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

410-1-10

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Louis A. Turner, Division Director

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I. EXPERIMENTAL NUCLEAR PHYSICS

1-2 The Fast Neutron Velocity Selector (5211-01, 5261-01)

L. M. Bollinger, R. R. Palmer, G. E. Thomas
Reported by L. M. Bollinger

A Monte Carlo calculation of the neutron capture efficiency of methyl-borate-containing liquid scintillation neutron detectors has been undertaken as a guide in the construction of such counters for use with the velocity selector. The calculations, which are being done by the Argonne IBM group, are for a one-dimensional geometry; that is, for infinite slab counters. The following simplifying assumptions have been adopted for this problem:

- a) For scattering atoms other than hydrogen, a single atomic weight is used; namely, $A = 13$.
- b) Scattering cross sections are assumed to be independent of energy.
- c) The atoms in the counting medium are assumed to be free and at rest.

The results that have been obtained to date are summarized in Table I, where the probability of neutron capture is given as a function of neutron energy and counter thickness for counters consisting of equal volumes of enriched methyl borate and phenylcyclohexane.

TABLE I
Probability for Neutron Capture

Counter Thickness (cm)	Energy of Incident Neutron		
	10 ev	173 ev	2000 ev
1	.69	.29	.13
2	.87	.52	.36
3	.96	.70	.52
4	.96	.82	.62
5	.96	.86	.70
6	.97	.88	.76
7	.97	.89	.77
8	.97	.89	.77

In constructing liquid counters for use with the velocity selector, it is desirable to obtain a high signal-to-background ratio for neutrons of about 100 ev energy. The data of Table I suggest that 3 cm is an appropriate thickness to use to meet this requirement, if it is assumed that the background counting rate is proportional to counter volume.

The Monte Carlo calculations will be extended to incident neutron energies of 40 and 250 kev.

2-2 Liquid Scintillation Neutron Detector (5211-01, 5261-01)

L. M. Bollinger and G. E. Thomas
Reported by G. E. Thomas

The over-all efficiency measurements of the liquid counters as a function of neutron energy, using the Argonne fast chopper, have been completed. These results using counter No. 6 are shown in Figure 1.

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The calculated efficiencies for a BF_3 gas counter are shown for comparison.

In view of its desirable mechanical properties, Lucite was tested as a cell material for the liquids. The cell in the coincidence counter was replaced by a solid piece of Lucite to determine its gamma sensitivity. It was found to be negligible. However, upon contact with the liquid for one month, the Lucite slowly dissolved and became soft. Consequently, it was totally unsatisfactory as cell material.

A permanent cooling system for the detector at the fast chopper has been completed. It is a closed circulating system, with cool, dry air being piped from a deep freeze into the insulated box containing the counter. The counter may be cooled to 0°C .

Our program for the near future includes the following:

- a) The properties of a counter containing enriched methyl borate will be determined.
- b) A larger liquid neutron detector will be constructed for use with the Argonne fast chopper.
- c) New materials will be tested. Efforts are being made to obtain $\text{B}_{10}\text{H}_{14}$, which may prove superior to $\text{B}(\text{OCH}_3)_3$.

3-2 Transmission Measurements with the Fast Neutron Velocity Selector (5211-01, 5261-01)

L. M. Bollinger and R. R. Palmer
Reported by R. R. Palmer

A. Total Cross Section Data

During the past quarter the measurements summarized in

the following table have been made with the velocity selector.

Sample	Thickness (gm/cm ²)	Resolution (μ s/meter)	Energy Range (ev)	Resonances and Comments
Antimony	12.5	0.4	5 - 40	Previously reported resonances (Phys. Rev. 71, 65, 1947) at 6.28, 15.6 and 21.8 ev more completely resolved. New resonance at 30 ev.
	1.79			
	0.170			
	12.5	0.3	18 - 1000	Transmission dip at 52 ev; others less distinct above 60 ev.
				Antimony-123 is on hand and will be run shortly.
Gallium	7.7	0.6	17 - 2000	Broad transmission minima at 100 and 300 ev.
		0.3	40 - 1500	Resonances at 96, 113, 290 (very prominent), 390, and 730 ev.
		0.13	350 - 30,000	Additional transmission dips at 1800 and 7200 ev. The 290 and 390-ev resonances are clearly resolved.
Gallium-69 (oxide)	2.2	0.3	40 - 1500	Resonances at 113 and 730 ev are due to Ga-69.
		0.13	350 - 30,000	730-ev transmission dip confirmed. Other dips at 1800 and 7200 volts do not appear assignable to Ga-69.
Gallium-71 (oxide)	1.14	0.3	40 - 1500	Resonances at 96, 290, and 390 ev are due to Ga-71.
	1.14	0.13	350 - 30,000	Data yet to be obtained.
				Normalization runs for gallium also yet to be obtained.

Sample	Thickness (gm/cm ²)	Resolution (μ s/meter)	Energy Range (ev)	Resonances and Comments
Germanium	3.72	0.3	40 - 1500	Transmission dips at 103 (deep), 220, and 340 ev; others not resolved in the vicinity of 500 and 1000 ev.
		0.13		Runs at higher resolution yet to be obtained.
Iron	12.3	0.6	15 - 2000	No resonances observed.
		0.13	400 - 40,000	Transmission dips at 7800 and 33,000 ev confirmed. However, there is no evidence of a dip at 16,000 ev, as suggested by the iron cross section curve in AECU-2040.
Mercury-200	1.57	0.3	15 - 5000	None of the prominent transmission dips of mercury (see preceding report) are assignable to Mercury-200.
Selenium	8.57	1.5	1 - 20	No transmission dips.
	8.57	0.6	7 - 2000	Major transmission dips at 27, 216, 280, and 2300 ev (all previously unreported).
	1.24	0.3	18 - 500	The 27-ev transmission dip still appears due to a single resonance.
		0.13		Runs at higher resolution yet to be obtained.

B. Analysis of the 2.58-ev Resonance in Gadolinium.

The values $\sigma_0 = 1600$ barns and $\Gamma = 0.07$ ev have been obtained as approximate values of the resonance parameters for the 2.58-ev resonance in Gd. This was accomplished by performing a numerical integration over the chopper resolution function at this energy, using the Breit-Wigner equation and various assumed values of σ_0 and Γ . It is then possible to select a pair of values for σ_0 and Γ which gives a value for $\sigma_0 \Gamma^2$ in agreement with the value calculated in the usual way from the area above the transmission dip.

4-2 Resonances in Separated Mo Isotopes (5211-01, 5261-01)

S. P. Harris

The results given in the preceding quarterly report are being prepared for publication.

5-1 The Absorption and Scattering of Neutrons by Hafnium (5211-01, 5261-01)

L. M. Bollinger, S. P. Harris, C. T. Hibdon,
C. O. Muehlhause, (Now at Brookhaven National Laboratory)
Reported by S. P. Harris

An article for publication in the Physical Review is in preparation.

Thermal activation, thermal absorption, resonance scattering, resonance transmission, and multiplicity of capture γ -rays have been measured for the stable isotopes of hafnium (see ANL-4746). Isotopic assignments of the various resonance levels are presented which are consistent with all the data observed. Where possible the level spacing is estimated.

6-1 Special Velocity Selector for Slow Neutrons (5211-01)

G. R. Ringo

This device was first reported in ANL-4277, p. 36, (Experimental Nuclear Physics Division Quarterly Report for January - March, 1949). Since that time, the construction has been completed except for the crucial detail of consolidating the laminations forming the rotor so that it can be balanced. A trial rotor has been assembled and consolidated by copper brazing in a hydrogen atmosphere furnace. This test, which was performed by the General Electric Company at Schenectady, New York, was reasonably successful.

This quarter a final rotor has been assembled and shipped to Schenectady, where it will shortly be brazed.

Next quarter, if the brazing has been successful, the rotor will be cadmium plated, balanced, and assembled with the motor. After this, it will be tested at high speeds and can then be used for experiments.

11-2 Installation and Operation of the Van de Graaff Generator
(5211-01, 5261-02)

R. E. Holland, A. Langsdorf, R. E. Malm, F. P. Mooring,
J. C. Wallace, R. R. Weeks

1. General Remarks - Reported by A. Langsdorf

The machine is in operation at about 2 Mev, with control of energy seemingly more precise than it was at Palos Park. The shape of the neutron yield curve near threshold of the $\text{Li}^7(p,n)\text{Be}^7$ reaction indicates control of the machine to between 500 and 1000 volts at 2 million volts, or about one part in 2000 to 4000.

2. The Corona System - Reported by F. P. Mooring

Ideally, in a Van de Graaff generator, the positive charge carried by the belt to the high voltage shell should equal the negative charge brought back. To see if this condition could be achieved with the existing corona system in the Argonne Van de Graaff generator, needle bars to sample the belt charge were installed. These needle bars were placed so they could wipe off a small fraction of the belt charge, one above and one below the belt, and were grounded through a microammeter. However, the difference between negative and positive point corona prevented the bars from giving any significant information.

Tests were then made in open air using a metal plate connected to an electrostatic voltmeter. By holding the plate between the belt and moving it up and down, one could determine the relative signs of the charge on the two halves of the belt and, roughly, their relative magnitudes. It was found that the net charge, in open air at least, was negative on both halves of the belt. The addition of another needle gap connecting the high voltage pulley to the high voltage shell did allow equal and opposite charges to be carried by opposite halves of the belt. However, the needle gap setting depends on several factors, such as tank pressure, focus voltage, and generator voltage.

To determine under actual operating conditions the state of the belt charge, a generating voltmeter, which looks alternately at the upper and lower halves of the belt, has been designed, built, and tested. Experiments

indicate that such a voltmeter will give the required information and allow the operator to adjust for equal and opposite charges on the belt while the tank is under pressure. It is planned to install the voltmeter in the Van de Graaff generator as soon as possible.

3. Control Circuits - Reported by R. R. Weeks

The first attempt at experimental use of the Van de Graaff machine after reassembly showed variations of the beam energy at the $\text{Li}^7(p,n)$ threshold. When the machine energy was "sitting" above but close to the threshold, neutron counting rates would vary erratically. A test for the possible cause was available, since there are pick-up electrodes in front of the target which allow the magnet to be used as an analyzer of high short-time stability. With this control, the jitter of energy was reduced materially. Three things were then done to reduce this jitter:

1. A Sorenson regulator was used to feed the analyzer high voltage supply maintaining the line voltage to 0.1%.
2. The loop gain of the high voltage regulator to the analyzer was increased somewhat (perhaps as much as 4 x) by using a variable transformer to transform the reactance of the saturable control reactor to a larger value which better "matched" the reactance range to the resistive load. In addition to giving tighter control, this increases the range of control, thus requiring less adjustments in tune-up and operation.

3. Large series resistors between the high voltage supply for the analyzer and the analyzer plates were shorted out. This reduces the possibility of incident beam currents varying the voltage on the analyzer plates.

These three changes reduced the energy fluctuations to less than 1:2000.

The energy control system still labors to maintain control at ~ 1 cps. This has been traced to lateral oscillations of the belt in the electrostatic generator. The lateral oscillations couple energy to a longitudinal oscillation, and consequently, the instantaneous belt velocity varies along with the rotational velocity of the driving motor and the upper belt pulley and 400-cycle generator. These velocity variations cause the rate of charge application to the high voltage shell to vary, and consequently, the machine voltage varies. The crowning of the belt pulleys was wrong for the width of the belt used. The belt pulley crowning is to be changed to try to reduce the effect. The non-linearity of the edges of the belt will probably still cause oscillations of smaller amplitude.

4. System for Handling Large Proton Beams - Reported by A. Langsdorf

The proton beam handling system is gradually being improved in design with the goal being to be able safely to handle beam currents of about 100 microamperes at 4 million volts. Such an intensity (400 watts) demands elaborate design to dissipate the intense heat. Over a long period of time designs have been worked on (by A. Langsdorf) for slits, viewers, shutters, and targets which can safely stand such beam currents. As a result of this work, a new slit system has been built, installed, and tested in operation

(at 10 to 20 microamperes and 2 million volts). It seems to function quite satisfactorily. More such slits will be built, as a result of the success of this first one. A new viewer is also in use and seems simpler and better than older ones. A new shutter is built but not yet installed or tested. The remaining part of this group of beam-handling projects is design of a lithium target for such intense beams. Ideas on how to do this are now about "jelled" and ready for design. Of course, this program is aimed to increase neutron flux available for inelastic scattering research, etc. Details of the designs should be published when the system is complete enough so that the large beams are actually being successfully employed.

12-2 R. F. Ion Source for the Argonne Van de Graaff Generator
(5211-01, 5261-02)

F. P. Mooring

The operation of the r. f. ion source has been improved since the last report. It was found that the r. f. oscillator as it was loaded was not working under optimum conditions. Changing the grid resistors, raising the plate voltage, and adjusting the coupling of the oscillator to the load increased the power transferred to the gas discharge by a factor of more than two. With these improvements, a magnetically analyzed proton beam of more than 30 microamperes was obtained at a probe voltage of about one-third of the five thousand volts available. Tests were not made to determine the maximum beam current that the source can produce, since there is at present no target with sufficient cooling capable of handling the power developed by such a beam.

Soon after the installation of the r. f. ion source, it was noticed that the position of the beam spot on the target moved as the focus voltage and generator energy was varied. Removal of the permanent ring magnet from around the ion source bottle almost completely eliminated the dependence of beam position on focus voltage and generator energy. Though the removal of the magnet undoubtedly limits the maximum current available, the ion source can still produce ion currents larger than the present target facilities can handle. It is planned to design a new magnet support that, one hopes, will allow its use without affecting the position of the beam spot.

No attempt has been made to measure the ratio of the mass one to mass two beams other than the qualitative observation that the beam spot produced by the mass one beam is much brighter than that produced by the mass two beam. The mass two beam current is, however, sufficiently large to be used for controlling the Van de Graaff generator energy.

13-2 A High Vacuum Plug Valve (5211-01)

J. A. Stark and A. Langsdorf

The article on this valve submitted to the Reviews of Scientific Instruments has not yet been scheduled for publication.

14-1 Pulsed Neutron Beams from the Van de Graaff Generator (5211-01)

R. E. Holland

A study has been made of various possible time-of-flight methods of measuring the distribution in energy of the neutrons produced in the target of the Van de Graaff generator or of those produced by inelastic

scattering of monoenergetic neutrons from such a target. Use of a pulsed proton beam for producing the neutrons appears to offer some advantages of higher counting rate and lower background over the use of delayed coincidences between neutrons and the gamma-rays produced in the (p,n,γ) or (n,n',γ) reactions. Three methods of pulsing the beam have been considered: (1) bunching by variation of path length (Mobley - Van de Graaff); (2) bunching by variation of velocity; and (3) pulsing of the ion source. The third method appears to be the most feasible one for use with the ANL machine. It is proposed to follow A. Langsdorf's suggestion of producing pulses by sweeping the ion beam sinusoidally across a beam-defining hole. It appears feasible to build in the high-voltage shell a system that will focus the ion beam at a hole at the entrance to the accelerating tube and sweep it transversely across the hole at frequencies of the order of 1 to 10 mc/sec. Bench tests will be made of an ion source and deflecting system of this kind.

20-2 Energy States of Light Nuclei from Charged Particle Reactions
 (5211-01)

D. R. Inglis and R. Malm
 Reported by R. Malm

The magnetic field regulating and control system for the 16-inch proton spectrometer, utilizing the field of a magnetically shielded Alnico V magnet as the standard for comparison, has been completed. Preliminary measurements indicate that drifts in the steady-state value of the magnetic field of the spectrometer are less than one part in 15,000 when the regulating system is in operation.

The system consists essentially of a null-indicating, direct-reading magnetic fluxmeter having a 30-cycle error signal, a 30-cycle mean-frequency band pass amplifier, a synchronous detector, a power amplifier, a Lincoln 600-ampere welding generator consisting of an exciter and a main generator, and the field coils of the proton spectrometer. These elements make up the main feedback loop. In addition, the alternating components of the outputs of the main generator and of the exciter are amplified and fed back to the input of the exciter. These supplementary feedback loops are provided for purposes of over-all stability.

The magnetic fluxmeter is essentially two generators on a common shaft coupled mechanically to a synchronous motor. One generator produces a voltage proportional to the field of an Alnico V permanent magnet; the other produces a voltage proportional to the field to be measured. The generators are connected in series and phased so that the voltages add. The combined output is connected across two decade resistance boxes connected in series. The measurement of a magnetic field in terms of the Alnico field is accomplished by varying the decade resistance boxes until a null is obtained between the junction of the generators and the junction of the resistance boxes. In practice, one resistance box (that connected to the Alnico generator) is fixed, and the reading of the other resistance box is, consequently, directly proportional to the magnetic field being measured.

There are a number of advantages to the present system: (1)
The magnetic field of the spectrometer is determined almost entirely by the

setting of one control. Two additional controls are provided for use when it is desired that the error signal from the fluxmeter be adjusted to zero; (2) The conversion of the reading of the resistance box to magnetic field involves only a constant factor; and (3) Small changes in field can be accomplished very rapidly. The net result of the above should be an increase in speed of obtaining data.

There are also several disadvantages: (1) The fluxmeter samples the magnetic field near the edge of the poles. Saturation effects in the iron at high flux densities could conceivably introduce errors in particle energy measurements; (2) The field of the Alnico magnet depends on the temperature. Present indications are that this is not too serious.

It is planned that an experimental program using the beam from the Van de Graaff generator will be initiated during the next quarter.

30-2 Scintillation Coincidence Spectrometer (5211-01)

S. B. Burson and W. C. Jordan
Reported by S. B. Burson

This instrument is now in full operation and has been used in conjunction with the investigations of several activities. A report will be prepared shortly for publication in one of the journals describing the instrument and some of the results obtained with it.

31-2 The 1.42-min Isomeric State in $^{192}_{77}\text{Ir}$ (5211-01)

S. B. Burson, B. Hamermesh, V. Hummel, W. C. Jordan
Reported by S. B. Burson

Several experiments have been performed in an effort to ascertain

the nature of the low energy (about 26 kev) electromagnetic radiation associated with the 1.42-min isomeric transition in ${}_{77}\text{Ir}^{192}$.

The experimental arrangement, as shown in Figure 2, consisted of a 1.5-inch hole bored through a 4-inch lead block, with the scintillating crystal package fitted into one end. The hole served as a collimator for the radiation which was admitted at the opposite end. A 1/8-inch lead plate was placed over the open end of the collimator, the plate having been provided with a 3/4-inch hole. Since all of the critical absorbers are 1.0-inch in diameter, the lead mask insured against any scattered radiation leaking around the absorbers when they were in place in front of the lead plate. Two types of experiments were done: absorption measurements, in which the sources were placed on the axis of the collimator about one inch from the face of the absorber, and fluorescence experiments, in which the sources were placed on a line perpendicular to the axis of the collimator and about 2 inches from the axis, so that no direct radiation from the source could reach the crystal. These two positions, one for transmission and one for fluorescence, are indicated as positions A and B on the diagram.

Normalization was accomplished by waiting until the 1.4-min activity had died out, and counting the residual 19-hr activity in Ir^{194} .

It was found that the source had been placed in a position which was difficult to reproduce during the transmission experiments. These measurements will be repeated.

26
FIGURE 2
EXPERIMENTAL ARRANGEMENT FOR TRANSMISSION
AND FLUORESCENCE EXPERIMENTS ON $^{192}_{77}\text{I}$ (1.42 MIN.)

While the data are still being analyzed, qualitative results of the fluorescence experiments can be stated at this time. The intensity of the fluorescence caused by exposing the critical absorbers to the 1.4-min Ir radiation steadily falls off with increasing Z , running from $_{46}\text{Pd}$ through $_{60}\text{Nd}$. The intensity reduction is by a factor of approximately 2.5, with no clear cut breaks appearing.

To ascertain the degree and nature of the contribution to the fluorescence from the unconverted 57-kev gamma-ray, a source of $_{72}\text{Hf}^{175}$ (providing an intense 53.2-kev K x-ray from $_{71}\text{Lu}^{175}$) was placed in the fluorescence source position and the intensity of the scattered radiation measured for all the critical absorbers from $_{40}\text{Zr}$ through $_{60}\text{Nd}$. The fluorescence steadily increased with Z . The increase from one end of the range to the other was by a factor of about seven. The effect noted with the Ir sources, therefore, cannot be attributed to the 57-kev gamma-ray, but must be due to the low energy component.

The results of these fluorescence experiments would tend to indicate, therefore, that the low energy radiation has components as high as 40 kev, although the peak of the pulse-height distribution is at about 26 kev. It remains to be seen whether the more carefully normalized transmission experiments will yield results consistent with this deduction.

32-2 Decay Schemes of $^{66}\text{Dy}^{165\text{m}}$ (1.2 min) and $^{66}\text{Dy}^{165}$ (2.3 hr) (5211-01)

S. B. Burson, J. M. Cork, W. C. Jordan
Reported by W. C. Jordan

In studying the 1.2-min metastable transition (108 kev), the presence of higher energy gamma radiation associated with this half-life was noted. This has led to a more careful examination of this activity. Gamma radiations of 515 ± 5 , ~ 360 , and ~ 155 kev have been detected. A K conversion line corresponding to the 515-kev transition has been observed, and it is probable that the ~ 360 -kev transition is identical to the 361-kev one associated with the 2.3-hr activity. Coincidence studies have shown that the 360 and 515-kev gamma-rays are not in prompt coincidence, but that both are coincident with a beta transition of ~ 1 Mev. The appearance of the beta distribution on spectrograms also suggests that a beta transition is associated with the 1.2 - min activity. However, the majority of the decays is via the metastable transition to the groundstate of Dy^{165} .

Additional beta-gamma coincidence studies have been made on the 2.3-hr activity. The results of these experiments indicate that, except for the 94-kev gamma-ray, all of the gamma radiation is coincident with a low energy beta transition (~ 0.3 Mev).

The study of these activities is now considered to be complete. It is planned to submit a report of these results for publication in the Physical Review.

33-2 Decay Scheme of ${}_{64}\text{Gd}^{159}$ (18 hr) and ${}_{64}\text{Gd}^{161}$ (3.7 min) (5211-01)

S. B. Burson, J. M. Cork, W. C. Jordan
Reported by W. C. Jordan

The 3.7-min Gd^{161} activity has been studied further with photographic conversion electron spectrometers and the scintillation coincidence spectrometer. Three hundred iterated exposures were made on one spectrogram in an attempt to build up line intensities. As a result, it appears that 53.4 keV is a better value for the energy of internal conversion electrons reported as ~ 55 keV in the last quarterly report. Evidence of 47.4 and ~ 305 -keV conversion electrons was also observed in addition to those previously reported.

Because coincidences between the K x-ray and 360-keV gamma-ray are easily detected, and since internal conversion lines are not easily observed, the possible presence of a K capture activity of about 3.7-min half-life was suspected. By comparison of the peak in the pulse-height distribution due to this activity with those due to x-rays of Eu and Ho, and from the results of critical absorption experiments, it may be concluded that no such K capture activity exists.

The results of beta-gamma coincidence experiments indicate that all of the electromagnetic radiation is coincident with a beta-ray of about 1.6 MeV.

The 164-keV peak in the pulse-height distribution may be due to a gamma transition of this energy or may be a Compton peak corresponding to the higher energy gamma-rays. Observed coincidences in this

region may be interpreted as due to Compton scattering of the higher energy gamma-rays in the detecting crystal, the back-scattered gamma causing the coincident pulse in the second detector.

In order to explain the intensity of the x-ray--360-kev gamma-ray coincidences, it is necessary to propose a highly K-converted gamma transition of ~ 60 kev. The K conversion electrons of such a transition would have an energy below the detection limit of the photographic spectrometers. The weak 47.4 and 53.4-kev conversion lines may be L and M conversion lines for this transition. However, one of these is probably a K line for the ~ 102 -kev gamma-ray.

The proposed level scheme shown in Figure 3 includes all of the observed transition possibilities with the exception of the questionable 164-kev one.

The results of this study are being prepared for publication in the Physical Review.

34-2 Decay Scheme of $_{45}\text{Rh}^{104m}$ (4.3 min) and $_{45}\text{Rh}^{104}$ (44 sec) (5211-01)

S. B. Burson, J. M. Cork, W. C. Jordan
Reported by W. C. Jordan

This study of the decay of neutron-activated rhodium is complete. A report on the results of this study is scheduled for publication in the June 1 issue of The Physical Review. A summary may be found in the last quarterly report, ANL-5031.

FIGURE 3
PROPOSED DECAY SCHEME FOR $^{161}_{64}\text{Gd}$ (3.7 min)

YNa 41E
5-18-53
E.S.

35-2 Decay Schemes of Long-Lived Rare Earth Isotopes (5211-01)

E. L. Church

Comparison of the conversion-electron spectra of fission europium ($A = 154 + 155$) and the activities induced by neutron bombardment of normal europium (152 and $152 + 154$), indicates the following transition assignments:

<u>Parent</u>	<u>Daughter</u>	<u>$hw(\text{kev})$</u>
${}_{63}\text{Eu}^{152}$	${}_{62}\text{Sm}^{152}$	121.6 ± 0.5
	${}_{64}\text{Gd}^{152}$	(344.1)
${}_{63}\text{Eu}^{154}$	${}_{62}\text{Sm}^{154}$	244.4 ± 0.6
	${}_{64}\text{Gd}^{154}$	122.8 ± 0.5

The presence of the 244.4-kev transition in fission europium requires the existence of a previously undetected K-capture branch in the decay of Eu^{154} . The energy and K/L ratio of the 344.1-kev transition were not re-measured in the present investigation.¹

The K/L ratios and L-conversion sub-structures of the above transitions are indicative of electric quadrupole transitions. The assumption that these transitions represent the decay of the first excited states in the even-even daughter nuclei indicated, leads to the following table:

Energies of First Excited States in Kev

A =	150	152	154	156	158
Z = 62	333.2	121.6	244.4		
Z = 64		344.1	122.8	88.8	79.1

¹ H. B. Keller and J. M. Cork, Phys. Rev. 84, 1079 (1951).

The data for the additional samarium and gadolinium isotopes have been taken from neutron-capture conversion data.²

36-2 The Decay Schemes of Mass 48 Nuclei (5211-01)

H. Casson, V. Krohn, L. Goodman
Reported by H. Casson

As discussed in the last quarterly report, ANL-5031, the energy levels of Ti^{48} were investigated by looking for real triple coincidences of gamma-rays produced in the decay of Sc^{48} and showed a positive result, namely, that the decay proceeded via a 3-gamma cascade.

Since then, we have investigated in similar manner the decay to Ti^{48} of V^{48} , which latter source was obtained by cyclotron bombardment of chromium followed by chemical separation. Analysis of the coincidence data has shown that the decay goes primarily via a 2-gamma process, with a small amount (about 5%) of 3-gamma cascade being present. Whereas the 2-gamma process can follow either positron emission or K-capture in V^{48} , energy considerations indicate that the 3-gamma process follows a K-capture only.

The existence of a 2.2-Mev gamma present in decay of V^{48} but not in Sc^{48} is verified from our work.

Sterk, et al.,* have compared the pulse-height distributions of Sc^{48} and V^{48} and found that whereas the 1.33-Mev gamma-ray is the same for both, the double gamma-ray at 0.99 Mev in Sc^{48} is actually an

² E. L. Church, to be published. See G. Scharff-Goldhaber, Phys. Rev. 90, 587 (1953).

* Sterk, Wapstra, Kropveld, Physica 19, Nos. 1-2, 135 (1953).

unresolved pair at slightly different energies, namely, 0.99 Mev and 1.05 Mev. Analysis of our data in similar manner has yielded the same result.

The results of our work are being prepared for publication in the Physical Review.

50-2 Internal Conversion of Capture Gamma-Rays Associated with Gd
(5211-01)

C. T. Hibdon

Work on the program has been suspended pending receipt of separated isotopes.

51-2 Characteristics of a Scintillation Counter Spectrometer (5211-01)

R. Culp and B. Hamermesh
Reported by B. Hamermesh

The new method of observing scintillations from our large NaI(Tl) crystal (3-1/2 x 3-1/2" right cylinder) has been tested. This method involves use of a bundle of three 5819 phototubes which is placed next to one of the large flat faces of the crystal. This avoids the use of a light pipe.

Figure 4 shows curves of resolution as a function of energy obtained by the two methods, i. e. , single phototube plus light pipe and bundle of three phototubes. By comparing the curve obtained with the bundle of three tubes with the curve shown in ANL-4963, Figure 1, it is evident that this large crystal is very similar in resolving power to our best small crystals (3/8" high by 1-1/2" diameter right cylinder). This result combined

with the behavior of the crystal in suppressing the effect of Compton processes makes the crystal very useful for capture gamma-ray studies.

It is planned to use the spectrometer with the large crystal to restudy many of the capture gamma spectra that were examined with the small crystal.¹ The fact that there is a tremendous reduction in the background effected by use of the large crystal should make it possible to observe additional gamma-rays.

52-2 Neutron Capture Gamma-Ray Studies with the Scintillation Spectrometer (5261-02)

R. Culp and B. Hamermesh
Reported by B. Hamermesh

Hydrogen

As an example of the improvement in the operation of the scintillation spectrometer caused by the use of the large crystal, a study was made of the capture gamma-rays from hydrogen.² Recent similar work was performed using 1.3-cm cubes of NaI. A comparison of Figure 1 in the paper of Bracci et al, with Figure 4 in the paper of³ Hamermesh and Hummel shows the usual rapidly rising background present at lower energies. The suppression of this background by our large crystal makes the lines stand out much more clearly over the background.

¹ B. Hamermesh and V. Hummel, Phys. Rev. 88, 916 (1952).

² Bracci, Facchini, and Malvicini, Phys. Rev. 90, 162 (1953).

³ B. Hamermesh and V. Hummel, Phys. Rev. 88, 916 (1952).

In the experiment, a sample of H_2O contained in a bundle of four lusteroid test tubes, each 1" in diameter and 6" long, was used. (See Figure 1 of Ref. 3 for experimental arrangement.) Since the capture cross section in hydrogen is only 0.3 b, a complete cycle of measurements was needed, namely:

1. Source in, no cadmium in beam;
2. Source in, cadmium in beam;
3. Source out, no cadmium in beam;
4. Source out, cadmium in beam.

The desired effect is given by 1-2-(3-4). The difference 3-4 is usually very small compared with 1-2 (see Figure 2 of Ref. 3); however, in this case, it was significant.

A complete pulse-height analysis was obtained in the energy range 20 kev - 3 Mev. A 20-channel pulse-height analyzer was used. Figure 5 shows the result. Below 1 Mev, the curve goes to zero, as it does above the high energy region shown. The two peaks occur at 2.23 Mev and 1.71 Mev, measured relative to the lines from Na^{24} . This energy comparison is made between the 2.23-Mev line and the peaks due to pair production produced by the 2.76-Mev gamma-ray from Na^{24} followed by absorption of one annihilation quantum. This latter peak is at 2.25 Mev, so that the 2.23 value can be obtained quite accurately.

The peak at 2.23 Mev is due to full energy absorption of a 2.23-Mev gamma-ray while the peak at 1.71 Mev is caused by pair production

FIGURE 5
THERMAL NEUTRON CAPTURE GAMMA RAY
SPECTRUM OF HYDROGEN

CALIBRATION: 50.6 kev/volt

PH-485
5-18-58
H.G.

processes from a 2.23-Mev gamma-ray, in which one of the annihilation quanta escapes. At 2.23 Mev, the peak due to the escape of both annihilation quanta from our large crystal is not visible.

The value of the large crystal in capture gamma work is readily apparent. From the height of the 2.23-Mev peak and the flatness of the background, one may conclude that in the energy range 20 kev - 3 Mev there are no other gamma-rays of intensity greater than 5% of the 2.23-Mev line.

It is planned to send a letter containing these results to the editor of the Physical Review.

60-2 8-Meter Bent Crystal Spectrometer (5261-02)

B. Hamermesh and D. Rose
Reported by B. Hamermesh

The basic mechanical design is being completed. Detailed drawings are now being prepared. The casting for the base, which will weigh about 7 tons, is to be made in the next few weeks. All of the shielding material has been ordered and should arrive shortly.

The Bragg angle is to be measured by use of a modified Twyman interferometer, and the 2-to-1 motion of the detector relative to the quartz crystal is to be maintained with an optical lever. The various optical parts are now being designed.

70-2 Measurements of Nuclear Moments by Angular Correlation (5211-01)

S. Raboy

The γ - γ cascade of 24-hr Hg¹⁹⁷ was studied. At first the source

was made by $\text{Hg}^{196}(\text{n}, \gamma) \text{Hg}^{197}$ in the pile. However, the 65-hr ground state of Hg^{197} completely overwhelmed the transitions from the isomeric state, and pile irradiation was given up.

During the period covered by this report, three cyclotron bombardments on Au were obtained. The first bombardment indicated that the Hg^{197} isomeric state was produced by a (D, 2n) reaction. Pulse-height analysis indicated that Au^{198} and Au^{196} were also produced by (D, p) and (D, p2n) reactions. These gold products added to the background by about 20%.

It was decided to try chemistry on the Au foil to separate the Hg^{197} . After the second cyclotron irradiation, the chemistry was attempted. Sheldon Moline of the Chemistry Division finally perfected the technique, which will be reported in a Chemistry Division report.

The angular correlation experiment was attempted after the third irradiation. The experiment was not a success. The singles counting indicated that 90% of the coincidences were accidentals. Apart from circuit troubles (which were turned up the next day), strong internal conversion could account for this. The preliminary calculations to determine the feasibility of the experiment were based on an internal conversion coefficient of 20 for the 164-kev line and a conversion factor of 2 for the 133-kev line. These coefficients were experimental determinations by Huber et al, reported in Helvetica Physica Acta 24, 127. Goldhaber and Sunyar (Phys. Rev. 83, 906 (1951)), give an empirically calculated value of 360 for the M-4, 164-kev transition. The 164-kev line follows the M-4 rules so well that this 360 value is considered good by Sunyar.

Another attempt is planned, and if the directional correlation experiment for Hg^{197} fails then, perhaps a lower limit on the conversion coefficient may be obtained.

The next isotope to be tried will be Pb^{204} , which has an isomeric state with lifetime of 68 min which decays by two gammas (905 kev and 374 kev, respectively) to a stable ground state. The intermediate state has a half-life of 3×10^{-7} sec. The separation of this isomer from 12-hr Bi^{204} is being studied now.

71-2 The Angular Correlation of β -Rays and Delayed Neutrons from Kr^{87} (5211-01)

L. Goodman

No progress has been made on this project during the quarter, except to make plans for carrying out experiments during the next quarter for determining the efficiency of the liquid scintillation counter for the delayed neutrons from K^{87} .

72-2 The Angular Distribution of Photoneutrons from Be Produced by 2.185-Mev Gamma-Rays (5211-01)

B. Hamermesh and R. Culp
Reported by B. Hamermesh

The neutron counter was 20 cm in diameter, and the beryllium rod was 0.6 cm in diameter and 5 cm long. The beryllium was mounted with its axis perpendicular to the axis of the counter and at a distance of 7 cm from the face of the counter. The source was placed at a distance of

7 cm from the beryllium in either the 0° or 90° position. The source was a right cylinder 1 cm high and 1 cm in diameter containing the Ce^{144} .

The following table shows the combined data from all of the runs obtained during the course of the experiment.

TABLE II

Combined Experimental Data on $\text{Be}(\gamma, n)$ Angular Distribution

	<u>Total Counts</u>	<u>Time (min)</u>	<u>Counting Rate (counts/min)</u>
Background	34,074	11,605	2.936 ± 0.016
0° position	36,758	11,687	3.145 ± 0.016
90° position	40,890	13,018	3.141 ± 0.017

The low counting rates that were available meant that the poor geometry of the experiment could not be improved upon. It would have been desirable to improve the geometry so as to limit the range of acceptance angles that were available at the 0° and 90° positions. The large range of angles that was used meant that large corrections had to be applied.

From the data in the table, we conclude that the results at the two angles are

$$I_{90} = 0.205 \pm 0.011 \text{ counts/min.}$$

$$I_0 = 0.209 \pm 0.011 \text{ counts/min.}$$

Since I is given by a relation of the form

$$I = a + b \sin^2 \theta$$

where a and b are both positive,

$$\frac{I_{90}}{I_0} = \frac{a + b}{a} = 1 + \frac{b}{a}.$$

This means that I_0 cannot exceed I_{90} . When I_0 is equal to I_{90} , the ratio a/b becomes infinite.

From the data and the corrections for the finite range of angles available at the 0° and 90° position, and using the maximum errors on the I_0 and I_{90} values so as to have I_0 less than I_{90} , one may conclude that a/b has a value between 2.5 and infinity. This is a very disappointing result. However, in order to obtain a better value of a/b , it would be necessary to improve the geometry by increasing the spacing between the beryllium and the gamma-ray source. These distances should at least be doubled. The consequent decrease in counting rate by a factor of 16 would have to be compensated by an increase in source strength. The source should be increased in strength by much more than a factor of 16, since the counting rates are very low. This would require a source of 4 or 5 curies.

In view of the above difficulties, it is planned to terminate the work on this problem.

80-2 Molecular Beam Studies (5211-01)

J. Dalman, L. Goodman, S. Wexler
Reported by L. Goodman

The vacuum plumbing has been completed. A large amount of time was consumed leak chasing, and the main vacuum box has gone back to Central Shops.

Electron bombardment heating techniques have been studied for heating of beam ovens. This scheme seems to be quite practical.

The hydraulic lift system for raising and lowering oven and detector tubes has been completed by J. Dalman.

The magnets were delivered, but have been sent back to the shop for alignment and repairs.

90-2 Cross Sections for 14-Mev Neutrons (5211-01)

H. Casson and L. Goodman
Reported by H. Casson

The basic electronic circuits (fast coincidence, etc.) needed for the work have been constructed. The 90° deflection magnet for bending the deuterons into a horizontal plane is in the final stages of construction.

The ion source of the accelerator has been adjusted and a new palladium leak installed. The new leak is heated by passing current directly through the palladium and is faster acting than the old system, which involved a heating coil surrounding, but electrically insulated from, the palladium. The undeflected deuteron beam has been focussed to a spot of the order of a millimeter in diameter.

The problem of making a zirconium-tritium target which (a) would not require a large amount of tritium and (b) could be adequately cooled in order to prevent accidental release of the tritium because of excessive heating produced by the deuteron beam, is being investigated. Mechanically rugged targets which show promise of being satisfactory have been prepared in the following way: Tantalum disks 3/4" in diameter and 1/8" thick were machined with a cylindrical depression (1/4" in diameter and

.010" deep) cut in the front face. By means of electron bombardment of the tantalum in vacuum it was possible to fill the depression with molten zirconium. After cooling, the disk was removed from the vacuum system, and the surface was machined to reduce the thickness of zirconium to the desired value of several mils. After filling with tritium, the disks themselves will be used to make the vacuum seal in the target assembly, with a gasket against the front surface. The rear surface will be exposed to the atmosphere, and easily accessible for cooling purposes.

91-2 Neutron Transport Cross Sections (5261-02)

A. Langsdorf

Detailed design drawings of the shielding and collimating system have been nearly completed, and processing of the requisition for boron trifluoride counters has been almost completed. Further work toward actual construction of the apparatus has been held in abeyance pending approval of the program.

92-2 Neutron Scattering Cross Sections by Use of the Scattering Chamber (5261-02)

C. T. Hibdon

No work has been done in this program during the quarter. It is planned to write during the next quarter a paper to be submitted to the Physical Review that will bring together the hitherto unpublished results obtained by this technique.

93-2 Be(γ ,n) Cross Section at 2.185 Mev (5211-01)

B. Hamermesh and C. Kimball
Reported by B. Hamermesh

This paper will appear in the June 15 issue of Physical Review.

94-2 The Cross Section for the Capture of Thermal Neutrons by Hydrogen (5261-01)

B. Hamermesh, G. R. Ringo, S. Wexler
Reported by B. Hamermesh

This paper appeared in the Phys. Rev. 90, 603 (1953).

95-2 Activation Cross Sections for Sb-Be Neutrons (5211-01)

C. Kimball and B. Hamermesh
Reported by B. Hamermesh

A letter on this subject was published in Phys. Rev. 89,
1306 (1953).

96-2 Pile Absorption Cross Sections (5261-01)

S. P. Harris, D. Rose, H. P. Schroeder
Reported by D. Rose

No work of this sort has been carried out during the quarter.

Results will be reported to the Neutron Cross Section Advisory Group
and eventually collected for publication.

98-1 Total Neutron Cross Sections in the kev Region (5211-01, 5261-01)

C. T. Hibdon and A. Langsdorf
Reported by C. T. Hibdon

With the Van de Graaff generator again in operation, measurements of total neutron cross sections in the kev region have been resumed. The method is that previously described.^{1,2} To get increased efficiency of detection, a new counter assembly has been made. The paraffin core is longer and the counters are more closely packed near the center to get increased probability of capture of neutrons in counters rather than in paraffin. Two monitors are used; one is a long counter placed beyond the target along the direction of the proton beam; the other is an assembly of counters, paraffin moderator, and shield similar to but simpler than the main detector. It is placed with its axis at an angle of 120° with respect to the proton beam, as is the main detector. (The main detector is at the side of the beam, the monitor below it.)

The background count with the new detector in the new location is about 65% of what it was in the Palos Park installation. Comparison of measurements made on Ni with the old results shows that there is substantial improvement in the energy resolution.

Preliminary data have been obtained with the Th, U, U^{235} , and Ni. Measurements for these substances in the range from 1.4 to 150 kev

¹ A. Langsdorf, Phys. Rev. 80, 132 (1950).

² C. T. Hibdon, A. Langsdorf, and R. E. Holland, Phys. Rev. 85, 895 (1952).

will be completed, and measurements will be made with C, Be, F, and Bi in the next quarter.

1. Counting Equipment

The measurement of total neutron cross sections in the kilovolt region has been resumed. In this work the detection scheme employed consists of the massive shield and large number of boron trifluoride proportional counters embedded in paraffin to increase the counting efficiency, to overcome the decline in yield of low energy neutrons, and to reduce the background as much as possible. This equipment has been described in unclassified publications.^{1,2}

This equipment has been gone over thoroughly, repaired or reconditioned where necessary, and some improvements made. A reconditioning became necessary, since it was not used for a long period of time.

Each component of the amplifiers was checked and repaired or parts replaced where needed. Some improvements were made, notably the addition of larger resistors in the plate circuits of the trigger tubes to increase the voltage output which is needed for the less sensitive scaling circuits now in use and since cable leads some 80 ft. long are now necessary. As a time-saving device, test jack plugs were added to the amplifiers to be used when troubleshooting, testing, or checking. All cable lead connectors on the amplifiers scaling circuits, power supplies, and cable lead panels were converted to the Amphenol No. 83 variety. This provides a much more rugged

connector and provides a convenience in versatility of connections.

One major improvement was made on the counter assembly. A longer drum which contains the annular array of counters was fabricated. As now constructed, the cylindrical drum is 18" long and again filled with paraffin plus 2% carnauba wax. Counting tubes up to about 16" in length are now usable. Further, the arrangement of counting tubes was changed. As now arrayed, the counting tubes are as near the axis of the drum as possible, consistent with the strength of the paraffin walls between the counting tubes. In order to increase the counting rate, the longest available counting tubes (11 to 12-1/2" long) were placed in the two innermost rings. Altogether, seven rings, each containing nine counters, are available in this new cylindrical drum.

The collimator of the counter shield is set up with its axis at 120° to the proton beam direction as determined by triangulation. The present setup is actually at $119^\circ 52'$.

2. Monitor

Monitoring of the neutron flux is achieved by a standard boron trifluoride "long counter" placed in the neutron flux along a line extended from the proton beam direction (at 0° with the proton beam). This monitor is primarily used for detection of neutrons when evaporating lithium onto the tantalum target.

Another monitor consisting of one annular ring of eight boron trifluoride counters in a large shield was constructed and is presently in use.

The large cylindrical shield is 24" in diameter and 30" long and filled with paraffin. This shield was further increased by extending its length one foot and filling this extension with water. The water is nearest the lithium target.

The collimating tube of the monitor is 2-3/4" inside diameter. In order to monitor the neutron flux at the same back angle, the axis of the monitor is also placed at an angle of 120° with the proton beam directions.

Counting tubes used in this monitor are the same variety as used in the main counter.

A Lucite scattering cylinder 2-3/4" in diameter and 6" long placed in the axial hole serves to scatter neutrons into the boron trifluoride counters. Its position was adjusted for maximum counting rate.

4. Results

Neutron transmission cross sections have been measured in the energy range from 1.4 to 100 kev on four samples using lithium targets evaporated onto the tantalum end of a rotating target. The neutrons, which were produced by the $\text{Li}^7(p,n)\text{Be}^7$ reaction with the Van de Graaff generator, were detected at an angle of 120° (119° 52') from the proton beam direction by the equipment presently described. Measurements were made with and without the transmission samples and with and without a Lucite neutron scattering plug 2-9/16" in diameter and 6" long placed at the scattering sample position inside the counter assembly. The Lucite plug was positioned for a maximum counting rate. (See Figure 1, Ref. 2, for counter assembly

and also for a detailed description of method.) Background measurements were made without the Lucite plug.

The thickness of the lithium targets was measured by the rise curve as described by Taschek.³ At any neutron energy the counting rate is sufficiently high that no need exists in the present work for a lithium target any thicker than 3 kev as measured by the long counter

Proton energies were measured relative to the Li (p,n) threshold at 1.882 Mev and neutron energies calculated as described by Hanson et al.⁴

The background count has been reduced to about 65% of the count in our previous work. This is attributable to two reasons, 1) semi-transparent floor beneath the counting equipment and 2) longer drum which holds the counters in place inside the large shield. The new geometry of paraffin and counters contributes materially towards reducing the background.

Paragraph deleted.

³ R. F. Taschek and A. Hemmendinger, Phys. Rev. 74, 373 (1948).

⁴ Hanson, Taschek, and Williams, Rev. Modern. Phys. 21, 635 (1949).

Table III
Deleted

The energy resolution is apparently better than in our previous work. This is evident from the variation of the cross section of nickel near a resonance, particularly the resonance in the 4-kev region, where a dip occurs before this resonance and was not seen in the previous work.

Results of the preliminary runs for Ni are presented in Figures 8 and 9.

Paragraph deleted.

Paragraph deleted

109-1 Neutron Diffraction Apparatus (5211-01)

R. W. Holmes (Central Shops), G. R. Ringo, S. S. Sidhu
(Metallurgy Division)
Reported by G. R. Ringo

The growing number of applications of neutron diffraction to studies of the physics of solids and liquids makes it clear that this laboratory should have efficient equipment for these studies using beams from CP-5. To this end we have designed equipment for the observation of neutron diffraction patterns of powders and similar materials. The design follows closely that

Figure 6

Deleted

Figure 7

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of E. O. Wollan at Oak Ridge National Laboratory (Phys. Rev. 81, 527 (1951)). The apparatus consists of a collimator going through the reactor shield, a monochromator crystal in a heavy shield, a movable arm which rotates around the monochromator, and another movable arm, attached to the first, which has the sample on the fixed end and a neutron counter on the other. It differs from the ORNL apparatus chiefly in that the monochromator and its shield can easily be moved away from the reactor, permitting changes in the collimation. This makes it possible to trade intensity for resolution, or the reverse, when desired.

During this quarter the design work has been nearly completed and the construction of the apparatus started.

During the next quarter the work should consist chiefly of construction, with some design work on the adjustable mounting for the monochromator crystal.

110-2 Crystal Spectrometer for 0.1 to 100-ev Neutrons (5211-01)

S. Raboy and G. R. Ringo
Reported by S. Raboy

Very little work was done on this project this past quarter.

The fission monitor was tried, and it performed as expected. Instrumentation was continued.

111-2 Neutron Spectroscopy in the 0.01 to 10-Mev Region (5211-01)

V. E. Krohn and G. R. Ringo
Reported by V. E. Krohn

Tests with normal-lithium-loaded glass specks have been completed by J. H. Roberts et al at Northwestern University, and glass loaded with lithium enriched to about ninety percent Li^6 has been ordered from Corning Glass Works. This glass will be ground into specks about three microns in diameter and loaded into emulsions which will be used in attempts to study neutron spectra in the 100 to 500-kev region without the requirement that the neutrons be unidirectional.

112-2 The Neutron Spectrum of a Standard Ra-Be Photo Source (5211-01)

C. Egger

Continued study of the operation of the parallel mesh coincidence counters in the cloud chamber exposed two difficult problems. Poor insulation characteristics in the presence of condensible vapors have prevented the use of increased voltages on the counter grids as a means of overcoming attenuated signals. Further, it has been found almost impossible to photograph tracks through the counter mesh because of glare produced by scattered light on the wires. It is proposed to replace the present parallel mesh counters with two strip counters oriented as chords.

113-1 Hydrogen-Filled Cloud Chamber for Neutron Spectrum Studies (5261-01)

C. M. Huddleston and C. Egger
Reported by C. Huddleston

A program has been initiated to measure the neutron spectrum from 50 to 100 kev by measuring the ranges of recoil protons in a hydrogen-filled cloud chamber. The method to be employed will be similar to that described by Nereson.¹ The apparatus will be tested and calibrated by using it to measure the low energy part of the fission spectrum of U^{235} , as has been done by Bonner.²

The cloud chamber, which has been successfully operated in a vertical position, is 2" deep and 12" in diameter.

An attempt was made to find and purchase a commercial camera which would be suitable for the investigation, but no satisfactory camera could be located on the market. It was decided, therefore, to build a completely automatic 35-mm camera.

Work has been almost completed on the camera and a stereoscope arrangement which will photograph simultaneously three views of the chamber at pre-set time intervals.

It is expected that the measurement of the fission spectrum will be underway by the first of June.

¹ Norris Nereson, LA-1234 (1951).

² T. W. Donner, LA-715 (1948).

120-2 Calibration of a Ra-Be Neutron Source (5211-01)

S. P. Harris

A coincidence circuit that can be set for a resolution time of 2, 5, or 10 microseconds has been received and thoroughly tested. The values of the computed efficiency of the β counter as used with one active sample are most nearly constant for different counting rates if a value of 2.4×10^{-6} min is assumed for the dead time of the counter. Efficiencies of about 5% are found for pressed pellets of sodium acetate of the kind that will be used. Counts taken with a similar pellet of potassium oxalate (effectively a constant source of β -rays of energy almost equal to those of sodium) indicate variations of counting rate greater than statistical fluctuations. The desirability of using a gas flow counter to reduce the dead time and increase the stability is being looked into.

A sample of the sodium acetate to be used has been activated and found to give only the sodium half-life.

The tank in which the solution will be irradiated is under construction. Ra-Be sources No. 312 and No. 313 have been enclosed in suitable secondary aluminum containers.

Because the β -rays from K^{40} and Na^{24} have almost identically the same endpoint energies, it should be possible to determine the K^{40} β decay rate by using a small amount of Na^{24} in a pellet of a potassium compound to determine the β -ray efficiency by the coincidence method. This is similar to the method of Stout,¹ except that he did not use β - γ

¹ R. W. Stout, Phys. Rev. 75, 1107 (1949).

coincidence from Na^{24} to calibrate the counting system.

121-2 Calibration of Neutron Sources (5211-01)

C. Egger

A 100-mg Ra-Be neutron source has been calibrated for John S. Laughlin of Memorial Center, New York, by comparing it with ANL source No. 312 in CP-2 by the sub-critical pile technique. The source was found to emit 1.59×10^6 neutrons per second as of April, 1953. This value is good to the $\pm 7\%$ assigned to the calibration of our source No. 312 with an intercalibration accuracy of $\pm 2\%$. No further report is anticipated.

131-2 Average Charge of Daughter Atoms After Nuclear Transitions (5211-03)

S. Wexler

Average Charge After Electron Capture by A^{37}

The chlorine daughter atoms from electron capture of $35\text{-d } \text{A}^{37}$ were found to carry an average charge of 3.0 ± 0.2 electron units. Individual data of six determinations varied from 2.7 to 3.2. The result is lower than the value of 3.85 ± 0.2 electron units reported by Miskel and Perlman¹ for this transition. Starting with relative probabilities of Auger transitions calculated by Pincherle,² an average charge of +2.7 is estimated after nuclear electron capture by argon and subsequent reorientation of the chlorine daughter by Auger and radiative electron transitions.

¹ J. A. Miskel and M. S. Perlman, Phys. Rev. 87, 543 (1952).

² L. Pincherle, Nuovo Cimento 12, 81 (1953).

As described in previous reports, the positive ion current of the daughter atoms is measured in a gas of the parent at very low pressures. The number of units of charge collected by a probe in unit time is compared with the disintegration rate of the parent to give the average charge per disintegration. The procedures for measuring the positive ion current have been described.³ The activity of the A^{37} was determined by introducing an aliquot of the gas into a calibrated proportional counter. The active argon used in these experiments was prepared by vacuum fusion of neutron-irradiated calcium metal.

Average Charge After Isomeric Transition of 113-min Kr^{83m}

The isomeric decay of Kr^{83m} to its ground state occurs in two steps. The 32.7 and 9.3-kev transitions are almost completely converted.^{4,5} The deep-lying shell vacancies are filled by Auger and radiative electron transitions, and the resulting ion may therefore carry a high charge. We have measured the average charge of krypton atoms from the isomeric transition and found it to be 7.7 ± 0.4 electron units. The variation was from 7.4 to 8.0 in six experiments.

The experimental procedures followed closely those used in the A^{37} studies. The krypton activity was prepared by successive bromine and krypton "milkings" of neutron-irradiated selenium.

³ S. Wexler, ANL-4963 and ANL-4982.

⁴ I. Bergström, Phys. Rev. 81, 638 (1951).

⁵ I. Bergström, Arkiv f. Fysik, Utgiv, Kungl. Svenska Vetenskap 5, No. 14 (1952).

Average Charge After β^+ Decay of N^{13}

It was previously reported that more than 90 per cent of the products from positron decay of N^{13} , as a mixture of N_2 and NO , appeared to carry a negative charge. Attempts were made to measure the average charge by varying the electric field conditions and thus distinguish between the negative ions and secondary electrons formed by the positrons at the chamber walls. Apparently because of overlapping of the energies of the recoils and the secondaries, this series of experiments gave inconclusive results. Consequently, a new chamber more suitable for the study of negative ions has been designed and is in process of being constructed.

132-2 Chemical Service Work (5211-03)

S. Wexler

A strong source of 16-d V^{48} was prepared from deuteron-bombarded chromium. The activity was used by V. Krohn and H. Casson in their study of the decay scheme of V^{48} .

133-2 Design Study of a Multi-Bev Proton Synchrotron (5211-01)

M. Hamermesh, J. J. Livingood, L. A. Turner, R. R. Weeks
Reported by J. J. Livingood

Numerous meetings have been attended at the University of Chicago and one at Washington to discuss technical features of the proposed accelerator and the cooperative organization which must be set up among the Midwestern institutes. These included a two-day meeting in Chicago,

attended by two dozen representatives from other centers, with E. D. Courant and J. P. Blewett (Brookhaven) and R. R. Wilson (Cornell) as guest speakers. A meeting in Washington included T. H. Johnson (AEC) and representatives from Chicago, ANL, Illinois, Indiana, Michigan, Minnesota, and Wisconsin.

Considerable discussion has been given to a proposed site, many of the above institutes having land available; some are much better equipped than others in housing facilities for visitors. ANL is notably lacking in this respect.

It seems to be generally agreed that the establishment of a separate corpus (analogous to Associated Universities, Inc.) is undesirable as an administrative organ; it would be better for a single institute to assume general responsibility and to sub-contract out various tasks to others. Mr. Johnson believed that a sum in the neighborhood of \$500,000 might be obtained from the AEC for a year's study programme.

The initial burst of enthusiasm over the alternating gradient principle has been replaced by the realization that the problem is very much more difficult than originally believed. Very comprehensive studies are under way at Cambridge, Brookhaven, Princeton, and Cornell, as well as in Europe, and it may develop that the most practical program, in terms of men and money, will be to await developments at these institutes before committing a large sum for an additional effort. Nevertheless, it seems possible that a group of about a dozen men from the Midwest might congregate during the summer to make one further attack

on the general feasibility of the scheme, provided funds are forthcoming, and to decide whether a further study effort of a year's duration is worthwhile.

134-1 Optical Excitation Spectra of the $(\text{He}^3)^+$ After β^- Decay of Tritium
(5211-01)

S. Wexler and M. Fred (Chemistry Division)
Reported by S. Wexler

The beta transition of tritium to He^3 may be to excited states of the helium as well as to the ground state. Migdal's relations¹ give the following probabilities for β^- transitions of tritium to various states of single ionized He^3 :

<u>State</u>	<u>Probability</u>
Ground	0.703
1st Excited	0.250
2nd Excited	0.014
3rd Excited	0.004
4th Excited	0.002

The de-excitation of the helium may occur by emission of radiation. It so happens that the transition from the 4th to the 3rd excited state of $(\text{He}^3)^+$ involves emission of light of near 4686 Å wave length, making observation of this line feasible. Calculations show that sufficient intensity of this wave length would be obtained from a moderate amount of tritium,

¹ A. Migdal, J. Phys. (USSR) 4, 449 (1941).

using an F-5 Roman spectrograph available in this laboratory. The source holder and accessory apparatus have been designed and are being constructed.

This experiment is being done in cooperation with F. W. Porter of Washington University under the participating institution program.

135-1 Electron-Neutron Interaction (5211-01)

G. R. Ringo

The earlier work on this problem is described in an article by M. Hamermesh, Ringo, and Wattenberg (Phys. Rev. 85, 483 (1952)). A considerable improvement in the accuracy of the measurement appears warranted by the theoretical interest and seems feasible.

The first step in such an improvement is to determine the coherent amplitude for neutron scattering of krypton and xenon, the gases used in the interaction measurement. Some apparatus for this measurement has been constructed.

In the next quarter, x-ray diffraction measurements will be made on frozen xenon and krypton to see if they give good powder patterns. If they do, measurements will be made at Oak Ridge National Laboratory of the neutron diffraction pattern at liquid helium temperatures. These will permit a determination of the amplitudes by standard means.

II. MASS SPECTROSCOPY

1-2 Mass Spectrometric Techniques (5211-08)

W. Chupka, R. J. Hayden, D. C. Hess, M. G. Inghram,
H. Stanton, C. Stevens
Reported by M. G. Inghram

Ratio Recording in Isotopic Analysis

The use of null methods^{1,2,3} to correct for ion beam instabilities in a mass spectrometer has improved the accuracy of isotopic comparison by more than an order of magnitude. The use of ratio recording methods⁴ with a mass spectrometer equipped with a vacuum spark source has also resulted in a large improvement. Neither of these methods is satisfactory without modification for use in a mass spectrometer equipped with a surface ionization source⁵ and an electron multiplier ion detector. The former² is in error because to use it, it is necessary that the gain of the multiplier stay constant over long periods of time. The latter⁴ is in error because it assumes that there is no elemental fractionation with time. This note describes a modification of the ratio recording system applicable to surface ionization sources.

As in all of the older methods, the technique consists basically of collecting an ion beam whose intensity is proportional to the total intensity

¹ H. A. Strauss, Phys. Rev. 59, 430 (1941).

² A. O. C. Nier, E. P. Ney, M. G. Inghram, Rev. Sci. Instr. 18, 191 (1947).

³ C. McKinney et al, Rev. Sci. Instr. 21, 724 (1950).

⁴ J. E. Gorman, E. J. Jones, and J. A. Hipple, Anal. Chem. 23, 438 (1951).

⁵ M. G. Inghram, W. A. Chupka, Rev. Sci. Instr., in Press.

of the element in question and comparing that beam with the ion beam of a particular isotope. The collector which accomplishes this object for the case at hand is in Figure 10. In this collector, a grid consisting of a number of parallel wires is placed in front of the usual defining slit in order to intercept a portion of each of the ion beams produced by the isotopes of the element in question. This current is then compared electrically with that passing through the defining slit. Thus, as the mass spectrum is swept across the collector, the current to the grid remains proportional to the total emission of the element in question, while that to the final collector represents successively the current due to individual isotopes.

Isotopic ratios may be determined either by reading the two ion currents simultaneously or they may be compared electrically, in which case only one reading is necessary. This electrical comparison may be accomplished by substituting the signal from the grid collector for the battery supplying the slidewire in a recording potentiometer, such as the Brown Elektronik Recorder, while the signal from the final collector is introduced as the comparison signal. Thus, the reading on the recorder is proportional to the ratio of the resolved to total beam and does not depend on ion intensity variations. It is advantageous from the operational standpoint to use a two-pen recorder, the second pen recording the grid signal. The second pen can be used for checking the ratio recording results, and it shows that the amplifiers are within their linear range.

FIGURE 10

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PHG-518
 8-18-53
 B.G.

The collector described above eliminates to a large extent the difficulties with the previously used null or ratio methods as applied to the surface ionization case. First, the gain of the multiplier has to remain constant for only that time necessary to sweep from one isotope to another and not from one sample to the next, and secondly, the comparison signal is proportional to the total ion beam of only those masses within a predetermined range, so that errors due to elemental fractionation are largely removed.

The major problem encountered with the collector described is in details of the grid collector. To insure a constant ratio of ions going through the grid collector to ions collected in spite of variations in intensity distribution in a direction parallel to the slit, the grid is made of a large number of parallel uniform wires 0.003" in diameter spaced 0.006" apart following the technique of Glenn.⁶

Errors due to secondary electrons and ions are minimized by introduction of suppressors. The following sets of suppressor voltages were found to be satisfactory on each of two different instruments.

<u>Set 1</u>	<u>Set 2</u>
Suppressor No. 1 + 45 volts	Suppressor No. 1 - 45 volts
Suppressor No. 2 - 45 "	Suppressor No. 2 - 225 "
Defining Slit + 1.5 "	Defining Slit - 1.5 "
Suppressor No. 3 + 45 "	Suppressor No. 3 - 45 "

The first of these sets permits the removal of the secondary electrons from both the grid and single slit collector, hence increasing the positive

⁶ W. E. Glenn, AEDC-3337, Jan. 3, 1953.

ion signals by a factor of three (a function of ion energy). The second set suppresses the secondaries so that only the incident ion beam is measured.

To make sure that suppressor voltages are correct, the ion beam must be scanned back and forth with an ion beam of constant intensity looking for non-uniformity in the grid signal. Since it is difficult to obtain constant intensities from a surface ionization source, this uniformity may be checked in the pertinent locations by measuring isotopic abundances both by direct and ratio recording or by calibration with standard samples.

Variations in the grid collector signal have been observed which can only be explained by the ion beam not being centered with respect to the grid collectors, since proper alignment of magnet and slits removed the difficulty.

For the best results during ratio recording, the intensity over the duration of each scan of all isotopes should be held fairly constant. While ratio recording is designed to eliminate errors due to intensity variations, large changes in the intensity will cause small errors. These errors are due to the zero readings of the single-slit collector amplifier. An offset zero in the recorder potentiometer cannot be used as the outputs if both amplifiers have a common ground and are balanced against each other in the recorder potentiometer slidewire. However, to insure that the true zero is recorded, there must be a small recording zero signal for all sensitivity ranges of the amplifier. This zero may be provided by a small increment of voltage of about 0.1 to 0.2 millivolts in series with the

amplifier output to the recorder, while the amplifier zero is kept as close to true zero as possible. With this arrangement the zero setting will not vary with the output amplifier sensitivity. Any zero reading, whether due to this amplifier zero or to the small series voltage, will be inversely proportional to the grid collector signal supplying the slidewire or, in other words, the intensity. Thus, a change in intensity between the times when the zero and peak height are recorded will cause a small error. The magnitude of the error is proportional to the fractional change in intensity multiplied by the ratio of the zero signal to peak height signal; for example, a change of intensity of 10% and a zero reading which is 10% of the peak height would cause a 1% error in the reading of the difference. If the intensity does not change between the zero and peak readings, there is, of course, no error.

The results of this technique so far indicate a possible precision as low as 0.2% using a surface ionization source. Better results than this would be difficult to obtain, since fluctuations in the distributions of intensity in the ion beam will limit the precision in the ratio of ions collected by the grid collector to those collected by the single slit collector. This ratio is dependent on the uniformity of the wires in the grid. If this technique is used on a gas source, this factor may not be a limitation, since the distribution in the ion beam is more constant and should not vary between samples.

2-2 Construction of MA-17 (5211-08)

H. E. Stanton

During the past quarter, the spectrometer tube and the analyzing magnet were installed in MA-17. The remainder of the machine vacuum system was completed and leak hunting more or less completed. The collector bonnet had to be remachined in certain places because of leaks in the stand-offs.

The magnet has been magnetized and the field measured. The heavy iron shunt permits a variation in magnetic field in the gap of more than 10 to 1 at 5000 gauss.

All parts for the completion of the machine are on hand and nearing final assembly, and early in the next period an ion beam should be obtained.

After this stage in the development is passed, some experiments allied with the heat of vaporization of carbon will be undertaken which should yield results of scientific interest.

10-2 Search for Rare Naturally Occurring Isotopes (5211-08)

D. C. Hess

No new isotopes have been discovered this quarter, but the limits of occurrence of some have been lowered.

For potassium, K^{35} , K^{36} , K^{37} , and K^{45} do not exist with an abundance greater than 10^{-8} of the total potassium. K^{38} and K^{44} are

rarer than 4×10^{-8} of the total. The abundance of K^{42} is less than 2×10^{-8} , and K^{43} , less than 5×10^{-8} . The limit on K^{46} is 10^{-7} .

Gadolinium: Gd^{159} is less than 6×10^{-5} , but further lowering will require a sample with less terbium impurity. Other limits are: 163, 6×10^{-6} ; 164, 3×10^{-6} ; 165, 2×10^{-6} ; 166, 2×10^{-6} .

Neodymium limits are: 140 and 151, 10^{-6} ; 141, 4×10^{-5} ; 147 and 152, 8×10^{-6} ; 149, 5×10^{-6} .

Europium: 150, 5×10^{-6} ; 152 and 154, 10^{-5} ; 155, 10^{-4} ; 156, 10^{-6} .

Many of the high (10^{-5}) limits on the rare earths are due to interference of other rare earths appearing as impurities.

Some work was done on manganese to look for the missing Mn^{53} . Some ions appeared at mass 53 but held no constant relation to the Mn^{55} intensity. Since many ions observed appeared to be due to hydrocarbons, it was decided that the greased joint used to introduce samples should be replaced by a glass seal which is reblown for each sample introduction. This has been done, but pressure exerted due to the demand for separate facilities for MA-15 and MA-18 led to "cannibalization" of MA-16 to supply some electronics, and further tests with MA-16 have been temporarily suspended.

11-2 Technetium in Nature (5211-08)

R. J. Hayden, M. G. Inghram, J. M. Miller (Columbia University)

Reported by R. J. Hayden

Mass analysis has been completed on molybdenum samples obtained by J. M. Miller from old ores having a high rhenium to molybdenum ratio. Excess molybdenum at masses corresponding to long-lived technetium isotopes, which if present would be found with rhenium, would have allowed a calculation of the time from the formation of the elements until the formation of the ores. Unfortunately, no excess of any molybdenum isotope was found. In the table below are the isotopic abundances of samples analyzed, together with the normal abundances of Hibbs¹ and of Williams and Yuster.² Errors are probable errors in ten determinations. The Williams and Yuster values are those accepted by Bainbridge and Nier³ in their critical collection isotopic abundance of the elements.

TABLE IV

<u>Molybdenum Isotope Abundances</u>						
<u>Sample</u>	<u>92/98</u>	<u>94/98</u>	<u>95/98</u>	<u>96/98</u>	<u>97/98</u>	<u>100/98</u>
Norway						
No. 1	.625±.002	.388±.002	.665±.002	.696±.002	.400±.001	.400±.001
Norway						
No. 2	.620±.002	.388±.001	.663±.002	.693±.003	.398±.001	.405±.001
South						
Africa	.624±.003	.389±.001	.668±.002	.697±.002	.401±.001	.402±.001

¹ R. F. Hibbs, AECU-556, Aug. 1949.

² Williams and Yuster, Phys. Rev. 69, 556 (1946).

³ Bainbridge and Nier, National Research Council Preliminary Report 9, Nuclear Science Series.

<u>Sample</u>	<u>92/98</u>	<u>94/98</u>	<u>95/98</u>	<u>96/98</u>	<u>97/98</u>	<u>100/98</u>
Normal (Published by Williams and Yuster)	.668	.384	.661	.695	.398	.405
Normal (Published by Hibbs)	.627	.390	.657	.690	.400	.403

Within experimental error the ratios for all three samples agree with each other and with each of the normal ratios except the Williams and Yuster 92/98. The close agreement of our 92/98 ratios with those of Hibbs and the wide divergence from the Williams and Yuster value indicates that Hibbs value should be accepted.

12-2 Double Beta Disintegration of Te^{130} (5211-08)

R. J. Hayden and M. G. Inghram
Reported by R. J. Hayden

Progress on this problem in the past quarter has been largely in instrumentation. After a series of leaks, cracks, and minor difficulties, the vacuum system of MA-18, the high-sensitivity gas machine, was finally made tight. After baking the entire vacuum system beyond the diffusion pumps to about 350° C for two days, the ion background in the xenon region was unobservable. With the electron multiplier gain so high that individual ions striking the collector gave observable pulses on the recorder, no peaks except I^{127} were seen in the xenon mass region. Retaining the high resolution and sensitivity previously reported, the instrument is now ready for the xenon measurements which must be made.

It has already performed xenon and krypton analyses requiring comparable sensitivity. These results will be reported by George Wetherill (University of Chicago) in a future Physics Division quarterly.

A gas purification line to extract xenon from tellurium ores is being constructed. Upon completion, several samples will be purified and analyzed.

30-2 The Heat of Vaporization of Carbon (5211-08)

W. A. Chupka and M. G. Inghram
Reported by M. G. Inghram

The previously reported study¹ of the atomic and molecular species evaporating from a hot carbon surface has been extended using the same techniques. The method employs mass analysis of the ions produced by electron bombardment of the vapor. The ionizing electrons are of such low energies that ions are generally produced only from the corresponding neutral species. The disadvantage of low ion intensities is overcome by the use of an electron multiplier for ion detection.

The ratio of C^+ to C_2^+ ions produced by bombardment of the carbon vapor has been measured more accurately. The ions are produced by 17-volt electrons, and it has been shown that at this low energy the C_2^+ ions are produced entirely from molecular species evaporating from the carbon surface and probably mostly from the C_2 molecule. In a series of runs, the C^+/C_2^+ ratio was reproducible at a particular temperature

¹W. Chupka and M. Inghram, J. Chem. Phys. 21, 371 (1953).

The graph of Figure 1 contains a drafting error. The scale of abscissa should extend from .40 to .49 instead of from .40 to .50.

and remained constant even when C_2H_2 gas was introduced, as long as the energy of the ionizing electrons was kept below about 19 volts. In previous runs using 20-volt electrons, the C^+/C_2^+ ratio did not remain strictly constant even without the introduction of C_2H_2 , evidently due to production of some C_2^+ from hydrocarbons, traces of which remained in the mass spectrometer.

The presence of the previously reported² C_3 molecule has been confirmed. Some trouble was caused by an HCl peak of the same mass, but this was minimized and a correction was made when necessary. A search for molecules of higher molecular weight indicated they were in negligible quantities compared to C.

The relative intensities of C^+ , C_2^+ , and C_3^+ were measured using both a carbon filament and a filament machined from spectroscopic graphite rod. The results from both were essentially the same. The relative intensities of C^+ , C_2^+ , and C_3^+ from the graphite filament at 2450° K using 17-volt electrons were approximately 1.0, 0.5, and 1.6, respectively. These values should be regarded as only a rough measure of the relative abundances of C, C_2 , and C_3 in the neutral vapor, since ionization cross sections are unknown and the ions are produced in the sharply rising region of the ionization cross section curve. However, the appearance potentials of

² W. Chupka and M. Inghram, ANL-4993, p. 14, February 28, 1953.

all three species appear to be roughly equal, thus reducing the error due to the latter factor.

Measurements of the temperature dependence of the C^+ ion intensity using 17-volt electrons have been repeated six times using both carbon and graphite filaments and a random sequence of temperatures over ranges up to 400° . The values of the apparent ΔH (2000° K) of sublimation all fell within the range 170-182 kcal/mole and gave an average value of 177 ± 6 kcal/mole and a ΔH (0° K) of 176 ± 6 kcal/mole.

In order to eliminate the possibility that an appreciable number of the C^+ ions were formed from C_2 or C_3 by the 17-volt electrons, measurements were carried out using 14-volt electrons. Within experimental error the same temperature dependence was obtained. The ionization efficiency curve for C^+ also shows no detectable break from the appearance potential up to about 21 volts, where a sharp break indicates formation of C^+ from another process, possibly from residual gases such as CO. Thus C^+ from higher energy processes made it difficult if not impractical to obtain good results with electrons of higher energy with our apparatus.

The temperature dependence of both C_2^+ and C_3^+ have been measured and indicate values of ΔH (2500° K) of sublimation of 200 ± 10 kcal/mole for both C_2 and C_3 . ΔH (0° K) for C_2 would then be about 211 kcal/mole. The value of ΔH (0° K) for C_2 calculated by the absolute pressure method, assuming that about 15% of the carbon evaporated in the usual rate

of evaporation experiments^{3,4} comes off as C_2 , is about 208 kcal/mole.

Since both of these methods give upper limits for ΔH , the present data

indicate that the value of Brewer, Gilles, and Jenkins,⁵ $\Delta H (0^\circ K) =$

233.1 ± 7.0 kcal/mole, is too high by about 23 kcal/mole or more. Brewer⁶

has recently stated that the value measured by Brewer, Gilles, and Jenkins

may be too high and that the $^3\Pi_u$ lower state of the Swan bands used in their

measurements may not be the ground state of the C_2 molecule as indicated

by the work of Norrish, Porter, and Thrush.⁷

The fact that C_2^+ and C_3^+ intensities have approximately equal temperature dependence suggests the possibility that a large part of the C_2^+ may be formed from C_3 . This seems improbable, since the appearance potential of C_2^+ agrees with the ionization potential of C_2 as measured by Kallmann and Rosen,⁸ and no detectable break in ionization curve has been observed below 19 volts. However, a more careful study of the ionization curve should be made before definitely excluding this possibility.

The concentration of C_3 in carbon vapor and its heat of sublimation are of interest, since Herzberg has recently tentatively assigned the so-called 4050 Å bands to C_3 . These bands have recently been observed in absorption in acetylene-oxygen explosions in the region of strong carbon

³ A. Marshall and F. Norton, J. Amer. Chem. Soc. 72, 2166 (1950); Simpson, Thorn, and Winslow, AECD, 2680 (1949); Farber and Darnell, J. Amer. Chem. Soc. 74, 3941 (1952).

⁴ Doehard, Goldfinger, and Waelbroeck, J. Chem. Phys. 20, 757 (1952).

⁵ Brewer, Gilles, and Jenkins, J. Chem. Phys. 16, 797 (1948).

⁶ Private communication.

⁷ Norrish, Porter, and Thrush, Nature 169, 582 (1952).

⁸ Kallmann and Rosen, Z. Physik. 61, 332 (1930).

deposition.⁷ The large amount of C_3 is also of interest, since it probably formed a major part of the carbon vapor collected in the usual rate of evaporation experiments^{3,4} and, together with C_2 , may account for the temperature dependences observed in these experiments, which indicate an activation energy for evaporation in the range 177-200 kcal/mole.

Since C atoms are probably a minor constituent of the vapor, the experiments of Simpson, Thorn, and Winslow³ on the accommodation coefficient of carbon must be regarded as inconclusive. A complete understanding of the evaporation process requires further knowledge, especially concerning the accommodation coefficients of the various species. This could probably be done best by use of a Knudsen cell as in previous experiments^{4,5} but accompanied by mass analysis of the effusing vapor.

A parallel study by R. E. Honig corroborates much of the above work, with the exception of ΔH of evaporation of C_3 .⁹

31-2 Studies of Electron Impact (5211-08)

W. Chupka (Harvard University) and R. J. Hayden
Reported by R. J. Hayden

No progress has been made on this program during the quarter.

32-2 Complex Ion Studies (5211-08)

W. A. Chupka and M. G. Inghram
Reported by M. G. Inghram

No progress has been made in this program during the last quarter because of concentration on the studies of the heat of vaporization of carbon.

⁹ R. Honig, Programm of the 1952 Washington meeting of the American Physical Society, Abstract L8; also private communication.

33-2 Molecular States in Rare Gases (5211-08)

D. Hess and M. Inghram
Reported by D. Hess

No work has been done specifically on this project during the past quarter. A gas sample handling system is being built for MA-16 which can be utilized for this experiment.

34-2 Argon Age Determinations (5211-08)

G. Wasserburg (University of Chicago) and R. J. Hayden
Reported by R. J. Hayden

No progress has been made in this program because of an accidental explosion that largely demolished the vacuum line being assembled. A new vacuum line is being assembled.

III. CRYSTALLOGRAPHY

1-2 Crystal Structures of Technetium Compounds (5211-11)

H. A. Plettinger and W. H. Zachariasen
Reported by W. Zachariasen

No further report on this project for the quarter.

2-2 Structural Studies of Boric Acids (5211-11)

H. A. Plettinger and W. H. Zachariasen
Reported by H. A. Plettinger

Further calculations are in progress.

V. THEORETICAL PHYSICS, GENERAL

1-2 The Interpretation of the Energy States of Light Nuclei (5211-07)

D. R. Inglis

The fact that the first excited state of O^{16} has the same angular momentum and parity as the ground state, 0^+ , poses a peculiar puzzle. This and the next three excited states have been identified and are in accord with the alpha model, but this model predicts one other state which is as yet missing, and it is the central model instead which appears to apply to the neighboring nuclei. The possibility that the central model, or some less drastic modification of it, may account for the first excited state of O^{16} is being investigated.

A non-isotropic deformation of the oscillator parameters in the potential forming the filled p-shell may be used to describe a collective motion analogous to that of the droplet model. As a refinement of the classical irrotational flow assumed in the droplet model, the mass motion associated with this oscillatory deformation has been analyzed in the adiabatic approximation. The rate-of-deformation dependence of the energy arises from temporary excitation to higher oscillator states. The result is that the collective oscillation is twice as rapid as the single-nucleon oscillation, so the adiabatic approximation is not valid, and this invalid estimate of the energy of the first excited state of collective oscillation is twice too high to account for the observed state in question.

This leaves the possibility that the difficulty is only a calculational one, and that the state does arise from collective motion.

A calculation is in progress concerning the possibility that two-nucleon excitation (giving the configuration $p_{1/2}^{-2}d_{5/2}^2$) might have 0^+ as its lowest state. Neglect of the interaction between the unexcited and excited nucleons leaves states with $J = 4, 5$, and 6 lowest, and it appears doubtful that inclusion of the interaction will alter this result.

2-2 Excited States of Light Nuclei (5211-07)

D. Kurath

The energy levels of the states arising from the ground configuration $(1p_{3/2})^m (1p_{1/2})^n$ and the first excited configuration $(1p_{3/2})^{m-1} (1p_{1/2})^{n+1}$ have been calculated for mass numbers $A = 10$ through 15 .

The levels up to excitation of 9 Mev are given in Figure 11 and are identified by (I, T) , where I is the total angular momentum of the nucleus and T is the isotopic spin. The spin-orbit energy which splits these two configurations is taken from the experimental observation of O^{15} and N^{15} , where the first negative parity excited state occurs at about 6.3 Mev.

This leads to a value of $a = 4.2$ Mev in the single particle spin-orbit term, $H' = a \underline{\ell}^i \cdot s^i$. The two-body interaction is assumed to be the central force combination, 0.8 Majorana plus 0.2 Bartlett used by Inglis¹ in the study of light nuclei. The integrals arising from this

¹ D. R. Inglis, Rev. Mod. Phys. to be published.

FIGURE II

ENERGY LEVELS OF NUCLEI OF MASS NUMBER A.
THE LEVEL IS IDENTIFIED BY THE SYMBOL (I,T).

GENERAL CONFIGURATION IS $(p_{3/2})^m (p_{1/2})^n$

IN SHORTHAND NOTATION THE COLUMNS ARE IDENTIFIED BY (m,n).

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86.

interaction² are given numerical values, $L = 5.5$ Mev; $K = 0.81$ Mev.

These states should be those low-lying levels observed to have the same parity as the ground states. The experimental results are given by Ajzenberg and Lauritsen,³ and the calculation is given some confirmation, to the extent that the experimentally observed spins are among those calculated to be low-lying. However, there are some unobserved calculated levels, generally of high spin, and the spacing and order of the observed levels are not always in agreement with experiment.

Two features of agreement resulting from comparison with experiment lend support to this approach. First, the lowest state of the excited $(1p_{3/2})^{m-1} (1p_{1/2})^{n+1}$ configuration gets closer to the ground state as A decreases. Second, the experimental spins are mostly the result of angular distributions from (d,p) and (d,n) stripping reactions. For nuclei where the target has $A \geq 12$, the excited configuration involves not only the capture of a nucleon into a $(1p_{1/2})$ orbit, but also the excitation of another nucleon from the $(1p_{3/2})$ shell to the $(1p_{1/2})$ shell. Experimental results in C^{14} and N^{14} indicate that while such states exhibit the angular distribution expected from capture into a p orbit, they are considerably suppressed in intensity. Such suppression would not be expected in the L-S coupling scheme where there is no closed shell at $A = 12$.

² E. Feenberg and E. Wigner, Phys. Rev. 51, 95 (1937).

³ F. Ajzenberg and T. Lauritsen, Rev. Mod. Phys. 24, 321 (1952).

The nuclei for $A = 6$ and $A = 7$ have been calculated by others,⁴ and the nuclei at $A = 8$ and $A = 9$ have too little experimental information on excited states and too much complexity in computation to warrant investigation. It is planned to include the other central forces for the nuclei treated here and to see whether any combination will give good agreement for the known levels occurring in mass number 10 through 15. The effect of interaction between levels of the two configurations will also be treated in cases where it will clearly have a large effect, as in $A = 10$. The effect on the magnetic moments will be compared with the effect desired to improve agreement with experiment.

3-2 Angular Correlation in the 3-Gamma Cascade in Ti^{48} (5211-07)

M. Brachman and E. J. Hellund
Reported by E. J. Hellund

The computations have been completed and checked. A paper will be written and submitted to the Physical Review.

4-2 Investigation of Nuclear Shell Structure

5-2 Book on Nuclear Shell Structure

M. G. Mayer

Work on the book on nuclear shell structure has progressed, and the book is nearing completion.

⁴ H. H. Hummel and D. R. Inglis, Phys. Rev. 81, 910 (1951). D. R. Inglis, Phys. Rev. 87, 915 (1952). E. A. Crosbie, Phys. Rev. 90, 138 (1953).

6-2 Inner Bremsstrahlung and the Magnetic Moment of the Neutrino
(5211-07)

E. J. Hellund

A paper on this subject will appear in the Physical Review for May 15, 1953, thus terminating the program.

7-2 Collective Description of Nucleon Interactions (5211-07)

M. Ferentz and D. Pines (University of Illinois)
Reported by M. Ferentz

This project has been relatively inactive this quarter, with work consisting principally of checking numerical calculations prior to publication.

Additional calculations have been done on the energies and A-dependence of the photonuclear resonances as predicted by this theory using various phenomenological two-body central interactions. Majorana exchange forces of the proper strength to fit the low energy nucleon-nucleon scattering and the deuteron lead to reasonably good agreement with experiment for the energies and an $A^{-1/3}$ dependence upon atomic weight. Present experimental knowledge is not precise enough to determine the A-dependence unambiguously, but an $A^{-1/3}$ dependence is not inconsistent with experiment.

8-2 Monoenergetic Neutrons from Charged Particle Reactions (5211-07)

W. A. Reardon

The relations developed by Monahan and Langsdorf (ANL-5031) were examined for order-of-magnitude, term by term for several assumed energies of proton bombardment. The relative sizes of several relativistic corrections are thus examined for a wide range of energies.

The derivatives of the function were examined in the vicinity of threshold (1.882 Mev for $\text{Li}(p,n) \text{Be}$) to find the effects of small errors in any of the parameters appearing, such as Q-value, mass, etc.

These studies showed the desirability of casting the relation between the neutron energy and proton energy into a new form involving the threshold energy instead of the Q-value. A consistent set of independent variables then appear in the equation, since the threshold energy is experimentally measurable.

The equations, together with a set of mass and threshold values, have been turned over to the computer group (Dr. Flanders) for detailed calculation over a wide range of energies.

28-1 Angular Distribution of Elastically Scattered Neutrons (5211-07)

M. Hamermesh

In view of the contemplated measurements of angular distributions of elastically scattered neutrons, we have derived the explicit theoretical formulas for angular distribution from target nuclei of

various spins, and for several values of the total angular momentum of the compound state. The general expressions of Blatt and Biedenharn¹ assuming a one-level resonance formula were worked out in detail for several specific cases. In principle, angular distribution measurements enable one to determine the partial widths of a resonance level for the various channel spins which are consistent with the angular momentum of the level. (This is analogous to the occurrence of both triplet and singlet neutron-proton scattering.) Since the formulas for angular distribution are quite complicated, the main problem which is now being studied is to determine what data and what accuracy are needed to give useful information beyond what is obtained from total cross section measurements.

29-1 Internal Conversion in Subshells (5211-07)

M. Hamermesh and J. Monahan
Reported by M. Hamermesh

The observations of Church,² Mihelich et al,³ indicate that for $Z^2/E \gg 1$, (Z = nuclear charge; E = energy of gamma-ray), electric quadrupole radiation is converted mainly on p electrons, while for magnetic dipole radiation, the conversion occurs almost entirely on s electrons. Since the effects are so large, we are trying to understand them without recourse to detailed computations. As a first step, for E-2 transitions, the non-relativistic formulas of Hebb and Nelson⁴ were applied to the L and M shells. To reduce computation to a minimum,

¹ Blatt and Biedenharn, Phys. Rev. 82, 123 (1951).

² Church, private communication.

³ Mihelich, et al, Phys. Rev. 87, 646 (1952).

⁴ Hebb and Nelson, Phys. Rev. 58, 486 (1940).

the ejected electron was assumed to have zero energy. For both the L and M shells, it was found that E-2 radiation is almost completely converted in the p subshell. After performing the computations, the wave functions of the various states were plotted. The reason for the preference of p electrons is clearly seen from the overlap of initial and final state wave functions.

We are now extending these considerations to M-1 transitions, and are also considering relativistic effects.

30-2 Consultation on Miscellaneous Theoretical Problems (5211-07)

M. Hamermesh

Geometrical corrections of data on angular distribution from Be photo-disintegration were computed for B. Hamermesh and are contained in his report.

An attempt was made to use data from Los Alamos on angular distributions of scattered neutrons to determine transport cross sections as a function of neutron energy. The results were quite unsatisfactory. It appears that the data with various threshold detectors are not accurate enough to give the group cross sections.

Some calculations were made for S. Wexler on the Auger effect in argon, and are included in his report.

31-2 The Configuration Interaction in Iron Group Elements

N. Rosenzweig

Further work in this program has been postponed until the AVIDAC is available for making the computations.

32-2 Plural Scattering of Electrons at Oblique Incidence (5211-14)

M. Hamermesh and J. Monahan
Reported by J. Monahan

The ratio of the intensities of reflected and transmitted electrons scattered through an angle of 90° from a thin foil has been calculated for the following case: 1.7-Mev electrons incident at an angle of 45° with the normal to an aluminum foil 7 mg/cm^2 thick. Assuming the distribution of deflections to be Gaussian plus a single scattering tail (E. J. Williams, Phys. Rev. 58, 292 (1940)), and considering the entire effective scattering volume of the foil, this asymmetry ratio was found to be $1.05 \pm .01$. The McKinley-Feshbach approximation formula (W. A. McKinley and H. Feshbach, Phys. Rev. 74, 1759 (1948)) was used for the single-scattering distribution.

The details of the calculation indicate that for electrons at oblique incidence the only serious deviation from single scattering is that due to combinations of two deflections of the same order of magnitude. This is essentially the condition for the validity of the approximation made by Goertzel and Cox.¹ Using Rutherford's formula

¹ Goertzel and Cox, Phys. Rev. 63, 37 (1943).

with relativistic electron mass for the single-scattering distribution, they obtain an asymmetry ratio less than 1.02 for the parameters considered above. The discrepancy is due almost entirely to the choice of different single-scattering distributions.

Perhaps the most interesting conclusion to be drawn from the present calculation is the surprising accuracy, apart from any assumptions as to scattering distributions, of the Goertzel-Cox approximation. This introduces an essential simplification in calculations of this type. The experiments of Waldman,¹ which were the reason for undertaking the present calculation, give asymmetries far larger than any possible according to the theory. An Argonne report will be written describing the calculations. No further work is planned for the present.

33-2 Geometry for Maximum Scattering and Minimum Dispersion (5211-07)

A. Langsdorf and J. Monahan
Reported by J. Monahan

No further work was done on this problem during the last quarter.

34-2 Quantized Space Time (5211-14)

E. J. Hellund and K. Tanaka
Reported by E. J. Hellund

A proof has been found that the plane wave solutions of the

¹ Waldman, private communication.

Dirac equation for free particles do not represent states for which the time can be specified with finite precision. The immediate consequence is that the plane wave basis used in all self-energy calculations is invalidated. The result can be shown to hold whatever the magnitude of the fundamental length introduced into the theory. The conclusion follows that the results of such a theory do not "go over" into the conventional quantum dynamics by making the fundamental lengths vanish. A similar conclusion is reached in non-linear field theories.

It is planned to submit a brief account of the analysis for publication in the Physical Review.

35-2 Scattering of Photons by Atoms (5211-14)

E. J. Hellund

The paper on this subject will be submitted to the Physical Review for publication in the next quarter.

37-1 On the Relation of the Schrödinger and Boltzmann Equations (5211-14)

E. J. Hellund

Transformation theory has been applied to the problem of determining the extent of the correspondences between wave mechanics and statistical mechanics. A representation was chosen permitting a space time analysis of the Schrödinger equation. Elimination of the classical Hamiltonian led to a formulation exhibiting a one-to-one

correspondence with the Boltzmann equation for ideal particles.

The proposal is made that the collision term of the Boltzmann equation is the basis by which the Schrödinger theory can be modified for high moments.

A paper was submitted for publication in the Physical Review.

VII. ELECTRONIC DIGITAL COMPUTERS

1-2 Report on the Design of the ANL Computer (4520-02)

R. F. Kramer

Work on this project has been suspended for the time being until other projects concerned with the ANL digital computer are completed. These projects, which are more pressing, deal with the improvement of the ANL computer and the auxiliary memory project.

Drawings and wiring diagrams for the ANL computer are being brought up to date.

2-2 Improvements of the ANL Computer (4520-02)

C. Bergstrom, J. C. Chu, D. H. Jacobsohn, R. F. Kramer
Reported by D. H. Jacobsohn

I. Console

An interim console was designed, constructed, and installed during the last quarter. This console allows for complete visualization of all information pertinent to computation and for the complete operation of the machine including the ability to insert individual numbers into the arithmetic unit. The interim console was designed to facilitate its use in a permanent console.

II. Williams Tube Selection

During the past quarter, considerable effort was spent on Williams tube selection and testing. Of the 12 Sylvania tubes with a

read-around of 96 or better, as mentioned in the previous report, all but 2 were unuseable due to impurities. The attempts to spark these tubes were completely unsuccessful. No tubes were recovered, even though some impurities were removed from tubes having multiple impurities. These attempts prove very time-consuming, as it took from two hours to two days of operating time to discharge the face of a sparked tube. In addition to sparking, attempts were made with 30 KV, AC, and DC potentials to remove impurities. These attempts were unsuccessful.

Owing to the great delay in the discharging of the face of the tube, a special piece of equipment was built to facilitate discharging. This equipment consists of the RCA tube manual 5CPIA scope circuit, two phase-shift oscillators, and amplifiers to generate a Lissajous pattern. It was later discovered that if a grounded wet cloth were placed on the face of the tube and the tube were then sparked between the phosphor and the third anode until some picture appears on the face of the tube, it would take from 5 to 15 minutes to discharge the tubes. In order for this technique to be fully successful, the pattern prior to sparking must cover the full face of the tube.

Later in the quarter, one hundred DuMont 5CPIA's were obtained. These tubes received special handling from the time of manufacture to insure that nothing could fall on the phosphor of the tubes. The read-around rate of 60 of these tubes was 256 or better. Because of this high percentage at this rate, 256 read-around was established as our first acceptance criteria. A breakdown of the read-around testing is as follows:

<u>Read-Around</u>	<u>No. of Tubes</u>	<u>No. Without Impurities</u>
768	4	1
512	6	3
384	13	7
256	37	16
rejects	<u>40</u>	<u>-</u>
Total	100	27

The sparking technique was tried with the DuMont tubes, with ten out of the initial twenty-one tubes sparked becoming useable.

These results with the DuMont 5CPIA's indicate that we should be able to use them successfully in the AVIDAC memory, although final proof can be obtained only in actual use.

III. Completion of Order List

During the past quarter, the A_x end chassis was constructed. This chassis will allow the completion of the order list when installed.

IV. Electronic Commutator and Control Equipment for Punched Paper Tape

The input-output equipment on the AVIDAC consists of modified teletype and Western Union equipment using standard teletype paper tape. The speed of operation on "read-in" to the computer is limited to about twelve four-digit characters per second. The "read-out" operation is at the speed of about six four-digit characters per second. The timing of these operations is controlled by a mechanical commutator with the resulting speed limitations. It would be desirable to increase the speeds of these operations, with resulting improvement in usefulness of the AVIDAC. To do this, the input-output equipment has been redesigned to include a photoelectric tape

reader with a top speed of 200 characters per second and a faster punch which can operate at twenty-four characters per second.

The control equipment logical design has been completed, and the engineering design is about 50% complete. The design is arranged so the equipment can be used with the present input-output devices as well as the faster equipment.

An electronic commutator using a series of one-shot multivibrators has been designed to control the timing of the input-output sequences. Four digits (one character) are read into and out of the machine in parallel, so a count must be kept of the number of characters; also, four shifts are required after each character. The gates, toggles, and counters for this purpose have been designed and are now being tested. The remainder of the design will be completed during the next two weeks. Construction of the electronic equipment will be completed during the ensuing quarter.

3-2 Operational Maintenance of the AVIDAC (4520-02)

C. J. Bergstrom

During the past quarter, work has been primarily aimed at raising the useable storage of the AVIDAC memory from 256 to 512 locations. By designing a "back-to-back" twitch circuit, it was possible to spread the raster more effectively over the face of the storage tube and minimize adjacent spot interaction. Preliminary testing of the memory since this installation was made indicates that the memory will have the same utility

at 512 as it did at 256. We can now consult a given location more than 200 consecutive times without destroying information.

The arithmetic unit has worked satisfactorily during this interval with very little maintenance. What trouble did appear was due to tube failure. This type of trouble we are minimizing by the tube replacement program described below under Preventative Maintenance.

During the period covered, the machine was used for solution of two actual problems over a period of several weeks. It worked increasingly well during this time, as original faults were located and corrected until it was possible to operate over 5 to 8-hour periods without detectable error.

Preventative Maintenance

During the past quarter, a program of tube replacement has been instituted with the expectation that by proper pre-aging and testing of tubes before use in the AVIDAC, many tube failures during machine operation can be avoided. It is planned that tubes at present in the machine will be replaced with these tubes in groups of 10 or 20 at a time and complete data retained on actual tube life and service in the machine.

All voltage and current measurements made while the machine is in operation have been recorded and are rechecked periodically to insure against drift.

A permanent equalizing setup for maintaining correct charge of the batteries has been built and is ready for installation. This will do much to prevent any slow rise or fall in critical battery voltages.

4-2 Test Routines for the AVIDAC (4520-02)

J. Alexander and J. Hall
Reported by J. Alexander

The memory tests for the AVIDAC were extended to test a 512 raster. No further tests have been developed.

5-2 Subroutine Library for the AVIDAC (4520-02)

M. K. Butler (Reactor Engineering Division), J. F. Hall,
R. H. McDowell
Reported by J. F. Hall

Subroutines will not be formally entered into the library until they have been thoroughly tested on the AVIDAC. Several routines have been completed except for their machine testing. This testing will be done as soon as the machine is available for this purpose. The titles of these routines are as follows:

S-3.3 The Three-Address Control for Standard 30-10 Arithmetic
(A Floating-Point Routine)

S-10.1 Sum and Punch Routine

S-10.2 Load Routine for Single Address Variable Address
Subroutines of Type I

S-5.1 Fixed Point Square Root

S-4.1 Standard 30-10 Square Root

Other routines nearing completion are:

S-5.2 Fixed Point $\sin x$

S-5.3 Fixed Point $\exp(-x)$

During the next quarter, we plan to start a program of using S-3.3 to make the AVIDAC quickly available for the computation of small, straightforward problems. This will require further attention on building routines to accompany the S-3.3 routine, such as base ten floating point to base two floating point and vice versa conversion.

6-2 Coding Manual for the AVIDAC (4520-02)

D. A. Flanders

The first three chapters of the manual are currently titled (1) "Brief Description of the AVIDAC," (2) "Binary Arithmetic in the AVIDAC," (3) "AVIDAC's Coded Instructions." About one half of Chapter 1 is in essentially final form, and another quarter has been written but is in need of revision. Chapter 2 has been started abortively. The descriptive material in Chapter 3 is in essentially final form. All material written thus far (except the false start on Chapter 2) has had the benefit of detailed criticism from other members of the group.

Mrs. Hall is reporting separately on the progress of the library subroutines that will appear as part of the manual.

The series of weekly lectures on programming for the AVIDAC referred to in the previous report began on April 17 and will continue through about the second week in June.

Titles of projected chapters of the manual are: (4) "Introduction to Programming," (5) "Subroutines," (6) "The Use of Three-Address Subroutines for General Purpose Programming." These chapters should be finished within the next quarter.

7-2 The Auxiliary Memory for the ANL and ORNL Computers (4520-02)

L. Merrill and R. F. Kramer
Reported by R. F. Kramer

During the last quarter much experimental work was done on recording-channel amplifiers. These amplifiers must withstand high input signals during the "write" period and then recover quickly so as to amplify the relatively weak signals during the "read" period. Also, the amplifiers must have good frequency response down to about 20 cycles so as to minimize base line shift. This implies long time constants in an AC coupled amplifier with its accompanying long recovery time after being overloaded by a "write" signal.

Such an AC coupled amplifier was designed with a relay to short circuit the input during "write" period. A very fast relay free of bounce was required. The Western Electric type 275 satisfies the requirement. Its operate time is 3 milliseconds; release time, 3.6 milliseconds. About 10 milliseconds is available for switching in each of the digit channels.

The control channel requires faster switching. The time available is about 200 microseconds. A very fast relay whose operate time is 150 microseconds is included in the design for this channel. A model of the digit-channel amplifier was built and is now undergoing test.

The drawings and process specifications for the 2-inch, 42-channel recording head were completed. Also, the construction faults in

the model of the 2-inch head, mentioned in the last report, were corrected. Some life tests will be conducted on this head before construction work begins on the ten heads for the ANL and ORNL auxiliary memories.

Complete drawings for the magnetic clutches for the ANL and ORNL auxiliary memories have been made. In general, the design is an improvement on the basket tape drive mentioned in previous reports. The clutches were designed so the drive mechanism can be easily opened to insert tape. Also, the bearings and friction mechanism was revised to strengthen the unit.

Drawings for the drive unit are about 75% complete.

Power supplies for the test rig modifications are about 90% complete; in the ensuing quarter the changes in the test rig will be completed.

Construction drawings for the main frame for the auxiliary memories will be made in the next quarter, and the mechanical design of the electronic equipment will be started. It is expected that the amplifier design will be completed in the next quarter.

8-2 A Problem in Partitions (5211-14)

D. A. Flanders

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

If time permits, the generation and listing of the partitions of n will be programmed and coded for the AVIDAC.

10-1 Report on AVIDAC Control (4520-02)

J. Alexander

A rough draft of a report on the control of the AVIDAC has been started. This report will contain a fairly complete description of the operation of the machine, but the bulk of the report will be a detailed explanation of the logic of the control. Its principal use will be in maintenance work.

21-2 Operation of the ORNL Computer (4520-02)

E. Burdette, J. C. Chu, W. Gerhard (ORNL), R. J. Klein (ORNL),
J. Woody (ORNL)
Reported by J. C. Chu

The teletype control has been completed and is now working successfully with the computer.

The memory system has been undergoing preliminary acceptance tests. This testing procedure is designed to detect and eliminate the noise sources before the memory is put into actual operation. The testing procedure is outlined as follows:

1) Run the memory without high voltage, deflection signals, astigmatism voltage, strobe pulse, or cathode-ray pulses. The small neon panel in the slave compartment will then indicate if a noise pulse gets into the amplifier. The source of this pulse is, then, the pre-amplifier, video amplifier, or discriminator, and can be found by substitution, tapping, examination for bad solder joints, etc. We call this test N 1.

After the machine has run for several hours on N 1 without failure, it is reasonable to assume that the amplifiers, discriminators, etc., are quiet.

2) Run the memory as above, but apply the high voltage and astigmatism voltage and remove all cathode-ray tubes. This is test N 2. Now, if a neon tube lights, it indicates noise from the high voltage system only. The source of this noise can again be located by the above-mentioned methods. However, because of the difficulty of substituting components in the high voltage system (they are not plug-in), it is expected to take considerably longer to find these high voltage faults. When the memory runs for several hours on N 2, then full scale testing can begin.

3) Run the memory with all pulses and tubes as per design. Insert a full raster of zeros and watch the slave scope for "1's" pickup; this is test N 3. Such pickups would lead to the suspicion of the CRT's or the deflection system, as the other components and voltages have already been proven. Of course, there is always the possibility of failure of a component in the time elapsed between the tests. Thus, an amplifier tube may get noisy during a high voltage test, thus complicating the hunt for noise.

4) After N 3 has run satisfactorily - all "1's" should be inserted in the memory - the drop-outs will show up on the slave scope. This is test N 4. CRT adjustments should be the main cause of difficulty on N 3 and N 4. Certain CRT adjustments will cause N 3 to work, but N 4 will fail, and vice versa.

5) The next step is to hook the memory to the arithmetic unit and run various read-around and reading and writing tests.

At the present time the memory has passed the above tests. The above memory-testing program was interrupted about three weeks due to the revision of the air conditioning and ventilating systems. We expect to begin the final ORACLE acceptance test during the ensuing quarter.

30-1 Computation of Cyclotron Trajectories (4520-02)

J. Alexander, D. Flanders, J. Hall
Reported by J. Alexander

Professor E. Fermi has suggested that the computation of trajectories of pions emerging from the magnetic field of a cyclotron would be a suitably simple first problem for the Argonne electronic computer.

In this study, all the trajectories considered lay in the horizontal plane midway between the cyclotron pole faces. The angle, $\theta_f - \theta_i$ (see Figure 12), through which a trajectory is bent, depends on the energy of the pion, and the initial direction, θ_i , and is always less than 180° in the cases considered. The calculation consisted of determining the intercepts, (X,Y), of the line along which the pion travels (the dotted line in the figure) after it enters the field-free region, as a function of the energy and θ_i .

The results of this calculation allow one to calculate the direction in which the pions of a given energy are travelling and their intensity at any point in the field-free region relative to the intensity at the radiator.

FIGURE 12
TYPICAL PION TRAJECTORY

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Mathematical Analysis

The Lorentz force on the pion due to the magnetic field gives the equation of motion $F = m\ddot{r} = -\frac{e}{c} H \times \dot{r}$

$$\begin{aligned} \text{or } \ddot{x} &= \frac{e}{mc} H (x,y) \dot{y} \\ y \ddot{y} &= -\frac{e}{mc} H (x,y) \dot{x}. \end{aligned}$$

Since v is a constant of the motion, we can let $s(=vt)$, the distance travelled in time, t , be the independent variable. The equations become

$$\begin{aligned} x'' &= \left(\frac{e}{mcv} \right) H y' \\ y'' &= -\left(\frac{e}{mcv} \right) H x', \end{aligned}$$

where primes indicate differentiation with respect to s .

$\left(\frac{e}{mcv} \right)^{-1}$ is the magnetic stiffness of the pion and $\frac{eH (x,y)}{mvc}$ is the radius

of curvature of the trajectory at the point, (x,y) .

The two second order equations can be reduced to four first order equations as follows:

$$\begin{aligned} u'_x &= k H u_y \\ u'_y &= k H u_x \\ x' &= u_x \\ y' &= u_y \end{aligned} \quad \left(k = \frac{e}{mcv} \right)$$

By using approximations

$$f_{(n+1)} = f_n + (\Delta s) f_{(n+1/2)}$$

$$f_{(n+1/2)} = f_n + 1/2 [f_n - f_{(n-1)}]$$

where $f_n = f(n(\Delta s))$, the following finite difference equations are obtained:

$$u'_{xn} = k H u_{yn}; u_{x(n+1)} = u_{xn} + \frac{\Delta s}{2} (3u'_{xn} - u'_{x(n-1)})$$

$$u'_{yn} = -k H u_{xn}; u_{y(n+1)} = u_{yn} + \frac{\Delta s}{2} (3u'_{yn} - u'_{y(n-1)})$$

$$x_{n+1} = x_n + \frac{\Delta s}{2} (3u_{xn} - u_{x(n-1)})$$

$$y_{n+1} = y_n + \frac{\Delta s}{2} (3u_{yn} - u_{y(n-1)})$$

The initial values of the variables (at $n = 0$ and $n = -1$) were computed by assuming that the trajectory begins as a circle of radius

$$R = \frac{mvc}{e H (x_i, 0)}$$

The difference equations were solved for $n = 1, 2, \dots, F$, where F is the first value of n such that

$$x_F^2 + y_F^2 > r_F^2,$$

where r_F is the radius of the boundary of the field-free region. X and Y were then found from the equations

$$\frac{x = x_F u_{yF} - y_F u_{xF}}{u_{yF}}; \quad \frac{y = y_F u_{xF} - x_F u_{yF}}{u_{xF}}$$

Professor Fermi supplied a table of the magnetic field of the University of Chicago cyclotron for the purposes of this calculation.

A table of x and y was computed for

$$u_i = \pi - 1/2 (2^{-8}) \pi + 1/4$$

$$\frac{mcv}{e} = 40 \times 2^{13} (2^{13}) 150 \times 2^{13}.$$

This table will be checked by repeating the entire calculation.

This work will not be reported upon further in the quarterly reports.

(Note: This report was inadvertently omitted from the previous quarterly report.)

VIII. APPLIED MATHEMATICS AND COMPUTATION, GENERAL

1-2 IBM Methods and Procedures (4520-02)

N. F. Morehouse

L. Renick, J. Nelson, and N. F. Morehouse have revised some of the wave equation decks to speed up solution.

J. Carter has found that if an India ink pen and ozalid carbon backing are used on the recording drum of the REAC, the curves require no retouching by a draftsman.

W. Feurzeig

A deck of 4500 cards, each consisting of ten random digits and three random logarithms, has been prepared and used in connection with the Monte Carlo calculations. The deck will be available for any future Monte Carlo problems to be done with the C. P. C.

2-2 Report on Technical Details of the General Purpose IBM Boards (4520-02)

N. F. Morehouse

The report is about one-fourth finished. Work on it has been delayed by pressure of other work. It is expected that it will be finished in the next quarter.

3-2 Report on Coding for the General Purpose IBM Boards (4520-02)

N. F. Morehouse

The report has been finished and is being typed for duplication for the use of interested persons in the Laboratory. No further publication is contemplated, since the board is usable only with the Model I CPC, which has been superseded by the Model II at most computing centers.

4-2 Tabulation of Fermi-Dirac Distribution Functions (5211-14)

E. L. Dershem and N. F. Morehouse
Reported by E. L. Dershem

The tabulation is now complete.

5-2 IBM Floating Point Subroutines (4520-02)

E. L. Dershem

Changes have now been incorporated which enable all real number routines, except $\arcsin x$, to check their own range limitations. It is hoped that the inverse trigonometric function routines can be developed during the next quarter.

6-2 Computation of Neutron Chopper Results (5211-01, 5261-01)

W. Feurzeig

Additional programming has been done to allow dead time corrections to be made when necessary. Several runs, reported elsewhere, have been completed. This routine service computation will continue through the next quarter.

8-1 IBM Computation of a Multigroup Problem (4520-02)

J. Alexander and J. Hall
Reported by J. Alexander

A reasonably general procedure for solving reactor calculations of six or fewer groups was set up and run on the IBM machines for the Reactor Engineering Division. No formal report is submitted for this procedure, since it is a close copy of work done by KAPL and ORNL. See, for example, KAPL-39 or ANP-58. The analysis of the results is being done by the Reactor Engineering Division. This work will not be reported on further in subsequent quarterly reports.

9-1 Monte Carlo Calculations on Liquid Neutron Counters (5211-01,
5261-01)

W. Feurzeig

The energy dependence of detection efficiency of liquid counters is being computed by Monte Carlo methods. The problem has been programmed for the CPC. Four problems have been completed, corresponding to initial energies of 173 V., 200 V., 40,000 V., and 10 V. At least one more problem will be done during the next quarter, corresponding to the initial energy of 250,000 V.