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ELECTROMAGNETIC RESEARCH DIVISION

QUARTERLY PROGRESS REPORT

Part II

for Period Ending March 31, 1952

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CLASSIFICATION CHANGED TO:
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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

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Index No. ORNL-1315
This document contains 21 pages
This is copy 5 of 48, Series A

Subject Category: Technology - Materials Testing Accelerator

ELECTROMAGNETIC RESEARCH DIVISION
Robert S. Livingston, Director

QUARTERLY PROGRESS REPORT, PART II
for Period Ending March 31, 1952

Edited by F. T. Howard

[redacted]

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

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Index No. ORNL-1315
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ABSTRACT

The January shutdown of the 86-inch cyclotron reduced polonium 208 production to four runs yielding 568 millicuries. The cyclotron now operates at higher energy, ~24 Mev, and an increase in yield is anticipated. A new type of target construction makes it possible to operate at about 50% greater power to the target.

The investigation of grid-type ion sources and their adaptability to lithium isotope separation has continued on a modest scale with a small unit having a five-inch radius for Li 6.

A resistance cycler is being used to test alpha-rolled uranium rods for determination of the maximum allowable cyclic stresses.

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TARGET TESTING	15
OPERATIONS SUMMARY	19

Other activities of the Division are described in Quarterly Progress Report, Part I, ORNL-1339.

[redacted]

POLONIUM PRODUCTION

The polonium 208 production program was interrupted by the shutdown of the 86-inch cyclotron on January 15 and had not been resumed by the end of the quarter. The shutdown was made in order to:

1. Increase the beam energy
2. Provide space for bombarding larger targets
3. Ground and position the ion source
4. Install refrigerated baffles in the vacuum system
5. Provide facilities for greater control of alpha contamination

Four bismuth bombardments were made in January, the last two of these being made with an improved target design. During the shutdown a supply of targets of the latest design has been fabricated and a new target dolly with provisions for high rate of water flow has been designed and constructed. As a result of changing the position of the ion source relative to the magnetic center of the cyclotron the maximum energy has been increased to ~ 24.4 Mev.

Production Statistics

Four bismuth bombardments made between January 1 and January 15 increased the total production of Po 208 on the 86-inch cyclotron to 4.945 curies. The results of these runs are tabulated below:

Target Number	Date	Average Beam (μa)	Bombardment Time (μah)	Yield (mc)	Specific Production Rate (mc/mah)	Percent Yield
101	1/5	467	21,460	108.5	5.055	79.0
103	1/9	887	65,879	282.0	4.28	61.2
100	1/11	654	15,624	93.0	5.952	85.0
104	1/13	772	17,914	84.5	4.712	67.4

Targets 100 and 101 were of the flattened-tube type and the other targets of the more recent slotted-plate design. With this slotted-plate target the average beam current is about 50% greater than the previous average permissible current. Consequently, this new design has been adopted and additional 6" by 10"

targets have been fabricated for use after the shutdown.

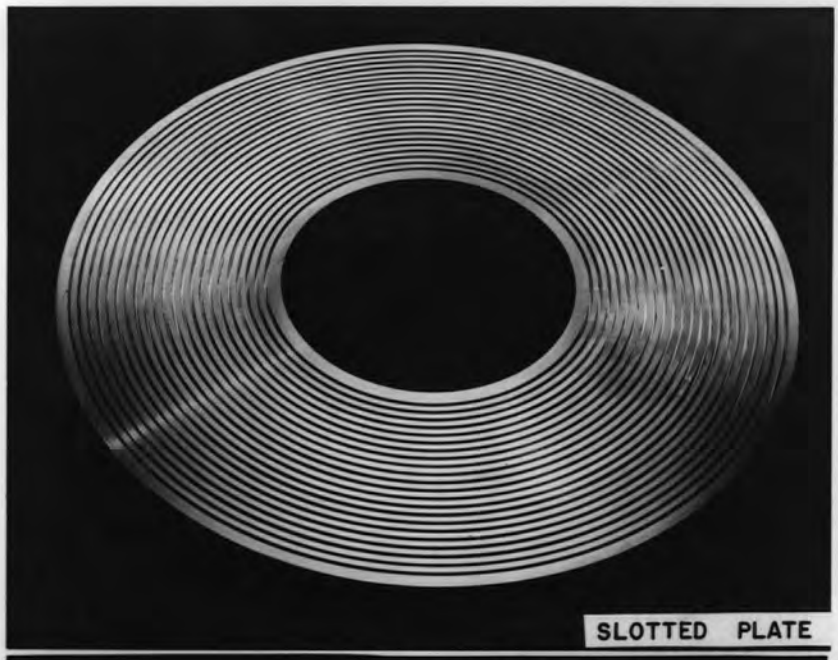
Rotating Targets

The 6" by 14" grazing incidence targets are about the largest stationary targets that can be placed in the cyclotron at present. Further increases in area can best be obtained with rotating targets. The problem of rotating a target has been under consideration and the advantages are fully appreciated. In the case of the stationary target, the minimum operating current is limited by "hot spots" in the beam which cause local melting. With rotation the effective peak current density in the beam can be reduced substantially. If a combination of rotation and grazing incidence is employed a maximum effective area is achieved.

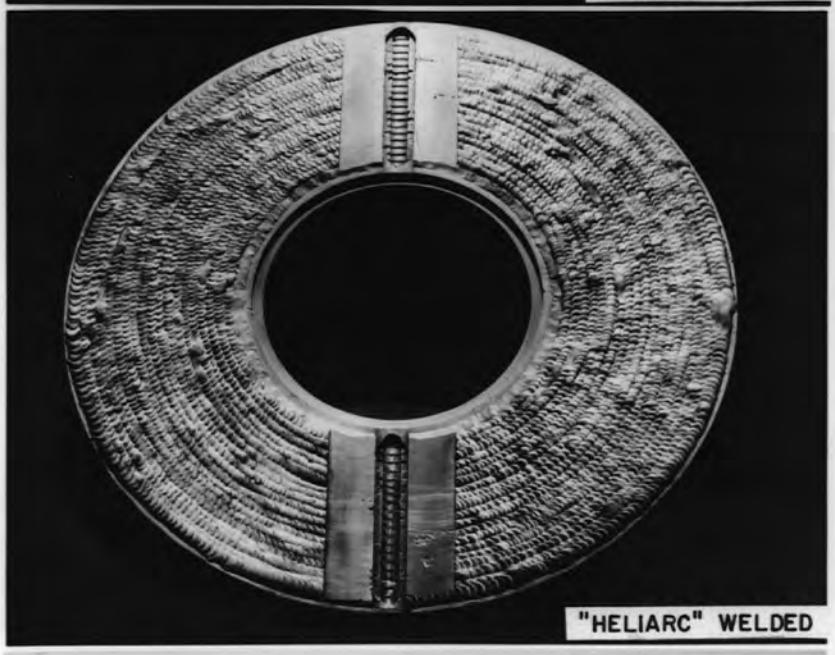
A 15" disc has been fabricated from an aluminum plate and is now being tested prior to installation. The plate is slotted for water passages; bismuth is applied to the surface of the aluminum by mechanical abrasion and then machined to 0.008"; and the target is then bent into a saucer-like shape to provide the proper grazing angle and radius of curvature to conform to the beam radius, Figure 1. The beam will strike a 4" by 4" area of the disc, and rotation will increase the area of bombardment to $\sim$140 square inches. At a heat load of 0.5 kw/in^2 a permissible heat load of 70 kw will be possible. This corresponds to 3 ma of beam current at 24 Mev.

Beam Measurement

The cyclotron was ready for intermittent test operation on March 10. Measurements of beam energy, shape, and center of rotation have since been made. After the upward relocation of the ion source and accelerating slit a one milliampere beam at 24.4 Mev was measured at the 30 1/2" radius;



SLOTTED PLATE



"HELIARC" WELDED

ASSEMBLED

FIGURE 1. 15" ROTATING TARGET

the energy at this radius had formerly been ~ 19 Mev. The effective center of rotation has apparently been raised to a point one inch above the magnetic center. The beam power at this higher energy has yet to be measured calorimetrically. The pattern of the beam on a 90° target is now 3 1/2" by 3/16" as compared with 4" by 1/4" previously obtained.

Contamination Control

At the time the cyclotron was shut down in January the dee system had been in continuous service for a total of over 1.1 million microampere-hours. Alpha contamination in the pit had at times exceeded 10,000 dis/min-m^3 during target change intervals. In September, 1951, when it was necessary to open the vacuum tank to make an adjustment, local airborne contamination had exceeded 70,000 dis/min-m^3. From these measurements it was known that a serious contamination problem would be encountered when the dee assembly and liner were removed for repairs and modifications. To limit the spread of contamination, several work areas were inclosed and separately ventilated, large plastic bags were used for transferring equipment, and special protective clothing was designed for workmen entering the enclosures. These provisions reduced the overall contamination of the building and provided safer work conditions in the sensitive areas.

Pit Change House Repair Area. An area of approximately 880 square feet, at the ground floor level adjacent to the entrance to the cyclotron pit, has been enclosed and partitioned to provide a clean changeroom, a shower and washroom, a contaminated changeroom, and a minor repair area principally for target dolly repair. Work benches in the repair area are provided with water and compressed air outlets and with welding equipment. The ventilation system for this enclosure is in series with the cyclotron pit. From the inlet, air passes

through a filter and a steam coil, is distributed uniformly along the length of the enclosure, and then flows through the maze into the pit from which it is exhausted through a series of deep-bed type filters and through a stack to the atmosphere above the roof of the building.

Target Handling Facilities. The very high alpha and gamma activity now produced in targets requires special facilities for safely handling the "hot" targets. Most of the gamma activity is due to the 5.7 hour decay of Po 207 from the (p,3n) reaction.

A 42-inch concrete radiation shield, with remote handling equipment and viewing window, has been constructed in the cyclotron pit directly opposite the cyclotron tank. From behind this shield the operator is able to remove a radioactive target and insert it into a plastic box, transfer it to a lead-shielded container, and seal this storage container. After the high intensity gamma activity dies out, in approximately one week, the target is transferred to a gloved-box facility. Five gloved boxes and two storage boxes are so arranged that access to the rear of the boxes is through a corridor adjacent to the minor repair area described above. Each dry box is separately ventilated and exhausted through a CWS filter into the pit exhaust system. The dolly with the lead container is brought to this corridor and sealed against the back of the first gloved box. The operator, on the front side, transfers the target from the lead box into the gloved box and removes the target head from the base. The target is then photographed, inspected, measured for activity, and boxed for shipment. A new target head is attached to the target base in preparation for a subsequent cyclotron bombardment.

Decontamination Area. On the main floor east of the cyclotron a second enclosure of approximately 280 square feet is used for the decontamination of the dees and liner. This facility is also provided with two changerooms, a

shower, and an independent ventilation system. About 600 cfm of exhaust air is filtered through two deep-bed filters, then through a CWS filter, and hence to a stack above the roof.

The cyclotron dees and liner are removed from the cyclotron tank into a plastic bag, Figure 2, and the sealed bag is transported overhead to the decontamination area. The equipment is lowered through the top of the enclosure and the plastic bag removed. Within the enclosure there is a large vat for dip-washing of the cyclotron equipment. Wash solutions flow into two 1,000-gallon and two 500-gallon receiving tanks on the floor below. There are provisions for heating and recirculating these solutions. After the major part of the contamination has been removed the equipment is hand scrubbed to further reduce the contamination level, Figure 4. For this operation, it is necessary for the worker to wear plastic suits and respirators supplied with fresh air, Figure 3.

Alignment Area. After the contamination is sufficiently reduced in the wash area the dees are transported by overhead crane to the alignment dock enclosure. This enclosure, like the previous two, has its own ventilation and change house facilities. The alignment dock is arranged so as to accommodate a dee and liner, or two dees, at the same time, Figure 5. Provisions are made for the alignment of components of the dees. Welding stations, compressed air, vacuum lines, and an elevated platform facilitate repair work. When welding is required it has been found necessary for the worker to wear a fresh-air respirator and plastic suit of the type used in the decontamination area.

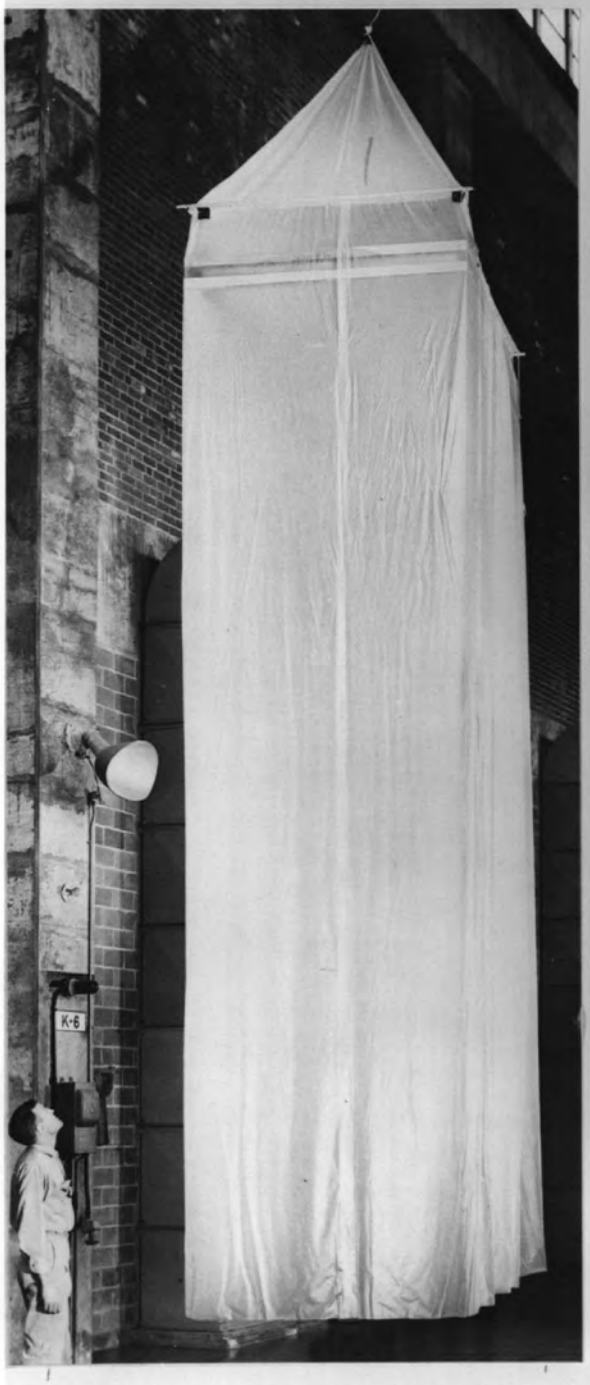


FIGURE 2. TRANSFER BAG

FIGURE 3. PROTECTIVE SUIT

FIGURE 4. SCRUBBING LINER

FIGURE 5. ALIGNMENT ENCLOSURE

ISOTOPE SEPARATION, LITHIUM

Investigation of grid-type ion sources and their adaptability to lithium isotope separation has continued on a modest scale in cooperation with the Stable Isotopes Division. Ion source development is chiefly the responsibility of the Electromagnetic Research Division while the Stable Isotope Division is concerned with problems of ion collection and "power regeneration."

Various geometries of flat, convex, and single horizontal grid-type ion sources have been tested without any appreciable increase in ion current density over the values previously reported. Flat grid sources produce a maximum of 1500 milliamperes of lithium ion current per square inch of actual arc area, and convex grids produce 900 milliamperes. Various mechanical improvements have been incorporated into the units which have increased the stability and efficiency of operation. Vapor leaks in the feed system have been almost totally eliminated, and rigidity in the grid alignment system has been greatly improved.

Investigation of feed materials has shown the possibility of developing useful charge materials with apparent eutectic properties which lower the operating temperature by approximately 75°C and tend to increase the useful life of the ion sources. A mixture of 15% LiCl and 85% LiBr reduces the temperature from the 600°C to 700°C range to the 500°C to 600°C range. LiCl alone has usually been used as feed material.

A unit utilizing a low positive potential (+ 4 kv) ion source, a negative potential (-14 kv) beam-path liner, and a collector at ground potential has been constructed and preliminary operating tests are being made. If workable, a system such as this would effect a simpler power supply arrangement than the conventional unit.

In one test run the collected product assayed 63% Li 6, an enrichment factor of 22.6. This assay does not completely reflect the unit improvements that have since been achieved to further reduce vapor leaks and to increase retention of ions in the collector pockets.

Optimum operating parameters have been rather well determined. A field of 3670 oersteds with 18 kv accelerating potential gives a 5.09" radius for the Li 6 beam and a 5.5" radius for the Li 7 ions. All the present work is being done under these conditions. These dimensions make it possible to mount the source and collector together on a conveniently small faceplate.

Up to this date all work has been done on a laboratory scale with units having an ion source grid of two square inches maximum arc area. For the determination of the practicality of longer arcs a unit is being constructed which will utilize an arc grid 16" long (8 square inches of arc area). For these tests the facilities of the Stable Isotopes Division will be utilized.

TARGET TESTING

The resistance thermal cycler is being used to test alpha-rolled uranium rods for determination of the maximum allowable cyclic stresses. With the results of the tests now underway, it is hoped that a fatigue type curve can be obtained which will allow one to predict more accurately the factor of safety and target life as controlled by stresses alone.

Uranium Testing

In the "A" and "B" series of tests, reported previously,* it was demonstrated that it was possible to study stress failure with the present equipment and that an elimination of the large temperature swing and a reduction of the mean stress allowed many more cycles to be applied to the test specimen.

It was decided that testing conditions which would be somewhere between the "A" and "B" tests should be obtained by proper adjustment of test conditions. The conditions were altered so that a calculated mean stress of 60,000 psi and a stress "swing" of 10,000 psi would result. The conditions were as follows:

Total cycle time	150 milliseconds
Duration of pulse	50 milliseconds
Duty cycle	33 1/3 percent
Pulse power input	~ 150 kw/in^3 (max obtainable from transformer)
Coolant (distilled water)	~ 50°C
Water velocity	17.7 ft/sec

Since this is a different pulse length and duty cycle than has been used previously, it was necessary to build a new commutator and a new reduction gear for the motor driving the commutator. The results of nine tests under the above conditions are summarized in Table I.

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* ORNL-1235, ORNL-1270.

Run No.	Surface Temp Limits °C	Center Temp Limits °C	Pulsing Rate (millisec) On	Pulsing Rate (millisec) Off	Pulse Power Input kw/in^3	Remarks
B-9	408	87 - 119	50	100	146.7	No center temperature swing noticed. Failed at thermcouple hole in 93,720 cycles.
B-7	*	*	50	100	145.5	First crack appeared at 63,000 cycles. Failed in the clamp in 445,100 cycles.
B-6	*	*	50	100	140.4	Sample warped after 315,000 cycles. Sample failed at 396,880 cycles inside the fixed clamp.
B-14	*	*	50	100	162	Sample pitted in center of test section. Failed at 233,720 cycles in center of test length.
B-12	*	*	50	100	144	Sample failed at near the center after 748,600 cycles.
B-17	*	*	50	100	145.2	Sample failed near center after 530,800 cycles.
B-16	*	*	50	100	130.5	Average power density reduced to 45 kw/in^3. Failed after 710,120 cycles.
B-15	*	*	50	100	134.7	Another test at 45 kw/in^3 with sample failing after 217,320 cycles. Sample very rough with many spines sticking up from the sample.
B-18	*	*	50	100	120.0	First crack noticed at 24,000 cycles with failure coming after 526,880 cycles.

* No thermocouple attached to test rod.

TABLE I: TARGET TESTS SUMMARY

The sample in Run B-9, the first of the series, contained two center thermocouples and two surface thermocouples. The center temperature was constant at 408°C while the surface temperature swung from 87°C to 119°C. The power density for the duration of the pulse was 146.7 kw/in^3. The power density averaged over a 150 millisecond cycle is 1/3 of 146.7 kw/in^3, or 48.9 kw/in^3. The sample failed after 93,720 cycles at one of the holes drilled through the rod for the center thermocouple, a common point of failure.

The two runs following the above test run, B-6 and B-7, failed after 396,880 and 445,100 cycles but failure occurred in the fixed clamp and not in the test section. Two steps were taken to prevent failure of the samples inside the clamps. First, the velocity of the water inside the clamp chamber was doubled by reducing the size of the chamber; second, the ends of the samples were silver plated to reduce power loss due to high contact resistance between the sample and the clamp.

The first silver-plated uranium samples received were pitted in the center where the current flowed into the sample while being plated. The sample with the fewest pits, B-14, was cycled to failure under the same conditions as B-6 and B-7, except that the power input was 12% greater because of lower contact resistance at the clamps. After 233,720 cycles the sample failed near the center where the pits were the most numerous. The ends of the sample held by the clamps were in perfect condition at the end of the run. Hence, the problem of failure in the clamp was considered solved.

Another sample was silver-plated on the ends with the plating current entering the sample at the ends instead of the center. The power input on this sample was reduced so that the temperature measurement made in B-9 would be applicable. The average power density was 48.0 kw/in^3. The sample failed

after 748,600 cycles. The fixed clamp was damaged in this run by the swelling of the uranium inside the clamp.

For the next run, B-17, the clamps, as well as the sample, were silver plated. The sample failed near the center after 530,000 cycles at an average power density of 48.4 kw/in^3. No damage to the clamps was noted.

Lower Power Input

After the above runs were completed it was decided to determine the effect of lowering the power input to the sample. This would result in a fatigue-type curve which would enable one to predict more accurately the factor of safety and target life as controlled by stress considerations. Three dumbbell-shaped uranium rods were tested at conditions similar to those mentioned earlier in this report. All of the failures occurred at approximately the midpoint of the samples.

For the first two runs, B-16 and B-15, the average power density was reduced to about 45 kw/in^3. Failure occurred after 710,120 and 217,320 cycles, respectively. In run B-15, a large number of small cracks appeared in less than one hour after starting the run, and in a short time the rod was very rough. Numerous spines were easily discernable on the surface of the sample.

The average power for run B-18 was reduced to 40 kw/in^3. The first crack was noticed at 24,000 cycles with failure coming at 526,880 cycles. After failure at this power density it was decided that a greater reduction in power should be tried in order to get out of the range of the normal scatter in the data. For the initial runs large changes were not made since it was anticipated that unduly long runs might be encountered.

OPERATIONS SUMMARY

A summary of operations in Buildings 9201-2 and 9204-3 for the months of January, February, and March includes the following experimental runs:

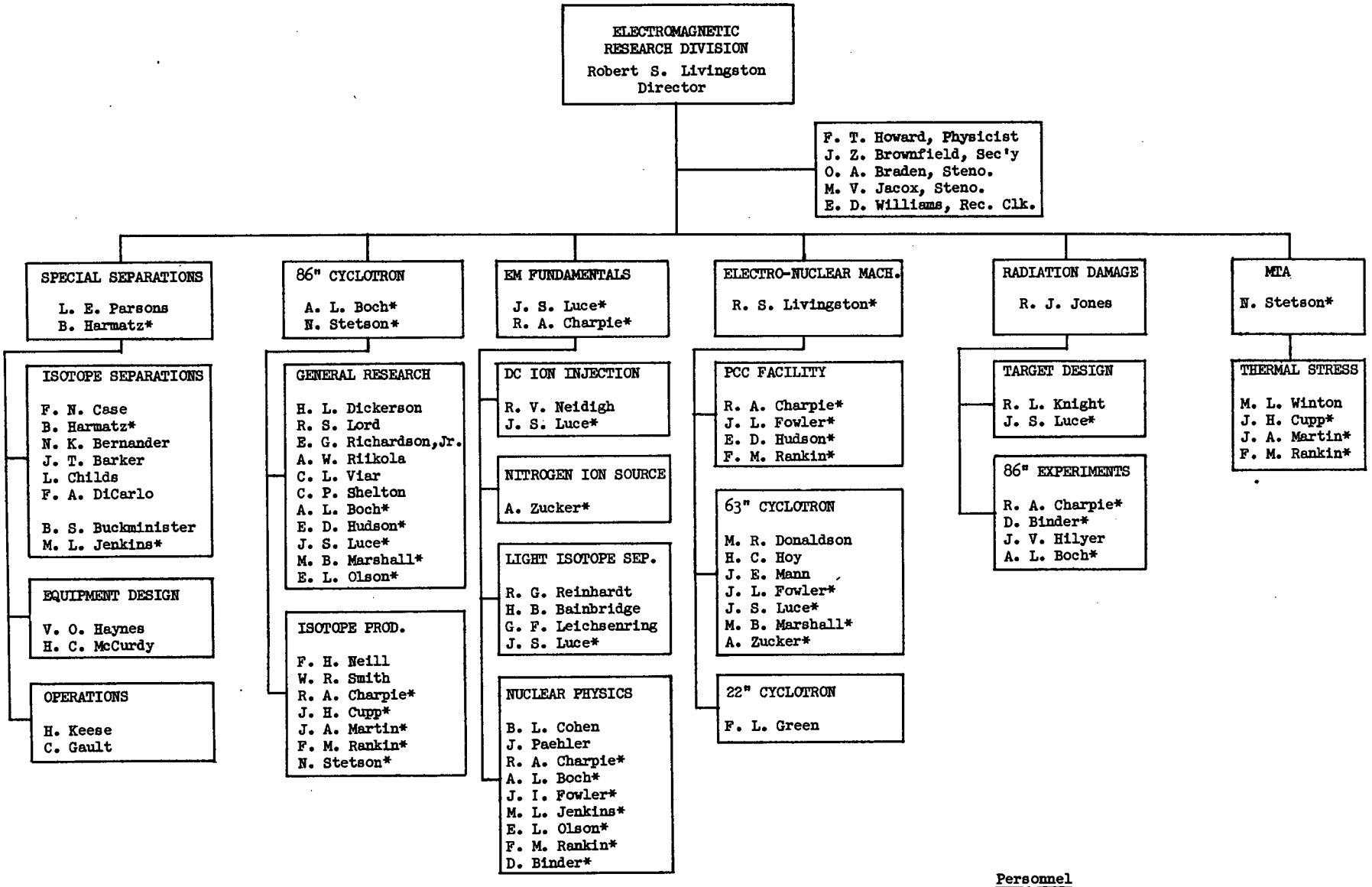
Special Separations	7
Isotope Production	8
Electromagnetic Fundamentals	61
Electro-Nuclear Machines	34
86-Inch Cyclotron	
Nuclear Physics	12
Radiation Damage	4
Experimental Operation	26

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

Assignment of personnel to various projects is indicated by the personnel chart on page 17.

		Mechanical Service		Machine Shop - Carbon		Machine Shop - Metal	
		Hours	% Used	Hours	% Used	Hours	% Used
33-238	Special Separations	2.0	0.02	285.2	30.2	128.0	4.6
33-240	U 236 Separation	89.0	0.9	55.0	5.8	40.0	1.4
		91.0	0.92	340.2	36.0	168.0	6.0
34-241	86" Cyclotron, Electrical	8.0	0.1	---	---	48.0	1.7
34-242	86" Cyclotron, Mechanical	4772.4	48.6	95.5	10.1	1272.0	45.1
34-243	86" Special Targets	592.0	6.1	29.0	3.1	84.0	3.0
		5372.4	54.8	124.5	13.2	1404.0	49.8
36	Electromagnetic Fundamentals	537.5	5.5	270.5	28.6	226.0	8.0
37	Electro-Nuclear Machines	24.0	0.3	20.0	2.1	2.0	0.1
38	Radiation Damage Research	141.0	1.4	12.0	1.3	24.0	0.8
3550-366-2	MTA Target	468.6	4.8	--	--	23.0	0.8
4900-132	Plutonium Laboratory Facilities	1402.0	14.3	128.0	13.5	154.0	5.5
4900-161	The 63" Cyclotron	1770.4	18.0	21.0	2.2	726.0	25.8
4900-181	Alignment Rack, 86" Cyclotron Dees	2.0	0.02	--	--	--	--
4900-217	Target Handling Facilities, 86" Cyclotron	4.0	0.04	29.0	3.1	90.0	3.2
	TOTAL	9,812.9		945.2		2817.0	

TABLE II: TIME DISTRIBUTION - MECHANICAL AND MACHINE SHOPS
January 1 through March 31, 1952



* Dual Capacity
R. L. Quinn on loan to Protective Equipment Evaluation Program

Personnel
40 Monthly
12 Weekly
52 Total

April 1, 1952