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The RMC Method to Handle Tritium Efficiently and Safely

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Abstract — *When it comes to the task of handling gaseous tritium, the challenge is to reduce losses of this precious, gaseous, hydrogen isotope. The driving force to achieve this is based on three requests:*

1. *Improve the safety and efficiency by spotting losses of gaseous tritium.*
2. *Embed the real-time tritium monitoring in the process and safety automation.*
3. *Be transparent in the whole workflow for its own safety and for auditable compliance.*

Many good and accepted single devices and working procedures have been proposed and used already. By introducing the Smolsys Ltd.® Radio Medical Container (RMC) method, a team at Smolsys Ltd. has brought the efficient and safe handling of tritium to a new performance level. The idea of the RMC method is to combine many of those approved single devices for gaseous tritium handling and link the workflow logically and digitally in a well-controllable confinement. In the case of the RMC, the working space or room is a container in which the working places and machines are run; hence, the room itself becomes part of the production process and tritium machine. It is monitored and controlled by the process logic and as such becomes a smart and digitized RMC for more safety and efficiency in tritium handling. This paper presents the RMC based on a realized tritium-processing factory in Switzerland. This RMC is a fully engineered tritium facility with a designed and engineered safety factor and is very flexible to be customized. The RMC is also transportable since standard container sizes are used.

Keywords — *Tritium handling, Radio Medical Container, real-time HTO and HT measurement.*

Note — *Some figures may be in color only in the electronic version.*

I. THE RMC-METHOD FOR TRITIUM HANDLING

I.A. Short Description

For the task to set up a production and handling site to process highly regulated and/or hazardous material, the costs to set up and the running costs are a large part of the costs of the produced products. Hence, it was our goal to set up a new production location by optimizing investment costs and running costs and also to reduce the setup time. This however has to be done by being compliant with all international and national regulations on safety and radio safety protection. It is also the company's mission to improve permanently the radio safety by using the production process of the current state of high-level automation, the so-called current Good Manufacturing Practice (cGMP).

Following the request to set up a production for glass sealed microsystems (GSM) in which pure tritium gas (T_2 gas) has to be used, Smolsys Ltd. came up with the idea to set up the process by designing the production machines, and—this is new for this application—we also designed the room around the whole workflow.

The room in which it was all designed and simulated is a 20-ft container: the Smolsys Ltd.® Radio Medical Container (RMC). The RMC concept is highly flexible in adapting after setup to new needs and specifications.

The specific case in this paper uses the following examples to produce GSM: gaseous tritium light sources for illumination of watches and instruments, glass-sealed medical implants and the longevity testing of them with tritium leak testing, loading (charging) of metal films for neutron beam

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targeting, laser targets, tritium batteries, etc. Of course, the RMC can be used also for other isotopes or hazardous material handling. Tritium is not one of the most hazardous materials, but since it is in gaseous form, most of the challenges of handling and tracing have to be solved in this specific case, and it is the goal of this paper to share with the community the experiences made with this method for the sake of radio protection and efficient workflow.

I.B. Comparison to Conventional Tritium Handling

To have a good understanding of what the current standards are and what the regulatory bodies in the different countries have accepted in these kinds of tritium handling and production facilities, the Canadian Nuclear Safety Commission has provided a well-documented report to which we will refer in this paper as the conventional methods.[1]

II. IMPROVE SAFETY AND EFFICIENCY

A facility to handle tritium must be designed with the risk assessment already in mind. The risk assessment has the purpose to find out and reduce the risk for the operators, the environment, and the products, while producing, and the decommissioning at the end of the life cycle. The advantage of the RMC method is that the room is designed like a machine and is part of the production process; consequently, one is faced with very clear conditions and interfaces. This gives one the ability to have the risk factors ready and documented for the application to the local regulatory body before having invested in a single machine or infrastructure.

As an overview, some findings during the setup phase and running the RMC are given here:

1. The probability for a fully deployed full fire—in case of this event—could be designed and calculated to $<2.2 \times 10^{-25}$.

2. Risk assessment calculation was easy to find due to intrinsically designed safety factors and achieved considerable higher safety factors than conventional sites (without RMC, see Ref. 1).

3. Potential surface contamination is reduced (by surface and choice of correct material in RMC).

4. There is a very short approval and qualification (validation) time.

5. There is a very short setup time (the RMC at Smolsys Ltd., Root D4, was set up and approved in 6 months).

6. Workflow and material flow are minimized and optimized.

7. There are much lower maintenance costs than comparable "controlled or clean room" sites.

8. The RMC concept is fully scalable to high-volume production.

9. The RMC is very adaptable to the product to be processed, even after installation.

10. Every glove box can be traced back for HTO and HT losses.

11. At the end of the life cycle, the costs for decommissioning can be reduced by at least two orders of magnitude compared to conventional tritium sites like the ones described in Ref. 1.

II.A. Automatic Monitoring (Imbedded Real-Time Tritium Monitoring in the Process and Safety Automation)

The task to monitor and document the environmental and tritium values in real time and online in the exhaust, in the room, and in every glove box can be a very laborious and time-consuming duty. Since as mentioned, the conditions and interfaces of the RMC are very clear, this process has made the task to do the needed monitoring and documentation in an automated way much easier and affordable.

In the RMC these values are measured every second and used for real-time processing like pre-alarm and alarm handling. These measurements have the goal to ensure the safety of the staff, the environment, the process, and the product.

In the actual RMC at the Smolsys Ltd. site, about 800 000 values/day are measured and stored with a time stamp. They can be used in real time or for later processing. As a nice example, we can mention here the possibility that with the following equation, preventive alarms can be processed and set:

$$A_{released}(t) = \int_{t_1}^{t_2} A_{concentration}(t) \cdot V_{air}(t) \cdot dt .$$

In other cases, real-time alarms and/or data preprocessing will very quickly note nonconformal, installed devices from third parties that do have an unacceptable permeation rate or an arising tritium leak during the automatically run production process.

In the RMC, HT and HTO are monitored in real time and online.[2]

II.B. Transparency in the Whole Workflow for Its Own Safety and for Auditable Compliance

Transparency of the monitoring and process data leads to more safety since the data are available in real time, locally, remotely from outside the RMC, and for later processing on the data storage media.

With this RMC method the task of the radio safety manager is highly automated, and the frequent reports for internal usage and for the regulatory body are much more consistent and easier to produce weekly, monthly, and yearly. Tracing of an event back to the corresponding work order is now feasible.

III. THE RMC HYPOTHESIS

The setup of a tritium-handling process in a RMC leads to better safety factors, reduced costs, and reduced environmental and operator risk. This could be shown during the design phase, the work on the risk assessment for the licensing process, the setup, and now after more than 2 years of practical usage in the full production process.

It could also be shown that the real-time measurement led to an optimization of the whole production process by reducing work cycles like filling and decanting tritium. This also reduced the losses of tritium through permeation by at least one order of magnitude.

Since the RMC allows monitoring every process step in real time, it was quickly found that the so-called decanting cycles, i.e., filling tritium from the metal-hydride getter beds to other cavities, led to losses of tritium by permeation through the walls of the steel vessels because they have to be heated to temperatures well above 250ºC. By changing the decanting process and using so-called TTT-getter beds, which do the desorption/resorption cycle between −197ºC (liquid nitrogen) and room temperature, the losses in permeated tritium could be reduced by at least a factor >50.

IV. RMC AND CONTAINMENT

The RMC is set up as a three-shell containment system (Fig. 1). The RMC itself is considered as containment 3 and is usually ventilated and run in underpressure. The installed glove boxes have a separated ventilation system and are run in underpressure to containment 3. The tritium-handling and -processing system is installed in containment 2 and is considered to be containment 1, the tritium machines.

Since the RMC is equipped with a full monitoring system, it will react on changes in tritium concentration (HT/m^3 and/or HTO/m^3) in any of the shells or glove boxes or other events that influence the pressure differences and airflow conditions; hence, the RMC can regulate the permanent air exchange from 6 times to 30 times full volume exchange per hour by automatically adjusting the ventilation. Besides being a safety aspect, this helps massively to reduce the running costs in energy for preparing the fresh air (extra cooling, heating filtering, humidity, etc.).

Short specifications of the RMC include the following:

1. three-shell containment (RMC = containment 3, glove boxes = containment 2, H-3 machines = containment 1), space for up to four glove boxes
2. three to ten times lower in investment cost compared to conventional tritium sites without RMC as described in Ref. 1
3. five times lower in running costs compared to conventional tritium sites without RMC as described in Ref. 1
4. two times faster delivery (6 months instead of >1 year)
5. 6 to 30 times full volume exchange of fresh air per hour (can be automatically controlled)
6. oxygen, humidity, temperature, volatile organic compound (VOC) monitored air
7. automatic HT and HTO monitored and documented
8. electro static discharge (ESD) protected
9. RMC reacts on process events of production process
10. volume: 27 m^3
11. fire protection class EIR 90
12. door F90/EL2 90, anti-panic door
13. Zone B without lock in change area, Zone A with lock entrance (optional)
14. underpressurized: 50 to 90 mbars.

(a)
(b)

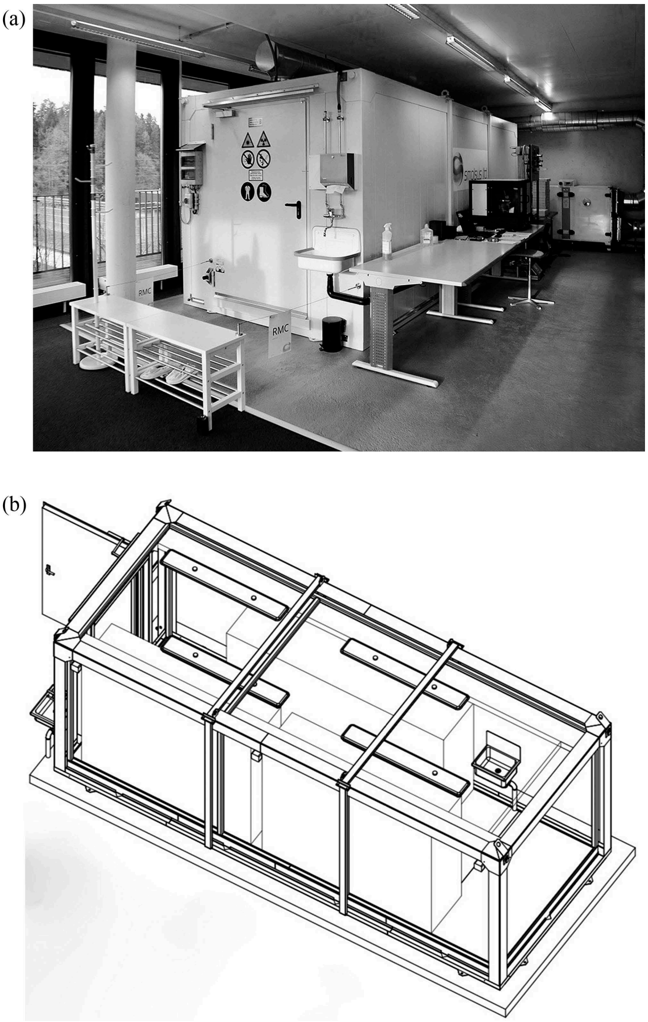

Fig. 1. (a) Photograph of the RMC and (b) drawing of the inside of the building, with shoe change area and RMC ventilation seen in the background.

V. SUMMARY

The setup of a tritium production facility in the RMC has led to the following findings:

1. The calculated safety factors for the requested worst-case scenarios could be improved massively by design, in the range of greater than six orders of magnitude.

2. The outlet of tritium to the effluent air and water could be reduced by factors >50.

3. The real-time measurement of HTO, HT, O_2, temperature, humidity, airflow, pressure, and VOC was shown to be a very valuable tool in improving workflow in safety and efficiency and production volume that could be handled with greater than three times less personnel.

4. Because of this real-time monitoring of HTO and HT, several devices like getter beds, valves, seals, etc., and the tritium-handling systems and glove boxes could be innovated, and hence, the HTO and HT exhaust was additionally reduced.

5. By the experiences in setting up and operating in shifts for more than 2 years, the RMC confirmed the targeted goals for safe and efficient production of devices with tritium.

6. The RMC was set up in record time for the start of production including the approvals of the regulatory body; only 6 months was needed to build it, including the workstations, and to slide it inside the building in the top floor.

7. The RMC concept can be easily scaled up by adding more RMC units without reducing the safety factors.

More potential improvements have also been determined for the different tritium-handling systems, and further work will be done on other tritium-handling processes to be installed in the existing or in new RMCs from Smolsys Ltd.

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