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Sandia National Laboratories

MOLY 99 REACTOR CASE STUDY

Unlimited Unclassified Release

IPO Integrated Partnerships Organizations

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U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

BACKGROUND

Molybdenum-99 (Moly 99) is a critical raw material for Technetium (Tc) 99m, a radioactive isotope most widely used in nuclear medicine procedures.[1] Moly 99 has a short half-life of about six hours, which means it cannot be stockpiled. When Moly 99 decays, it turns into Tc 99m, which has a half-life of 214,000 years. The photon energy emitted from the decay of Moly 99 is used in a variety of nuclear imaging technologies such as gamma cameras.[2] Furthermore, radiopharmaceutical manufacturers use the photon energy emitted from the decay of Moly 99 to produce generators for hospitals, clinics, and radiopharmacies. Once Moly 99 decays to Tc 99m, it is used to make individual patient doses for a variety of diagnostic imaging procedures.[3]

The Moly 99 Reactor Design is a conceptual blueprint for Moly 99 production that does not use weapon-grade uranium; instead, the reactor has a target core of low-enriched uranium. The reactor design is small, reaching a foot-and-a-half in height and diameter and consumes less than two megawatts of power. The reactor's only purpose is for medical isotope production and with every fission, Moly 99 is produced.[4]

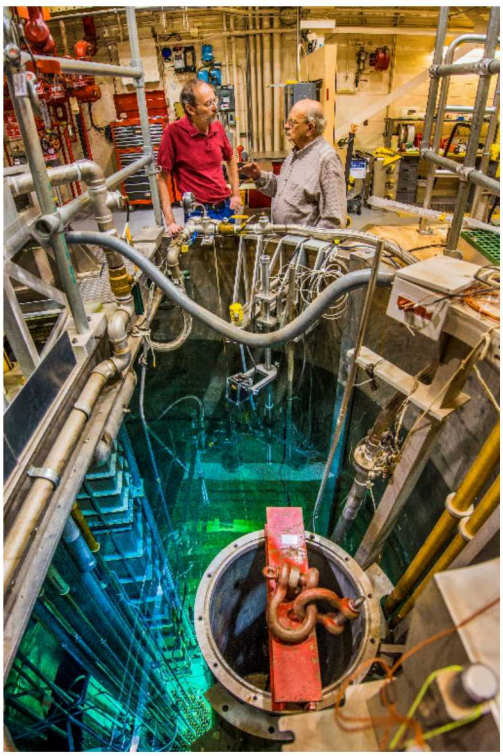


Figure 1: The reactor sits in a pool of cooling water 28 to 30 feet deep.

CURRENT ADVANTAGES

Current advantages of the design include:[5]

- no pumps required for core cooling
- produces minimum unprocessed fuel waste
- simple control system, easy to operate
- cost effective and low-power
- passively safe – no back-up power supply or shutdown cooling requirements.

RETURN ON INVESTMENT

PROGRAM DEVELOPMENT

Between 95 and 98 percent of the world's supply of Moly 99 is produced by five reactors from four organizations: MDS Nordion (Canada), Mallinckrodt (Netherlands), Institut National des Radioelements (Belgium), and Nuclear Technology Products Radioisotopes (South Africa). MDS Nordion and Mallinckrodt

[1] http://www.isotop.ru/en/production/medical/426/molybdenum-99/
[2] https://www.ncbi.nlm.nih.gov/books/NBK215133/
[3] https://www.prnewswire.com/news-releases/eden-radioisotopes-llc-secures-reactor-project-funding-for-medical-isotope-production-300854716.html
[4] https://share-ng.sandia.gov/news/resources/news_releases/moly_reactor/
[5] http://local.ans.org/trinity/files/parma091106.pdf

supply all of the Moly 99 used in the US under normal operating conditions. However, due to concerns about medical isotope availability, the US Congress created the Isotope Production and Distribution Program to ensure a stable supply of medical isotopes in the US. In 1991, the Department of Energy (DOE) was funded by this program to study the feasibility of using its facilities to develop a US domestic supply of Moly 99 and associated fission products.

From 1993 to 1995, the DOE evaluated alternative facilities for Moly 99 production capabilities. In 1996, the DOE issued a Record of Decision that selected the Chemistry and Metallurgy Research facility at Los Alamos National Laboratory for target fabrication and associated hot cell facilities in Technical Area V at Sandia National Laboratories as the preferred alternatives for Moly 99 production. From 1996 to 1999, the DOE made capital investments and supported the operating costs ranging from $20 million to $50 million for Sandia to develop a Moly 99 production capability. Then in 1999, the DOE issued an Expression of Interest to gauge commercial interest in further development of the Sandia Moly 99 production initiative, which was never completed.[6,7]

In 2013, Sandia developed a Moly 99 Reactor Conceptual Design based on technology in the DOE-funded Sandia medical isotope production program of the late 1990s. Furthermore, in 2013, former Sandia researchers Bennet Lee, Dick Coats, and Milton Vernon, formed Eden Radioisotopes with the goal to commercialize Sandia's Moly 99 Reactor Design.

In 2015, Eden Radioisotopes signed a licensing agreement with Sandia to use the Moly 99 Reactor Design with the goal of producing a US domestic supply of Moly 99 for use in nuclear medicine.[8] In addition, Eden Radioisotopes is currently seeking a license from the Nuclear Regulatory Commission and the Food and Drug Administration for approval of the Moly 99 Reactor manufacturing process. Eden Radioisotopes aims to meet the entire global demand with their production capacity.[9] In May 2019, Eden Radioisotopes established an investment agreement with Abo Empire, an oil and gas company, to help build the Moly 99 reactor for producing medical isotopes.[10] The Eden Reactor would operate 22 hours, seven days a week, which would allow for Moly 99 targets to be continuously irradiated and readily available for processing as needed.[11]

LICENSES

In 2015, Eden Radioisotopes signed an exclusive license and one commercial patent for Sandia's Moly 99 Reactor Design.[12] Eden Radioisotopes plans to have the technology commercially operational by 2023.[13]

PUBLIC GOOD

Eden Radioisotopes aims to create a stable supply of Moly 99, using Sandia's Moly 99 Reactor Design. The recent investment agreement between Eden Radioisotopes and Abo Empire will fund the development of the Moly 99 Reactor for producing medical isotopes, which can provide a stable supply of

[6] https://www.ncbi.nlm.nih.gov/books/NBK215157/
[7] http://local.ans.org/trinity/files/parma091106.pdf
[8] https://www.sandia.gov/news/publications/lab_accomplishments/articles/2015/tech-transfer.html
[9] https://share-ng.sandia.gov/news/resources/news_releases/moly_reactor/
[10] https://mmr.sandia.gov/article/eden-radioisotopes-llc-secures-reactor-project-funding-for-medical-isotope-production/
[11] https://www.dotmed.com/news/story/47381
[12] https://info-ng.sandia.gov/ESP/output.php
[13] https://mmr.sandia.gov/article/eden-radioisotopes-scores-funding-for-isotope-reactor-production/

Moly 99 for nuclear medicine as well as create highly technical jobs for people within New Mexico. Eden's Work with Moly 99 will ensure a steady future supply of Moly 99 for the nation, which will potentially help ensure that thousands of Americans receive timely and potentially less-costly medical procedures.

Nuclear Medicine

Approximately 30 million nuclear diagnostic procedures are completed worldwide each year; about 80 percent of those procedures use Tc 99m, and 90 percent are cardiac or cancer-related. The US is the largest consumer of Tc 99m, carrying out approximately 40,000 to 50,000 procedures daily. Within the US, myocardial perfusion imaging for coronary artery disease creates the highest demand for Tc 99m, which is required in large amounts to image the disease.[14] Other applications for Moly 99/Tc 99m include whole body imaging for detection of bone metastases; benign bone diseases such as inflammation; sentinel node imaging before surgery for breast cancer or melanoma; and thyroid, lung, and renal imaging.[15]

[14] https://www.ncbi.nlm.nih.gov/books/NBK487238/
[15] https://www.ncbi.nlm.nih.gov/books/NBK487238/

MOLY 99 REACTOR

ORIGIN

- Molybdenum (Moly) 99 is a critical raw material used in nuclear medicine imaging.
- In 1991, the DOE funded programs to create a US domestic supply of Moly 99.
- Based on technology in the DOE-funded Sandia medical isotope production program in the late 1990s.

DEPLOYMENT

- Eden Radioiostopes licensed Sandia's Reactor Design to develop and manufacture the reactor.
- Once built, the reactor will run 22 hours per day, seven days a week.

ROI

Public Good

Recognition & Credibility

Program Development

1991 — *DOE funds programs for developing a US domestic supply of Moly 99*

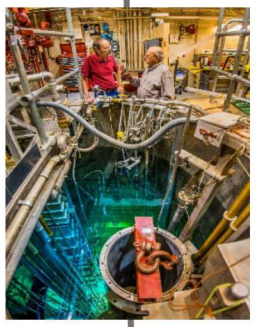
1993-1995 — *DOE evaluates facilities for Moly 99 production capabilities*

1996 — *DOE selects Sandia and the CMR facility at Los Alamos as alternative Moly 99 production facilities*

1999 — *DOE invests between $20-50 million to develop Moly 99 production capability*

DOE gauges commercial interest in Sandia Moly 99 initiative

2013 — *Sandia develops Moly 99 Reactor Design*



2015 — *Eden Radioisotopes licenses the Reactor Design*

2019 — *Eden Radioisotopes partners with Abo Empire to build Moly 99 Reactor*