

MASTER

Conf- 751130--17
UCRL - 77173
PREPRINT

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.



LAWRENCE LIVERMORE LABORATORY
University of California/Livermore, California

Activation Measurements of High Energy Deuterons
in the Plasma Focus Device

R. L. Gullickson and H. I. Sahlin

December 4, 1975

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

This paper was prepared for submission to
1975 Plasma Physics Divisional Meeting of the American Physical Society,
10-13 November 1975
St. Petersburg, Florida

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
Ry

ACTIVATION MEASUREMENTS OF HIGH ENERGY DEUTERONS IN THE PLASMA FOCUS DEVICE

R. L. Gullickson* and H. L. Sahlin

Lawrence Livermore Laboratory, University of California
Livermore, California 94550

ABSTRACT

Nuclear activation techniques have been used to measure the fluence of high energy deuterons in a plasma focus device having a stored energy of 75 kilojoules at 18 kV. The $C^{12}(d,n)N^{13}$ (330 keV threshold) and $Al^{27}(d,p)Al^{28}$ reactions were used to provide both an absolute number of high energy deuterons and an average energy, evaluated from the N^{13}/Al^{28} ratio calculated for various energies by Young.¹ Previous measurements indicated more than 10^{15} deuterons could be accelerated to energies above 330 keV in the low pressure mode of operation, with a highly anisotropic distribution.² Present measurements show that more than 10^{12} deuterons achieve energies greater than 5 MeV on some high intensity shots in the low pressure mode. The presence of multi-MeV deuterons in the plasma focus device was substantiated by measuring activation as a function of depth in 1 mil Al foils, and by measurements of neutron energy using time-of-flight.

INTRODUCTION

The plasma focus device is a form of linear pinch discharge which produces a dense, magnetically compressed plasma at the end of a coaxial electrode system.³ The plasma focus device has produced neutron yields of more than 10^{12} (with a 420 kilojoule capacitor bank)⁴, and is an intense pulsed x-ray source. The plasma focus device can be operated so as to produce high axial electric fields at the termination of the dense pinch phase, resulting in the acceleration of electrons and ions to many times the energy of the capacitor bank charging voltage. Maisonnier has suggested that the bulk of the neutron yield in the plasma focus device may arise from a lower density plasma ($n = 10^{18} \text{ cm}^{-3}$) turbulently heated to 10 keV by an energetic electron beam generated at the time of the disruption of the dense pinch phase.⁵

Other measurements of high energy deuterons in Filippov geometries and in a hybrid Filippov-Mather geometry have been made using nuclear emulsions, a deuteron reaction on lithium, and neutron time-of-flight.⁶⁻⁸

* Present Address: Air Force Office of Scientific Research, Bolling AFB, Washington, D. C. 20332

The calculation of energetic deuteron distributions has been accomplished by Bernstein and Comisar,⁹ and by Gary.¹⁰ In the first reference an electric field generated by a rapidly constricting current discharge is calculated, causing an ion acceleration to axial energies in excess of 400 keV. In the second, an anomalous resistivity caused by a microinstability is assumed, and the resulting electric and magnetic fields calculated.

EXPERIMENTAL

The plasma focus device capacitor bank used in these experiments consisted of 32 fourteen microfarad capacitors, connected in modules of four and switched with eight vacuum spark gap switches³ through a parallel plate transmission line to the plasma focus electrodes. In these experiments the maximum operating voltage was 18 kV, resulting in a stored energy of 76 kilojoules. Maximum current is 900 kiloamps at 18 kV and the quarter cycle time is approximately 3.5 microseconds.

A 10 cm diameter copper anode with a hemispherical end and removable tantalum insert was used. The cathode is 15 cm in inner diameter and is made from twelve 1.2 cm diameter copper rods. The anode extends 29 cm from the base of the cathode, the pyrex insulator, 13 cm.

Standard diagnostics include silver activation neutron detectors,¹¹ a neutron time-of-flight detector,¹² current and voltage monitors, x-ray pinhole cameras, silicon "PIN" detectors with Ross filters,¹³ and thermoluminescent dosimeters.

PREVIOUS RESULTS

In previous experiments at Livermore, the acceleration of electrons was analyzed by x-ray measurements,¹⁴ and the acceleration of ions with carbon activation.² A carbon crystal spectrometer, silicon "PIN" detectors, and thermoluminescent dosimeters were used to evaluate the spectrum, absolute intensity, and spatial distribution of x-rays with energies greater than 3 keV. A maximum single shot x-ray yield of 140 joules above 3 keV was observed, operating with a stored energy of 57 kJ (16 kV). Operating at low pressure (1 torr D₂), it was determined from an analysis of hard x-ray intensity, that 1200 joules of energetic electrons with an average energy of 150 keV, were produced in a burst less than 20 nanoseconds in duration. This corresponds to about 2% efficiency from stored capacitor bank energy to energetic electrons.

Carbon discs, 3.8 cm in diameter and 0.79 cm thick were mounted at various positions ahead of the plasma focus anode to monitor high energy deuterons through carbon activation. Radioactive N^{13} from the reaction $C^{12}(d,n)N^{13}$ (threshold is 330 keV) was measured after each series of shots using a gas flow proportional counter or geiger tube detector. N^{13} is a positron emitter with a half life of 9.97 min. These measurements showed a dramatic difference between activation for low and high pressure operation. Shots at one torr produced up to 1.4×10^8 N^{13} atoms on the O^0 pellet located 23 cm ahead of the anode (neutron yield was 1.2×10^{10}) whereas at 5 torr the neutron yield was higher (2.4×10^{10}) but the maximum activation observed was 2.8×10^6 , a factor of 50 less.

The distribution of high energy deuterons was found to be highly anisotropic with a 0^0 to 90^0 ratio of greater than 10^4 for most high intensity shots. These high intensity shots could be fitted to an exponential spatial distribution, centered at C^0 , and falling off a factor of two in seven degrees. The measured activation showed a strong positive correlation with the hard x-ray intensity, and did not demonstrate a consistent correlation with anode insert material (although the highest intensity shot employed a titanium anode insert). Based upon a thick target yield value of 2.86×10^{-7} N^{13} atoms per incident deuteron at 735 keV, a total high energy deuteron emission of 2×10^{15} deuterons above 330 keV was calculated for the highest intensity shot. Using a power law distribution for the deuteron intensity as a function of energy as suggested in reference 9, the number of deuterons above 5 MeV for a shot with the same intensity, was estimated to be 9×10^{12} .

CURRENT RESULTS

Carbon - Aluminum Activation. To establish both a mean deuteron energy and absolute intensity, carbon and aluminum targets were irradiated at the same position in front of the plasma focus anode (see figure 1). The carbon reaction was the same as previously described; the aluminum reaction used was $Al^{27}(d,p)Al^{28}$. While this reaction has no threshold, the cross section is less than 2 mb below 3 MeV. The N^{13}/Al^{28} ratio calculated for various energies by Young,¹ determined the mean deuteron energy. The nitrogen and aluminum activities were counted with a gas flow proportional counter or geiger tube, and the measured half live. provided positive identification of each isotope.

The thick target yield curves for the carbon and aluminum reactions, taken from reference 1, are shown in figure 2. The plasma focus activation results giving the highest average deuteron energies are presented in Figure 3. A number of shots gave N^{13}/Al^{28} ratios indicating average deuteron energies at or above 5 MeV. No appreciable activation on carbon or aluminum was produced at pressures higher than 3 torr D_2 , although the maximum neutron yields were produced at 5 torr (3×10^{10}). The total number of high energy deuterons was calculated from the number of activation product atoms at shot time, the thick target yield at the energy determined by the N^{13}/Al^{28} ratio, and by integrating the exponential angular deuteron distribution over 2π steradians. The calculated number of high energy deuterons for various shots is listed below.

Shot #	Pressure	N^{13}/Al^{28}	E_{av}	Deuterons	Neutrons**
1910	1.0 torr D_2	35.5	2.3 MeV	7×10^{10}	2.1×10^9
1914	1.0	7.0	4.9	2×10^{12}	2.6×10^9
2111	3.0	4.5	5.0	1×10^{12}	9.0×10^9
2105	0.7	2.6	6.8	1×10^{11}	2.5×10^9
2010	1.0	1.7	8.0	4×10^9	3.2×10^9

Note that there is not a strong correlation between the total neutron yield and either the number of high energy deuterons or their average energy.

Copper Activation. To verify these high average deuteron energies indicated by the N^{13}/Al^{28} ratios, we looked for deuteron induced reactions with thresholds above 4 MeV. Copper targets provide two such reactions: $Cu^{63}(d,2n)Zn^{63}$ and $Cu^{65}(d,2n)Zn^{65}$. Pertinent data for these and other copper reactions is listed in table 1. High purity copper discs, 2.5 cm in diameter and 0.5 cm thick, were mounted on an axial rod located 15 cm ahead of the plasma focus anode. The activity in the copper targets was measured using the gamma spectroscopy system of the LLL Radiochemistry Department which includes various lithium drifted germanium detectors, 4096 data channels, a minicomputer controlled sample changer, and a sophisticated data analysis code for the CDC 7600 computer.¹⁶

All of the copper targets irradiated on low pressure shots showed substantial beta activity (a few mr/hr), as indicated by a portable geiger tube survey meter, with a half life of 11 ± 3 minutes. However gamma analysis of these targets failed to confirm the presence of deuterons with energies above 5 MeV.* The gamma analysis data from shot 2449 is shown in table 2. Zinc 63 should produce gamma peaks at 669.8 and 961.2 keV, zinc 65 at 1115.5.

* One shot did show small quantities of Zn^{65} . However this result was discarded because it couldn't be reproduced, and because of uncertainty in the origin of the copper target used for that shot.

**Measured with silver activation detector.

To determine the sensitivity of these measurements the thick target yield for these two copper reactions was calculated from cross section data.¹⁷⁻¹⁹ The thick target yield is given by

$$Y = \int \sigma(E) dx = \int \frac{\sigma(E) dE}{dE/dx}$$

dE/dx values for copper were taken from reference 21 and the function was numerically integrated using Simpson's rule. The calculated thick target yield for $\text{Cu}^{65}(d,2n)\text{Zn}^{65}$ reaction was 2×10^{-7} Zn^{65} atoms per incident deuteron at 5 MeV; for the $\text{Cu}^{63}(d,2n)\text{Zn}^{63}$ reaction the yield at 8 MeV was 4×10^{-7} . The minimum target activity which gives 25% statistical error in the counting system is 20 photons/min. With this detectability, the minimum number of 8 MeV deuterons which could be detected from Zn^{63} activity is 2×10^{11} . The minimum number of 5 MeV deuterons which could be detected from Zn^{65} activity is 3.2×10^{14} . Thus the sensitivity of both reactions is low since they are being used just above their thresholds and because of the long half life (243.7 days) of Zn^{65} . Since these values are substantially higher than those indicated by the N^{13}/A^{28} ratio, the two measurements are consistent.

The detectability of Zn^{63} was verified in a different experiment with the plasma focus device operating with a mixture⁴(50-50) of deuterium and helium 3. The reaction $\text{He}^3(d,p)\text{He}^4$ produces a 14.6 MeV proton which then can produce Zn^{63} in copper targets from the reaction $\text{Cu}^{63}(p,n)\text{Zn}^{63}$. The thick target yield of this reaction was calculated in the same fashion with cross section data from reference 20. The results of this experiment will be reported elsewhere, but 1.6×10^5 Zn^{63} atoms were measured in the copper target.

An interesting anomaly in these gamma analyses of copper targets is the observation on one shot of substantial quantities of bismuth 207. Gamma peaks from Bi^{207} at 569 and 1063 keV are evident on shot 2449, shown in table 2. These counting rates indicate that 3.5×10^8 Bi^{207} atoms were formed in or on the copper target. The anode insert for these shots was titanium; the only plausible explanation for the presence of the Bi^{207} was that the Ti tip became contaminated with lead in removing the insert from the anode with the aid of a lead hammer. This lead was then vaporized and deposited on the copper target. Deuterons striking the lead produced the Bi activity from the reaction $\text{Pb}^{206}(d,n)\text{Bi}^{207}$ or $\text{Pb}^{207}(d,2n)\text{Bi}^{207}$.

Foil Penetration. On a number of shots stacks of 2.54×10^{-3} cm (1 mil) aluminum foil were positioned in front of the plasma focus anode to evaluate deuteron energy from the range. Activity was consistently produced on the first and second foil in the stack with the ratio of activities of first foil to second varying from 3/1 to 30/1. For example, shot 2105 produced 8.62×10^3 atoms of Al^{28} in the second foil, 3.04×10^5 in the first, with the foil stack located 21° off axis at 24.6 cm from the end of the anode. If the activity in the second foil were produced by 2 MeV deuterons, the total number implied would be 1.4×10^{11} . This is roughly consistent with the total number calculated from the N^{13}/Al^{28} ratio. On one shot (1914) activity was produced on an aluminum foil shielded by another aluminum foil .088 cm thick. Deuterons of more than 15 MeV would be required to penetrate this thickness. However this result was never repeated.

Neutron Time-of-Flight. The neutron time-of-flight detector, consisting of a plastic scintillator and photomultiplier tube, surrounded on all sides by 2" of lead was positioned 3.1 meters ahead of the anode, at 45° . The energy of a neutron with time-of-flight t , over distance, d is just

$$E = \frac{1}{2} m (d/t)^2$$

The energy of an energetic deuteron striking a stationary deuteron is related to the neutron energy through the equation ²²

$$E_3^{\frac{1}{2}} = v \pm (v^2 + W)$$

$$v = (M_1 M_3 E_1)^{\frac{1}{2}} \cos \theta / (M_3 + M_4)$$

$$W = \frac{M_4 Q + E_1 (M_4 - M_1)}{M_3 + M_4}$$

where E_3 and M_3 are the neutron energy and mass, E_1 and M_1 the deuteron energy and mass, M_4 is the helium 3 reaction product mass, Q is the energy released in the reaction, and θ the angle between the deuteron velocity vector and the neutron velocity vector (the angle to the detector).

This is solved for E_1 by finding the root of the equation using Newton's method.

Because of the limited size of the plasma focus vault, the time-of-flight distance was short (3.1M), limiting the accuracy of the energy measurement. However this distance is adequate to temporally resolve the neutron pulse from the hard x-ray pulse, permitting determination of the maximum neutron energy from the time of the beginning of the neutron pulse.

Over a large number of shots the neutron pulse consistently began at 165 to 180 ns following the hard x-ray pulse, a time-of-flight corresponding to a neutron energy of 4.8 to 5.3 MeV. This neutron energy corresponds to a deuteron energy of 2.5 - 3.3 MeV. An interesting feature of this data is that, unlike the other results on high energy ions, the maximum deuteron energy, as measured by neutron time-of-flight, showed no correlation with fill pressure.

DISCUSSION

Substantial activation of carbon and aluminum targets was observed on most low pressure shots. N^{13}/Al^{28} ratios, foil stack activation measurements, and neutron time-of-flight all consistently show deuteron energies above 2 MeV. Copper activation failed to confirm the presence of deuterons with energies above 5 MeV because the measurement technique was too insensitive for the quantities produced.

In our previous work² a power law distribution for deuteron intensity with an exponent of -3 was used to estimate the number of deuterons as a function of energy, as suggested in reference 9. To see if this was consistent with the N^{13}/Al^{28} ratios which indicated average deuteron energies of 5 MeV on some shots, this distribution was used to calculate the activation of aluminum and carbon targets. The activation is given by

$$N_x = \int_0^{E_{max}} G N_d(E_d) Y_x(E_d) dE_d$$

where G accounts for the fraction of the deuteron beam intercepted by the target and the thick target yield, Y_x , was fitted with a power law function for the carbon and aluminum reactions. This function was analytically integrated from 0 to 8 MeV, and gave a N^{13}/Al^{28} ratio of 6.3, which is consistent with observed values and indicates an average energy of about 5 MeV. Based upon measured activation for shot 2111 (4.6×10^6 N^{13} atoms, 1.0×10^6 aluminum 28 atoms for the ^{21}O targets), the coefficient for the power law distribution is 1.3×10^{14} . That is, $N_d(E_d) = 1.3 \times 10^{14} E_d^{-3}$. Then the total energy in ions between 0.33 MeV (the carbon d-n reaction threshold) and 8 MeV (the maximum energy obtained from the N^{13}/Al^{28} ratios) is $(1.6 \times 10^{-13})(1.3 \times 10^{14}) \int_{E_d}^{8.0} E_d^{-2} dE_d$. This gives a total energy of about 60 joules, which represents a 33 conversion efficiency of 0.1% from stored energy (57 kJ) to total energy in energetic deuterons above 0.33 MeV.

These measurements illustrate that the plasma focus device can be operated in two distinctly different modes, with low pressure operation resulting in the acceleration of deuterons and electrons to many times the capacitor bank charging voltage. A substantial fraction of the neutron yield in the low pressure mode of operation may be accounted for by beam-target reactions.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge many useful discussions with Robert Barlett, Robert Howerton, John Luce, George McFarland, and Oved Zucker, and the technical assistance of Craig Riley.

This work was performed under the auspices of the U. S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

REFERENCES

1. F. C. Young and M. Friedman, "A New Approach to Ion Acceleration with Electron Beams," *Journal of Applied Physics* 46, 2001, 1975.
2. R. L. Gullickson, "A Measurement of the Distribution of Very Energetic Ions in the Plasma Focus Device," UCLL-76831, May, 1975. (presented at the IETE International Conference on Plasma Science, Ann Arbor, Mich, May 14-16, 1975.)
3. J. M. Mather, "Lense Plasma Focus," Methods of Experimental Physics, 7, B. Academic Press (1971)
4. K. D. Ware et al., "Operation of a 720 kJ, 60 kW, Lense Plasma Focus Device," *Quill Amer. Phys. Soc. II*, 12, 1364 (1973); A DD neutron yield of 10^{12} from a plasma focus driven by a 340 kJ bank was reported by A. Bernard at the Third Topical High B Conference, Culham England, Sept. 5-9, 1975.
5. Ch. Maisonnier, et al., "Structure of the Lense Plasma Focus," *11th European Conference on Controlled Fusion*, Grenoble, Vol. 2, 195 (1973).
6. I. F. Beljaeva and K. V. Filippov, "Locations of Fast Neutrons in a Plasma Focus," *Nuclear Fusion* 13, 881 (1973)
7. H. Conrads, et al., "Velocity Distribution of the Ions Producing Neutrons in a Plasma Focus," *Physics of Fluids* 13, 209 (1972).
8. A. Bernard, et al., "Study of the Neutron Emission and Turbulence in the Focus Experiment with a Time resolution on the Order of a Nano-second," *Proceedings of the 5th International Conference on Plasma Physics and Controlled Nuclear Fusion Research*, Tokyo (1974).
9. M. J. Bernstein and G. G. Comisar, "Neutron Energy and Flux Distributions from a Crossed-field Acceleration Model of Plasma Focus and Z-pinch Discharges," *Physics of Fluids* 15 (1972).
10. S. F. Gary, "Ion Acceleration in a Plasma Focus," *Physics of Fluids*, 17, 2135 (1974).
11. R. J. Lanter and D. E. Bannerman, "The Silver Counter, a Detector for Bursts of Neutrons," LA-3498-FC, Los Alamos Scientific Laboratory (1966).
12. B. L. Freeman, "Electron Beam-Deuterated Target Experiment," UCLL-51t08, Lawrence Livermore Laboratory (1974).
13. D. J. Johnson, "X-Ray Spectral Measurement System for Nanosecond Plasmas," *Review of Scientific Instruments* 45, 191 (1974).
14. R. L. Gullickson and R. H. Barlett, "X-Ray Analysis for Electron Beam Enhancement in the Plasma Focus Device," Advances in X-ray Analysis, 18, Plenum Press (1971).
15. E. Amaldi, L. R. Hafstad, M. A. Tuve, "Neutron Yields from Artificial Sources," *Physical Review* 51, 876 (1937).

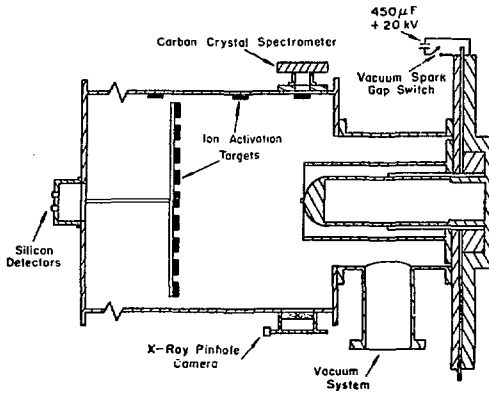
16. R. Gunnink and J. B. Niday, Computerized Quantitative Analysis by Gamma-Ray Spectrometry, Lawrence Livermore Laboratory Report UCRL-51060, vol. 1 (1972).
17. L. J. Gilly, et al., "Absolute Cross Sections and Excitation Functions for (d,p) and (d,2n) Reactions on Mn⁵⁵, Cu⁶³, Cu⁶⁵, Zn⁶⁶, and Zn⁶⁸ Between 3 and 11.6 MeV," Physical Review 131, 1727 (1963).
18. P.P. Dmitriev and N. N. Krasnov, "Excitation Function of Reaction Cu⁶⁵(d,2n)Zn⁶⁵ and Yield of Isotope Zn⁶⁵," Atomnaya Energiya 18, 184, (1965).
19. H. Okamura and S. Tamagawa, "Excitation Functions for the Deuteron Induced Reactions on ⁶³Cu and ⁶⁵Cu," Nuclear Physics A169, 401, (1971).
20. J. W. Meadows, "Excitation Functions for Proton-Induced Reactions with Copper," Physical Review 91, 885, (1953)
21. William Price, Nuclear Radiation Detection, McGraw-Hill Book Company (1964)
22. R. D. Evans, The Atomic Nucleus, McGraw-Hill Book Company (1955)

FIGURE CAPTIONS

- Figure 1. One hundred kilojoule plasma focus device with activation targets.
- Figure 2. Thick target yield curves for the carbon and aluminum $d,2n$ reactions. N^{13}/Al^{28} ratio versus deuteron energy. (from reference 1).
- Figure 3. N^{13}/Al^{28} ratios for plasma focus shots. The filling pressure and anode insert material are indicated.
- Table 1. Reactions from deuterons incident upon copper targets.
- Table 2. Gamma analysis of the copper target from shot 2449. Only those peaks with a "PCT ERROR" less than 30% should be considered. The peaks at 569 and 1063 kiloelectronvolts are from bismuth 207.

Figure 1.

100 Kilojoule Plasma Focus Device



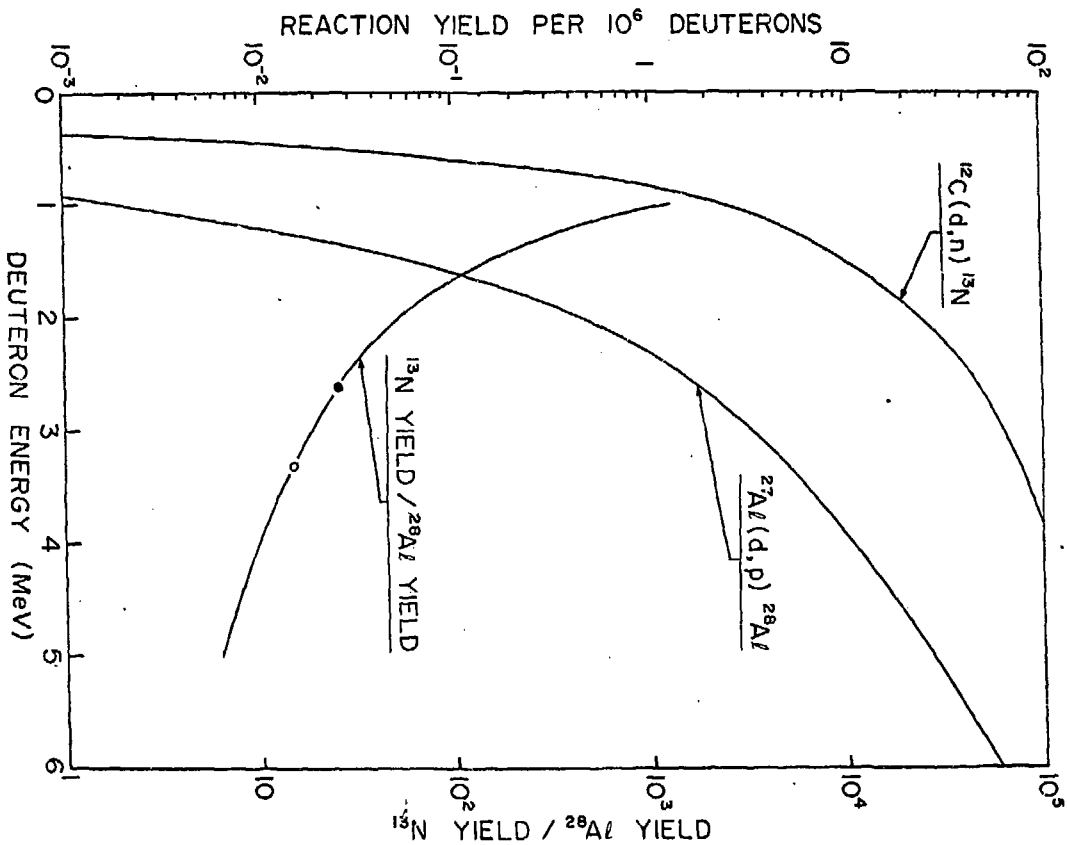


Figure 2.

Figure 3.

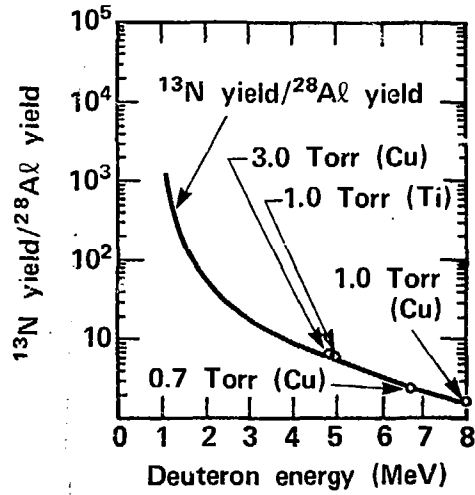


Table 1.

DEUTERON REACTIONS WITH COPPER

Reaction	Threshold	Half life of product	Comments
$\text{Cu}^{63}(\text{d},\text{n})\text{Zn}^{63}$	6.58 Mev	38.5 min	
$\text{Cu}^{65}(\text{d},\text{n})\text{Zn}^{65}$	4.49	243.7 days	
$\text{Cu}^{63}(\text{d},\text{t})\text{Cu}^{62}$	4.72	9.78 min	cross section small
$\text{Cu}^{63}(\text{d},\text{p})\text{Cu}^{64}$	0 (small below 5 Mev)	12.8 hrs	
$\text{Cu}^{65}(\text{d},\text{p})\text{Cu}^{66}$	0 (small below 4 Mev)	5.1 min	

Table 2.

1 SAMPLE GULLICKSON 2449 Z. DELTAT = 0.639 DAYS. 666 MIN COUNT BEGAN 252.007 (1975) ON DETECTOR-C1
LIVE-TIME OF COUNT (TAKEN FROM CHANNEL 1) = 666.67 MINS

SUMMARY OF ENERGY CALIBRATION

CHANNEL	INPUT DATA		CALCULATED FIT		**BASED ONLY ON EXTERNAL DATA **
	ENERGY		ENERGY	DELTA E	
290.915	145.440		145.817	0.177	
640.116	320.100		320.247	0.147	
1209.508	604.700		604.430	-0.270	
2241.776	1120.500		1120.181	-0.319	
3382.961	1691.030		1691.295	0.265	

GAIN = APPROX. 0.500 KEV/CHANNEL

AVG. DEVN. = NOT VALID.

PHOTONS/MIN DATA TAGGED WITH * WERE CORRECTED FOR BACKGROUND PEAKS AS MEASURED 11/21/74 ON DET C

SUMMARY OF PEAKS WITH SIGNIFICANT NET TOTALS IN SPECTRUM NO. 251106

INDEX	CHANNEL	KEV (+/-)	- PEAK -		CALC. COUNTS	PROP. COUNTS	PHOTONS/MIN	PCT ERROR	QFIT	FWHM	PCT USED	INDEX	
			START	END									
1	127.043	63.429	0.145	124.0	130.0	104	105	3.247E-01	475.50	1.0	1.225	11.8	1
2	149.745	74.823	0.106	147.0	157.0	116	164	2.566E+00	72.42	1.0	1.081	-2.2	2
3	169.336	84.657	0.189	165.0	172.0	76	81	5.400E-01	180.55	1.0	1.245	11.8	3
4	185.397	92.717	0.055	181.0	190.0	291	293	-6.372E-02	1893.32	1.0	1.210	8.0	4
5	297.795	144.054	0.220	285.0	292.0	63	70	1.086E+03	85.53	1.0	1.331	11.8	5
6	371.260	185.848	0.080	368.0	374.0	137	142	-6.130E-01	177.02	1.0	1.093	-8.7	6
7	418.743	209.606	0.372	414.0	421.0	33	42	1.698E+00	70.76	1.0	1.359	11.8	7
8	476.786	238.634	0.055	472.0	479.0	211	212	-9.542E-01	181.43	1.0	1.130	-8.7	8
9	855.776	427.909	0.204	854.0	859.0	22	22	2.570E+00	54.12	1.0	1.257	-8.7	9
10	1022.005	510.861	0.102	1016.0	1027.0	258	254	1.325E+01	29.08	1.0	2.594	81.1	10
11	1139.705	569.595	0.106	1134.0	1143.0	89	94	1.529E+01	18.24	1.0	1.526	3.7	11
12	1167.309	583.374	0.173	1162.0	1170.0	34	36	-1.667E+00	153.14	1.0	1.351	-8.7	12
13	2128.544	1063.551	0.203	2123.0	2134.0	46	49	1.607E+01	26.27	1.0	1.971	11.8	13
14	2549.222	1273.984	0.280	2544.0	2552.0	18	18	0.046E+00	117.09	1.0	1.710	-8.7	14
15	2664.759	1331.799	0.260	2662.0	2668.0	23	26	4.095E+00	75.92	1.0	1.737	-8.7	15
16	2921.834	1460.440	0.226	2916.0	2925.0	33	35	-4.833E-01	829.10	1.0	2.198	11.8	16

PROGRAM ENTERING INPUT ROUTINE AFTER 1.073 SEC. (CPU:1/D:SYS=34:65:0D) CLOCK READS 06:19:33 R 09/10/75

ELAPSED TIME FOR NO. 48 WAS 3.8195 SECONDS.