



**AUSTRALIAN ATOMIC ENERGY COMMISSION
RESEARCH ESTABLISHMENT
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**THE DENSE PLASMA FOCUS AS A PULSED DEUTERIUM-TRITIUM
NEUTRON SOURCE**

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ABSTRACT

A dense plasma focus of the Mather type has been operated at a capacitor bank energy of 13 kJ with deuterium-tritium gas fillings. An average neutron yield of 1.1×10^{11} neutrons per pulse was measured. The pulse width was 80 ± 5 nsec (FWHM) and the energy of the peak of the neutron pulse was determined by neutron time of flight to be 15.1 MeV in the 0° direction.

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BINARY MIXTURES; DEUTERIUM; GAMMA RADIATION; GASES; MEV RANGE 10-100; NEUTRON SOURCES; NEUTRONS; NUCLEAR REACTION YIELDS; PEAKS; PHOTOMULTIPLIERS; PLASMA; PLASMA FOCUS; PLASMA GUNS; PULSES; SCINTILLATION COUNTERS; TIME-OF-FLIGHT METHOD; TRITIUM

CONTENTS

	Page
1. INTRODUCTION	1
2. EXPERIMENT	1
3. RESULTS	1
4. DISCUSSION	2
5. CONCLUSION	3
6. ACKNOWLEDGEMENT	3
7. REFERENCES	3

Table 1 - Neutron Output from Coaxial Plasma Guns with Deuterium-Tritium
Gas Mixtures.

FIGURE 1 Dense plasma focus - pulse output from photomultiplier detectors.

1. INTRODUCTION

The dense plasma focus is capable of producing intense pulses of neutrons with energies of 2.5 MeV and 14 MeV, resulting from the reactions ${}^2\text{D} + {}^2\text{D} \rightarrow {}^3\text{He} + \text{n}$ and ${}^2\text{D} + {}^3\text{T} \rightarrow {}^4\text{He} + \text{n}$ respectively (Mather 1966b). Some results of work with deuterium-tritium mixtures have been published (Mather 1965, Patou et al. 1968 and Gates and Demeter 1971), but the neutron energy has not been well determined.

The small size of the neutron producing plasma (1 mm diameter x 30 mm long) provides a source with high fluence of 14-15 MeV neutrons which may be used for radiation damage studies and activation analysis.

2. EXPERIMENT

The dense plasma focus device used at the AEC Research Establishment is of the Mather type (Hogg and Tendys 1973) with inner and outer electrode diameters of 50 mm and 100 mm respectively. In this experiment the capacitor bank was operated at 19 kV (stored energy 13 kJ) and the system was filled to a total gas pressure of 0.4 kPa (3 torr). Discharges were made with pure deuterium and with mixtures of deuterium and tritium (35 per cent tritium and 50 per cent tritium). A closed cycle vacuum system utilising activated charcoal absorption pumps was used to handle the gas mixtures, thereby keeping tritium leakages well below the permitted maximum level. The tritium activity per filling was approximately 65 Ci.

The neutron pulses produced by the focus were recorded by two photomultiplier-scintillator detectors situated 5.2 m (PMT1) and 17.5 m (PMT2) from the focus at 0° . The neutron energy was then determined by time of flight. A time reference was provided by measuring the γ -ray pulse with a surface barrier semiconductor detector, situated 2 m from the focus. The neutron flux was determined with a silver activation detector placed at 90° to the focus at a distance of 1 m.

To condition the electrodes the system was initially operated with pure deuterium fillings. A total of more than 40 discharges with deuterium-tritium mixtures were made and it was possible to use a single filling for approximately ten discharges. Unless otherwise stated, all results are for mixtures of 50 per cent deuterium and 50 per cent tritium.

3. RESULTS

Figure 1 shows a typical pulse output of the two photomultiplier detectors. The γ -ray and neutron components of the pulses can be determined and there is a time reference mark. The closer detector (PMT1) was screened with 40 mm of lead which is sufficient to block out γ -rays of energy $\lesssim 1$ MeV, and the more

distant detector (PMT2) was screened with only 1.2 mm of lead and thus detected γ -rays of energy ≥ 0.1 MeV.

The PMT1 trace shows the start of the γ -pulse, followed after approximately 50 nsec by the sharply rising neutron pulse. The γ -pulse is thought to originate from the energetic γ -rays (average energy ~ 3 MeV) generated by inelastic neutron scattering in the tungsten insert in the centre electrode of the coaxial gun.

On the PMT2 trace the neutron and γ -pulses are separated. The γ -pulse has a sharp rise, and long decay as observed on the PMT1 trace. This long decay is attributed to neutron capture γ -rays in the materials surrounding the experimental area.

The energies of the neutrons were averaged from the results obtained from over thirty discharges. The energies were derived from measuring the time differences between:

- (i) The starts of the two neutron pulses (E start).
- (ii) The peaks of the neutron pulses (E peak).
- (iii) The points at which the leading edge of the neutron pulses have attained 50 per cent of their peak heights (E 50% peak).

The average results were: $E(\text{start}) = 14.9$ MeV, $E(\text{peak}) = 15.1$ MeV and $E(50\% \text{ peak}) = 14.7$ MeV, with an associated error of ± 0.1 MeV.

The average width of the neutron pulse was 80 ± 5 nsec (FWHM) with extremes of 60 and 100 nsec. Over the 12 m flight path, the width did not change significantly, and thus indicates a small energy spread of the pulse. Generally the pulses were of the shape shown in Figure 1, but some were double peaked and these tended to be of 100 nsec width.

The average neutron yield was determined to be 1.1×10^{11} neutrons/pulse, compared to a neutron yield of 1×10^9 neutrons/pulse with a pure deuterium filling. The maximum neutron yield with deuterium-tritium filling was 2.8×10^{11} neutrons/pulse. When a mixture of 35 per cent tritium - 65 per cent deuterium was used, the average neutron yield was decreased by a factor of more than two to 4.5×10^{10} neutrons/pulse.

4. DISCUSSION

The results are presented in Table 1 together with those from other workers' experiments using deuterium-tritium mixtures. The yields and capacitor bank energies generally agree but not the values of the peak energy and the width of the neutron pulse. It is believed that the ratio of the neutron yield with a pure deuterium filling to that with a 50 per cent deuterium - 50 per cent tritium filling should be equal to the ratio of the average reaction

rates for a Maxwellian distribution of ions at the temperature of the plasma (approximately 2 keV). This latter ratio is 100 in the range 1-10 keV and similarly the neutron yield ratio is ~ 100.

This measurement of the time of flight energy of the peak of the neutron pulse, 15.1 MeV, is 1 MeV higher than the value derived from nuclear reaction data. The shift can be compared with the average energy shift of 0.5 MeV from the centre of mass energy measured with a pure deuterium gas filling (Bernstein et al. 1969). These energy shifts indicate that neutron production is associated with an acceleration mechanism, as proposed in the model of Bernstein (1970).

5. CONCLUSION

The present coaxial plasma gun operates satisfactorily with deuterium-tritium gas fillings and produces average neutron yields of 1.1×10^{11} neutrons per pulse with a capacitor bank energy of 13 kJ and a peak yield of 2.8×10^{11} neutrons per pulse. This yield would be expected to increase when the bank energy was increased to its maximum value of 25 kJ. The mean energy of the neutron pulse is 15.1 MeV and the average pulse width is 80 ± 5 nsec. It is possible to perform about 10 discharges per gas filling, but the neutron yield tends to fall as the gas becomes contaminated with impurities from the electrodes.

6. ACKNOWLEDGEMENT

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TABLE 1 - NEUTRON OUTPUT FROM COAXIAL PLASMA GUNS
WITH DEUTERIUM-TRITIUM GAS MIXTURES

Reference	Bank Voltage and Energy	Average D-D Neutron Yield Neutrons/Pulse	Average D-T ¹ Neutron Yield Neutrons/Pulse	E _{peak} MeV	D-T Neutron Pulse Width nsec
Gates and Demeter (1971)	20kV, 450kJ	Not Reported	3.6×10^{12}	Not Reported	100
Mather (1966a)	16kV, 12kJ	4×10^9	3×10^{11}	14	220
Patou et al. (1968) This Experiment	20kV, 30kJ 19kV, 13kJ	1.2×10^{10} 1×10^9	2×10^{11} 1.1×10^{11}	14 15.1	Not Reported 80

1. Gas Mixture 50% deuterium - 50% tritium.

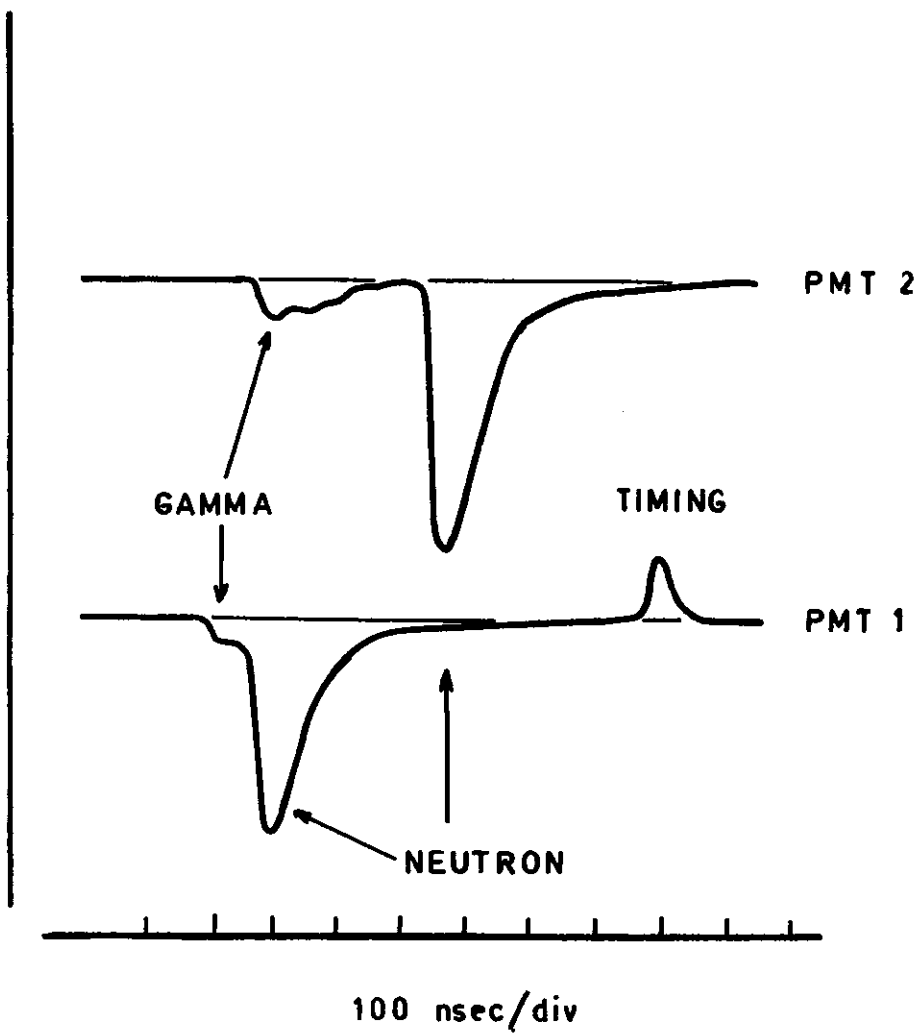


FIGURE 1. DENSE PLASMA FOCUS - PULSE OUTPUT FROM PHOTOMULTIPLIER DETECTORS

