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Boron-coated straw detector technology as an alternative to helium-3 and boron trifluoride based proportional counters for ground level neutron monitoring: a design study.

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The global network of neutron monitors comprises predominantly of the monitor standardised by Carmichael in 1964, the NM-64. The design of these existing monitors and their instrumentation have changed very little over the last sixty years. For example, their neutron detectors rely on gas filled proportional counters that are either filled with highly toxic boron trifluoride (BF_3) or helium-3 (^{3}He). Almost the entire global supply of ^{3}He is derived from a waste product of nuclear weapons programmes and, with the termination of such programmes and reducing nuclear weapons stockpile, the supply of ^{3}He has become limited. Consequently, ^{3}He supply became strictly controlled in 2008 and its price has fluctuated since. In some cases, new neutron monitors have reverted to BF_3 filled counter tubes when the price of ^{3}He has been at a premium. Helium-3 filled proportional counters are also used extensively in radiation portal monitors deployed for homeland security and non-proliferation; objectives which have increased significantly over the last two decades. The reduced production and increased demand for ^{3}He has led to concerns over its supply and provided the research motivation for alternative neutron detection methods which are viable in terms of sensitivity, stability and gamma-rejection for certain applications. One of these alternative technologies is based on boron-coated straws (BCS) manufactured and supplied by Proportional Technologies, Inc (PTI). The technology is built on a patented low-cost technology that enables long copper tubes, known as 'straws', to be coated on the inside with a thin layer of ^{10}B-enriched boron carbide ($^{10}B_4C$). Thermal neutrons captured in the ^{10}B are converted into secondary particles, through the ^{10}B(n, α) reaction. The straws can be of various diameter (circa 4 mm to 15 mm), length (up to 2 m) and shape (round, star or pie) to increase the surface area of ^{10}B. Multiple straws can be packed inside a 1" diameter aluminium tube acting as a single drop-in replacement for traditional ^{3}He detectors or individually distributed directly throughout the moderating medium, thus increasing efficiency by detecting the thermal neutrons at the point that they are created. BCS-based detectors are widely used in systems for homeland security, safeguards and neutron imaging in direct exchange for ^{3}He tubes. This study aims to design a neutron monitor utilising BCS technology that is cheaper, more compact and produces comparable results to the existing network of NM-64 monitors. Monte Carlo simulations using the

MCNP radiation transport code to model several BCS-based solutions and an NM-64 computational benchmark are reported. These models are validated experimentally using a standard PTI portal monitor (PTI-110-NDME) to determine its efficiency, dieaway, deadtime and gamma rejection using a combination of bare ^{252}Cf, AmLi and ^{137}Cs sources. The PTI-110-NDME consists of a 12" x 5" x 1 m high density polyethylene (HDPE) slab with thirty ~15-mm diameter straws, 93 cm active length, embedded uniformly throughout the moderator. Funded by UK Research & Innovation (UKRI), this research is part of the Space Weather Instrumentation, Measurement, Modelling and Risk (SWIMMR) programme.