Summary Abstract: Safe tritium handling at the Tritium Systems Test Assembly

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A major objective of the Tritium Systems Test Assembly (TSTA) is to develop and integrate all tritium technologies required for on-site deuterium–tritium fuel processing at fusion reactors. The TSTA has been in operation for 3 yr, processing tritium inventories of over 1 000 000 Ci. Except for the large plasma-chamber cryopumps, which will be installed and operated in 1988, all technologies originally defined have been demonstrated during extended periods of continuous tritium operation.[1]

This summary addresses a second but coequal objective of TSTA—demonstrating that large tritium inventories required for fusion reactors can be routinely handled, with neither radiation exposure to operating personnel nor significant environmental releases. The techniques by which TSTA has achieved low releases and personnel exposures include (1) high-integrity primary piping systems that exclude contact between tritium and organic materials, (2) a secondary containment system that encloses all tritium piping in a controlled environment, (3) an efficient, all-purpose tritium waste-treatment plant with 100% availability, and (4) ultrasensitive, real-time diagnostics for detection and location of tritium leaks in a low-risk mode.

TSTA process piping standards include (1) all-metal construction of piping, pumps, and instrument sensors; (2) exclusion of all elastomers, liquid metals, organic or halogenated lubricants, and all plastics except polyimide for valve stem tips; and (3) hermetic, nonlubricated mechanisms for valves and pumps. A previously described vacuum system[2] that meets these requirements comprises a two-stage metal-bellows pump in series with a moving-spiral pump. This system has provided leak-free and reliable gas transfer and evacuation functions for virtually every operation conducted at TSTA. All valves are bellows sealed, pneumatically operated, and remotely controlled. Every valve, pump, and transducer can be removed and replaced without cutting or welding because of the generous use of zero-clearance coined-gasket fittings. In typical systems containing hundreds of such fittings, we have achieved a degree of leak tightness that rivals that of an all-welded system, and yet retains excellent serviceability because faulty components can be so readily replaced.

Our process piping standards also require that each process system be enclosed in an inert-atmosphere glovebox. Tritium piping that interconnects process systems runs in vacuum-tight conduit, while the atmospheres of interconnected gloveboxes remain isolated from each other. The gloveboxes and interconnecting conduit are built to vacuum system standards. The gloveboxes contain static dry nitrogen, purged automatically upon detection of high oxygen (2%) or tritium (1 mCi/m^3) concentration. For a typical nitrogen glovebox fresh purge gas flows once-through to the tritium waste treatment system at a flow rate of only 2 m^3/h. At this miniscule flow rate, all 12 TSTA gloveboxes can be purged simultaneously without overloading the waste treatment system.

The TSTA tritium waste treatment system[3] differs from similar systems at most other installations in that it was designed as a single system to process effluents from all sources: glovebox purging, passbox flushing, service vacuum pump exhausts, and gaseous impurity streams from TSTA processes. If conversion efficiency falls off, waste gases are automatically recycled through the catalyst, and the system also has reserve effluent-gas storage capacity.

The tritium control and containment features discussed thus far were incorporated into the design of TSTA from the beginning, though many details have been improved as a result of our early operating experience. One final technique (computer-assisted diagnostics) is a bonus resulting from our adoption of computer control and remote instrumentation. Computer control was chosen for operational rather than safety considerations; nevertheless the high degree of leak tightness evidenced by our primary piping would have been difficult to achieve without this elegant diagnostic capability. Every valve position and analog parameter at TSTA is logged automatically every 60 s; these disk-archived data are available from graphic terminals in the control center. The history of any TSTA parameter can be selected and displayed graphically with a few simple commands. Another useful capability allows a user to plot up to six parameters simultaneously in real time during operations. This progam allows us to track the tritium concentration in a glovebox, along with the pressures in several different sections of piping in the same glovebox. A steady increase in tritium concentration can then be correlated with one of the pressure sensors, greatly speeding up location of the leak. Extremely small leaks can then be precisely located by using a hose-connected sniffer probe attached to an external tritium ion chamber.[4]

The results of our efforts at tritium control and containment are gratifying. Because of the integrity of the primary piping, several TSTA gloveboxes have gone through many weeks of tritium operations without requiring a purge for high tritium concentration. Other gloveboxes with more typical tritium leakage from the process piping were maintained at tritium concentrations below 10 mCi/m^3 (28 parts per 10^9) by the slow purge of 2 m^3/h. TSTA's releases to the atmosphere over 3 yr of operation have totaled < 30 Ci (80% as HTO), and the largest monthly release was 3.5 Ci. Most of this, which is derived from continuous stack bubbler data, represents the unrecovered portion of the $\sim 30\,000$ Ci that has been treated by the TSTA waste treatment system. The remainder came from untreated releases during low-level maintenance operations, mostly on the nonsecondarily contained waste treatment systems themselves. Cumulative tritium exposure to the entire operating staff to date totals < 150 person mrem. Thus the entire staff of 15 has received less tritium exposure than the 170 mrem/yr/person allowed to an average member of the general population by current Department of Energy regulations.[5]

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[5]U. S. Department of Energy Order No. 5480.1, XI, "Requirements for Radiation Protection," 1981.