Cyclotron Operations	2157 8	25 9	84	10 9	270	12 2
34-596	86-Inch Cyclotron Special Targets	946 5	11 4	1	0 1	131	5 9
34-597	86-Inch Cyclotron Development	28 0	0 3	-	-	27	1 2
		3132 3	37 6	85	11 0	428	19 3
36	Electromagnetic Fundamentals	1075 8	12 9	304 7	39 4	591	26 7
37	Electro-Nuclear Machines	308 0	3 7	38 0	4 9	116 5	5 2
38	Radiation Damage Research	182 0	2 2	33 0	4 3	252	11 4
39	86-Inch Cyclotron Nuclear Physics	176 0	2 1	17 0	2 2	139	6 3
40	63-Inch Cyclotron Physics and Operations	1072 8	12 9	101 0	13 1	310	14 0
4900-217	Target Handling Facilities, 86-inch cyclotron	--	--	--	--	4	0 2
4902-281	Fabricate 180° Probe, 86-Inch Cyclotron	17 0	0 2	--	--	6	0 3
4902-282	Fabricate DC Injector Hot-Cathode Source for 86-Inch Cyclotron	117 5	1 4	--	--	34	1 5
43204-1	Building Maintenance Service	51 0	0 6	--	--	--	--
		8,326 3		772 7		2,214 5	

TABLE IV TIME DISTRIBUTION - MECHANICAL AND MACHINE SHOPS
July 1 through September 30, 1952



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P rs nn l 38 Monthly
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