ARGONNE NATIONAL LABORATORY
P. O. Box 299
Lemont, Illinois

PHYSICS DIVISION
SUMMARY REPORT

MARCH AND APRIL, 1955

Louis A. Turner, Division Director

May, 1956

Preceding Reports:

ANL-5412 May, June and July, 1954

ANL-5420 August, 1955, through February, 1956

Operated by The University of Chicago
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Contract W-31-109-eng-38

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Correction Notice

The following corrections should be made in this copy of ANL-5497:

P. 11	- last line	Change "26.26-meter" to "60-meter."
P. 21	- line 16	Should read "0.5 Mev in Xe."
P. 66	- line 1	Change "independence" to "dependence"
P. 75	- line 9	Parentheses should be placed around the title of program 30-9. (Also in Table of Contents, P. 6)
P. 75	- line 17	Parentheses should be placed around the title of program 34-9. (Also in Table of Contents, P. 7)
P. 76	- line 15	Change "due to" to "because of"
P. 100	- last sentence	Change to read "...of the abstract of a paper presented...."
P. 105	- line 12	Delete "a" so as to read "...to specific R. A. points."

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Titles given in parentheses are those of continuing programs in which no progress has been made, either in work done or in publication, during the current quarter.

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I. EXPERIMENTAL NUCLEAR PHYSICS1-9 The Argonne Fast Neutron Velocity Selector (5200-01)

Lowell M. Bollinger, Robert E. Cote'
James M. LeBlanc and George E. Thomas
Reported by Lowell M. Bollinger

a) Chopper M II

No important changes have been made in the chopper that is now in use. A new liquid scintillation neutron detector, having a surface area of about 37 in.², has been installed and found superior to previous detectors in both counting rate and signal to background ratio.

b) Chopper M III

The new fast chopper has been completed and tested at the design speed of 15,000 rpm. No mechanical defects worthy of note have been revealed. The chopper will be installed at CP-5 as soon as its radiation shield is completed. The chopper rotor which has been completed is expected to give a resolution of about 0.04 μ sec. per meter with a 60 meter flight path. A second rotor, designed for a resolution of 0.02 μ sec. per meter at 60 meters, will be constructed as soon as the first one has been thoroughly tested in use.

c) 1024 Channel Time Analyzer

The new large time analyzer being constructed by the Electronics Division is about 2/3 completed. Its completion is expected in early August.

Lowell M. Bollinger and George E. Thomas
Reported by George E. Thomas

The boron-loaded liquid scintillation neutron detector having an active surface area of thirty seven square inches has been tested and is now in operation at the sixty-meter station for transmission work with the fast chopper.

Mechanical Properties

- (a) Counting area - 5 -1/2" x 7"
- (b) Counter thickness - 1"
- (c) Counter material - 1/32" thick Armco
- (d) Four DuMont 6292 photomultipliers facing 5-1/2" x 7" counting area. The signal from each two diagonally opposite photomultipliers is wired in parallel.

Optical Properties

- (a) The inside of the detector is coated with a highly reflecting porcelain.
- (b) The pulse height distribution is approximately triangular with a width at half maximum that is sixty-five percent of the value at maximum.

A liquid scintillation counting unit of the type described in quarterly report ANL-5273 with a counting area of 2" x 6" has been installed at the 26.26-meter station and is being used with the fast chopper.

The large general purpose scintillation detector has been installed at the twenty-five-meter station. The four outside sections are now in use and tests are being made using this system.

3-9 Transmission Measurements with the Fast Neutron Velocity Selector

Lowell M. Bollinger, Robert E. Cote' and
James M. LeBlanc

a) $\overline{\Gamma_n^0} / \overline{D}$ for Slow Neutron Resonances - Robert E. Cote'

In the extension of the program to evaluate $\overline{\Gamma_n^0} / \overline{D}$ for nuclei whose masses are between 60 and 110 bromine and selenium have been studied.

The previously known resonances in bromine have been well resolved and isotopically identified. Much new structure has been observed at higher energies and isotopic identification made in several cases.

The study of selenium has shown some new structure in the energy region above 1000 ev. and several of the resonances below 1000 ev. have been identified as belonging to Se^{77} .

These studies are being continued.

b) Measurements on Plutonium-239 - James M. LeBlanc

Transmission measurements on low 240 samples of Pu-239 have been made with the fast neutron velocity selector. The isotopic content of the samples are listed in Table I.

TABLE I

<u>Isotope</u>	<u>%</u>	
Pu 238	0.00106	± 0.00003
Pu 239	99.38	± 0.01
Pu 240	0.61	± 0.01
Pu 241	0.015	± 0.001
Pu 242	0.01	

The measured cross sections in the energy range of 0.1 to 90 ev are illustrated in Figure 1. The "thin sample" data on the 0.294-ev resonance were obtained with a one-mil sample which contained 4.17% Pu 240. The resonance parameters of the prominent resonances with energies less than 23 ev were determined and are listed in Table II. For all but the 0.294-ev resonance, values of $\gamma = 0.1$ were assumed.

TABLE II

<u>E_o</u>	<u>σ_o/γ</u>	<u>σ_o/γ^2</u>	<u>$\bar{\sigma}_o$</u>	<u>γ</u>
0.294	520	52	5200	0.100
7.82	—	18.7	—	—
10.9	—	47	—	—
11.9	176	—	—	—
14.2	71.8	—	—	—
14.6	—	25.4	—	—
17.6	161	—	—	—
22.2	176	—	—	—

14

FIGURE 1

6-8 (Spiral Velocity Selector for Slow Neutrons) (5200-01)

G. R. Ringo

No work has been done on this problem during the past quarter.

11-9 Installation and Operation of the Van de Graaff
Generator (5200-01)

Jack Wallace

1. New Structural Textolites. The new structural textolites with their changes as described in quarterly report ANL-5420 have been installed in the generator. The complete disassembly and reassembly was accomplished in seventeen working days of fifteen hours per day. The location of the beam spot required only minor adjustments of the equipment in the experimental area after the rebuilding.

The machine has operated successfully to 2.5 Mev since the rebuilding. There have been no indications that it will not go higher when the need arises.

2. Targets. A new beam-bending magnet for deflecting the beam into an additional experimental set-up has been built, but has not yet been tested or installed. Further work on the installation of the new rotating target on the east side's 25° beam has been held up until the magnet is installed.

3. Operational Experience. During this period (February, 1955 to April, 1955) the Van de Graaff generator has been operating at various energies up to 3.0 Mev and with proton beam currents from a fraction of a micro-ampere up to 15 microamperes, as required by experimenters.

The following time distribution shows the division of time between experiments and work on the Van de Graaff generator. There has been no effort made to show the efficiency factor for the times allotted to experimenters.

1. Angular Distribution	Langsdorf, Lane	119.9 hours
2. Lithium Layer Thickness	Ringo, Krohn	10.6
3. Beam Oscillator	Holland	8.0
4. Checking Proportional Counter	Perlow	24.9
5. Proton Dosimetry	Hart, Ramler, Rocklin	121.2
6. Lithium Layer	Mooring	8.6
7. Alignment of 90° Analyser	Mooring, Burgy	20.5
8. Total Cross sections	Hibdon	7.4
9. Testing Machine		9.3
		<hr/> 330.4 hours
Time available	(64 days x 15 hours)	960.0 hours
Start up and daily maintenance	(64 x 1.0)	64.0 hours
Experimental setup which ties up generator and time machine was available but not used.		173.8 hours
Generator out of action including rebuilding with new textolites (17 days x 15 = 255 hours)		391.8 hours

The machine was out of operation not only for rebuilding but also because of minor troubles such as broken control strings, broken wires, ion source gas changes, etc.

The machine was operated at very low proton currents for a group of chemists. Proton beam currents down to a few hundredths of a microampere were brought out through a mica window into their chemical solutions. A paper describing the experiment entitled "Proton Dosimetry" will be written by them in the near future.

14-8

Pulsed Neutron Beam for the Van de Graaff Generator
(5200-01)

Robert Holland

Work has begun on a multi-channel delayed coincidence circuit for use with a neutron time of flight experiment. After initial investigation of a chronotron timing unit and a time to pulse height converter circuit, the time to pulse height converter was chosen. This circuit, together with other electronics necessary for preliminary runs on the Van de Graaff machine, are now in the process of construction.

15-5

Cross Sections for Stopping of Heavy Ions
(5200-02)

Merle T. Burgy

Construction of parts needed for the experiment has continued during the past quarter. A device to facilitate alignment of the gas cell with the ion beam and connecting parts between the gas cell and the 90° electrostatic analyzer have been made. Most of the parts

needed to supply stopping gases to the gas cell have been made. Thus a needle valve and a palladium leak were built for controlling the gas flow rate and mountings made for an alphasatron and a McLeod gauge for pressure measurement. The mounting pieces needed to complete the 25° electrostatic analyzer system have been finished. Numerous parts needed for operation of the equipment, as cables and panels of switches, transformers and selsyns have also been made.

A four-way gas valve has been designed and its construction is nearly complete. It will permit one to obtain a proton beam or a helium, nitrogen or neon ion beam without opening the Van de Graaff tank and thus bring about a great saving of time in changing ion beams.

The major item remaining to be made before beginning measurements is the adjustable high voltage supply for the 25° electrostatic analyzer.

16-2

A New Neutron Counting System

(5200-01)

Alexander S. Langsdorf, Jr. and
F. Paul Mooring
Reported by F. Paul Mooring

Further design studies have been made for the proposed neutron counting system.

The Energy Spread of Neutrons from Lithium Targets
(5200-01)

Alexander S. Langsdorf, Jr., James E. Monahan
and F. Paul Mooring
Reported by F. Paul Mooring

Further experimental studies of the problem of uniformity of lithium layers have been conducted. The additional evidence seems to confirm the hypothesis that the lithium layers are non-uniform. A paper on this subject will be given at the Neutron Energy Conference to be held at Argonne National Laboratory on June 3 and 4, 1955.

20-9

Energy States of Light Nuclei from Charged Particle Reactions. (5200-01)

David R. Inglis, Linwood L. Lee, Jr., Robert E. Holland, F. Paul Mooring
Reported by Linwood L. Lee, Jr.

Papers based on previously reported work on energy levels in Be^8 and Be^9 have been written and are scheduled for publication in the July 1 Physical Review.

It is planned to move the 16" magnetic proton spectrometer to a new experimental location to make room for more effective use of the 90° electrostatic analyser for neutron cross section measurements. The Van de Graaff beam will be deflected an additional 15° to the new location. A magnet has been constructed to accomplish this deflection and will be ready for installation soon.

A target chamber is now under construction for use in $p - \gamma$ and $\alpha - \gamma$ angular correlation experiments in reactions with

light nuclei. This should make possible more definite assignments of spins and parities to low-lying levels. The new chamber will permit charged particle observation at 0° , 45° , and 90° to the incident beam, and gamma-ray observation at all angles in any of three mutually perpendicular planes through the target.

27-1 Decay of I^{128} (25-min) (5200-01)

S. Bradley Burson, James M. Cork (University of Michigan), and David W. Martin
Reported by David W. Martin

A 25-min beta emitter in iodine was first produced in the irradiation of iodine with neutrons, by Fermi and associates¹, and assigned to mass 128. Early cloud-chamber experiments indicated that the beta spectrum was complex.² The half-life has been measured to be 24.98 min³. About 5% of the decay is reported to proceed to Te by K-electron capture or positron emission.^{4,5} The maximum beta-ray energy has been given as 2.02 Mev in a spectrometer measurement.⁶ The principal gamma ray has been variously measured as 0.429, 0.455, and 0.436 Mev^{6,7,8}, with intensity of 7% of the maximum beta ray.⁶

-
1. Fermi, Amaldi, D'Agostino, Rasetti, and Segre, Proc. Roy. Soc. (London) 146A, 483 (1934); Amaldi, D'Agostino, Fermi, Pontecorvo, Rasetti, and Segre, Proc. Roy. Soc. (London) 149A, 522 (1935).
 2. Bacon, Grisewood, and van der Merwe, Phys. Rev. 54, 315 (1938); Phys. Rev. 59, 531 (1946).
 3. D. E. Hull and H. Seelig, Phys. Rev. 60, 553 (1941).
 4. J. H. Reynolds, Phys. Rev. 79, 789 (1950).
 5. W. B. Mims and H. Halban, Proc. Phys. Soc. (London) 64A, 753 (1951).
 6. K. Siegbahn and N. Hole, Phys. Rev. 70, 133 (1946).
 7. Wapstra, Verster, and Boelhouwer, Physica 19, 138 (1953).
 8. Germagnoli, Malvicini, and Zappa, Nuovo Cim. 10, 1388 (1953).

A second gamma ray of 0.98 Mev, of intensity about 2% of the first one, has been reported⁷. There has also been a report of a third gamma ray of 0.255 Mev⁹. No details of the level scheme of Te^{128} have been proposed, and only one excited level of Xe^{128} is established. Study of the activity with the scintillation coincidence spectrometer has been initiated in the hope of establishing the decay scheme.

The results to date are very preliminary. The most prominent features of the NaI (Tl) pulse-height distribution are the gamma ray of about 0.43 Mev and the X ray. A peak at about 0.98 Mev is also clearly seen, and there is possibly a very weak peak at about 0.72 Mev. There is, however, no definite peak in the region of 0.255 Mev. There is also a very pronounced shoulder on the high side of the 0.43-Mev peak, representing radiation of about 0.5 Mev. Wapstra, et. al.⁷ report a definite broadening on the low-energy side of the annihilation peak in the decay of Cs^{128} to Xe^{128} and suggest the existence of a transition of about 0.5 Mev and Xe. It is quite possible that such a transition exists and is the same one observed here.

It is expected that work will be pursued further in the coming period.

9. M. Reier and M. H. Shamos, Phys. Rev. 95, 636 (1954) (A).

S. Bradley Burson, James M. Cork (University of Michigan), and David W. Martin
Reported by David W. Martin

Essentially all X rays found to be in coincidence with the 0.294-Mev peak must arise from internal conversion of the 0.0574-Mev transition. Comparison of the X-ray and 0.0574-Mev peaks in this coincidence distribution therefore provides a direct measurement of the K-conversion coefficient of the latter transition. The result obtained, after suitable corrections, is $\alpha_K = 5.9$.

Only a single L-conversion line is seen for this transition, and it is believed to be the L_1 . Further, it is evident that the lifetime of the 0.0574-Mev state is less than the resolving time of the coincidence circuit (2 microseconds).

Thus all indication are that the transition is M1, although a small E2 admixture is possible. Uncertainties in extrapolation of available theoretical values of α_K do not permit setting any definite limit on this possibility.

A recent spectrometer investigation of the beta spectrum has confirmed the existence of five components¹. The abundance of the highest-energy component, which proceeds to the 0.0574-Mev level, is found to be 37%. From the log (ft) values, both this transition and the further decay of the Pr ground state to the ground state of Nd^{143}

1. Mary K. Brice, Private Communication.

are characterized by $\Delta I = 0$ or 1, yes.

The ground state of Nd^{143} has a measured spin of 7/2. A set of assignments for several of the levels in the Ce^{143} decay scheme consistent with all the known facts and with the shell model is as follows:

Ce^{143}	Ground state:	h 9/2 (-)
Pr^{143}	0.0574-Mev level:	g 7/2 (+)
Pr^{143}	Ground state:	d 5/2 (+)
Nd^{143}	Ground state:	f 7/2 (-) .

These assignments would make the transition from Ce to the ground state of Pr "L-forbidden" with a ΔL of 3 units.

The experimental work is considered to be essentially complete. A preliminary report of the results was presented at the Washington meeting of the American Physical Society, and they are now being prepared for publication in the Physical Review.

29-2 Decay of Nd^{151} (12-min) and Pm^{151} (27-hr) (5200-01)

S. Bradley Burson, James M. Cork (University of Michigan), and David W. Martin
Reported by David W. Martin

A recent report¹ has proposed a new decay scheme for the principal gamma rays in the decay of Pm^{151} based on scintillation coincidence studies of the activity. The two new gamma rays of 440 and 660 kev mentioned in the previous quarterly report, ANL 5420, are also reported in this paper, and are included in the scheme.

1. H. S. Hans, B. Saraf, and C. E. Mandeville, Phys. Rev. 97, 1267 (1955).

The proposed scheme is, however, still inconsistent with our observation that the 715-kev gamma ray is coincident with X rays.

No further work has been done on either activity since the last quarterly report, but it is anticipated that the study will be pursued in the coming period.

35-9

Decay Schemes of Long Lived Rare-Earth Isotopes
(5200-01)

Eugene L. Church

Introduction - The decay schemes of Sm^{153} , Gd^{153} and Eu^{155} have been examined, and evidence obtained for the presence of low-lying electric-dipole transitions in Eu^{153} and Gd^{155} .¹ The present experimental results, as well as a tentative explanation of the origin of the low-spin "odd"-parity states, are summarized below.

Sources of 47-hour Sm^{153} were prepared by vacuum evaporation of samarium oxide onto aluminum foils, which were then bombarded in the Argonne Heavy-Water Reactor (CP5) for several days. A source of 236-day Gd^{153} was prepared by irradiating a thin layer of gadolinium oxide in the center of the Brookhaven Reactor for three months. Two sources of 1.7-year Eu^{155} were employed, a high-specific-activity source of fission europium ($\text{Eu}^{154} + \text{Eu}^{155}$), separated ~ 1948 ,² and a low-specific-activity source of pure Eu^{155} prepared by successive neutron capture in enriched Sm^{154} . Comparison of these activities with that of neutron-activated normal europium ($\text{Eu}^{152} + \text{Eu}^{154}$) led to unambiguous

1. ANL-5317, 22.

2. Obtained through R. J. Hayden.

mass assignments for all transitions < 250 kev.³

The conversion-electron spectra of these activities were examined with a high-resolution 180° -focussing beta-ray spectrograph. The absolute uncertainty associated with the reported energies is ~ 0.5 kev and the relative errors less than half this. Unconverted gamma spectra were studied with a conventional NaI (Tl) scintillation counter feeding an Atomic Instruments Company single-channel pulse-height analyzer.⁴ A $1/4$ " thick anthracene crystal was used for the detection of beta rays. Gamma-gamma and beta-gamma coincidence measurements were made with the aid of a BNL Coincidence Grey-Wedge Analyzer.^{4,5} The coincidence resolving time of this equipment is $\sim 0.1 \mu$ second, thereby setting an upper limit of $\sim 10^{-6}$ second on the lifetimes of transitions observed in coincidence.

Experimental Results

1. A = 153.

Examination of the conversion-electron spectrum of Sm^{153} indicates the presence of transitions of 69.8, 83.3, 97.3 and 103.1 kev in Eu^{153} . The 70- and 103-kev transitions are by far the more intense, and their properties have been reported extensively.^{1,6} The 83- and

3. ANL-5174, 23.

4. Equipment generously loaned by A. W. Sunyar, Brookhaven, June, 1954.

5. R. L. Chase, BNL-263, T-42

6. Hollander, Perlman and Seaborg, Rev. Modern Phys. 25, 469 (1953).

97-keV transitions are extremely weak, and are observed only conversion-wise. Unfortunately, the K line of the 83-keV transition falls adjacent to the KLL-Auger pattern, and no reliable estimate of its K/L conversion ratio could be made. However, its relative conversion in the L sub-shells is indicative of an $M1 + E2$ mixture, with $\gamma_{M1} < \gamma_{E2}$. L-conversion of the 97-keV transition was not observed following the decay of Sm^{153} . The decay of Gd^{153} excites the 70-, 97- and 103-keV transitions in Eu^{153} . Relative to the 103-keV transition, the 70-keV transition is slightly less, and the 97-keV transition ~ 30 times more intense, than when observed following beta decay. The presence of the 83-keV transition was not detected, possibly because of the relatively low specific activity of the gadolinium sources available.

McGowan,^{6,7} and Sunyar^{6,8} have independently estimated the K-conversion coefficients of the 70- and 103-keV transitions to be 3.5 and 1.2, respectively. These values do not correspond to those of any pure transitions, indicating the possibility of dipole-quadrupole mixtures. However, the present data on the absolute and relative conversion properties of these transitions do not allow unambiguous multipolarity assignments to be made.¹ In the present investigation, relative values of conversion coefficients were estimated by comparison of relative unconverted gamma intensities with the corresponding relative

7. F. K. McGowan, Phys. Rev. 93, 163 (1954).

8. A. W. Sunyar, private communication (1954).

conversion-line intensities. The unresolved 97- and 103-keV full energy peaks in the gadolinium source were resolved by comparison with that of the "pure" 103-keV transition following the samarium decay. Assuming the value $\alpha_K(103) = 1.2$ from the results of McGowan and Sunyar, the following absolute values are obtained

$$\alpha_L^{(60)} \sim 0.6, \quad \alpha_K^{(97)} \sim 0.2.$$

Comparison of the latter with the theoretical estimates shown in Fig. 2,⁹ indicates unambiguously that the 97-keV transition is a pure electric-dipole (E1) transition. Its K/L conversion ratio of ~ 5 , and L sub-ratios of $\sim 1:0.1:0.1:3$, are in agreement with theoretical expectations.^{9,10}

McGowan has reported that the 70- and 103-keV transitions have life-times of $\sim 3 \times 10^{-9}$ second and form a cascade leading to the ground state.⁷ Gamma-gamma coincidence measurements on Gd^{153} indicate that the 97-keV transition is not in coincidence with this cascade, but does possess an x-gamma lifetime of $< 1 \mu$ second, in agreement with McGowan's subsequent estimate of $< 10^{-9}$ second.⁷ The 97- and 103-keV transitions are, therefore, assumed to proceed independently to the ground state.

9. J. R. Reitz, Phys. Rev. 77, 10 (1950).

10. Gellman, Griffith and Stanley, Phys. Rev. 85, 944 (1952).

FIGURE 2

Values of α_k for $Z = 64$ interpolated from the calculations of Reitz.
The circled points are the unscreened threshold values of Spinrad
(private communication).

The present results on the mass-153 activities are summarized in the decay scheme shown in Figure 3. The beta-decay data for Sm^{153} are those of Lee and Katz¹¹ as modified by Marty¹² and are consistent with the observed gamma intensities. As indicated, there is the possibility that the 97-keV level is fed by a higher energy gamma-ray.¹³ The branching ratios in the Gd^{153} decay have been inferred from the relative gamma-transition intensities. The lack of positrons in this activity indicates the Gd-Eu ground-state separation to be $< \sim 2\text{mc}^2$ and, hence, log ft values for K-capture lying between 7 and 9.

2. A = 155.

Examination of the conversion-electron spectrum of fission europium indicates the presence of transitions of 45.3, 59.8, 86.3 and 105.1 keV in Gd^{155} , and 123.4 and 247.7 keV in Gd^{154} . The 45-keV transition is extremely weak and only its (three) L-conversion lines are visible. A number of low-energy lines are visible, which may be interpreted as L and M conversion lines of transitions of ~ 19 and 27 keV in Gd^{155} . However, source and instrumental effects make uncertain any measurements and assignments in this region.

Conversion coefficients of transitions in Gd^{155} were determined relative to those of the 123-keV transition in Gd^{154} by comparison of their relative converted and unconverted intensities. However,

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11. M. Lee and R. Katz, Phys. Rev. 93, 155 (1954).
 12. N. Marty, Comptes Rendus, 238, 2516 (1954).
 13. J. W. Mihelich, private communication (1954).

30

FIGURE 3

Tentative Decay Scheme of the Mass-153 Activities.
Log ft values are given in parentheses.

this transition has been interpreted as the E2 ground-state transition in even-even Gd¹⁵⁴ on the basis of its relative conversion properties,¹⁴ energy¹⁵ and lifetime.¹⁶ Assuming from Figure 2 the value $\alpha_K = 0.7$ for this transition, the following absolute conversion coefficients are obtained:

$$\alpha_L^{(60)} \gg 1.2, \quad \alpha_K^{(86)} \sim 0.3, \quad \alpha_K^{(105)} \sim 0.2.$$

It follows from comparison with the theoretical estimates in Figure 2 that both the 86- and 105-kev transitions are pure electric-dipole transitions. This assignment is also in agreement with the observed relative conversion properties of these transitions.^{9,10}

To determine the K-conversion character of the 60-kev transition, the composite X-ray intensity was compared with the corresponding unconverted gamma-ray intensities. Assuming the above values of α_K for the remaining transitions, it is found that $\alpha_K^{(60)}$ must be at least 5 to account for the observed abundance of X rays. The present data on the 60-kev transition are insufficient to determine a unique character assignment. However, its L-conversion pattern ($\sim 1:0.1:0.3$) is identical with those of the 86- and 105-kev transitions and is apparently consistent with only an E1 and/or M2 assignment. The L-conversion pattern of the 45-kev transition is indicative of a predominantly M2 transition.

14. ANL-5080, 32.

15. G. Scharff-Goldhaber, Phys. Rev. 90, 587 (1953).

16. A. W. Sunyar, BNL-2157 (to be published).

Gamma-gamma and beta-gamma coincidence measurements indicate that although the 86- and 105-keV transitions are not in coincidence, they both follow beta rays of < 200 keV with lifetimes of $< 1 \mu$ second. These results are in agreement with the early work of Marinsky et al.¹⁷ who further resolved beta branches of ~ 150 keV (80%) and 250 keV (20%), the latter leading directly to the ground state. Similar beta groups have been reported by Lee and Katz.¹¹ Because of its low intensity, no coincidence data are available on the 60-keV transition. However, energy and intensity considerations indicate that it is the lower component of a two-step cascade paralleling the 105-keV transition. The present results on the decay scheme of Eu^{155} are summarized in Figure 4, where the fine structure of the low-energy beta group has been inferred from the observed gamma-transition intensities.

Discussion - Electric-dipole transitions in ${}_{63}\text{Eu}^{153}_{90}$ and ${}_{64}\text{Gd}^{155}_{91}$ require the presence of nuclear states lying within ~ 100 keV of the ground state, having the opposite parity and differing in spin by 0 or 1 units. Such states must be interpreted in terms of the $h_{11/2}$ and $i_{13/2}$ orbitals, since they are the only "odd"-parity states within the 50-82 and 82-126 shells, respectively. However, the strict Shell Model implies large energy and spin changes for transitions involving these states. The present results indicate both the depression in energy of the Shell Model levels and the breakdown of the usual rule $(j)^{\text{odd}} = j$, for the combination of nucleon spins.

17. Marinsky, Glendenin and Metzger, NP-1727 (1949).

33

FIGURE 4

Tentative Decay Scheme of Eu¹⁵⁵.
Log ft values are given in parentheses

Nuclei in the rare-earth region exhibit large positive quadrupole moments, corresponding to a strong prolate (cigar) deformation. As pointed out by Bohr and Mottelson in their discussion of the Unified Model,¹⁸ the character of energy levels in such deformed nuclei may be radically different from those in a simple spherical potential. That the observed nuclear shape is aspherical implies the lowering of particle configurations relative to their positions in an undeformed well of similar depth. This lowering is greatest for states of high spin, and may result in a reordering of the shell-model levels. In the "strong-coupling" limit, valid for large deformations, the first-order magnitude of this depression is¹⁸

$$D = D_0 \left[\sum_{N, P} \left(1 - \frac{3\Omega^2}{j(j+1)} \right) \right]^2, \quad (1)$$

where $D_0 \sim 1/3$ Mev for $Z \sim 64$, j is the nucleon spin, and Ω its projection along the nuclear axis. Neutrons and protons outside major closed shells are assumed to independently fill the available shell-model states in such a way as to maximize (1). A positive $\sum$ corresponds to prolate deformation, and negative to oblate, in which cases states fill pairwise in the order $\Omega = 1/2, 3/2, \dots$ and $j, j-1, \dots$, respectively.

18. A. Bohr and B. R. Mottelson, Det Kongelige Danske Videnskabernes Selskab 27, 16 (1953).

Data on nuclear ground states are very useful in identifying the particle configurations involved. Since in the strong coupling limit the vector j precesses rapidly about the symmetry axis, the measured spin of an odd A nucleus equals $\frac{1}{2}$ of the last odd particle. The corresponding magnetic moment is given by¹⁸

$$\mu = \frac{I}{I+1} (I g_p + g_r), \quad (2)$$

where $I > 1/2$ is the measured spin, g_p the gyromagnetic ratio of the odd particle, and g_r that of the nuclear surface. For a uniformly charged nucleus, $g_r \sim Z/A \sim 0.4$. Electrostatic quadrupole moments Q are usually expressed in terms of the intrinsic quadrupole moment Q_0 , where¹⁸

$$Q_0 = \frac{(I+1)(2I+3)}{I(2I-1)} Q, \quad (3)$$

is a direct measure of the nuclear distortion. Independent estimates of Q_0 may also be obtained from the energies and lifetimes of rotational states of excitation.¹⁶ In terms of the particle configurations, Q_0 (barns) $\sim 4\sqrt{D(\text{Mev})}$, where the numerical factor is appropriate for $Z \sim 64$.

The ground state of Eu^{153} has $I = 5/2$, $\mu \sim +1.6$ nm and $Q \sim +2.5$ barns.^{19,20} This nucleus is a Shell-Model anomaly in that the Schmidt-limit interpretation of its magnetic moment corresponds to an $f_{5/2}$ -proton state when such does not occur in the 50-82 proton shell.

In the strong-coupling limit this situation can be understood in terms of a

19. P. F. A. Klinkenberg, Rev. Mod. Phys. 24, 63(1952).

20. B. Bleaney and W. Low, Proc. Phys. Soc. 68A, 55 (1955).

$(g_{7/2})^5 = 5/2$ configuration, in which case (2) yields $\sim +1.2$ nm, in reasonable agreement with the spectroscopic value. In the case of Gd^{155} , Murakawa has reported $I > 3/2$ and $g \sim -0.05$ ²¹. These values imply that the ground state involves odd $f_{7/2}$ or $i_{13/2}$ neutrons, although the small g -value is difficult to understand.

The Shell Model would interpret the ground state of Eu^{153} as a closed shell of 50 protons plus 13 in the $g_{7/2}$ and $d_{5/2}$ states. The presence of an electric-dipole transition in this nucleus indicates that the negative parity $h_{11/2}$ state must lie nearby. Assuming reasonable shell-model spacings for these three states, it may be shown from (1) that the two configurations $\left[(g_{7/2})^5 (d_{5/2})^{2,4} (h_{11/2})^{6,4} \right]_Z \left[(h_{9/2})^8 \right]_N$ are energetically possible, and are consistent with the measured spin, magnetic moment and sign of the quadrupole moment of the ground state. Low-lying excited states can then involve unpaired $h_{11/2}$ protons, accounting in a natural way for the observed E1 transitions. Less can be said about Gd^{155} since less is known about its ground state. However, (1) indicates that $i_{13/2}$ orbitals can be depressed several Mev relative to the $f_{7/2}$ and $h_{9/2}$ states which follow the closed shell of 82 neutrons. The observed electric-dipole transitions may then be associated with the $i_{13/2}$ state in analogy with the situation in Eu^{153} . A similar explanation can be offered for the known low-lying electric dipole transitions in odd-proton nuclei

21. K. Murakawa, Phys. Rev. 96, 1543 (1954).

having $Z = 89, 91$ and 93 .¹ However, more experimental data are needed to specify the particular configurations involved.

Coulomb-excitation experiments may provide information about low-lying nuclear states not obtainable by other means. This process preferentially excites those levels which can be reached by low-order electric transitions. For the 100-kev excitation of gadolinium by 3-Mev alpha particles,²²

$$\frac{\sigma(E1)}{\sigma(E2)} \sim 2 \times 10^{-4} \frac{\tau(E2)}{\tau(E1)}, \quad (4)$$

where τ is the lifetime of the inverse gamma-ray transition.

Independent-particle (IP) estimates of τ indicate $(4) \sim 10^3$.

However, rare-earth nuclei have rotational states of excitation of about this energy which can be reached by E2 transitions possessing lifetimes of up to 100 times shorter than the IP values.^{16,18,23} In addition, measurements of the lifetimes of known E1 transitions in heavy elements indicate that they are slowed down by factors of 10^5 or more relative to the corresponding IP estimates.²³ This may be understood by the fact that they involve particle states of very different j , and hence, small overlap. In the cases considered the IP lifetimes are $\sim 1.5 \times 10^{-13}$ second, so that inhibition factors of $> 10^3$ would be consistent with observed lifetimes of $< 10^{-9}$ second. In the rare-earth region, therefore, Coulomb

22. K. A. Ter-Martirosyan, J. Exptl. Theor. Phys. (USSR) 22, 284 (1952).

23. M. Goldhaber and A. W. Sunyar, Chapter 16 of K. Siegbahn's forthcoming book on Beta and Gamma-Ray Spectroscopy.

excitation might be expected to preferentially excite rotational states of excitation. In odd-mass nuclei such states have spins $I' = I, I + 1, \dots$ and energies proportional to $I' (I' + 1)$. Since they have the same parity, transitions between such levels occur by M1 + E2 transitions. For a 100-kev transition in gadolinium the mixing ratio is given by¹⁸

$$\frac{\gamma_{M1}}{\gamma_{E2}} \sim 140 \left(\frac{g_p - g_r}{Q_0} \right)^2 I (I + 2) \quad (5)$$

where I is the spin of the final state, Q_0 is in barns and the g 's are the same as in (2). Since Q_0 may be large and $g_p - g_r$ small, (5) may become ~ 1 , in sharp contrast with the independent-particle estimate of $> 10^4$.

Temmer and Heydenburg have examined the gamma rays following the Coulomb excitation of Eu^{153} and Gd^{155} by alpha particles. In the case of Eu^{153} they observe transitions of 81, 108 and 189 kev, which have been interpreted in terms of rotational levels 81 and 189 kev above the spin 5/2 ground state.²⁴ The 81-kev transition is probably identical with the weak 83.3-kev transition observed following beta decay of Sm^{153} .¹² The L-conversion properties of this transition require $\gamma_{M1} < \gamma_{E2}$, which, in conjunction with (3) and (5), indicates $\left| g_p - g_r \right| < 0.2$. Of all the available proton states, only $g_{7/2}$ ($g_p \sim 0.5$) is found to satisfy this condition for $g_r \sim 0.4$. The observed attenuation of the magnetic component

24. G. Temmer and N. Heydenburg, Phys. Rev. 94, 1399 (1954).

between rotational levels, therefore, favors the previous $(g\ 7/2)^5$ assignment of its ground state. The relative importance of the cross-over transition is also in agreement with this interpretation. In the case of Gd^{155} , a single transition of 146 kev is reported,²⁵ which is not seen following the beta decay of Eu^{155} . This is due in part to the low energy of its preceding beta group.

In principle, beta-decay data may be used for the determination of the spins and parities of nuclear levels. Based on the conventional log-ft classification,²⁶ the present beta- and gamma-ray data indicate the ground state spins of Sm^{153} and Gd^{153} to be $3/2^-$ and $5/2^-$, respectively, and the spins and parities of the excited states in Eu^{153} as: (83) $7/2^+$, (97) $7/2^-$, (103) $3/2$ and (173) $1/2^+$. Similar arguments for the mass-155 activity indicate a spin of $5/2^+$ for Eu^{155} and $7/2^-$ or $9/2^-$ for the ground state of Gd^{155} . In the former case the remaining assignments would be (60) $11/2^-$, (86) $7/2^-$ and (105) $5/2^-$. Although the above level assignments are consistent with the available beta and gamma-ray data, definite character assignments have been made only for the three electric-dipole transitions discussed previously. Unfortunately, the conventional interpretation of log ft values in terms of nuclear spin and parity changes is often ambiguous, since particular configurations may cause a wide variation in the corresponding nuclear matrix elements.^{18,27} In the cases

25. N. Heydenburg and G. Temmer, *Bul. Am. Phys. Soc.* 30, 1, X6.

26. Mayer, Moszkowski and Nordheim, *Rev. Mod. Phys.* 23, 315 (1951).

27. A. de-Shalit and M. Goldhaber, *Phys. Rev.* 92, 1211 (1953).

considered, K capture to the 97-kev level in Eu^{153} and the beta transitions to the 86- and 105-kev levels in Gd^{155} are apparently "allowed", but are slowed down by factors of ~ 100 . This may be attributed to the complexity of the "odd"-parity states in the daughter nuclei, which also accounts for the retardation of the electric-dipole transitions from these states. The majority of the remaining beta transitions involve parity change and are classed as first forbidden. However, the specific spin assignments quoted above must be considered as purely tentative.

Summary

Evidence has been presented for the presence of low-lying electric-dipole transitions in odd-proton Eu^{153} and odd-neutron Gd^{155} . These transitions were identified by their low absolute conversion coefficients measured by a comparison method not requiring a knowledge of the decay schemes involved. These and similar electric-dipole transitions may have been previously overlooked because of their strong similarity to magnetic-dipole transitions. Low-lying E1 transitions have already been reported for several very heavy elements ($Z \sim 90$). The existence of such transitions is contrary to the predictions of the strict Shell Model, but may be correlated with the large nuclear deformations observed in these regions of the periodic table. The present results, as well as independent data on Eu^{153} and Gd^{155} , have been interpreted in terms of the strong-coupling limit of the Unified Model. Although there

is evidence that the strong-coupling limit is not reached in the vicinity of 90 neutrons, ^{16,28} there is little doubt that the qualitative features of the present discussion are correct, and that the present experimental results may be taken in support of the basic features of the Unified Model.

41-7 (The Decay Scheme of Cd¹¹⁷ and In¹¹⁷) (5200-01)

S. Bradley Burson, James M. Cork (University of Michigan), and James M. LeBlanc
Reported by James M. LeBlanc

No further results have been obtained since the previous report was made.

47-5 (The Decay Scheme of 30-min, Pt¹⁹⁹) (5200-01)

S. Bradley Burson, James M. Cork (University of Michigan), and James M. LeBlanc
Reported by James M. LeBlanc

No further results have been obtained since the previous report was made.

49-2 Decay of ₅₀Sn¹²⁵ (9.7-d and 9.4-min) (5200-01)

S. Bradley Burson, Robert C. Doerner and David W. Martin
Reported by S. Bradley Burson

9.7-day: There is no new information to report on the 9.7-day activity.

28. G. Scharff-Goldhaber and J. Weneser, Bul. Am. Phys. Soc.
30, 1, S6.

9.4-minute: In the previous report, a gamma-ray peak was discussed which was found to decay with the 9.4-min. period and to have an energy of about 1.4 Mev. At that time it was presumed to be identical with the 1.41-Mev transition observed in the 9.7-day period. Further studies show this presumption to be in error.

The 1.4-Mev peak is found to be in coincidence with the 0.326-Mev radiation and to have an energy of 1.39 ± 0.02 Mev. This result vitiates the earlier conclusion and further implies the existence of an energy level in Sb^{125} at about 1.71 Mev.

In the normal spectrum, a peak is seen which decays with the 9.4 - min. period and represents a gamma ray of about 0.64 Mev. Because this is approximately the difference in energy between the newly discovered state at 1.71-Mev and the 1.07-Mev state, coincidences with the 0.64-Mev peak were sought and found in the 1.07-Mev region. The 1.07-Mev peak is not resolved in the normal distribution because it is "washed out" by the Compton distribution of the stronger 1.39-Mev gamma ray.

These results are sufficient to establish a new level at 1.71-Mev in Sb^{125} and to show that the 1.07-Mev gamma ray is common to both of the activities of Sn^{125} .

to 10 ev. A monochromatic neutron beam from CP-5 is obtained with a beryllium crystal. Gamma rays will be studied with two NaI (Tl) scintillation counters at right angles to the neutron beam.

Preliminary studies have indicated that extensive shielding is needed for the scintillation counters. At present the shielding is being engineered. The shield will contain approximately eight inches of lead, one inch of boron carbide, and six inches of paraffin, will weigh seven and one-half tons, and will move on a track at the end of the monochromator arm.

60-9 (7.7-Meter Bent Crystal Spectrometer) (5200-01)

Bernard Hamermesh and David Rose
Reported by Bernard Hamermesh

During the past quarter the instrument has been virtually completed.

The track sections were mounted and the crystal table drive was corrected. The lapping of the crystal clamp blocks was finished and a focal length of about 7.72 meters was found.

The assembly of the instrument at CP-5 is complete except for the quartz crystal. The crystal is expected momentarily. The coupling of the electronic and mechanical systems is well underway.

It is hoped that the instrument will be put into operation during the next quarter. In addition, a report describing the instrument should be completed.

70-9

Measurement of Nuclear Moments by Angular
Correlation (5200-01)

Victor E. Krohn and Sol Raboy
Reported by Victor E. Krohn

A. Am²⁴¹

The major part of this quarter was spent in amassing more data about the $\alpha - \gamma$ correlation of Am²⁴¹. The attenuation of the pattern in liquid media was studied extensively using two sets of apparatus. Coincidence circuits with resolving time 5×10^{-8} sec. and 10^{-8} sec., respectively, were used. The gyromagnetic ratio of the 7×10^{-8} -sec. Np²³⁷ state was measured by several different methods.

B. Pb²⁰⁴

No work was done on the prompt coincidence (374-899 kev) gamma rays in Pb²⁰⁴. It is planned to do this next with a coincidence resolution time of 5×10^{-8} sec. It is hoped that inelastic scattering of fast neutrons will make the one-hour 2.2 Mev state. Lead, enriched in the 204 isotope, will be used.

C. W¹⁸⁷

No work was done on this isotope but it is next on the list after the Pb²⁰⁴ prompt decay. The apparatus is essentially automatic now; this will serve to reduce the tedium involved in the measurement of the W¹⁸⁷ $\gamma - \gamma$ correlation.

John A. Dalman, Leonard S. Goodman, Sol
Wexler

Reported by Leonard S. Goodman

a. Atomic beam magnetic resonance studies of radioactive 50-d. $\text{In}^{114\text{m}}$ are underway. Resonances of the atomic $P_{1/2}$ state have been found at 7.299 ± 0.020 , 14.650 ± 0.020 and 27.847 ± 0.020 Mc/sec. for homogeneous magnetic fields in which In^{115} resonances were observed at 8.000 ± 0.010 , 16.061 ± 0.010 , and 30.455 ± 0.010 Mc/sec. respectively.

The spin is thus established as $I = 5$; the magnetic moment, $\mu_n = 4.6 \pm 0.1$ n.m. and the hyperfine splitting, $\Delta = 9650 \pm 100$ Mc/sec.

The studies were somewhat complicated by the observation of multiple quantum transitions¹ in both active and inactive material.

b. Work on $\text{In}^{114\text{m}}$ is continuing. We have hopes of measuring $\Delta F = 1$ transitions of the $P_{3/2}$ atomic state near zero field and thus of measuring the electric quadrupole moment.

We are planning to try to make measurements on the ground state radioactive 72 s In^{114} . Because of the short half-life, the active beam will be condensed on a metal tape at liquid nitrogen temperature and moved under vacuum to a scintillation counter. The tape mechanism has already been designed and fabricated. Counting equipment is on order from the Electronics Division. Calculation shows that it should be

1. V. Kusch, Phys. Rev. 93, 1022 (1954).

feasible if we can obtain an M. T. R. irradiation. We have written to Mr. Lewis at M. T. R. to find out details of obtaining such irradiations.

Work on 54-m. In^{116} will follow the 50-d. $\text{In}^{114\text{m}}$ studies. Plans are to irradiate the sample in a graphite oven, thus eliminating the radioactive hazards and the delay associated with transferring the sample.

It appears to be feasible to make atomic beam measurements of 4.5-h. $\text{In}^{115\text{m}}$. The source preparation has been the big problem up to now. Pile irradiation near a rod to make use of the inelastic (n, n') events would produce large backgrounds of $\text{In}^{114\text{m}}$ and In^{116} .

The 53-h. Cd^{115} β^- decays to $\text{In}^{115\text{m}}$, with 60-80% going to the metastable state. The $\text{In}^{115\text{m}}$ can be taken out of the Cd by using In carrier and doing fractional distillation. Experiments will have to be made to test the feasibility of the separation procedure. We do know, however, that Cd vapor pressure is well over an atmosphere at a temperature at which In vapor pressure is less than 0.1 mm. It is important, in order to prevent neutron flux depression, to use Cd in which the Cd^{113} isotope is depleted. The Special Materials Division is writing to M. T. R. to try to obtain some "burnt out" Cd control rod material. Such material would have low Cd^{113} isotopic content and would be enriched in the Cd^{114} isotope.

90-9

Cross Sections for 14-Mev Neutrons (5200-01)

Louis A. Rayburn, Leonard S. Goodman
Jack Haugsnes and Harvey Casson
Reported by Louis A. Rayburn

During the last quarter a fast coincidence circuit of the Fischer and Marshall 6 BN6 gated beam tube type was delivered. RCA-6342 photomultiplier tubes are used in the circuit, which is to be used in the angular distribution measurements of elastically scattered 14-Mev neutrons. The circuit was constructed by R. Epstein of the Electronics Division. Several minor modifications resulted from thoroughly testing the circuit in our experimental arrangement. Measurements using the time of flight of 14-Mev neutrons indicate a resolving time of 2.5 millimicro-seconds. A spectrometer table, to be used in the angular distribution measurements, has been constructed and placed into position. An angular resolution between 2 and 3 degrees is expected. Measurements relative to the selection of the proper shield for the neutron counter (that is, shielding the neutron counter from the direct neutron beam) are now in progress. Angular distribution measurements are expected to begin after the shield has been placed in position and some final adjustments are made on the spectrometer table.

A preliminary value of the total cross section of hafnium, $\sigma_t = 5.72$ barns, has been obtained using the method described in the last progress report. Sample collection and fabrication for other total cross-section measurements have been in progress. All of the preliminary measurements incidental to the total cross-section measure-

ments have been completed and these total cross-section measurements are now in progress.

91-9

Neutron Transport Cross Sections, Angular
Distribution of Scattered Neutrons (5200-01)

Raymond O. Lane and Alexander Langsdorf, Jr.
Reported by Raymond O. Lane

The analysis and reduction of all data from the apparatus (ANL-5317, pgs. 37-40) for the measurement of the angular distribution of scattered neutrons has continued. The first test results of the analysis of data as computed on the AVIDAC agree well with hand-computed results. Steps are now under way to have all the data of the first and second runs analyzed on the AVIDAC. A discussion of these runs will be found in the previous report, ANL 5420.

a) Comments on Corrections

The feasibility of an analytic method of making the plural scattering correction to the data is currently being studied.

Experiments have shown that the correction due to the back scattering of neutrons from the face of one of the detectors into the collimator of an opposite one amounts to two per cent of the counting rate in the opposite detector.

A third run similar to the first two is planned for the near future with samples of several additional elements.

Consideration is being given to the desirability and practicality of placing the detectors on a circular track allowing a convenient flexible choice of angles for observation.

A preliminary experiment on resonance scattering from sodium is being planned employing the present arrangement of the apparatus. It is hoped that results of such an experiment will be definitive enough to make parameter assignments with considerably less ambiguity than is afforded by total cross section measurements.

98-9

Neutron Cross Sections in the Kev Region (5200-01)

Carl T. Hibdon

No further measurements of cross sections were made during the quarter.

Before continuing on with measurements for analysis of resonances, the cross sections of Cr, Fe, Ti, Al and Na over as wide energy range as possible are to be measured, since these cross sections are desirable for reactor designs. When the counting equipment is again in position for high energy measurements, the resonances of the lithium isotopes near 250 kev will be re-investigated.

The counters of the shielded detector are being tested. Faulty ones are being replaced by new ones.

102-6

(Neutron Cross Section Measurements by the Self-
Detection Technique) (5200-01)

James E. Monahan

There is nothing further to report on this subject.

108-3

An He³ Neutron Spectrometer (5200-04)

Frank Lynch

Experimental work on construction of alumina porcelain to Kovar brazed insulator assemblies for a high pressure proportional counter is delayed because a vacuum furnace is not available. One atmosphere liter of He enriched with 4% He³ has been ordered from Oak Ridge. It is expected that there will be present an objectionable quantity of H³ in the gas. The counter will be filled by slowly passing the gas through a liquid He cold trap.

The machine shop is constructing a simple magnetic solenoid pump which will be used in the high pressure filling system to re-circulate gas through a hot copper purifier.

A regulating circuit for the 10,000-volt supply which has been constructed is being tested. A fixed portion of the d. c. output and a standard cell are alternately connected into the input of an a. c. amplifier by means of a chopper. The difference signal, of 60 cps. fundamental frequency, is introduced into the primary of the power transformer in series with the line. Regulation of 0.1% has been obtained, but the stability and speed of response is not satisfactory.

114-9

Development of a Recoil Type Neutron Spectrometer
(5200-04)

Gilbert J. Perlow

The double proportional counter recoil spectrometer described in previous reports was altered slightly to permit changing the pressure at the measurement site. For this purpose, a mobile evacuation, gas purification and filling system was constructed. In addition, the proton-recoil collimator was changed in order to accept larger scattering angles and hence to improve the efficiency. It had been determined previously that the resolution was worse than that predicted by the collimation alone. This proved still to be the case with the wider angle collimator.

A trial was had at the Van de Graaff generator in late February using neutrons from the $\text{Li}^7(p,n)$ reaction. To conserve machine time a set of runs was taken with relatively wide (5%) channel-width settings on the pulse-height analyser. Using counter pressures of 1.84, 4.77 and 13.70 cm. Hg., with a CH_4 filling, good peaks were obtained for neutron energies between 43.5 Kev and 1 Mev. With 2% channel-widths the resolution was tested at 250 and 350 Kev. The width at half maximum was 10%.

The low energy tail found in previous runs at the higher pressures and energies was reduced in the present case by the use of the wider-angle collimation as expected. It was, however, still of sufficient strength to mask the lower energy neutron group (abundance $\sim 10\%$)

corresponding to the first excited state in Be^7 .

With the aid of Leslie Merrill, some calculations were made on the effect of double scattering on the pulse-height distributions. The probability increases as the pressure squared and sets an upper limit to the usable pressure, and hence to the measurable energy. This limit is below 2 Mev.

The system of comparison of electronic pulse-height for rejection of the recoils produced by too energetic neutrons is reasonably successful, except that the efficiency is reduced too much for many problems. A new counter has therefore been designed using an anti-coincidence chamber following the second proportional counter. The shop work has been completed but the counter not yet fully assembled.

115-5

Boron Trimethyl

(5200-02)

Louis Basile

As was reported in the previous quarterly report, ANL 5420 , a supply of boron trimethyl gas was ordered from a commercial source. We are awaiting shipment of the gas from the company.

133-9

Design Study of a Multi-Bev Proton Accelerator

A. Space Charge Effects in Mark Ib FFAG - Melvin Ferentz

The ideas of Laslett (LJL(MAC)-2) with regard to the effects of space charge in an AGS are applied to the case of a Mark Ib FFAG machine.

B. Approximate Treatment of Field and Misalignments for FFAG -

Edwin A. Grosbie

The methods of analysis to determine the effects of errors and misalignments in an AG accelerator, previously derived by Courant and Snyder and by Hamermesh, are altered to become applicable to an FFAG machine.

C. Examination of Methods for Increasing the Beam Intensity from FFAG Accelerator - Morton Hamermesh and
John J. Livingood

Symon has suggested (MURA-KRS-6) that the frequency range of the oscillator in an FFAG accelerator can be reduced by running the oscillator repeatedly over a modest frequency range, each pass being a lower multiple of the rising rotation frequency. This proposal is studied, and it is shown that since the time duration of all frequency passes must be identical, the energy gained per turn in the initial stages must be unduly reduced, with a consequent large loss of ions because of gas scattering. Alternative schemes obviating this difficulty are suggested, employing separate sets of oscillators at different radii and azimuths.

134-1 Atomic and Molecular Excitation Following β -decay of Tritium (5200-02)

Sol Wexler

In negative beta emission the recoiling atom carries at

least a single positive charge as a result of the increase in Z . In addition, the ion may be electronically excited, or even multiply ionized. This behavior results from the sudden change of coulombic field experienced by the electronic cloud surrounding the nucleus and is caused by the rapid exit of the beta from the atom. The subsequent reorientation of the electron shells to fit the $Z + 1$ nucleus may promote a K-electron to a bound excited level consistent with the Pauli Principle or to the continuum. Similar events may occur in shells more distant from the nucleus. Several calculations have been made of the probability of hole formation in the K- and outer shells due to this effect, and order of magnitude agreement has been obtained with experiment only for the K-shell studies.

Exact theoretical treatment appears to be possible only for the case of atomic tritium. Probabilities that the $(\text{He}^3)^+$ ion formed in the β^- transition will be in various excited electronic states have been evaluated. It would be of interest to check one of the finer details of the "sudden change of nuclear charge" theory by attempting to demonstrate the presence of several of the excited states of $(\text{He}^3)^+$ following β^- decay of H^3 . This may be done by observing certain optical transitions of the singly ionized He^3 , the radiation lying in the spectral region from $2500 \text{ \AA}$ to $6500 \text{ \AA}$.

Literature studies and calculations are currently being conducted to determine the feasibility of this experiment. The following are some of the problems being considered: -

1. The best method of producing atomic tritium from T_2 .
2. Steady state concentration and lifetime of the atomic state in relation to the pressure of the T_2 , the surface of the containing vessel, the beta particle density, etc.
3. The geometry of the extended gas source which throws the largest fraction of its radiation into the fast spectrograph available.
4. Sensitive detectors in the visible region.
5. Handling and purification of approximately 50 curies of tritium.

When the beta-emitting atom is part of a molecule the molecular ion formed may appear in an excited vibrational-rotational state following the transition. This effect is due to the recoil of the decaying atom. The simplest case, that of $T:T \rightarrow (T \cdot He^3)^+ + \beta^- + \gamma$, has been studied theoretically in some detail. The probability that the molecular ion will be found in each of several vibrational states of the ground electronic level has been evaluated; in addition, the energies of these states have been estimated. Similar calculations have been performed on the molecular ions formed in the beta decay of $H:T$ and $D:T$.

A direct test of the theory would be the demonstration of the existence of these vibrational levels by observing the corresponding

spectra, which is in the measureable near infra-red (3.0 to 7.5 μ wavelength region). Further, the relative intensities of the various spectral bands may serve to check the transition probabilities estimated in the theory.

At present effort is being directed toward literature searches and calculations to determine if the experiment has a possibility of being successful. Some of the considerations being made are:-

1. Best geometry of the extended gas source and the needed source strength.
2. Available infra-red equipment.
3. Possible non-radiative processes which compete with the looked for transitions.

135-8

(Electron Neutron Interaction)

(5200-04)

G. R. Ringo

No work has been done on this problem during this quarter.

139-1

Liquid Scintillators

(5200-02)

Warren L. Buck and Robert K. Swank
Reported by Warren L. Buck

Certain types of liquid scintillators exhibit relatively inefficient high-energy-induced fluorescence, due (a) to the use of a solvent (e. g., an alkyl borate) which does not readily transfer excitation

energy to the dissolved fluor, or (b) to the presence of an additive (e. g., a metallo-organic compound) which may give rise to pronounced quenching of excitation energy in the usual solvents.

It has been reported that the light output from such liquid scintillators may, in some cases, be enhanced considerably by the addition of naphthalene to the solution¹. When added to a solution wherein solvent-to-solute energy transfer is otherwise inefficient, it appears that the naphthalene serves as a "bridge" over which such transfer may occur more readily and that the excited naphthalene molecules are also relatively immune to quenching.

The fact that naphthalene is a solid having only limited solubility in various solvents may, in some cases, present a limit to the effectiveness of its use in this manner. For this reason an investigation has been undertaken of various liquid or low-melting naphthalene derivatives which, it is hoped, may yield liquid scintillators with more efficient energy transfer and greater immunity to quenching. Currently an attempt is underway to purify commercially obtained methyl-and dimethyl-naphthalenes for use in this investigation.

Tests are also being made using mixed liquid solvents composed largely or entirely of compounds which are, by themselves, solids at room temperature. For example, naphthalene melts at about 80°C.

1. M. Furst and H. Kallmann, Phys. Rev. 97, 583-7, (1955).

and biphenyl at about 70°C. However, a mixture formed by melting together two parts (by weight) of naphthalene and three parts of biphenyl remains liquid above about 38°C. Addition of as little as two parts of toluene results in a liquid mixture suitable for use at room temperature. This mixed solvent was found to give the following results (compared to pure toluene as solvent) when activated as indicated and exposed to radiation from Cs¹³⁷:

<u>Solvent</u>	<u>Activator (solute)</u>	<u>Relative light output</u>
Biphenyl, naphthalene, toluene (in ratio 3:2:2 by weight)	PPO (6 g/liter)	0.49
"	PBD (13 g/liter)	0.57
"	None	0.05
Pure toluene	PPO (6 g/liter)	0.38
" "	PBD (13 g/liter)	0.50
" "	None	0.003

In the above table, PPO denotes 2,5-diphenyloxazole, and PBD denotes 2-phenyl-5-(4-biphenyl)-1, 3,4-oxadiazole. The concentrations indicated are those found to give maximum light output. The standard anthracene crystal gives a relative light output of 1.00 on the same scale.

Charles Egger and Charles M. Huddleston
Reported by Charles M. Huddleston

Until recently it was necessary to use plastic color shifters or a gas color shifter (nitrogen) in order to convert the primary light generated in noble gases by alpha particles into the visible region to allow detection by a photo-multiplier tube. Now it has been found that one can look at the primary light directly by using a quartz or CaF window and an E M I photo-multiplier tube with a quartz envelope. In this manner a stable counter is obtained with a resolution of 15% at 5 Mev when the gas cell is filled to a pressure of 60 p. s. i. g. with krypton.

A group at Los Alamos¹ has employed the gas scintillation technique to measure fission excitation. They used a xenon counter with quaterphenyl in VYNS as a color-shifter. Our subsequent experiments with quaterphenyl indicate it is not a much better wavelength shifter than TPB for krypton and lighter noble gases, except that it shows less tendency to poison. We have a small supply of xenon and are trying to acquire some VYNS resin in order to determine whether significant improvement can be achieved.

1. R. A. Nobles, R. L. Henkel, and R. K. Smith, Bul. Am. Phys. Soc., 30-3, (April 1955), and R. A. Nobles, private communication.

142-3

(Electron Accelerator)

(5200-02)

H. B. Phillips

No progress was made during this quarter because of priority given to work in the School of Nuclear Science and Engineering.

143-3

Plastic Scintillators

Louis Basile

Loaded Plastic Scintillators with Heavy Elements

We are investigating the effects of the addition of various metallo-organic compounds upon the relative light output of plastic scintillators. Thus far, one compound, diphenylmercury, has been studied. Tentative results indicate that this substance acts as a quencher.

The purity of the metallo-organic compound has a very marked effect on the light output. The diphenylmercury that was commercially available proved to be very impure. The material was purified by repeated recrystallization from solvents and finally by vacuum sublimation. Unfortunately, as work progressed, it was observed that diphenylmercury turned yellow on standing. This definitely indicated that a reaction of some sort was taking place. We are resubliming the compound and storing it under an inert atmosphere for future use.

In view of the fact that diphenyl mercury discolors on standing, not much can be said about the results that have been obtained. Quantitative data are meaningless since precautions for preventing the dis-

coloration from taking place were not taken. Some general trends were observed which will be discussed qualitatively. We feel that these trends will prove to be characteristic of metallo-organics in general.

Addition of a small amount of diphenylmercury to polyvinyltoluene, which contains some fluor-additives, decreases the relative light output. Increasing the concentration of diphenylmercury decreases the light output markedly. Of the fluors tried thus far, addition of 4% terphenyl and 0.10% tetraphenylbutadiene gives the best results. If diphenyloxazole is used as the fluor additive, much lower light output is obtained. An effect on the relative light output is observed when naphthalene is added. If diphenyloxazole is used as the fluor, addition of naphthalene results in a small increase in light output. With terphenyl, and terphenyl plus tetraphenylbutadiene, a small decrease in light output is observed with addition of naphthalene.

These experiments will be repeated and extended using conditions which we hope will prevent the decomposition of diphenylmercury. The study will also be extended to other metallo-organic compounds.

Boron-Loaded Plastic Scintillators: During the past quarter we have not worked on boron loaded plastics. We do not plan to work on this phase of the program in the coming quarter.

144-3

Scintillation Counter Techniques

(5200-02)

Robert K. Swank and John S. Moenich
Reported by Robert K. Swank

The technique for canning sodium iodide crystals has been modified to permit the canning of larger crystals. In these cans, a partial vacuum inside serves to hold the crystal securely in optical contact with

the glass window. For small crystals, evacuation is accomplished by bringing the assembly together inside a vacuum dessicator. To extend this technique to crystals larger than 3-1/2 inches diameter would require a larger dry box than is now used for this purpose. A can was made with a tapered hole in the sidewall, parallel to the axis of the cylinder. This blind hole was connected to the interior of the can by drilling a second hole from the inside of the can at right angles to the first at its base. This hold can then be used for evacuation of the can, using a hypodermic needle tapered to fit the hole as an exhaust tube. After the can is evacuated, the exhaust tube is pulled out, and a solid plug placed into the hole. Air is prevented from entering the hole during this process by liberal application of a viscous silicone fluid. A four-inch diameter crystal was canned by this process.

Twenty-nine photomultipliers were potted and six crystals were canned during this quarter.

145-2

Organic Crystal Scintillators

(5200-02)

Robert K. Swank and Warren L. Buck
Reported by Warren L. Buck

During this quarter four boules of activated 4-methyl-biphenyl crystal were prepared and tested, each boule being 20-25 cm. long and about 1 cm. in diameter. The activated boules were grown using the zone-melting technique described in our report for the preceding quarter, resulting in a gradual change in activator concentration along the length of

of the boule. Relative scintillation light output from thin, transverse sections of each boule was measured with the photomultiplier-electrometer equipment which was also described in our preceding report. Finally, the activator concentration in each section was measured by a spectrophotometric technique.

The first boule was activated with 1, 1, 4, 4-tetraphenyl-1,3 - butadiene, a fluor which has found considerable use in plastic scintillators. Activator concentrations ranged from about 0.05% down to less than $10^{-4}\%$, with scintillation light output varying from 0.06 to 0.09 (compared to 1.0 for a standard anthracene crystal). Light output appeared to decrease with increasing activator concentration, over the range studied.

The three subsequent boules were activated with 2,5-diphenyloxazole, in concentrations ranging from about 1% down to $\sim 10^{-3}\%$. Light output was found to increase with activator concentration, the highest value obtained being approximately 0.30 (relative to anthracene crystal). For higher concentrations of diphenyloxazole the mixture appears to crystallize heterogeneously, and evidence was obtained to indicate that for sufficiently high concentrations of diphenyloxazole the molten mixture will remain liquid at or below room temperature.

A fifth boule was grown from pure (unactivated) 4-methylbiphenyl. The scintillation light output (relative to anthracene) was found to be about 0.09, independent of the location along the boule.

In all cases, the crystals were found to be quite soft and were easily cleaved or shattered. Also, they were difficult to polish, and they tended to lose weight and to develop a cloudy surface if left exposed to air. At the present time it is felt that 4-methylbiphenyl is not likely to yield efficient crystal scintillators of practical value.

146-3 A Rotating Condenser Electrometer (5200-02)

Frank Lynch

A complete electrometer incorporating the rotating condenser convertor is nearly finished. It consists of a low frequency amplifier and a synchronous detector. The synchronizing signal for the detector is obtained from a PbS photoconductor which receives light modulated by the rotating condenser.

147-2 A Reliable Alpha Air Proportional Counter (5200-02)

Frank Lynch

The final draft of a report on this topic is being worked on, measurements, drafting and photographic work having been completed.

148-3 Electrical Conduction in Dielectrics (5200-03)

Raymond J. Munick

Most of the quarter has been devoted to refining the experiments in several promising ways. One promising line is improvement

of the measurement of the steady currents, with emphasis upon the independence on temperature and voltage. More convenient and more precise temperature measurement and control over the range of 25 to 90° C were achieved with the use of thermistors as the heat-sensitive elements. The precision of relative current measurements was improved by using a Leeds and Northrup Type K-2 potentiometer to measure the voltage required to nullify the potential drop produced across a multimegohm resistor by the current, the resistors themselves being compared in a disguised Wheatstone bridge. An Applied Physics Corporation vibrating reed electrometer is used as null detector for the above arrangements and as a direct reading instrument when changes with respect to time are followed on a Brown recording potentiometer connected to it. The Type K-2 potentiometer is also used to determine the voltages of batteries before and after use.

With the improved setup, considerable data were obtained from four specimens of Plexiglas, which is a brand of polymethyl methacrylate similar to Lucite or Perspex. Two of these 0.1-cm thick specimens were coated with colloidal carbon electrodes, two with evaporated aluminum electrodes. The gross features of interest are the following. From 25 to 75° C the steady current is better fitted by an expression of the form $AT^C \exp(-B/T)$ than by a simple exponential, T being the absolute temperature and A , B , and C being constants. At a constant temperature around 60° C the steady current obeys Ohm's law for voltages from 300 to 2400, which are far below breakdown. Even though the carbon-coated

specimen is maintained at constant voltage at a constant temperature above 60° C, there is a noticeable exponential decrease of steady current with time. The time constant is about 10 days at 75° C and increases as the temperature is lowered. A tentative conclusion, which provides a viewpoint for examining these and other features more closely is that the steady current through Plexiglas is electrolytic.

Less time was devoted to one of the other promising lines of investigation, that of extending the time-dependent measurements to times from 10^{-3} to 10^2 sec. to overlap vibrating reed electrometer data from 10 to 10^4 sec. in order to determine the limits of validity of the t^{-n} decay of current (t is the time after voltage change and n is a constant). Some modifications to the electrometer circuit that couples specimen to oscilloscope were tried, with little improvement in the functioning of the setup. Plans have been made for revising the entire circuit.

The writing of an article on the electrical behavior of Lucite, Fluorethene, polyethylene, polystyrene and Teflon, based on the results already obtained, has been started.

149-1

Dynamic -Condenser Magnetometer

(5200-02)

S. Bradley Burson, Robert C. Doerner and
David W. Martin
Reported by S. Bradley Burson

The storage battery previously used to energize the magnet of the 180° beta-ray spectrometer was replaced with an electronic current

supply. It was found that, using this supply, it was no longer possible to establish a fixed hysteresis loop by varying the magnet current through a given cycle. It was therefore decided to procure a magnetometer in order to measure the field directly.

A type of magnetometer has been designed which employs a rotating coil within the field to be measured. Unlike most instruments of this type, it does not employ Helmholtz coils as a reference. A dynamic condenser is mounted on the same shaft as the rotating coil, both being driven by a 1800-R. P. M. synchronous motor. The condenser is composed of two stator sections juxtaposed on either side of a plane passed through the axis of the shaft. These stator sections are maintained at a fixed D.C. potential symmetrically above and below ground. Each section is isolated by means of a high-valued resistor, but the two sections are maintained at the same A.C. potential capacitatively. The plates of the rotor are shaped so that the potential of the rotor follows a sine wave when undergoing uniform angular motion. The rotor is insulated from the shaft and connected to one side of the rotating coil. The other side of the coil is connected directly to the shaft, which in turn is grounded by means of a slip ring. Any unbalance between the E. M. F. produced in the rotating coil and the E. M. F. generated by the condenser produces an A.C. current in the system which is picked off the isolated stator sections. A synchronous detector will be used which will enable detection of the null which is established when the applied D.C. potential is sufficient to balance the E. M. F. produced in the rotating coil. The synchronous detector will also indicate a phase

shift when unbalance is present. This shift of phase can be used to operate appropriate servomechanisms which will automatically adjust the field current. The magnetometer is now under construction in the machine shop.

II. MASS SPECTROSCOPY

1-9 (Mass Spectrometric Techniques) (5200-02)

Mark G. Inghram

There is nothing to report for this quarter.

2-9 (Construction and Operation of Ma-17) (5200-02)

Henry E. Stanton

Only normal maintenance was maintained during
this quarter.

Separate reporting on this topic will be discontinued.

10-9 (A Search for Rare Naturally Occurring Isotopes) (5200-01)

David C. Hess

Nothing much has been accomplished on this program
this quarter. A surface ionization source has been installed but only
testing has been done.

12-9 (Double Beta Disintegration of Te ¹³⁰) (5200-01)

Mark G. Inghram

No further reports will be made on this subject.

14-9 (Fission Yield Determinations) (5200-01)

Mark G. Inghram

No further reports will be made on this subject.

17-4 Long-Lived Activities (5200-01)

David C. Hess

Approval has been obtained for heavy neutron bombardments of several elements in the MTR. Some samples have been encapsulated in quartz and will be sent out shortly.

The samples being bombarded in EBR are still in the reactor.

18-1 Lead Ages of Meteorites (5200-01)

George Edwards (Institute for Nuclear Studies)
and David C. Hess
Reported by David C. Hess

Wet chemical methods as applied to extraction of lead from meteorites are slow and difficult. Contamination control requires that hundreds of ml of reagents be treated to decrease their lead content below certain limits. The whole process is such that it may take many days to separate the lead from a single meteorite sample. Since it has been found that the total contamination is roughly proportional to the processing time and therefore is probably due to air borne lead, careful control of the atmosphere in the laboratory is necessary.

In an attempt to speed up the process of separating out the lead, one of us (GE) has applied a method,¹ previously described for extracting potassium from meteorites, to this problem. This technique requires only a few grams of reagents and promises to reduce the total time required to perform a lead separation to a few hours, as well as to simplify the problem of obtaining lead-free reagents.

The process briefly consists of separation of the volatile chlorides by evaporation at about 1300°C from a graphite crucible with the chloride supplied by calcium chloride. The chlorides, lead with the remainder mostly iron, are dissolved and the lead precipitated as the sulfide with a copper carrier. The sulfide is re-dissolved and the lead electrolyzed as lead oxide onto the anode of an electrolytic cell. This final product is again converted to the sulfide and deposited on the tantalum filament of a single filament surface ionization source for use in the mass spectrometer.

In order to study the process a sample of Holbrooke meteorite was treated and the lead run on the 12-inch 60° spectrometer (MA-15). A large amount of lead was found which appeared to be normal lead. Investigations were made to track down the sources of contamination if this result was due to other than meteorite lead.

1. G. Edwards and H. Urey, *Geochim. et Cosmochim. Acta* 7, 154 (1955).

During these tests it was found that the meteorite sample used had been sieved through a soldered mesh. However, since several small sources of contamination were found, it was felt that these should be eliminated to prevent further questions.

By "spiking" with a known amount of lead sample containing about 90% lead-206, 7% lead-207 and 3% lead-208,² it was possible to measure the total amount of lead contributed by various parts of the system. For example, a crucible was ashed by induction heating in an oxygen atmosphere. Lead was extracted from the residue. About 1.25 μ g is present in the crucible. The calcium chloride contributes about 1 μ g and the rest of the reagents about 2 μ g. Attempts are now being made to reduce these contributions.

Since the total amount of lead in the Holbrooke sample was greater than could be accounted for as coming from the reagents, it must be assumed that either the sample was contaminated or this meteorite contains much more than the usual concentration of lead found in meteorites.

2. Obtained from R. J. Hayden and G. J. Wasserburg

28-2

(Adsorption of Mixtures of He³ and He⁴) (5200-02)

Mark G. Inghram

No further reports will be made on this subject.

29-3

Gaseous Species in Equilibrium with Metal-Metal
Oxide Systems (5200-02)

Mark G. Inghram, William A. Chupka and
R. F. Porter (University of Chicago)
Reported by William A. Chupka

Gaseous species in thermodynamic equilibrium with BaO solid have been studied. Positive ions were produced by electron bombardment of vapor effusing from a Knudsen cell and were analyzed by a mass spectrometer. At cell temperatures between 1500° K and 1800°K, ion currents of Ba⁺, BaO⁺, Ba₂O⁺, Ba₂O₂⁺, and Ba₂O₃⁺ were observed. The variations of ion intensities with temperature were measured and appearance potential curves were obtained. Evidence for the existence of gaseous molecular species of BaO, Ba₂O, Ba₂O₂, and Ba₂O₃ was obtained. The major molecular species effusing from the cell was BaO. A thermodynamic treatment of ion currents yields the following heats of reaction:

SrO and MgO solids were investigated in the same manner.

In the SrO system, the ions observed were Sr^+ , SrO^+ , and $\text{O}_{1/2}$ in the relative amounts 300:1:36. In the MgO system, Mg^+ was the major ion observed. A thermodynamic treatment of the ion currents yielded a value of $\Delta H^\circ_{298} = 155.1 \text{ kcal/mole}$ for the sublimation of SrO (g) and a lower limit of 149.4 kcal/mole for the ΔH°_{298} of sublimation of MgO.

These results have been published in two articles, J. Chem. Phys. 23, 1347 (1955) and J. Chem. Phys. 23, 2159 (1955).

30-9 The Heat of Vaporization of Carbon (5200-02)

Mark G. Inghram

No further reports will be made on this subject.

31-9 (Studies of Electron Impact) (5200-02)

William A. Chupka and Henry A. Stanton
Reported by Henry E. Stanton

No work has been done on this subject during the past quarter.

34-9 Argon Age Determinations (5200-01)

Richard J. Hayden

No further reports will be made on this subject.

William A. Chupka and Henry E. Stanton
Reported by Henry E. Stanton

According to Hagstrum (R. M. P. 23, 185 (1951)), when the CO molecule is bombarded with electrons of proper energy, O^- ions are formed. If the electron energy is increased from a low value the O^- ions first appear at around 8 v., rise through a maximum at about 9 v. and disappear again at approximately 12 v. If the increase in electron energy continues, the ions reappear again at about 21 v. and continue to increase in numbers up to a hundred volts and beyond, in the usual manner. It was this resonance phenomenon which was particularly under study in MA-17 because of its relationship to the carbon-oxygen bond and related energies.

The experiments to be described, however, failed to confirm or deny the existence of this resonance, due to bombardment peaks which partially masked the phenomenon sought.

The source arrangement is shown in Figure 5. Electrons are supplied by a tantalum cathode which was heated by electron bombardment and radiation from the filament. Voltages up to 1500 v. were maintained between the filament and cathode to supply the energy necessary to heat the cathode to emitting temperatures. The cathode was electrically connected to the thick plate marked J_1 and was mounted in it in a way to approximate an equipotential plane. The plates designated J_2 and J_3 were

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NEGATIVE ION SOURCE

FIGURE 5

PHG-1030
5-18-56
B.G.

provided with slits to admit the electrons and permit escape of the negative ions formed between them. A piece of pyrex tubing was placed between these two plates and gas was supplied to the volume so enclosed from outside of the machine through the indicated side tube. The plates J_4 and J_5 permitted side deflections of the ion beam by varying the applied voltages between them, J_6 was a focussing plate, and the beam was brought to a sharp focus at the fine slit in the plate marked "Elbow". This slit was the source for the electrostatic deflecting system of the spectrometer.

In this experiment, the machine was operated as an energy selector which meant that initial ion accelerations were around 500 v. (J_1 - Elbow voltage) or less, electric analyzer deflecting potentials were around 70 - 75 v. and final accelerations of from 2-6 kv. were applied between the electric analyzer and the magnetic analyzer, this acceleration depending on the mass of the ion in question. Since negative ions were used, the electrode J_1 was negative with respect to the elbow, J_2 and J_3 were carefully controlled and the other electrodes were supplied with voltages to suitably focus the beam.

In principle, electrons leaving the cathode would pick up energy in traversing the space between J_1 and J_2 , generally, and those that entered the slit into the gas chamber would continue to pick up energy between J_2 and J_3 . Consequently by suitable adjustment of the potential in J_2 and J_3 with respect to J_1 , electrons with energies between known limits could be introduced into the gas chamber.

In the event of ion formation which depends critically upon electron energy, these ions would be formed in a well-defined region in the gas chamber, and at a well-defined potential with respect to J_1 , and consequently with respect to the "elbow", so that the initial acceleration of such ions would depend upon the electron energy necessary to form them. This initial ion energy could be resolved, presumably, from other ion energies which might also be present.

Results

In practice the theory of operations as outlined above was generally observed. A typical trace, characteristic of many runs, is shown in Figure 6. The abscissae represent the potential difference of the electric analyzer plates necessary to permit ions of a given energy to enter the magnetic analyzer. The total energy of the ions as they leave the electric analyzer is related to this by the design of the machine and in MA-17 is about seven times the value of the abscissa.

The two large peaks shown are for O^+ ions which were formed at the source plates indicated. In the particular trace shown, J_1 and J_2 had the same potential so only a single peak appeared. The J_3 peak, which is quite broad (half width representing about 14 v. spread in ion kinetic energy), indicated a machine constant of from 7 to 7.5 since it appears from 7.5 to 8 volts lower in deflection voltage and the measured energy difference was 55 volts.

FIGURE 6

These two peaks are presumed to arise from positive ion bombardment of the plates indicated. Electrons emitted from the cathode pass completely through the gas chamber and into the $J_4 - J_5$ region. Thus they form positive ions in the background gas. These ions are accelerated back toward the cathode and cause O^- emission by bombarding the plates. By proper adjustment of the electrode voltages, the number of peaks observed were from one to three in number, and their abscissal positions were at the discretion of the experimenter. These secondary ion bombardment peaks were quite troublesome.

The process of resonance capture should have produced a peak of O^- ions at energies at from $10/7$ to $12/7$ lower voltages in the electric analyzer than the J_2 peak. In the particular sample shown in Figure 5 one would assume that the lowest energy ions from the J_2 electrode are at about 82.8 v. and subtracting off 1.5 v. the resonant O^- peak would be expected to occur at about 81.3 v. This is close to the minimum of the trace and differs from zero only by the statistical background. Any peak of this origin was certainly too small to be observed in this case. The high energy tail of the J_6 peak (which is characteristic of ions formed by bombardment on surfaces) was chiefly possible for the background, although some gas scattering of the $J_1 - J_2$ peak is also evident, and may have increased the background.

Numerous runs were made with CO and O_2 as the gases, with varying "positions" of the bombardment peaks, but in virtually no

instances were there any indications of ion formation in the gas, either of the resonance type at about 9 v. electron energy or at the higher energy around 20 v. which could be unambiguously interpreted as such. Despite numerous type of adjustments of the coarse electrode voltages, the bombardment peaks always seemed to mask the effects sought.

36-1 Field Emission Studies

Mark G. Inghram and Robert Gomer (University
of Chicago)
Reported by Mark G. Inghram

A Letter to the Editor on the subject "Applications of
Field Ionization to Mass Spectrometry" has been submitted to the
Journal of the American Chemical Society.

37-1 Ion Bombardment of a Solid Target

Henry E. Stanton and Mark G. Inghram
Reported by Henry E. Stanton

In the field of isotopic analyses, it has been a problem to obtain really satisfactory ion sources for some metals including lead, tin and zinc. In the hope of developing improved methods of forming these ions, a series of experiments was undertaken on MA-17 to study the behavior of solid targets under ion bombardment. The mass spectrometer MA-17 had the distinct advantage of being capable of analyzing the energy of the ions issuing from such a target, and thus perhaps assist in reaching an understanding of the mechanism.

Experimental Arrangement

The experimental arrangement of the ion source used in this investigation is shown in Figure 7. A gas from which the bombarding ions were obtained could be introduced into the gas chamber where a transverse beam of electrons (issuing from the opening marked "a") formed the ions. These were then accelerated through a number of slits for focussing and directing the beam and impinged onto a stainless steel target. Ions formed at the target were accelerated through another stack of slit plates at right angles to the first and into the electric analyzer of the spectrometer. Argon gas has been used exclusively up to the present as a source of ions, but there was some residual pressure of background gases which also contributed ions to the bombarding beam.

At first, the machine was operated approximately as a double focussing machine, which means that the electric analyzer plates were operated with their electrical neutral at about ground, and all of the ion acceleration from the target took place in the target source. Later on, the machine was adjusted for energy selection which required raising the electrical neutral of the electric analyzer to within about 500 v. of the target potential and introducing from 2-6 kv. of final acceleration before entering the magnetic analyzer.

In order to assure the proper operation of the machine, a second filament was provided which supplied electrons which could enter

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FIGURE 7

the target chamber through the opening "b". These electrons would ionize the residual gases and permit adjustment of the target source and the analyzers. Also it was thought that if the bombarding ions dislodged neutral atoms from the target, an auxiliary ionizing agency would permit detection of them.

Results

The results to date from this type of study have not been gratifying. Ion bombarding voltages up to 3400 volts have been employed but no detectable patterns among the various isotopes which could be recognized as components of the target base metal have been found, even with auxiliary filament supplying electrons to ionize any neutral ions. On the other hand, the several background peaks were observed which indicated that the machine was functioning properly. In some instances, there was question about whether the target was under bombardment, but target currents up to 5×10^{-9} ampere were measured, and the bombarding beam appeared to behave as expected. The metals chiefly sought were iron, nickel and chromium.

With the failure to find any recognizable pattern of peaks which could be attributed to any of the metals in the target, other investigations which were readily made, and which might have indicated the reasons, were tried. With the machine reconnected for energy selection, it was possible to analyze the energy distribution of the various peaks that were found.

It was first noted that there was difference in the patterns for the various mass numbers when the source of ionization was switched from electrons entering at "b" and ion bombardment of the target. The hydro-carbon peaks changed somewhat in relative intensity, and there was an occasional peak which was very strong with the electron bombardment but was almost non-existent with the ion bombardment. For example, the CO_2 peak produced in ion bombardment was but little above the detectable minimum. Even more noteworthy was the change taking place in the mass 39 and mass 41 peaks. With the electrons through "b" the peaks were roughly of comparable sizes, while for the ion bombardment, the ratio of peak heights approached the ratio of about 14 to 1, as for potassium ions. From this, it appeared that potassium was being emitted from the target under bombardment. Sodium also was emitted relatively strongly, whereas the 23 position is usually a very "clean" position from the standpoint of hydro-carbon background.

When the kinetic energy of formation of the ions was examined, two types of curves appeared, as shown in Figure 8. The upper curve was characteristic of most of the mass peaks examined, especially the potassium peaks, and including most of the hydro-carbon peaks. It is characterized by a rather sharp rise on the low energy side coupled to a very large high energy tail, with over-all half widths of the order of 1.5 v. or greater.

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POTASSIUM 39^+ ARGON 40^+

ION KINETIC ENERGY
AFTER ELECTRIC ANALYSIS

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FIGURE 8

Peaks at masses 40 (A^+), 44, (CO_2^+), 32 (O_2^+) and 28 (CO^+) in contrast had somewhat slower increases on the low energy side, much sharper cut-offs on the high energy side and about a third of the half width.

On the basis of this classification, the surmise has been advanced that peaks similar to the upper curve are formed as a result of ion bombardment, since they appear quite similar in form to bombardment peaks previously observed and discussed, whereas the peaks similar to the lower curve in Figure 8 are formed by a different mechanism. In the latter case, charge exchange of the impinging ion with a neutral molecule either on the surface or close to it appears likely.

This hypothesis was examined further, in the case of A^+ as compared with K^+ . The integrated beam intensity (integrated over the kinetic energy distribution) for A^+ was determined as a function of argon pressure in the source, and found to vary as the square of the pressure, which would characterize such a charge exchange phenomenon. The corresponding quantity for the potassium peak, which appeared to be formed on the surface, decreased only linearly with the argon pressure. Experiments earlier had shown that the target current varied linearly with this pressure. These results appeared to confirm the mechanism, but further investigations are planned for the future.

V. THEORETICAL PHYSICS, GENERAL

- 1-9 Interpretation of Energy States of Light Nuclei (5200-01)
 David R. Inglis

It is tempting to attribute a few maverick states in the p-shell nuclei, such as the ones at 5.31 Mev in N^{15} , 6.4 Mev in Li^7 , and perhaps 7.3 Mev in C^{12} , to excitation from the 1s to the 1p shell. Some apparent confirmation can be obtained by simply comparing the observed H^3 - He^3 mass difference with the corresponding "observed" p-shell difference. This oversimplified procedure neglects i.a., the change in the contribution of interactions between the s and p nucleons. Calculations based on phenomenological two-particle interactions indicate that the neglect is serious and give excitation energies of over 20 Mev. The utter inadequacy of calculation with these interactions for nuclear stability or comparison of different configurations, in contrast to their success in estimating separations within a configuration, as exemplified in recent work of Kurath, presents an interesting problem.

- 2-9 Excited States of Light Nuclei (5200-01)
 Dieter Kurath

In obtaining energy levels in the 1p shell the three parameters convenient for physical interpretation are:

a/K , The relative strength of spin-orbit coupling
energy to central-interaction energy.

L/K , A measure of the ratio of range of nuclear
forces to nuclear size.

K , The direct integral of central interaction.

The matrix diagonalization is carried out in units of K , which is then available as a parameter to vary the energy scale. However, its magnitude should be about 1 Mev.

The diagonalization has been carried out for the four sets of parameters:

	<u>a/K</u>	<u>L/K</u>
CALC. 1	5.2	6.79
CALC. 2	4.5	6.79
CALC. 3	3.0	6.79
CALC. 4	4.5	4.30

The first three show the dependence on spin-orbit coupling from truly intermediate coupling to relatively weak coupling. The fourth case will show the dependence on the range of nuclear forces, the range in CALC. 4 being about $2/3$ that in CALC. 2.

As an example of the results we consider mass number ten, the one for which the most experimental evidence is available. The

experimental information as taken from Ajzenberg and Lauritsen¹ is given on the right in Figure 9. The other four level schemes are the results of the four calculations with energy levels given in units of K. It is apparent that somewhere in the region of Calculations 1 and 2 a good fit can be found for the first five levels of B^{10} and the first two in Be^{10} by choosing a suitable K. The effect of reducing the range of nuclear forces can be seen by comparing Calcs. 2 and 4 in Figure 9. The most pronounced effect is the lowering of the $T = 1$ states relative to the $T = 0$ states.

The eigenfunctions resulting from the diagonalization have been extracted for the first two cases. The nuclei of interest are those near the center of the shell: Be^9 , B^{10} and B^{11} . Magnetic moments obtained for these cases are listed in Table III.

TABLE III
Magnetic Moments for Be^9 , B^{10} and B^{11} as a
function of a/K .
(The Unit is the nuclear magneton)

a/K	∞ (JJ-limit)	5.2	4.5	0 (LS-limit)	Exp.
Be^9	-1.15	-0.75	-0.79	-1.56	-1.18
B^{10}	1.88	1.76	1.77	---	1.80
B^{11}	3.79	2.89	2.81	3.37	2.69

1. F. Ajzenberg and T. L. Lauritsen, Rev. Modern Phys., 27, 77 (1955).

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FIGURE 9

For B^{11} the intermediate-coupling wave function gives a moment much closer to experiment, while B^{10} seems relatively insensitive. Be^9 , on the other hand, seems to indicate that a lower a/K is needed to get agreement with experiment, a tendency that is present also in the level scheme.

When the results from a few more points have been obtained, one should get a fairly complete picture of the dependence of a/K and L/K on mass number which is required in order to fit the level schemes and moments in the $1p$ shell.

4-9 Investigation of Nuclear Shell Structure (5200-01)

Maria Mayer

Investigations of β -decay interactions. On Leave
of Absence for one month.

5-9 Book on Nuclear Shell Structure (5200-01)

Maria Mayer

The book entitled "Elementary Theory of Nuclear Shell Structure" by Maria Goeppert Mayer and J. Hans D. Jensen was published in April by John Wiley and Sons, Inc.

There will be no further reports on this subject.

7-9

(Collective Description of Nucleon Interactions)
(5200-01)

Melvin Ferentz

Work on this program has been deferred and there will be no further reporting until it is re-activated.

10-5

The Effect of Inelastic Scattering in the Analysis
of Scattering Resonances (5200-01)

James E. Monahan, F. Paul Mooring, and
Sol Raboy
Reported by James E. Monahan

The calculated values of the cross section for inelastic scattering of neutrons from the 542-keV resonance in Na²³ indicate that, by observing the 430-keV gamma ray from the excited state of the residual nucleus, a measurement of the energy dependence of this cross section should be possible. The apparatus for such an experiment has been designed making use of conventional ring-geometry. These measurements should be completed in the very near future.

12-2

Investigations of Neutron Scattering Under the
Feshbach Porter-Weisskopf Model of the Nucleus
(5200-01)

Morton Hamermesh and Jack Sokoloff
Reported by Jack Sokoloff

The coding of the problem for the AVIDAC has progressed to the debugging of the detailed code by Jean Hall. James Butler and Joseph Cook completed the preliminary coding of the problem.

Since the shell model is, in a sense, bracketed by the square well potential and the harmonic oscillator potential, we have attempted to adapt the FFW formalism to the harmonic oscillator potential.

For a potential of the form:

$$V = (-V_0 + \frac{V_0}{R^2} r^2) (1 + i \zeta), r \leq R$$

$$V = 0, r > R$$

the radial equation has solutions in terms of the confluent hypergeometric series. As can be seen, the harmonic oscillator has the same number of parameters as the square well. It is hoped that it is superior to the square well since, unlike the square well, it is continuous and thus may have less marked spurious edge effects.

The problem has been set up for the AVIDAC and the preliminary coding will be done by Joseph Cook.

13-2

(Multipolarity of Neutron-Capture Gamma Rays)
(5200-01)

Morton Hamermesh and Jack Sokoloff
Reported by Jack Sokoloff

No work was done on this subject during the past quarter.

34-9

(Quantized Space Time)

(5200-02)

Robert H. Bryan and Katsumi Tanaka
Reported by Katsumi Tanaka

No work was done on this subject during the past
quarter.

39-7

Applications of the Theory of Angular Correlation
(5200-01)

Melvin Ferentz and Norbert Rosenzweig
Reported by Norbert Rosenzweig

Tabulation of F Coefficients

The definition of the F coefficient was given and its usefulness was described in our last report. The bulk of the computations leading to the more than 13,6000 entries has been completed. Two independent answer tapes were obtained. We are now locating and resolving the discrepancies between the two results. The table should be in the hands of Graphic Arts before the end of the coming semester.

43-5

(The S Matrix)

(5200-02)

Katsumi Tanaka

No progress to report for this period.

Katsumi Tanaka

The Bethe-Salpeter equation for two nucleons in the center of mass system in momentum space is given by (all symbols are defined in their paper Phys. Rev. 84, 1232 (1951))

$$\psi(p_{\mu}) = i \left[(1/2 \not{K} + \not{p} - m_a) (1/2 \not{K} - \not{p} - m_b) \right]^{-1} \int d^4 p' G(p, p') \psi(p'_{\mu}). \quad (1)$$

For the case of one meson interaction of two nucleons (ladder approximation), (1) becomes,

$$\begin{aligned} & (H_a(p) + H_b(-p) - E) \psi(p, p_0) = \\ & i \frac{G^2}{(2\pi)^4} \left\{ \left[H_a(p) - \frac{E}{2} - p_0 \right]^{-1} + \left[H_b(-p) - \frac{E}{2} + p_0 \right]^{-1} \right\} \\ & \int \frac{\Gamma_i^a \Gamma_i^b \psi(p') d^4 p'}{(w_{p-p'} + p_0 - p'_0) (w_{p-p'} - p_0 + p'_0)} \end{aligned} \quad (2)$$

We integrate both sides over the relative energy variable p_0 with boundary conditions that satisfy the hole theory, i.e., we let masses m and μ have a small negative imaginary part.

$$\begin{aligned}
& (H_a(\underline{p}) + H_b(-\underline{p}) - E) \psi(\underline{p}) \\
&= \frac{G^2}{16\pi^3} \int \frac{d^3 p' d p'_0}{w_{\underline{p}-\underline{p}'}} \left\{ \Gamma_i^b \left[\gamma_a(\underline{p}) (E_p + w_{\underline{p}-\underline{p}'}) - \frac{E}{2} - p'_0 \right]^{-1} \Gamma_i^a + \Gamma_i^a \left[\gamma_b(-\underline{p}) \times \right. \right. \\
&\quad \left. \left. (E_p + w_{\underline{p}-\underline{p}'}) - \frac{E}{2} + p'_0 \right]^{-1} \Gamma_i^b \right\} \psi(\underline{p}', p'_0)
\end{aligned} \tag{3}$$

where the 3-dimensional Tamm-Dancoff amplitude is defined as

$$\psi(\underline{p}) = \int \psi(\underline{p}, p_0) d p_0 \quad \text{and} \quad \gamma_i(\underline{p}) = H_i(\underline{p}) / E_p.$$

We introduce an Ansatz

$$\psi(\underline{p}') = \psi(\underline{p}') \delta(p'_0 - E')$$

$$E' = \frac{E}{2} - \gamma_b(-\underline{p}') E_{p'} = -\frac{E}{2} + \gamma_a(\underline{p}') E_{p'}, \tag{4}$$

integrate both sides of (3) over the relative energy variable p'_0 and

change variables $\underline{p}' = \underline{p} - \underline{k}$,

$$\begin{aligned}
& (H_a(\underline{p}) + H_b(-\underline{p}) - E) \psi(\underline{p}) \\
&= \frac{G^2}{16\pi^3} \int \frac{d^3 k}{w_k} \Gamma_i^b \left[\gamma_a(\underline{p}) (E_p + w_k) + \gamma_b(\underline{k}-\underline{p}) E_{\underline{k}-\underline{p}} - E \right]^{-1} \Gamma_i^a \\
&+ \Gamma_i^a \left[\gamma_b(-\underline{p}) (E_p + w_k) + \gamma_a(\underline{p}-\underline{k}) E_{\underline{p}-\underline{k}} - E \right]^{-1} \Gamma_i^b \psi(\underline{p}-\underline{k}).
\end{aligned} \tag{5}$$

Equation (5) is the new Tamm -Dancoff equation for two particles obtained by Dyson. This equation was obtained in accordance with the hole theory with the aid of an Ansatz.

Ansatz (4) does not give suitable results in the case of 2-meson interaction represented by crossed diagrams (fourth order in coupling constant G).

A characteristic difficulty of the Bethe-Salpeter and Tamm-Dancoff methods in the derivation of a two-nucleon Schrodinger equation is that the potential is dependent on the total energy of the system as seen in the previous equations. Even after the total energy is eliminated by an iteration procedure the potential is non-hermitian. A method to avoid this is to introduce a unitary transformation $\psi = U \psi'$ to the Schrodinger equation $H \psi = E \psi$ so that the coupling between, say the 2-nucleon and 2-nucleon-plus-one-meson state, is removed or in other words to partly diagonalize the hamiltonian. This aspect of the Tamm-Dancoff equation is studied.

45-2

Renormalizable Field Theory

(5200-01)

F. Coester and Katsumi Tanaka
Reported by Katsumi Tanaka

In the previous report, we obtained an integral equation to determine the binding energy of the $V + N$ system as the following:

$$\begin{aligned}
 & \underline{B} \underline{U}(\underline{S}) \left[1 - g_c^2 \underline{B} \sum_k (2w_k)^{-1} (w + m_n - m_v + B)^{-1} (w + m_n - m_v) \right] \\
 & = -g_c^2 \underline{U}(-\underline{S}) \sum_k e^{i \underline{k} \underline{s} / 2} w_k (w + m_n - m_v + B).
 \end{aligned}$$

The only solution of this equation is $\underline{U}(\underline{S}) = 0$, from which follows $\underline{a}(\underline{p}) = 0$, $\underline{b}(\underline{p}, \underline{k}) = 0$ and consequently $\underline{I} = 0$. In other words, there are no eigenstates of the system $V + N$ considered by the authors. This is not a surprising conclusion because Lee's formulation proposes infinitely heavy particles, as there is no recoil. One must include the recoil of the particles in order to consider the bound states. When we extend Lee's formalism so that the recoil is included, one obtains an integral equation which involves a divergent integral.

This is the content of the Abstract presented at the Washington meeting 1955, of the American Physical Society.

VII. ELECTRONIC DIGITAL COMPUTERS

2-9

The AVIDAC

(4520-02)

1. The Use of the AVIDAC - Jean F. Hall

Most of this quarter the AVIDAC has been working in a canvas tent while walls were being removed around it. Several time-consuming calculations were being run and the AVIDAC was in use two shifts a day.

The data-processing programs for the fast exponential experiment and the neutron chopper data were in extensive use.

A new data - processing program made its appearance. It analyses Borax flux plots and calculates the excess reactivity with respect to time. Again computation time is hardly noticeable; almost all the time is spent in punching the plot of excess reactivity.

The Serber-Wilson criticality calculation program was in use, and new approaches to solving the reactor kinetics equations were tried.

Tables of excess reactivity as a function of the asymptotic period and effective neutron lifetime were calculated.

Three other tables were computed. One tabulated a set of numbers which were used as initial conditions in a REAC calculation of Kinematics of Injury and Recovery in a tissue.

The second was the tabulation of a certain integral. The

routine used in evaluating this integral is one which is often applied.

The AVIDAC keeps on halving the interval size until the integral stops changing noticeably. This has the advantage of giving enough points to insure the accuracy but has the disadvantage that twice as many points are computed than were actually needed. We don't mind thirty-second integrals taking a minute, but it is unpleasant to have a twenty-minute integral take forty minutes. There are a few things which we can do to remedy this when we have the latter case.

The third table was a tabulation of a simple arc-sin function for use in setting up experiments on a mass spectrograph.

Several sets of simultaneous linear equations were solved using a routine adapted for the AVIDAC from the ILLIAC library.

The AVIDAC continued to work on the calculation of the Excited States of Light Nuclei and was in use in checking out new programs still under construction.

2. Preventative Maintenance - Carl J. Bergstrom

1. The tube rotation schedule is up to date and complete records are being maintained.

2. Marginal checking methods are being devised in addition to tube rotation as a means of spotting tubes which may fail during operation. These tests are being enlarged in scope each month to include particularly troublesome circuits.

3. Time during the period of this report was divided

as follows:

Time spent on scheduled maintenance.....172 hours
 Time spent on unscheduled maintenance..... 145-1/2 hrs.
 Charged effective operating time.....422 hours
 Non-charged effective and non-effective operating time.....100.1 hrs.
 Total machine "on" time.....845.6 hrs.

A breakdown by months results in the following totals:

	<u>Maintenance</u>		<u>Operating</u>		
	Scheduled	Unscheduled	Eff. Charged	Non-Eff. (Non-charged)	
Feb.	52	35	103	79.6	269.6
March	64	76-1/2	129	14.5	284.0
April	62	34	190	6.0	292.0

Improvements of the AVIDAC

1. In order that better "read in" operation may be obtained preliminary tests are being made on circuits using photo diodes in place of the present vacuum photocells. It is hoped that should the diodes prove stable enough a less critical light source may be used with better reliability.

2. Considerable difficulty has been experienced with the Type 5687 tubes used in the AVIDAC, particularly in the clear and

transfer driver circuits. These circuits will be replaced, during the next quarter, by a simplified circuit using a single heavy-duty type tube for each clear or transfer instead of the 6 to 8 parallel tubes used at present.

3. In order to improve the read-around ratio of the memory a pulser was added within the pulse chain to hold the beam on somewhat longer when writing a zero. This pulser existed in the original design of the memory but early results led to the conclusion that it was unnecessary. Since then, however, changes in other circuits have been made and it again seems desirable that it be used. Since its installation no further testing has been possible and therefore no conclusions can be drawn at this time.

3. Equipment for Testing Cathode Ray Tubes - David Jacobsohn

It has become essential to design and construct a new Williams tube test rack in order to test and maintain a supply of good memory tubes for AVIDAC. This test rack should be designated so as to facilitate further testing on CRT memory systems in order to improve our present memory wherever possible.

The proposed test rack should be able to:

- (1) generate a 1024 roster of either square or diamond pattern
- (2) operate with various inspection systems

- (3) operate with dot-slide or double dot switch systems
- (4) use normal, back to back, or pyramid switch patterns
- (5) simulate AVIDAC parameters and operating conditions
- (6) automatically scan for impurities
- (7) check read-around (R.A.) in the following ways
 - a) be able to generate a sub-roster of R. A. points
 - b) be able to check one specific neighbor with respect to a specific R. A. points
 - c) be able to modify (change zero's to one's and one's to zero's) one neighbor or the entire roster several times prior to R. A. testing
 - d) be capable of inserting time delays of up to 30 seconds at various stages in the testing routines
 - e) be able to record errors during any automatic test.

7-9

The Auxiliary Memories for the AVIDAC and ORACLE

(4520-02)

David H. Jacobsohn, Raymond F. Kramer and
Leslie C. Merrill

Reported by Leslie C. Merrill

Modifications of the design of the ORACLE read/write units have been completed. Sample units have been built and arrangements have been made for the construction of 40 units for "GEORGE" auxiliary memory. The control logic for the unit is finished.

13-6

Computer GEORGE

(4520-02)

Jeffrey C. Chu, Raymond F. Kramer, Leslie C.
Merrill and David Jacobsohn
Reported by David Jacobsohn

1. Crystal Diodes

Crystal diodes are being used as logical elements of GEORGE in both the control and the plusser. The diode being used is the Hughes diode, Type 1N191, with the following standards imposed.

- a. Maximum forward current of 30 milliamperes.
- b. Maximum back voltage of 50 volts.
- c. Assumed back current of 200 microamperes.

In all cases where the diodes are used in conjunction with vacuum tubes protective diode clamps are installed to prevent destruction of the diodes when the machine is turned on, and when tubes are removed or burnt out.

Owing to current and speed considerations no circuit more complicated than triple cascade gate is contemplated. Diodes of the same type are also being used in the order decoding matrix.

2. Shift Counter

A dynamic type shift counter of seven stages has been designed and constructed. This unit uses 1 type 5670 and 1 type 6463 vacuum tube and 2 type 1N191 diodes per stage. The carry propagation time through the seven stages is one microsecond.

3. Pulsers

The Dynamic Programmer consists of two pairs of RC timed pulsers so arranged that a clear and transfer pulse shall start simultaneously and the transfer pulse shall remain on for a fixed interval after the completion of the clear pulse. Each pair of pulsers (clear and transfer) is triggered by the differentiated trailing edge of the previous transfer pulse. By the use of feedback networks both rise and fall time and the D.C. levels of the pulses are precisely maintained.

4. Neon Bleeders

Neon bulbs (Type NE-2) are used as coupling elements in circuits where direct coupling and change of voltage level are required.

The circuit design criterion is based on the data collected during the past six months on the neon aging and regulation studies.

5. Pulse Transformers

To obtain a better impedance match condition, pulse transformer coupled drivers are used extensively. These transformers designed by ANL will be manufactured by Technitrol Company of Philadelphia.

VIII. APPLIED MATHEMATICS AND COMPUTATION, GENERAL

13-4

REAC Problems

(4520-02)

Nye F. Morehouse, Jr.

(1). Some control rod problems were run for the Reactor Division Safety report. The answers are being reported by J. Carter.

(2). A system of ordinary linear differential equations for determining our concentrations of isotopes in a decay chain is being solved for our Chemistry Division. The answers will be incorporated in a report by A. Jaffey.