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Characterization of a D-T Generator in Radiation Equipment Fab. Center

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1. Introduction

Neutrons can determine elementary composition by virtue of their unique interaction characteristics with matter. Thus, material discrimination by using fast neutron is attractive for cargo inspection to screen contrabands such as narcotics, explosives and nuclear materials. Combination of the detailed imaging of X-ray (or dual energy X-ray) and material discrimination capability of neutron can improve screening contraband. In this study, characteristics of D-T (Deuterium-tritium) fusion neutron generator, which was recently installed in the radiation equipment fabrication center for the development of a mixed radiation container inspection system, are described. And its neutron flux is also experimentally determined by using neutron activation analysis.

2. Methods and Results

2.1 D-T generator

A GENIE 35 neutron generator from Sodern company was chosen to develop an air cargo inspection system due to its maximun neutron output (14MeV). Specification of a D-T generator is described in Table 1.

Table I: Specification of a D-T generator [1]

Max output (n/s)	1.10^{10}
Max peak output (n/s)	1.10^{11}
MEN insulation	Oil
Emission	Continuous or pulsed up to 5 kHz Min. neutron pulse width 10µs
Neutron ouptut	Adjusted by control software
Safety	1 safety loop (personnel protection) 1 automatic loop (for integration in automatic system)
	Emission authorization by means of key-locked selector and coding device
	Emission indication outputs (dry contact and 230 V AC / 50Hz)
	Output limitation (software and coding device)
	Communication link watchdog
Synchronization (ion source pulses control)	Output and input available
Interconnecting cables	15 meters between cabinet and NEM
Control software	SODERN MMI or custom software by using SODERN Active X driver
Power	230 V AC / 50 Hz

Principle of neuron generation from D-T fusion reactor and its fusion reactions are shown in Fig.1 and 2, respectively. When Deuterium gases cladded in a replenisher are heated, the replenisher delivers part of this gas inside the tube. Deuterium gas is ionized in the ion source, as soon as a voltage is applied. Ions are extracted and accelerated toward the tritium target by means of VHV (Very High Voltage). The beam of deuterium ions impinges the target with tritium inside. Neutron output is proportionally controlled by the ion beam current.

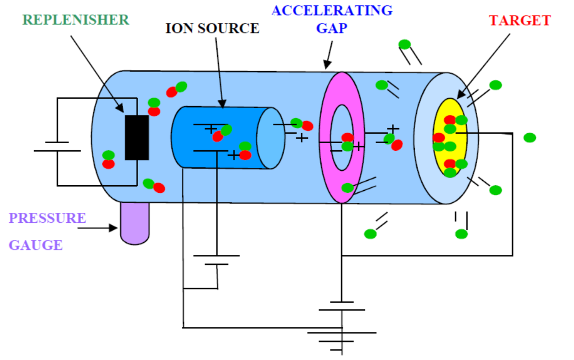

Fig. 1. Schematic of D-T fusion reactor

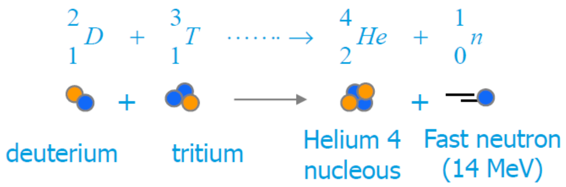

Fig. 2. D-T fusion reaction to produce fast neutrons

2.2 Determination of neutron flux

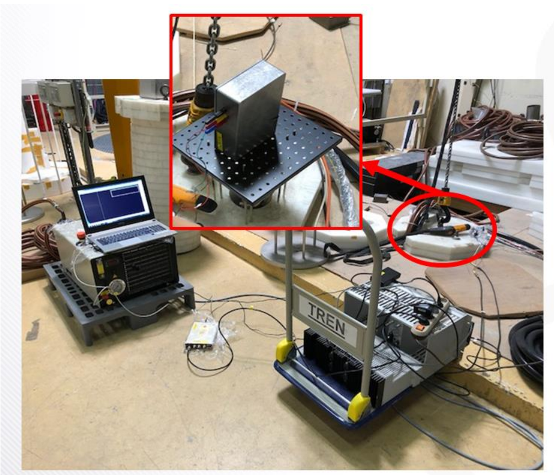

Fig. 3. Experimental setup for neutron flux measurements.

Determination of neutron flux with respect to its energy is standardly used Bonner sphere and scintillator spectroscopy system. Another method to determination of neutron flux is neutron activation analysis. Gold, Copper, Aluminum are commonly used to neutron activation analysis. We used copper to neutron flux determination of D-T fusion neutron reactor. Natural abundance of Cu-63 is about 69.1% and its gamma emission energy is 511 keV after β^+ annihilation. Its decay time and neutron energy threshold are 9.7 min. and 11.9 MeV. Cross section of Cu-63 is shown in Fig.3.

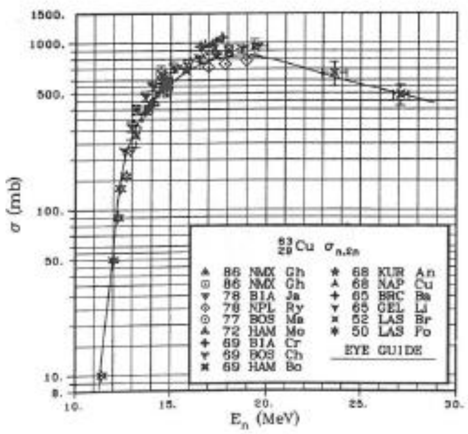

Fig. 3. Cross-section of Cu-63 with respect to neutron energy. [2]

511 keV gamma-ray was measured with 2-inch NaI(Tl) scintillator spectroscopy system. From the activated Cu-62. Mass of the used Cu-63 was 13.86 g, and irradiation time was 10 m. Acquisition time was 7 min.. Detection efficiency was set at approximated 50%. Neutron yield was set at 5×10^9 n/s.

Neutron flux calculated by using neutron activation equation is as follows.

Activity Equation

A = number of decays per second (Activity) dps

N = number of atoms of the target isotope
$= \frac{m}{W} \times \theta \times 6.023 \times 10^{23}$

m = mass of the element in the irradiated sample g
θ = isotopic abundance
w = Atomic weight of the element

λ = decay constant = $0.693/t_{1/2}$
$t_{1/2}$ = Half-life of the isotope

ϕ = neutron flux $n.cm^{-2}.sec^{-1}$
σ = activation cross-section 10^{-24} cm^2
t_{irr} = irradiation time

$$A = N \sigma \phi [1 - \exp(-\lambda t_{irr})]$$

After a delay of time t_d
$$A = N \sigma \phi [1 - \exp(-\lambda t_{irr})] \exp(-\lambda t_d)$$

For a counting time of t_c
$$A = N \sigma \phi [1 - \exp(-\lambda t_{irr})] \exp(-\lambda t_d) [1 - \exp(-\lambda t_c)]$$

A measured energy spectrum from activated Cu-62 is shown in Fig. 4. The calculated neutron flux was 1.27×10^9 n/s. The set neutron yield of D-T generator and the measured neutron flux are in 10% error range.

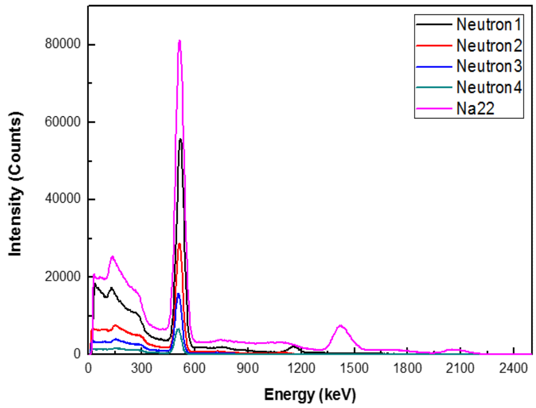

Fig. 3. The measured energy spectrum of the activated Cu-62 t_d (elapsed time after irradiation) of a Neutron 1 through 4 were 7 min., 11 min., 20 min., 34 min., respectively.

3. Conclusions

Neutron flux of the recently installed a D-T generator in KAERI was measured by means of neutron activation analysis. The set value of neutron yield and the measured neutron flux are in 10% error range. The installed D-T generator will be used for development of an ULD (Unit Load Device) or pellet inspection system. And we plan to provide neutron irradiation service in a radiation equipment fabrication center.

Acknowledgements

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