Sustainability of Helium-3 Gas Supply

For neutron detectors in homeland security and nuclear safeguards applications

Reuter-Stokes
a Baker Hughes business

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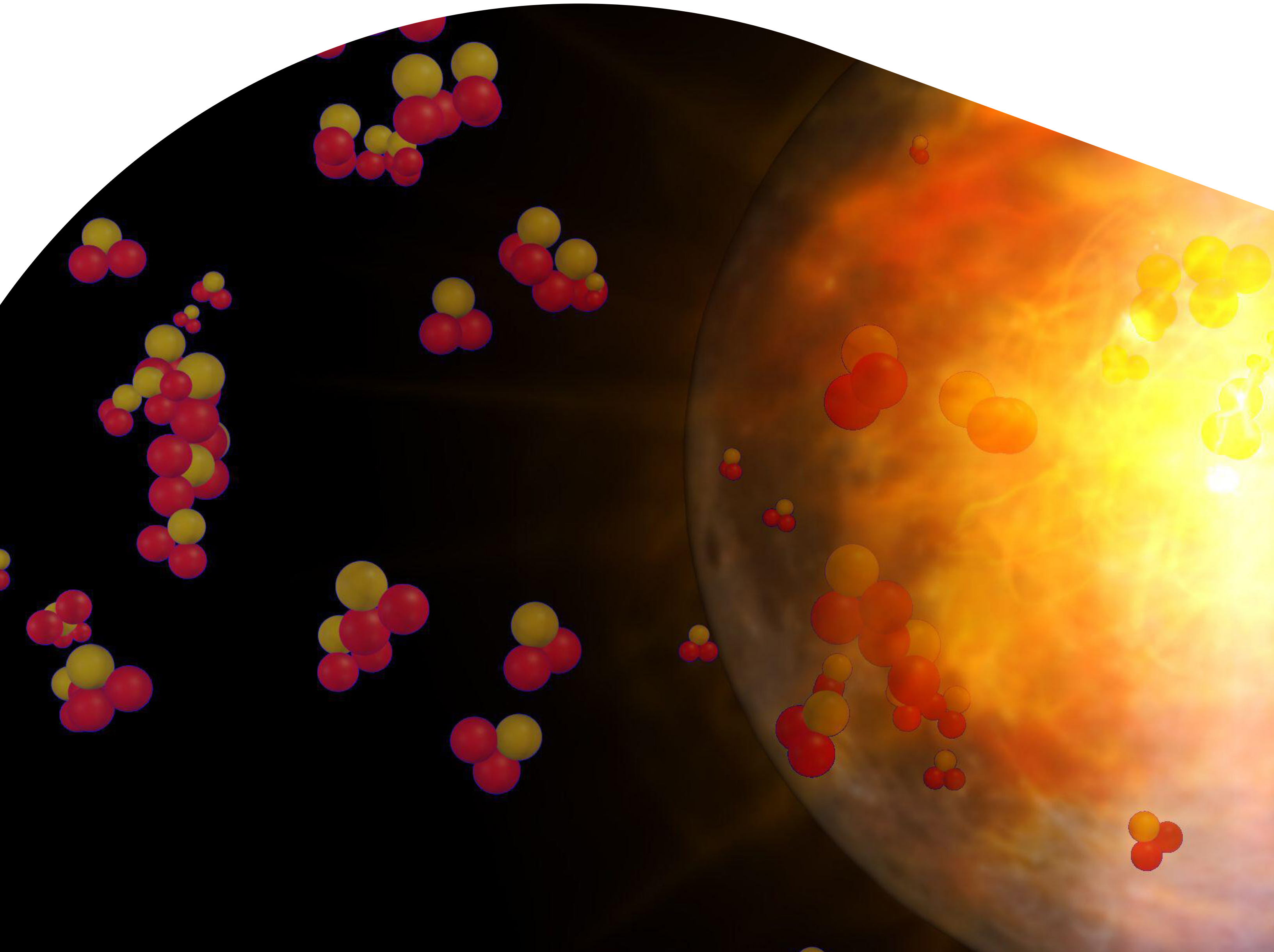
Helium-3 (^3He) gas is a rare isotope of Helium that has a large neutron capture cross-section, enabling its use as a neutron detection medium. As a secondary benefit, ^3He gas exhibits the characteristics of a proportional gas, i.e. a gas that, when an appropriate high-voltage is applied, will produce a charge pulse proportional to energy deposited by charged particles in the gas. Other proportional gases commonly used for detection of x-rays, gamma-rays, alpha, and beta particles include Argon or Nitrogen mixed with polyatomic quench gases such as carbon-dioxide. Detectors making use of these types of gases are referred to as proportional counters or gas-filled proportional counters.



Helium-3 sensitive volume

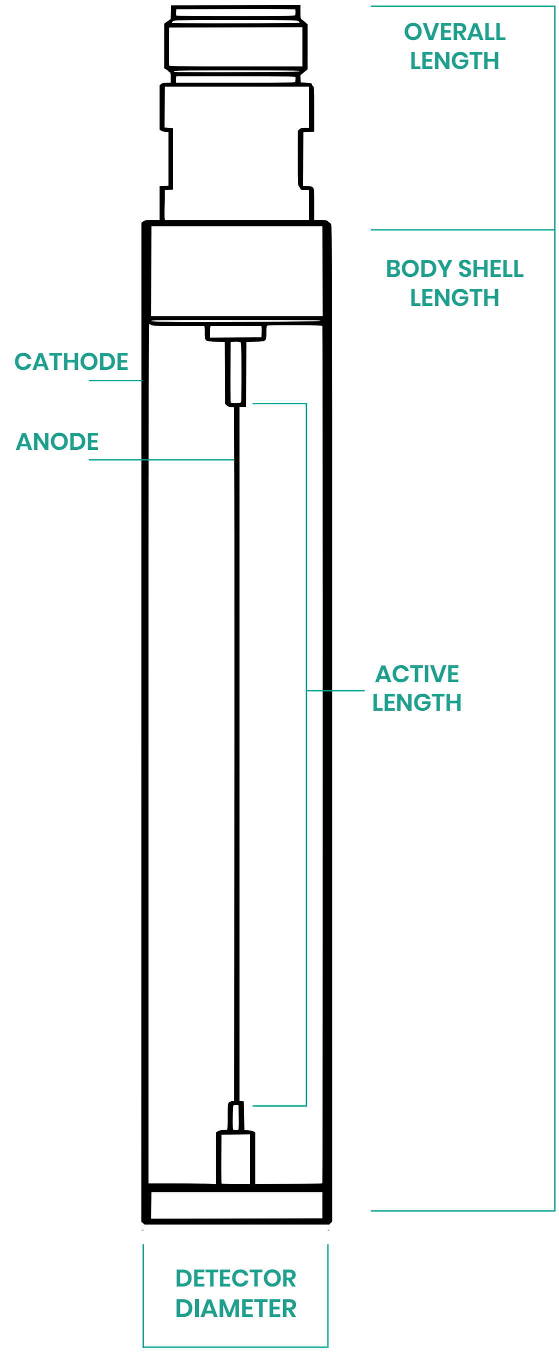
A typical configuration is shown on the right.

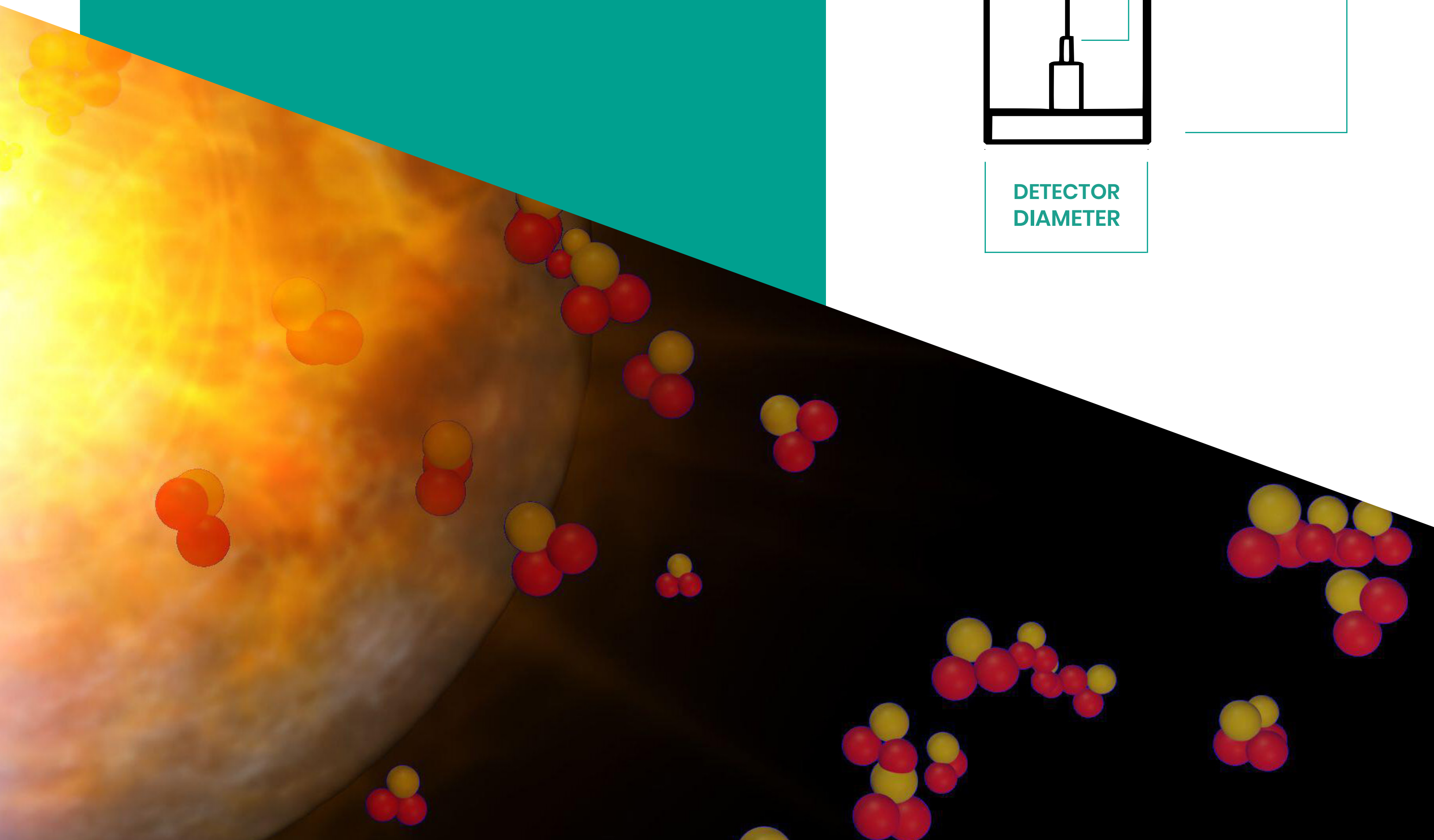
A cylindrical housing (cathode) (~.3" – 3" diameter, 2"-115" length) contains the proportional gas and anode (~0.001" diameter) running axially along the detector.

A positive high voltage is applied to the anode relative to the cathode allows for charge produced due to particle interactions in the gas to be drawn toward the anode.

In the region near the anode, high electric fields produce secondary charge due to collisions between the initial charges and the molecules of the proportional gas.

The result is an amplified signal pulse that can be processed using basic commercial electronics.





From conversion to detection

As neutrons are charge-neutral particles, they cannot be directly detected using most practical detector technologies; therefore neutron detectors typically employ a conversion medium to convert the neutron to a charge particle, and then a detection method for detecting the resulting charged particles. For example, the Microstructured Semiconductor Neutron Detectors (MSND) shown below uses a structured silicon charged particle detector coated with a Boron-10 (^{10}B) "reactive film". The Boron-10 layer converts neutrons into alpha and Lithium-7 ions, which may travel into the semiconductor structure where they deposit charge and generate a charge pulse. In this case, some particle energy is lost in the converter material before the ions enter the silicon detector, and some trajectories exist in which the charged particles do not enter the silicon detector.

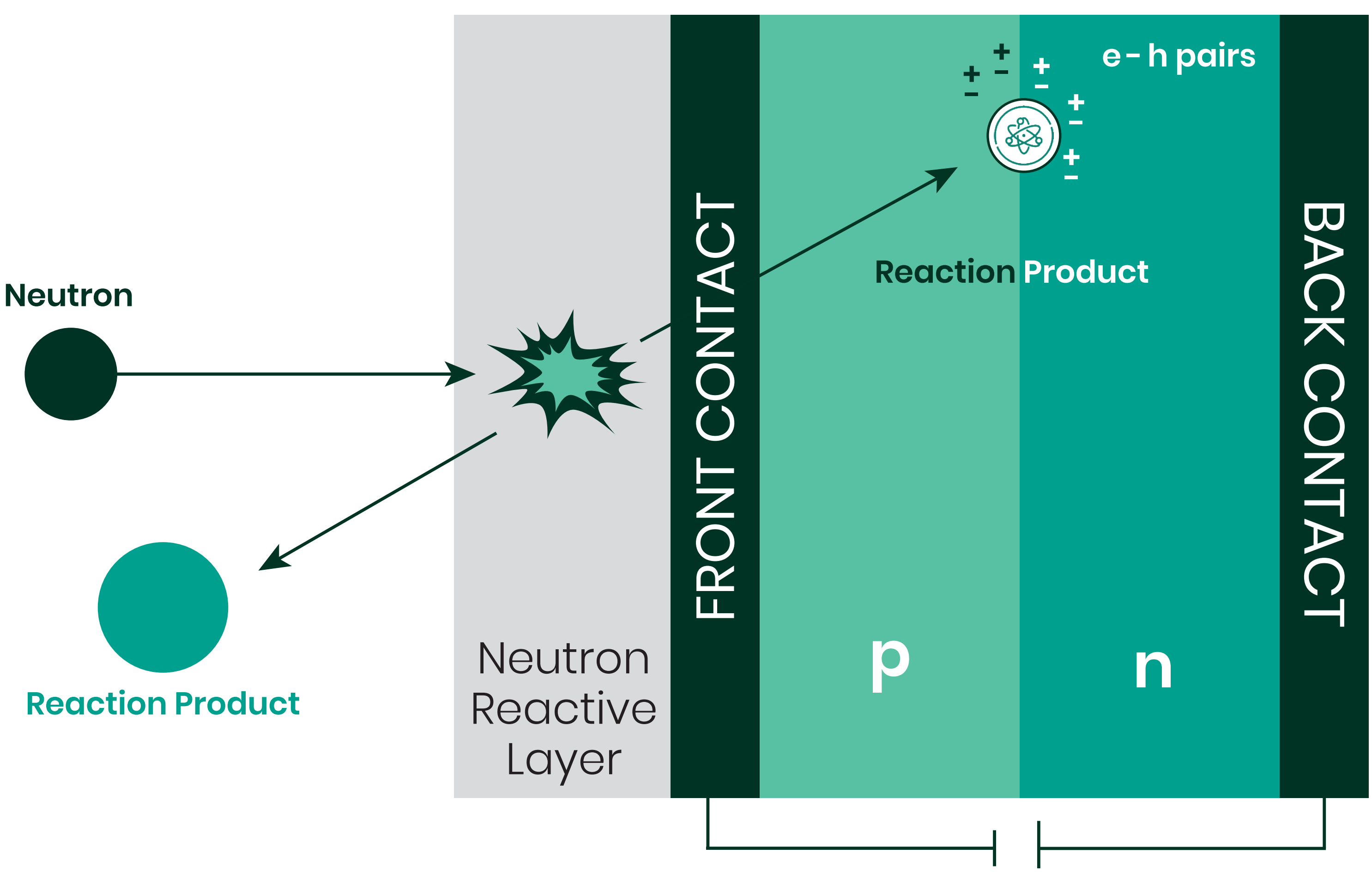
In the case of ^{3}He proportional counters, the conversion medium serves as the charge particle detector. A neutron entering the gas volume of the detector is captured by a ^{3}He nucleus, resulting in the emission of charged Triton and proton particles. The Triton and proton then deposit their energy in the ^{3}He gas through ionization. The charge resulting from this ionization is amplified and collected on the anode as described previously.

^{3}He proportional counters have proven scalability advantages over alternative technologies. The MSND example below has a stated thermal neutron efficiency of 20%-30%, with a $(12.6\text{ mm})^2$ area.

By way of comparison:

- A 0.5" diameter ^{3}He detector containing 6 atmospheres of gas has an efficiency of ~50%, independent of length.
- A 1" diameter ^{3}He has a 75% efficiency.
- A 2" diameter detector has an efficiency of 92%.

^{3}He Detective active lengths of up to 72" means very large area, very high efficiency detection capabilities are achievable.

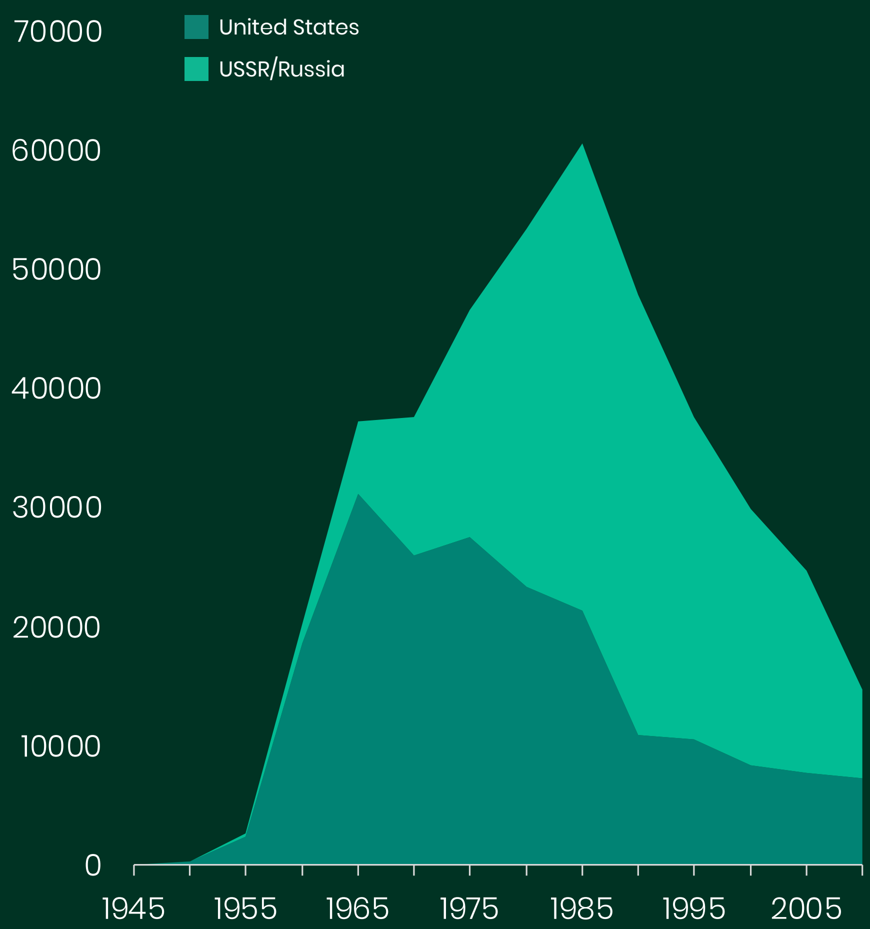


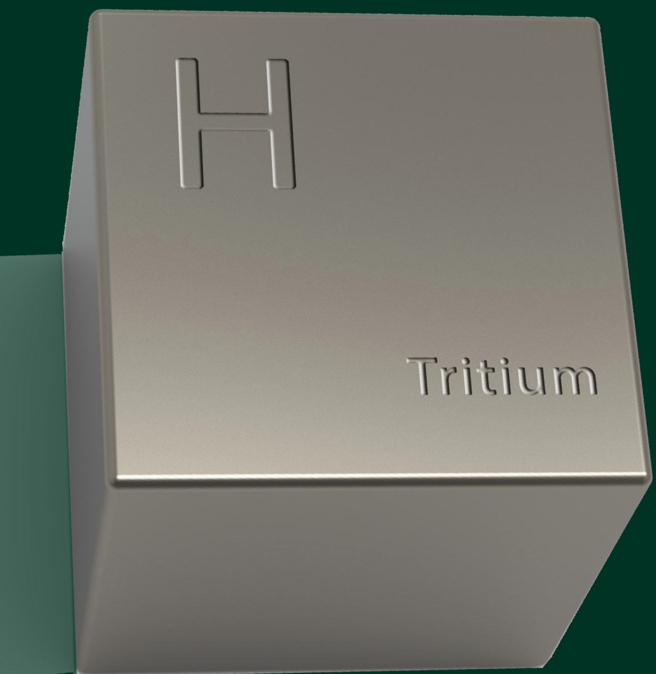
Supply Chain Challenge:
Perception vs. Reality

Traditionally, ^3He gas has been produced as a byproduct of U.S. and Soviet/Russian nuclear weapons programs. Tritium, an isotope of Hydrogen, is a key component of modern nuclear warheads. Over time (12.4 years for 50% decay), Tritium decays into ^3He gas. That gas was collected and stockpiled by the U.S. government over decades during the cold war between the U.S. and U.S.S.R. Tritium production, and thus ^3He production, scaled with the nuclear stockpile over those decades.

Reductions in weapons stockpiles following adoption of nuclear weapons reduction treaties, beginning with the Intermediate-Range Nuclear Forces Treaty in 1989 and up to the new START treaty in 2010, resulted in significant reductions in Tritium, and thus ^3He, production.

Nuclear Warhead Estimates During the Cold War





The perception of a ^3He supply crisis is the result of decreased ^3He production and a period of increased consumption for Homeland Security radiation portal monitors.

Well, where's the gas?!

The Department of Energy (DOE) once sold ^{3}He through auctions to private corporations. As shown below, sporadic auctions of more than 1,000 liters were offered to the market until 2014.

2003

DOE auctions 95,800 liters of ^{3}He

2005 - 2006

DOE auctions an additional 50,848 liters of ^{3}He

2008

A direct allocation of 23,000 liters of gas was made to GERS (General Electric Reuter-Stokes) and Spectra Gases, Inc.

70% of the ^{3}He sold to GE Reuter-Stokes was controlled by the National Nuclear Security Administration (NNSA) for the Second Line of Defense (SLD) Program.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Why ^{3}He for Homeland Security?

From 2003 to 2009, the Radiation Portal Monitor Program (RPMP) was successfully implemented across the United States in response to the September 11th terror attack.

Reuter-Stokes supplied over 40,000 ^{3}He proportional counters for portal monitors and homeland security applications in that time. The sudden reduction of the ^{3}He stockpile led to a dramatic increase in cost and decrease in availability of the gas. The impact to the supply chain of ^{3}He gas was immediate as a shock to the system drove the price of gas to all-time highs.

The U.S. and the scientific community shifted resources towards research and development of alternative technologies such as Boron-10 lined tubes, Boron-10 Straw Detectors, Lithium-6 glass, LiF/ZnS scintillators, polyvinyl toluene (PVT) plastic, and Micro-Structured Semiconductor Neutron Detectors (MSNDs). After almost two decades of research and development, each of these technologies still fall short to meet the technical requirements that ^{3}He proportional counters provide.

To this day, there is not a technology that is a one for one replacement in all categories of longevity, stability, and sensitivity.

Reuter-Stokes is the world leader in radiation detection technology and continues to manufacture the most sensitive and ruggedized sensors for the harshest environments. With over 187,000 liters of ^{3}He processed since 2002, Reuter-Stokes understands the importance of gas conservation. Detectors are designed and manufactured to have a mean time before failure (MTBF) greater than 100 years.

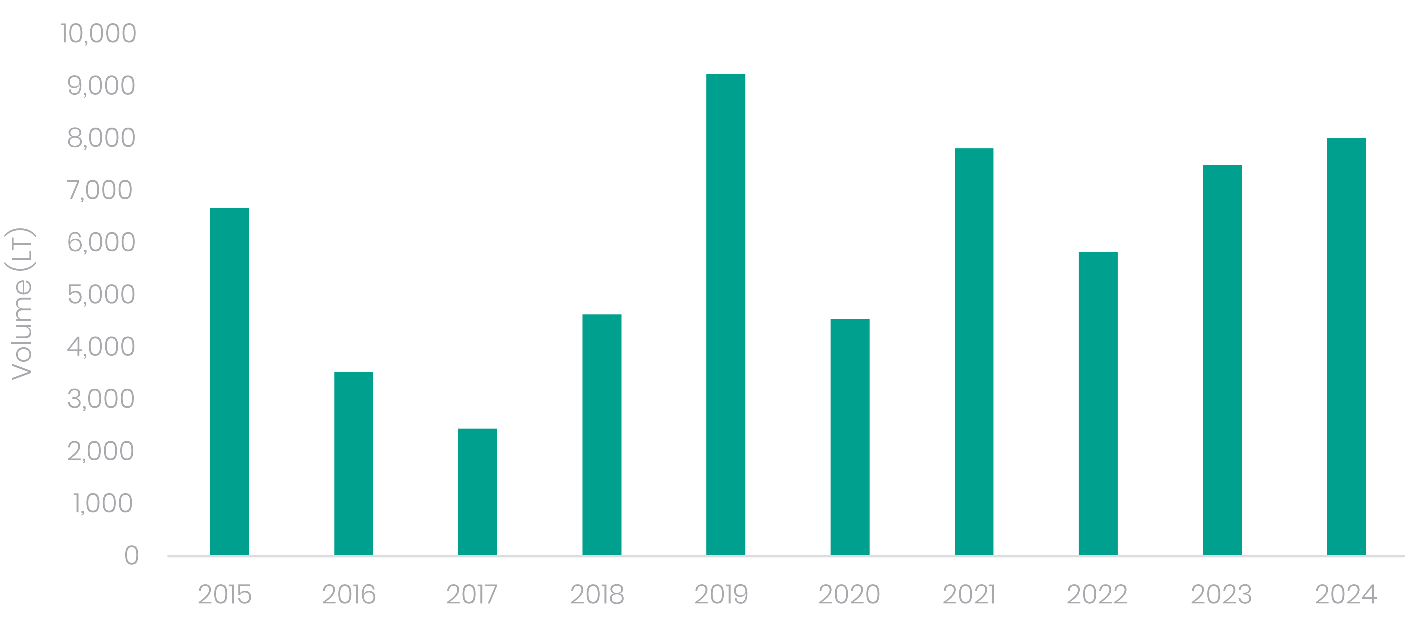
Every detector and seal component are helium leak checked to be less than 1×10^{-9} cc/sec – air to assure that the gas will not be lost over time. This provides peace of mind and security that the detector will outlive its required use and the gas can be recycled for different purposes.

Since gas conservation efforts, Reuter-Stokes still maintains the position as the world leading consumer of ^{3}He gas. The production of gas-filled proportional counters has been steadily increasing over the past decade since alternatives continue to fall short of technical requirements.

The capability to reclaim ^{3}He gas from detectors that are no longer required for their original intent, as well as the use of government-allocated gas, allows Reuter-Stokes to continue to support the U.S. market. Beyond detector recycling, the market has adapted to optimize the production of ^{3}He gas without relying on the weapons program's surplus.

Reuter-Stokes has secured a multi-year strategic supply chain commitment through commercial producers to ensure reliable supply of ^{3}He.

Reuter-Stokes Helium-3 Consumption



Conclusion

The usage of gas spiked after September 11, 2001 for use in Radiation Portal Monitors (RPM) – many of which are still in use today and as they were originally installed. With this, there is over 120,000 liters of ^{3}He gas that is contained in Reuter-Stokes detectors and can be reused for upgrading next generation Radiation Portal Monitors or alternative applications.

The Department of Homeland Security - Countering Weapons of Mass Destruction (CWMD) and NNSA's mission requires neutron detection technology that will limit false alarms and protect from all threats, foreign and domestic.

^{3}He proportional counters for use in the Radiation Portal Monitors, Handheld RIIDs, Mobile Detection, and Personal Backpack equipment are the only option to provide safety and security against nuclear attacks. Reuter-Stokes continues to take actions to ensure that ^{3}He gas will be available for these critical applications.

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