This document is
PUBLICLY RELEASABLE

James K. Kent (OSTI)
Authorizing Official

Date: 7-6-89

TERTIARY CONTAINMENT IN A MULTI-ROOM TRITIUM FACILITY

L. R. Kent
Monsanto Research Corporation
Mound*
Miamisburg, Ohio 45342
(513)865-4153

ABSTRACT

An experimental system to provide tertiary containment at Mound has been upgraded to support a new multi-room tritium handling facility. This system is used to remove tritium from room air in the event of primary (process) and secondary (glovebox) containment failure. The upgraded system includes a faster response time, piping and valves that are more leak-tight, and a new control panel that better indicates the system status and operating conditions.

INTRODUCTION

The concept of tertiary containment in a tritium facility is not new. Mound has had such a system for over ten years. Only in the past year, however, has this system, called the Emergency Containment System (ECS), been upgraded from an experimental system. It now provides continuous tertiary containment protection for a new multi-room tritium handling facility.

SYSTEM FUNCTION

The Emergency Containment System functions in a fairly straightforward way. The tritium handling facility has been divided into twelve rooms. The area is compartmentalized into several rooms to minimize the volume of air exposed to tritium in the event of a release, and thereby minimize the amount of time required to clean up the release by the ECS. If a room (or rooms) contains tritium as a result of secondary containment failure, the air is circulated through the ECS to remove tritium and returned to the room from which it was taken. The air is recirculated in this manner until the tritium level in the affected room(s) is reduced to a level that is safe for workers to re-enter.

SYSTEM DESCRIPTION

A hermetically sealed blower with a 28.3 m³/min (1000 scfm) capacity is used to circulate the air from the room(s) containing high tritium levels through the ECS. Air drawn from the room(s) through the ventilation ductwork passes through an electric preheater that heats the air stream to 177°C, the minimum temperature needed to achieve near complete conversion of tritium to tritium oxide. The heated air stream then passes through a reactor containing a precious metal on alumina catalyst, which changes the elemental tritium to tritium oxide. Exiting the reactor, the air stream then passes through a shell-and-tube heat exchanger to reduce the temperature to approximately 25°C. The cooled air stream then enters one of two exchange beds. Each bed is filled with 1700 kg of activated alumina that has been saturated with water vapor. The tritiated water vapor in the entering air stream exchanges with the protium water vapor on the alumina as it passes through the bed. If one bed becomes saturated with tritium, the air stream can be diverted manually to the second bed. After the air exits the exchange bed, a small fraction of the stream (approximately 25 scfm) is stacked to keep the room(s) being processed at a pressure negative to the surrounding areas. The rest of the air stream is sent back to the room(s) from which it was taken. The exact amount of air that is stacked to maintain negative pressure varies over a small range, because the flow is determined automatically from the differential pressure reading of the room being processed. If more than one room is being processed, the direct digital control system that controls room pressure differentials uses the reading from the room that is most positive to control the amount of room air that is stacked by the ECS. A schematic of the Emergency Containment System is shown in Fig. 1.

*Mound is operated by Monsanto Research Corporation for the U. S. Department of Energy under Contract No. DE-AC-04-76BP00053.

Fig. 1 - Emergency Containment System flow diagram.

FAST START CAPABILITIES

One of the more important changes made to the ECS was the addition of auxiliary heating to provide a fast start capability. All piping and equipment from the blower outlet to, and including, the reactor is continuously heated to 177°C. Previous experience has shown that it takes 30 min for the air stream exiting the reactor to reach a temperature of 177°C from room temperature (20°C). However, by keeping the system continuously heated with the auxiliary heater, which requires only 0.84 kW of electricity, there is no time delay in achieving the 177°C reactor outlet temperature. Fig. 2 shows both of these conditions. The reactor catalyst (a platinum-palladium on an alumina substrate) is highly temperature dependent, and previous work¹ was done in order to determine the rate constant for the first order reaction of tritium to tritium oxide for this particular catalyst. The resulting rate constant was:

$$k = 2.27 \times 10^5 \exp[-7100/RT] \quad (1)$$

where k = first order surface rate constant (liter/sec-liter catalyst)

R = gas constant (1.987 cal/gmole-K)

T = absolute temperature (Kelvin)

The result of this study found the catalyst to have a conversion efficiency rate for tritium to tritium oxide of 99.97 and 99.98% for two different tests. Using the rate constant in Eq. (1) above, a graphical representation of the relation between catalyst efficiency and temperature is shown in Fig. 2. To illustrate the

difference preheating the system makes in relation to the amount of tritium that is stacked, a simulated release curve was generated by using the following relationship:

$$\frac{dC}{dt} = (R/DF - 1) \frac{QC}{V} \quad (2)$$

which can be integrated to obtain the expression:

$$\frac{C}{C_0} = \exp[(R/DF - 1)(Qt/V)] \quad (3)$$

where C = concentration, $\mu\text{Ci}/\text{m}^3$

C_0 = initial concentration, $\mu\text{Ci}/\text{m}^3$

R = fraction of purification system exhaust that is recycled back to the room (ranges from 0 to 1)

DF = purification decontamination factor, C_{in}/C_{out} per pass (ranges from zero to infinity)

Q = system flow rate, m^3/min

t = time to reach concentration, °C

V = room volume, m^3

The following example will be used to illustrate the difference auxiliary heating can make in the capture of tritium by a detritiation system. A simulated release curve can be generated by using Eq. 3. For this example, the following values will be used in Eq. 3: $R = 0.975$, $Q = 28.3 \text{ m}^3/\text{min}$, $V = 500 \text{ m}^3$,

Fig. 2 - Reactor heating as a function of time.

$C_0 = 20,000 \text{ } \mu\text{Ci}/\text{m}^3$ (10 Ci release in a 500 m^3 room), and $DF = 100$. The decontamination factor, DF , is a constant when the system is maintained at reaction temperature prior to startup. If auxiliary heating is not used, then DF would vary from a low value of 1 at process startup to its upper value (which is assumed to be 100 in this example) when the reactor reached 177°C . To simplify the mathematics involved, a constant value of $DF = 100$ will also be used for the nonpreheated case. (This assumption will somewhat underestimate the amount of tritium that will be stacked.)

The resulting concentration-as-a-function-of-time curve for this example is shown in Fig. 3. The curve closely represents concentration-as-a-function-of-time curves from actual releases that were made several years ago.² Using data shown in Fig. 3, along with data for catalyst efficiency as a function of temperature (shown in Fig. 4), and the data for reactor temperature as a function of time (shown in Fig. 2), it was possible to determine how much tritium and tritium oxide would be in the stream exiting the reactor.

The amount of tritium and tritium oxide in the stream exiting the exchange bed as a function of time was then calculated. The tritium concentration in the stream exiting from the exchange bed is the same as the tritium concentration in the stack stream. Fig. 5 shows stack exhaust tritium concentration as a function of time for both a preheated and a nonpreheated

system. The tritium concentration of the stack stream peaks at $220 \text{ } \mu\text{Ci}/\text{m}^3$ at the onset of processing for a preheated system, and at $18,400 \text{ } \mu\text{Ci}/\text{m}^3$ for a nonpreheated system. The area under each curve was used to determine the total amount of tritium (elemental and oxide) that would be stacked. For a preheated system, a total of $2,800 \text{ } \mu\text{Ci}$ would be stacked, whereas $76,100 \text{ } \mu\text{Ci}$ would be stacked where auxiliary heating was not used. These values represent respectively a total of 0.028 and 0.76% of the initial 10 Ci release being sent to the stack. The system without auxiliary heating released 27 times as much tritium as the preheated system. In the event of a much larger release, this could be a significant amount of tritium.

Eq. (3) was again used to predict what would happen if the entire $28.3 \text{ m}^3/\text{min}$ (1000 acfm) were stacked. This would simulate a once-through system, or one where the room being processed was so leaky that all of the airflow was stacked in an attempt to keep the room negative to the surrounding areas. For this example, the values used for Eq. (3) were: $R = 0$, $Q = 28.3 \text{ m}^3/\text{min}$, $V = 500 \text{ m}^3$, $C_0 = 20,000 \text{ } \mu\text{Ci}/\text{m}^3$, and $DF = 100$. (Again, the assumption of a constant DF value was made for the nonpreheated system.) The resulting concentration as a function of time is almost identical to that shown in Fig. 3, and the resulting curves for tritium concentration stacked are almost identical to those shown in Fig. 5. When the total amount of tritium released to the stack was calculated, however, there was a significant

Fig. 3 - Room concentration as a function of time for release of 10 Ci in a 500 m³ room.

Fig. 4 - Catalyst efficiency as a function of temperature.

Fig. 5 - Tritium concentration stacked as a function of time.

difference. Where the detritiation system was preheated to 177°C , 113,600 μCi or 1.14% of the tritium would have been stacked; whereas in the case where the system was started up from room temperature, a total of 3.03 Ci or 30.3% of the initial 10 Ci release would have been stacked. Again, the ratio of tritium released with the system at room temperature at startup to the tritium released using a preheated system is about 27. As with the previous example, a much greater fraction of tritium is stacked from a nonpreheated system, even though the amount of tritium released by a nonpreheated system is underestimated from the simplifying assumption of a constant DF value. Therefore, it is important to maintain the system at operating temperature to insure maximum conversion efficiency from the start of processing. It is just as important to make the room or facility being processed as leak-tight as possible, because the quantity of airflow stacked to keep the contaminated room negative to the surrounding rooms and corridors is directly proportional to the amount of tritium that is stacked and released to the environment.

ROOM DESIGN

All of the rooms in the tritium handling facility were specially prepared to make them as leak tight as possible. All rooms have a leak rate between 25 and 40 cfm while maintaining a pressure differential of 0.05 to 0.20 in. of

water negative to the surrounding corridor. To obtain this degree of tightness, the room walls were painted with an epoxy-type paint to minimize the porosity; all penetrations in the walls and ceiling from such items as piping, monitors and electrical conduits were sealed; and all doors are close-fitting and fitted with scripping to minimize airflow.

EXHAUST DUCT AND BUBBLER EXHAUST DESIGN

All duct piping used to carry room air to and from the ECS is made of stainless steel and is of welded construction. This piping, as well as the butterfly valves installed in the piping, is leak tight to 1×10^{-4} std. cc He/s. The leak tightness of the ductwork and dampers minimizes the potential loss of tritium. The butterfly valves are located on the room supply duct, the room exhaust duct, the ECS supply duct, and the ECS exhaust duct. A schematic of the ductwork and valves is shown in Fig. 6. Each room in the tritium facility has one or more tritium monitors installed in the room exhaust duct. The duct monitor, which can be set anywhere in the range 0-20,000 $\mu\text{Ci}/\text{m}^3$, and is currently set to alarm at 1000 $\mu\text{Ci}/\text{m}^3$. In the event of a tritium release in one or more of the rooms, the duct monitor will automatically signal the control room, which will then send a signal to the valves located on the ductwork for the room with a high tritium level. The time required for the duct monitor to read a

Fig. 6 - Flow logic for tritium facility and Emergency Containment System.

1000 $\mu\text{Ci}/\text{m}^3$ level, send a signal to the control room, and for the control room to send a signal to the appropriate valves is only 1 s. The time needed for the valves to switch over is 1 to 2 s. The valves themselves are located a distance from the exhaust point that is equivalent to the distance the air would flow in 4 s. The quickness of the duct monitor and the strategic location of the valves reduce the amount of tritium that could potentially be sent to the stack. All glovebox bubbler systems exhaust to a main header, which is also monitored by a duct monitor. The bubbler header exhaust can also be sent to the ECS for tritium removal if the tritium level exceeds 1000 $\mu\text{Ci}/\text{m}^3$. The bubbler exhaust was set up this way, because the probability of having high tritium levels in the bubbler exhaust is much greater than having a high tritium level in the room itself. Cleaning up the bubbler header exhaust also helps to minimize the amount of tritium that may potentially be stacked.

SYSTEM LOGIC

The Emergency Containment System is designed so that one or more rooms can be processed simultaneously. If multiple rooms are being processed at the same time, specific rooms can be left on the ECS and the remainder stacked, if conditions warrant. Because the ECS is not quite 100% efficient in tritium removal, the recirculated air does contain some tritiated water vapor. In some cases, therefore, it may be more prudent to stack a low concentration of

elemental tritium instead of recycling a low concentration of tritium oxide into the room. The ECS currently provides tertiary containment for 12 rooms in the tritium facility. Two more rooms will be added to the system this year.

FUTURE PLANS

The ECS was tested with tritium in the mid-1970's so that an overall tritium capture efficiency could be determined. The results of those tests indicated an overall efficiency of 90%. With the upgraded system, the efficiency should be somewhat higher than that of the old system. Tests that involve releasing tritium into a lab and having the ECS automatically actuated are being planned for mid-1985 so that the tritium capture efficiency of the upgraded system can be determined.

REFERENCES

1. J. C. BIXEL and C. J. KERSHNER, "A Study of Catalytic Oxidation and Oxide Adsorption for the Removal of Tritium from Air," in Proceedings of the Second ABC Environmental Protection Conference, April 16-19, 1974, WASH-1332 (74), Sandia Laboratories, Albuquerque, NM, pp. 261-284, MLM-2140(OP).
2. T. M. FLANAGAN, M. L. ROGERS, and W. R. WILKES, Tritium Waste Control, April-September 1977, MLM-2484 (January 9, 1978), pp. 25-40.