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This paper gives a brief overview of the Safety and Tritium Applied Research (STAR) facility operated by the Fusion Safety Program (FSP) at the Idaho National Laboratory (INL). FSP researchers use the STAR facility to carry out experiments in tritium permeation and retention in various fusion materials, including wall armor tile materials. FSP researchers also perform other experimentation as well to support safety assessment in fusion development. This lab, in its present two-building configuration, has been in operation for over ten years. The main experiments at STAR are briefly described. This paper discusses recent work to enhance personnel safety at the facility. The STAR facility is a Department of Energy less than hazard category 3 facility; the personnel safety approach calls for ventilation and tritium monitoring for radiation protection. The tritium areas of STAR have about 4 to 12 air changes per hour, with air flow being once through and then routed to the facility vent stack. Additional radiation monitoring has been installed to read the laboratory room air where experiments with tritium are conducted. These ion chambers and bubblers are used to verify that no significant tritium concentrations are present in the experiment rooms. Standby electrical power has been added to the facility exhaust blower so that proper ventilation will now operate during commercial power outages as well as the real-time tritium air monitors.

I. INTRODUCTION

The Safety and Tritium Applied Research (STAR) facility began its life in 1984 in a small building near the Advanced Test Reactor (ATR) at the Idaho National Laboratory (INL). The building designator was TRA-666A and it was re-tasked to be the Tritium Research Laboratory (TRL) in 1984. After remodeling and addition of new equipment beginning in 1986, the TRL began tritium operations in 1989.[1] The TRL used very small quantities of tritium, typically on the order of milliCuries, and most of the tritium was bound in various solid or liquid materials of interest.

In 2000, the DOE selected INL as the site of the tritium experiment lab and INL began preparations for a larger tritium experiment lab at the 100-acre ATR complex. The building adjacent to the TRL, TRA-666, was no longer in use and was retasked to house the tritium lab. In 2001, the TRA-666 building was radiologically decontaminated and reconfigured to be the tritium experiment lab. Progress in setting up the STAR lab has been discussed in the literature.[2,3] Presently, the STAR facility is comprised of these two adjoined buildings, TRA-666 and TRA-666A, as shown in Fig. 1. A number of tritium experiments are housed in the STAR facility. The main tritium experiments are briefly described in the next section.

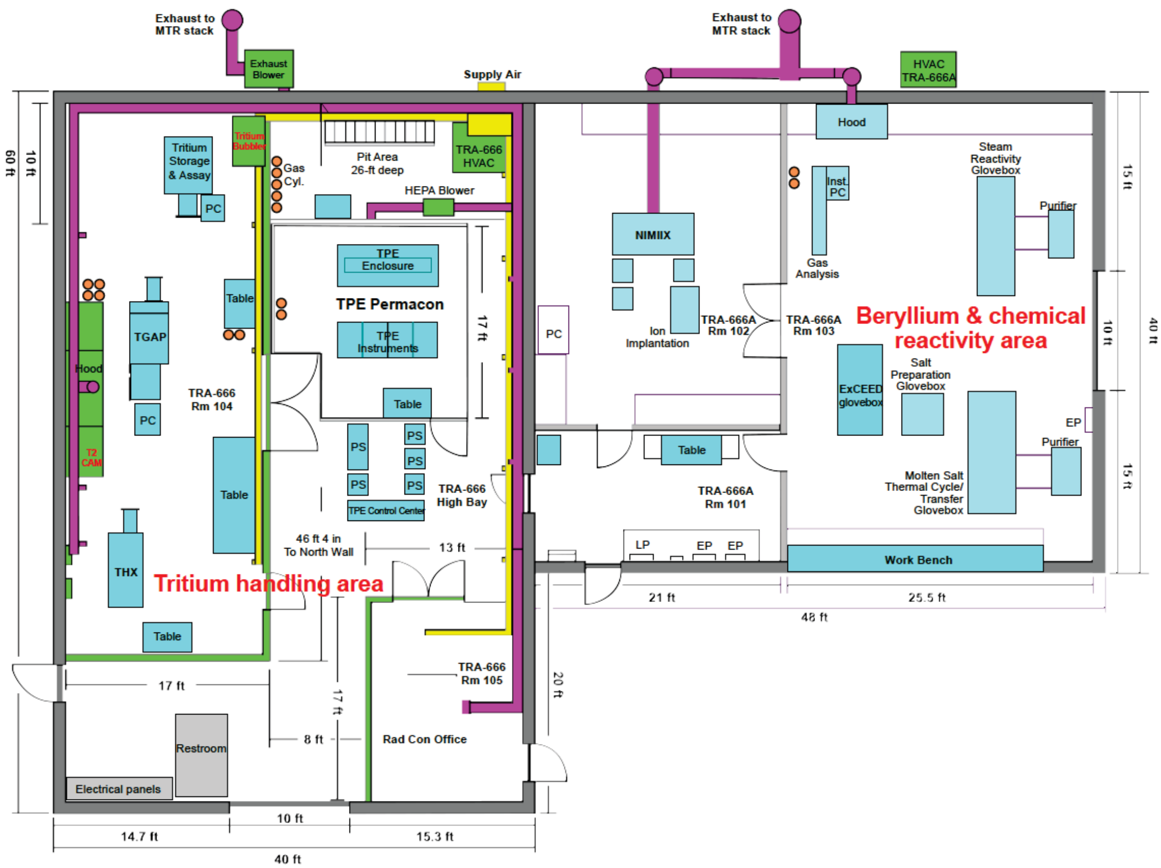

Fig. 1. The STAR lab floor plan.

Elemental tritium gas comprises the largest radioactive inventory at STAR. The tritium inventory is maintained below the 1.6 grams (16,000 Curies) threshold for DOE hazard category 3. Personnel safety when using tritium is provided by experiment containment systems, confinement and facility ventilation systems, and by radiation monitoring systems. The older, single-pass ventilation philosophy for worker protection, as described by the Department of Energy[4] is followed since STAR is a less than hazard category 3 facility and the smaller experiments typically tend to use between 1 and 200 Curies of tritium. The large experiment tends to use from 200 to 500 Curies of tritium in a session or campaign, and it applies the preferred approach of capture, containment and cleanup by trapping tritium out of the exhaust gas flow using a uranium getter bed. In both cases, ventilation air follows standard ventilation practice by always flowing from clean areas to low contamination areas, then to higher contamination areas. From highest contamination areas the ventilation air is either sent through a trap or is sent directly to the facility vent stack. STAR uses a 70-meter-tall vent stack (referred to as the Materials Testing Reactor (MTR) stack in Fig. 1). This stack is shared with another building at the complex. The room air exchange rate that has generally been accepted to be adequate for worker protection in tritium facilities is 6 to 10 air changes per hour.[4] The STAR tritium experiment room 104 generally operates at more than 12 air changes per hour. The PermaCon modular panel containment enclosure that houses the Tritium Plasma Experiment (TPE) operates at 4 air changes per hour. The PermaCon is no longer routinely habited during experiment sessions. The High Bay portion of STAR is a clean area, and it operates at less than 2 air changes per hour.

Radiation monitoring is accomplished with two types of instruments, ion chambers for continuous measurement and indication of tritium concentration in air and bubblers that capture tritium from air samples for periodic counting with a liquid scintillation counter. This paper describes the upgrade to the ventilation system, as well as the additions and upgrade to the radiation monitoring system in 2015.

II. TRITIUM EXPERIMENTS AT STAR

The STAR facility has several tritium experiments. Table 1 gives a list of the experiments. The largest experiment is the Tritium Plasma Experiment (TPE), housed in the PermaCon structure. This is a unique facility for experimentation on the behavior of deuterium/tritium in toxic and radioactive materials for fusion plasma-wall interaction studies.[5] TPE is a linear plasma device that can place a 5% tritium and 95% deuterium ITER-like plasma onto neutron-irradiated samples of tungsten, beryllium, and other materials. TPE can use 200 to 500 Ci of tritium in an operating session. Recent upgrades to TPE include new power supplies, replacement of wiring, gas piping, and coolant piping, a new control system, and other repairs that also enhance personnel safety when operating this experiment. Shimada describes these upgrades, including remote TPE operation.[6,7]

The tritium gas absorption permeation (TGAP) experiment is used to examine small levels of tritium permeation (1 to 200 Ci) in heavy liquid metals such as lead-lithium and in solid fusion materials, such as silicon carbide, tungsten, molybdenum, nickel, and low activation steels. This apparatus uses a furnace to heat the test samples to fusion operating temperatures to test permeation or absorption. The TGAP apparatus is confined in a ventilated enclosure (VE) in room 104. Pawelko has described some of the work with this experiment.[8]

The tritium heat exchanger materials permeation experiment (THX) is used to determine tritium permeation from a tritium-helium gas mixture through the walls of heat exchanger tube materials. The first tubes tested were Incoloy 800H and Inconel 617.[9] The apparatus uses a primary helium-and-tritium gas mixture (0 to 10 liters/minute flow and up to 200 Ci of tritium) in the tube to be tested, then an outer tube of quartz with pure helium gas flowing in the annulus to capture any permeating tritium. The gas in the annulus is analyzed for tritium content. An induction heater heats the test article up to a maximum of 950°C. The THX apparatus is confined in a ventilated enclosure in room 104.

STAR also has some support systems in room 104. The tritium Storage and Assay System (SAS) consists of two depleted uranium storage beds housed in an argon-atmosphere glovebox.[10] These beds store the bulk of the STAR tritium inventory. The tritium exhaust purification (TEP) system works in conjunction with the TGAP experiment described above. The TEP is housed in a laboratory hood. The Tritium Supply System (TSS) holds up to 25 Curies of elemental tritium gas to dispense to the TGAP experiment as needed. The TSS is mounted next to the TEP in the laboratory hood.

TABLE 1. Tritium Experiments and Support Systems at STAR

Experiment or System Name	Purpose	Tritium Limit (Ci)	Location
TPE	Expose plasma facing materials to plasma	1 to 500, experiment limit	VE in the PermaCon in the High Bay
TGAP	Test tritium permeation in coolants and materials	1 to 200, experiment limit	VE in Room 104
THX	Test tritium permeation in heat exchanger materials	1 to 200, experiment limit	VE in Room 104
SAS	Tritium storage and assay system	16,000, storage limit	Glovebox in Room 104
TSS	Tritium supply system for TGAP	25, storage limit	Lab hood in Room 104
TEP	Tritium exhaust processing from TGAP	25, capture limit	Lab hood in Room 104

III. POWER UPGRADE FOR THE VENTILATION SYSTEM

The STAR building TRA-666 has a supply fan, and an exhaust fan that directs air to the vent stack. The supply air fan is interlocked, it will not energize unless there is outlet air flow. This interlock provides ventilation control so that air flow reversals will not occur resulting in the spread of contamination inside the building and the building will not overpressurize and potentially allow contamination to move out of the building. The fan interlocks preclude the possibility of unmonitored ground-level releases. The 70-m vent stack has its own air movers, two large 7 horsepower (hp) fans near the base of the stack. One of these fans uses commercial power while the other has commercial power with standby power from the diesel generator; both fans also draw air from STAR. With the facility exhaust fan off, the two stack fans draw about 2,200 to 2,300 cubic feet per minute (cfm) of air out of TRA-666. With the building exhaust fan also in operation, normal exhaust air flow is about 4,000 cfm. The 2,200 cfm air flow drawn by just the stack fans has been ruled by the ATR Radiological Engineering organization to be sufficient to provide for personnel radiological protection from any idle experiment that may outgas tritium during a commercial power outage. Indeed, we have found that our laboratory hoods still meet INL safety requirements of at least 80 feet/minute air face velocity into the hoods when only the stack fans are operating. As mentioned above, the STAR tritium experiments are all housed either in gloveboxes, ventilated enclosures, or lab hoods so the directed ventilation carries any small amounts of tritium away from personnel breathing zones. In a commercial power outage, all fans are de-energized. The STAR exhaust fan is a 3.5 hp fan, and when operating without the stack fans it will draw about 2,200 cfm flow from TRA-666. To better provide for personnel safety, in 2015 standby power was installed for the STAR exhaust fan so that it will continue to operate during outages of the normal, commercial electrical power system. The standby power is supplied from a diesel/commercial bus that is backed by the ATR emergency diesel generator. This diesel generator has strict rules about fast startup and loading. The reactor's electrical loads are primary and "outer area" loads such as STAR are secondary. The loads are time-staggered so that the diesel generator is not overwhelmed by the demand and does not trip off-line at startup. STAR can expect standby power in less than a minute after commercial power is lost. The exhaust fan controller has been set up to automatically restart when power is restored.

The STAR exhaust fan to the stack has two regular preventive maintenance sessions each year. Nonetheless, STAR personnel pay close attention to the exhaust fan. In November 2015 it was noted that the fan was making noise and unusual vibrations were occurring in the exhaust flow return ducts. Mechanics removed the fan's weather cover, investigated and found that the dual drive belts were badly worn and "chunked out"; that is, missing pieces or chunks from each v-belt. The belts were replaced and the fan operates normally. Belt issues tend to arise every 2 to 3 years for this continuous operation fan.

IV. RADIATION MONITORING UPGRADE

STAR has had a Mound Technical Solutions (MTS) bubbler as a stack monitor, and Femto-TECH ion chamber monitors in the tritium experiment room and on the exhaust from the PermaCon confinement structure that encloses the TPE. All of these monitors were powered from commercial power supplied to the ATR complex. If commercial power was lost, all monitoring was also lost. In such events, personnel had to make an immediate, precautionary evacuation of the building since the status of tritium confinement was not positively known; both monitoring and ventilation were lost during commercial power outages.

In 2015, additional radiation monitoring instruments were added. MTS Bubblers were added for the PermaCon, High Bay, and the tritium experiment room 104 (see Fig. 1). The bubblers serve as a diverse means to accurately measure very small quantities of tritium that could be outgassed or released from experiments. Another Femto-TECH U24D ion chamber monitor was added to sample High Bay air. All Femto-TECH radiation monitors at STAR are response checked weekly with a small, sealed Cs-137 check source. The Femto-TECHs are calibrated every three years using NIST-traceable Cs-137 sources by the INL Health Physics Instrument Laboratory. These monitors have shown good stability in instrument response (less than ± 10%) during routine response checks so INL Radiological Engineering has established a three-year period rather than the annual calibration suggested in radiation monitor standards such as ref [11]. The bubblers have flow checked monthly by STAR personnel using a bubble tube or calibrated flow rate meter. This additional monitoring, along with the original monitors, was also provided with standby power like the fan motor discussed above. With this power upgrade, monitoring is not lost during commercial power outages. A 90-minute uninterruptible power supply (UPS) was also installed to provide continuous operation of these instruments. A data logging computer was also added on standby and UPS power to accept input from the ion chamber monitors so that facility conditions are always monitored and recorded. The data logger also accepts condition signals from the bubblers.

Our radiological engineer performed smoke tests to verify that the ion chamber air sampling collector locations in room 104 and the High Bay were correct. The new bubblers draw from the same collector tubing as the ion chambers. The multiple instruments and data recording will also serve to show if there is simply an electronic noise spike that gives a momentary radiation alarm or if there is an actual tritium release to room air. The ion chambers can measure down to the 0.1 μCuries/m^3 level, and values recorded on the data logging computer can be compared to bubbler results from liquid scintillation counting. A refurbished Beckman liquid scintillation counter at STAR is used to count the samples collected by the bubblers; this counter has a minimum detectable activity level of about 13 disintegrations/minute for a sample vial of tritium. Operating procedures have been written for the scintillation counter. At present, the air monitors generally read <3 μCuries/m^3. Initial results from the bubblers show that the Perma-Con is about 1E-05 derived air concentration (DAC) for HTO and 1E-10 DAC for elemental tritium. 1 HTO DAC is 20 μCuries/m^3. The High Bay and room 104 values were less than the Perma-Con values. This is the first time the operating background concentration has been accurately determined at STAR. This not only gives a better estimate of worker exposure, but also can identify any increases in low level, chronic tritium outgassing from experiments in STAR.

The STAR emergency alarm response (EAR) plan has been modified to reflect that personnel are not potentially at risk during commercial power outages and there is no need for a fast evacuation of the building. With these upgrades in place, if commercial power is lost, personnel can make an orderly shut down of experiments and vacate the building without undue urgency. The EAR directs a precautionary evacuation because in a loss of power event, normal building lighting is lost and it is safer to shut down experiments (e.g., close gas cylinder manual valves, close laboratory hood sashes, etc.) and leave the building than it is to linger where the only illumination is provided by battery-powered emergency lighting.

V. CONCLUSIONS

The upgrades to the STAR lab have improved personnel safety when working on experiments with tritium and other materials. The exhaust ventilation fan having standby power means the engineering control of ventilation for exhausting outgassing tritium is enhanced to operate in off-normal conditions so personnel remain protected. The addition of more radiation monitors provides better real-time coverage of all tritium areas at STAR. Adding bubbler monitors allows measurement of very small tritium concentrations in the room air, and allows comparison of readings from the two types of instruments. Bubbler coverage can identify any increases in low level, chronic tritium outgassing from experiments in STAR. Placing the radiation instruments on standby power means retaining tritium monitoring capability in commercial power outage events, so personnel know they are safe from tritium exposure and can conduct an orderly departure from the building.

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