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DT NEUTRON GENERATOR
FOR USE WITH NMIS**

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SMALL, PORTABLE, LIGHTWEIGHT DT NEUTRON GENERATOR FOR USE WITH NMIS

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ABSTRACT

The advantages of 14.1 MeV DT neutrons as an alternate source for the Nuclear Materials Identification System (NMIS) are mainly increased sensitivity and accuracy which will extend applications considerably as well as result in shorter measurement times for present applications. Since NMIS requires a neutron source of $\sim 5 \times 10^6$ n/sec, a small, lightweight (<30 lbs. including the power supply and is 3-in.-OD pipe, $\sim$ 4-ft. long) is under development at MF Physics Corporation for the Oak Ridge National Laboratory (ORNL). By associated particle (alpha) detectors, a cone of neutrons can be defined which is particularly useful for active neutron interrogation of fissile materials in containers. After final test at ORNL, this DT neutron source will be useful at the Y-12 National Security Complex for routine use with NMIS.

INTRODUCTION

NMIS is a time correlation technique¹ that can be used passively for plutonium and in the active mode with an external source to excite fissile material. It is useful for highly enriched uranium (HEU) and plutonium. In an active measurement, the results of a passive measurement can be separated for Pu. It is presently being used in the template matching mode at the Oak Ridge Y-12 National Security Complex for confirmation of HEU weapons components upon receipt and for inventory.² For heavily shielded containers, like the AT400R, the ²⁵²Cf source neutrons have difficulty penetrating the hydrogenous material of the container and the inserts to reach the fissile material to induce fission. Another difficulty with ²⁵²Cf source is that the slow neutrons from the source mix with the fast neutrons from the induced fission in the fissile material and reduce sensitivity with distance from the object. Difficulty of operation of the DT source in the 1960s led to the use of ²⁵²Cf in an ionization chamber as a timed source of fission neutrons and gamma rays.³ The reliability and portability of present DT sources makes it practical to replace the ²⁵²Cf with a small-portable DT source. This has a variety of advantages over ²⁵²Cf and makes NMIS more useful. This paper describes a small, portable DT neutron generator designed by one the authors (Jack Reichardt) and states many of the improvements in NMIS such a source would produce.

SMALL, PORTABLE DT NEUTRON GENERATOR

Description of DT Neutron Generator

Thermo MF Physics is developing a unique neutron generator to be incorporated into an associated particle system for use by Oak Ridge National Laboratory in the Nuclear Materials Identification System. This neutron generator differs from others developed for API applications in that it is lightweight and completely portable. The design of the neutron generator is adapted from that of larger associated particle imaging generators developed for other national laboratories.

The generator is pictured in Figure 1. It is configured as a cylinder 40 inches long by 3 inches in diameter. The neutron tube has a built in alpha particle detector that is used to provide directional and temporal “tagging” of neutrons produce at the tube target. The target is oriented at 45 degrees to the face of the alpha particle detector. The target is at ground potential and is in a region that is entirely free of electric fields. The latter feature is necessary in order to achieve accurate information on the angular distribution of detected alpha particles.

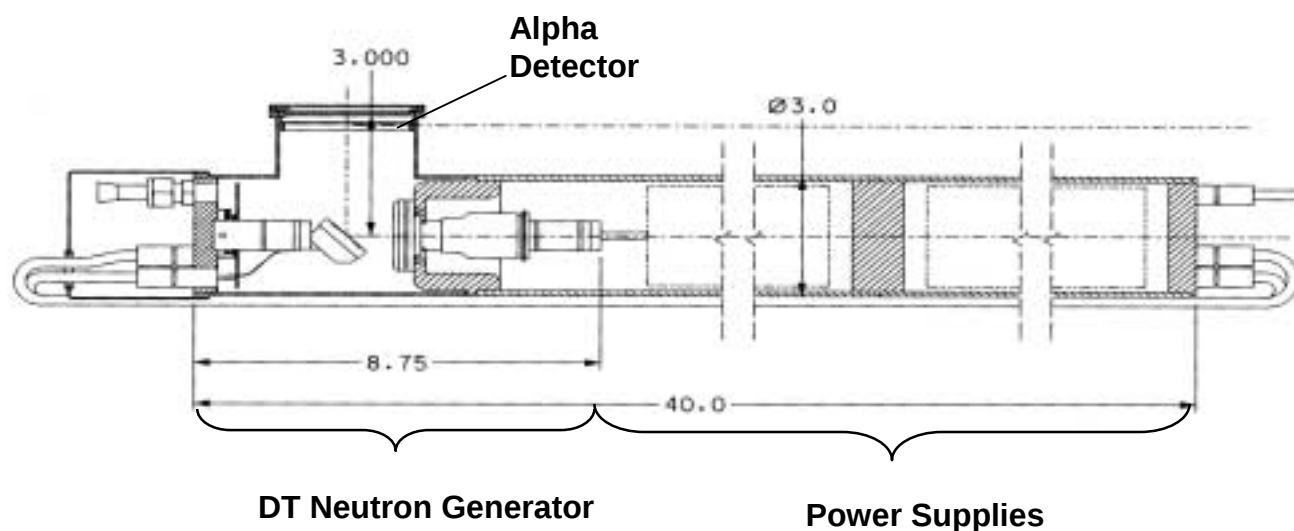


Figure 1. Sketch of a Small, Portable, Lightweight DT Generator

The design of the ion optics and the ion source is adapted from that used in the Thermo MF Physics miniature neutron tube, the A-3062, that is used primarily in very small neutron generators for oilfield applications. The neutron tube, target assembly, and alpha particle detector are physically integrated as a sealed vacuum device. The design of the ion optics is such that a beam spot approximately 10 mm or less in diameter is produce on the target. The beam spot is fixed in that there is no provision for adjustable focus of the beam. The accelerator section and ion source are welded onto the target chamber such that the entire structure may be processed to ultra-high vacuum. Effective vacuum processing of the tube structure requires that it be heated to approximately 300°C to remove contaminants from the system. This, in turn, determines that the alpha particle detector must be able to withstand the processing temperatures

without degradation and precludes the use of any organic materials, such as binders, in the detector material.

The high voltage power supply is attached directly to the neutron tube. The neutron tube and power supply are immersed in liquid Fluorinert FC-40 for dielectric insulation. Use of a liquid dielectric, rather than high-pressure gas such as SF₆, precludes any safety and transport constraints brought about by the use of high-pressure gas. Because of the necessity for a grounded target, the ion source power supply must be “floated” on the accelerator HV supply. The accelerator high voltage power supply can provide up to 75 kV accelerating potential with a maximum of 30 microamperes beam current. The maximum neutron yield is 1×10^7 neutrons per second. The yield under normal operations is 5×10^6 neutrons per second. Under these conditions, the expected operating life of the neutron tube is four thousand hours.

The neutron generator is entirely self-contained. All electronic circuitry necessary to control the neutron generator is integrated into the 3-in.-diam, 40-in.-long package. The only input requirements are 50 watts power at 50 Volts dc and an adjustable 0-5 Vdc signal to adjust the voltage output of the accelerator power supply. The total weight of the system is about 30 pounds.

ADVANTAGES OF A DT NEUTRON GENERATOR

There are several advantages that a small, reliable, portable DT neutron generator (with an alpha detector that can be used to define a cone of neutrons) would produce for the NMIS.

The 14.1 MeV neutron from the DT neutron generator penetrate hydrogen-bearing materials more readily than the lower energy ²⁵²Cf neutrons. It then makes NMIS more practical for active measurements with AT400R containers used in Mayak and those like the transport containers at VNIITF. This increases sensitivity.

The fact that the DT generator can be turned off when not in use reduces ALARA concerns, makes it more easily transportable, and simplifies storage in that no shielding or radioactive areas are needed for storage like a radioactive source (²⁵²Cf). The ability to turn off the source makes remote applications more practical since it can be turned off for movement. This source reduces radioactive exposure and thereby makes it use more convenient.

This DT source of 5 ± 10^6 n/s can have over 4000 hrs of operational life. Since the half-life of tritium (12 yrs.) is a factor of 5 longer than ²⁵²Cf (2.6 yrs.), the source will last longer. The source design described can operate at 10^7 n/sec. So after one-half life of DT, the output can be increased by a factor of 2. Then it would be 24 yrs. before a reduction in output of a factor of 2 because of tritium decay. In the long term, DT neutron generator source would be cheaper.

The directionality of this source by the use of an alpha detector to define a cone of neutrons makes it more useful. The cone of neutrons would be in the direction of the fissile material and thus makes it useful for scanning. The ²⁵²Cf source triggers on fission neutrons that go in all directions and this is not the most efficient use of the processor in that it looks for events in the detector from neutrons going away from the container. If a container is in an array, neutrons

from the Cf source go to a nearby container induces fission that creates particles that reach the detectors and contribute to the correlative signal. This produces a correlated background that will not occur with a DT neutron generator with a defined cone of neutrons (from alpha particle detection) aimed at the fissile item in the container. This increases sensitivity. In addition, floor reflection and other reflection effects are eliminated since they are not correlated to triggers.

A DT neutron generator produces neutrons of one energy (14.1 MeV) and thus all source particles arrive at the detector at a fixed time after a trigger from the alpha detector. Detection at other times must be from particles from induced fission. All induced fission neutrons arrive after source emissions. This results in no intermixing of source and induced fission particles at the detector. This increases sensitivity and makes measurements at increased distance practical.

The DT reaction produces one neutron per alpha trigger event. Correlated pairs of particles then detected come from induced fission in the sample and not from source multiple particles. For a ^{252}Cf source and no fissile, there are correlated pairs of events. Quantities that depend on correlated pairs of events can now be zero with no fissile material. This increases the variation in some signatures and thus increases sensitivity. For example, a certain ratio of signatures varies from 0 to infinity for a DT source rather than from 0 to 0.9 for a ^{252}Cf source.

The source described in the previous section is lightweight and portable (<30 lbs.) including the power supply and alpha detector. The source and 75 Kv power supply are inside a 3-in.-OD, 40-in.-long pipe. This greatly simplifies electrical safety since the 75 Kv is inside a grounded pipe.

Since the source neutrons and induced fission neutrons are clearly separated, NMIS measurements can now be performed with the source and detector on the same side of the container. This makes NMIS measurements more practical for arrays of stacked containers since both source and detector can be located in the aisles between stacks of containers. This can lead to expanded applications and more convenient operation for inventory confirmation.

The pulses from the alpha particle detection system are easily incorporated into the NMIS system. The ^{252}Cf source triggers are replaced by alpha detector pulses (both are random) and the data acquisition needs no modification. The fact that only triggers for neutrons in the cone towards the target are used as input simplifies the processing requirements. For example, for a 5×10^6 n/s ^{252}Cf source, there would be a 1.2×10^6 triggers, but for a DT neutron generator of 5×10^6 n/s, the alpha detector of Figure 1 would only receive 10^5 alpha pulses but from neutrons all going in the right direction. Thus, the required processing power of the computer is less. The reduced triggers from the alpha detector would allow the source size to increase without processing limitations. This makes measurements at a larger distance practical as well as measurements with larger DT sources for larger containers.

CONCLUSIONS

This improved source, a lightweight, portable, DT neutron generator, has a variety of advantages that enhance the sensitivity of NMIS and extend its application to larger distances. The advantages lead to increased sensitivity, more convenience, more cost-effectiveness, and

expanded applications of NMIS. It makes active NMIS measurements possible with heavily neutron-shielded containers like the AT400R.

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