TRITIUM HANDLING SYSTEMS FOR TFTR AND PITR

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K. E. Lind, L. Yemin, R. Rossmassler, H. O. Phillips, N. S. Youssef, J. D. Levine,
(EBASCO SERVICES, INCORPORATED)

H. J. Howe, C. W. Pierce
(PRINCETON PLASMA PHYSICS LABORATORY)

Operation of the Tokamak Fusion Test Reactor (TFTR) and the proposed Princeton Ignition Test Reactor (PITR) will involve the generation and burning of a deuterium-tritium plasma. Systems associated with both the TFTR and PITR will be designed to minimize the potential release of tritium and other radioisotopes under both routine operational and accidental conditions. Systems have been proposed for the control and processing of large tritium inventories.

INTRODUCTION

A major objective of the TFTR (Tokamak Fusion Test Reactor) now under construction is to demonstrate the production of energy by the fusion of deuterium and tritium nuclei in a magnetically confined toroidal plasma based on the tokamak principle. The fusion power densities attained in TFTR will approach those required for a fusion power reactor. A secondary objective of TFTR is to study plasma conditions which will yield valuable data for future generations of tokamaks. TFTR will also provide experience in solving engineering problems associated with large fusion reactors.

The principal objectives of the proposed PITR (Princeton Ignition Test Reactor) are to demonstrate the attainment of thermonuclear ignition in a deuterium-tritium plasma and to demonstrate an optimized prototypical plasma for power reactor design and operation. PITR is a versatile copper-coil ITR which is capable of testing a variety of start-up techniques for plasma heating and current induction in order to determine the most favorable means of reducing the size and cost of power reactors.

Systems associated with both the TFTR and PITR will be designed to minimize the potential release of tritium and other radioisotopes under both routine operational and accidental conditions. The tritium control systems presently being designed for TFTR and PITR will limit the annual release to the environment to less than 100 curies.

To minimize the potential release of tritium to the environment surrounding TFTR and the proposed PITR, the following design objectives have been established:

(a) Containment - As much of the tritium inventory as is practicable will be contained in the TFTR Tritium Area and in the Tritium Source and Handling Complex (TSHC) for PITR. Due to the larger inventory for the proposed PITR, that amount of tritium present outside of the TSHC will be contained within three physical barriers.

(b) ALAP - Routine tritium releases will be reduced to levels that are "as low as practicable" (ALAP). In all cases, releases will be less than the appropriate DOE guidelines.

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Systems design techniques for both TFTR and PITR will emphasize the prevention of tritium releases to large volumes in order that clean-up systems may operate on the high tritium concentrations for which they are most effective. All tritium containing components will be designed to high standards of reliability in order to minimize the probability of accidental releases. In addition, administrative procedures will be specified that will require controlled recycling techniques in order to minimize the accumulation of tritium outside the Tritium Storage, Cleanup and Waste Handling Area of TFTR and the Tritium Source and Handling Complex of PITR. Appropriate recycling techniques could include vacuum vessel bakeout, discharge cleaning, cryopanel regeneration, gettering, etc. Table 1 presents a comparison between TFTR and PITR tritium system parameters.

TFTR-TRITIUM HANDLING SYSTEMS

Tritium will be received as a gas from a DOE facility. Once on site, the container will be taken to the Tritium Vault located in the Tritium Area and placed in the Tritium Receiving Glove Box before being opened. The Tritium Area is designed and will be constructed to structurally withstand the most intense predicted natural phenomena as determined by historical studies of the Princeton area. Figure 1 presents the Tritium Storage, Cleanup and Waste Handling Area general arrangement.

The shipping container contents will be assayed, isotopic purity verified, and the gas transferred to the TSDS. The TSDS can store up to the site limit of 50,000 curies of tritium as uranium tritide (UT_3) on two uranium beds which serve as tritium generators. Although a stoichiometric excess of uranium is required, the maximum bed loading is administratively limited to 25,000 Ci/bed. A third bed is normally kept empty for use as a pump to recover excess tritium from the system and as part of a purification operation for removal of He-3 resulting from tritium decay during prolonged storage.

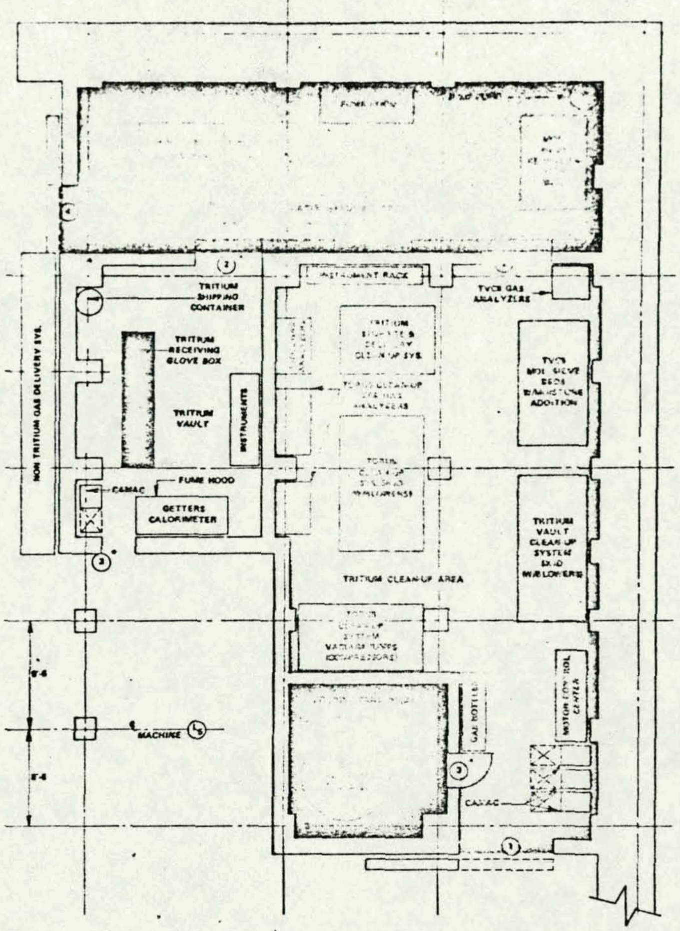

FIGURE 1. TFTR TRITIUM AREA GENERAL ARRANGEMENT

To further reduce the inventory available for accidental release, the tritium generators are isolated from the portion of the system outside the glove box by holding volumes which store only enough tritium as a gas for a single pulse at a maximum pressure of 2500 torr. Since rapid gas flow modulation rates are required, secondary injection valves, are located within about 2 meters of the torus. Tritium gas is generated on demand by external heating of the tritium generators. Through regulation of the tritide temperature, control of the pressure of gas generated can be achieved. The tritium gas required for a planned pulse is pumped to a holding volume which is filled to a pressure that is calculated to fill, as required, the three

TABLE 1. TFTR-PITR TRITIUM SYSTEM COMPARISON

PARAMETER	TFTR	PITR
ON-SITE INVENTORY	50 kCi	2.3 MCi
INVENTORY/PULSE	400 Ci	20-40 kCi
PULSE LENGTH	100 msec	5 sec
PULSE FREQUENGY	1 per 5 min	1 per 10 min
PULSES/YEAR	1000	1000-3000
CONTAINMENT LEVELS	2	4
NUMBER OF CLEANUP SYSTEMS	4	6
MAXIMUM ANNUAL RELEASES	100 Ci	100 Ci
ANNUAL DOSE @ EXCLUSION BOUNDARY (MREM)	10 Total (3 Tritium)	10 Total (3 Tritium)
T_2 RECYCLE CAPABILITY	NO	YES
ON-SITE WASTE DISPOSAL	NO	NO
ANNUAL T_2 USE	400 kCi	60 MCi

injection volumes near the torus. Filling of the injection volumes is by equilibration with the holding volumes. The gas in the injection volumes is metered into the torus through two fast delivery valves in parallel providing a 100:1 flow rate variation during the injection scenario. The fast valves will have a time constant of approximately 5 milliseconds.

Redundant system pathways with connections between critical components will provide a highly flexible and reliable system. Double containment of the most critical components of the system will permit access for repairs, adjustments, and calibrations.

During normal TFTR operation the delivery system will be operated remotely from the central control room. Pressure and temperature instrumentation will be provided to meet accurate programmed injection scenarios and to acquire data concerning key parameters.

During normal operation most of the tritium, as well as deuterium, will be pumped out of the torus after each pulse by the torus vacuum system turbomolecular pumps. These gases will be absorbed on zirconium-aluminum getters. The getters will be packaged and shipped off-site for disposal or regeneration and recycle.

Although the maximum site inventory is comparatively low, four cleanup systems will be provided to insure that tritium releases are kept as low as practicable. The systems are the Torus Cleanup System (TCS), the Tritium Storage and Delivery Cleanup System (TSDCS), Tritium Vault Cleanup System (TVCS), and the Test Cell Cleanup System (TCCS). The first two systems have both normal operating and emergency functions while the second two systems are exclusively emergency systems. All except the TCCS catalytically oxidize the tritium and absorb the resulting water on molecular sieve beds. All of the cleanup systems are designed to withstand and operate through the most probable natural phenomena defined for the TFTR site. The TFTR tritium cleanup systems may be operated from either the main facility control room or from a local control room located outside of the tritium seal envelope on a mezzanine in the Test Cell Basement. A thorough description of the TFTR Tritium Cleanup Systems will be found in reference 1. Locating the local control room outside the tritium seal area assures control room habitability under potential accident conditions. Figure 2 is a schematic representation of the TFTR tritium systems.

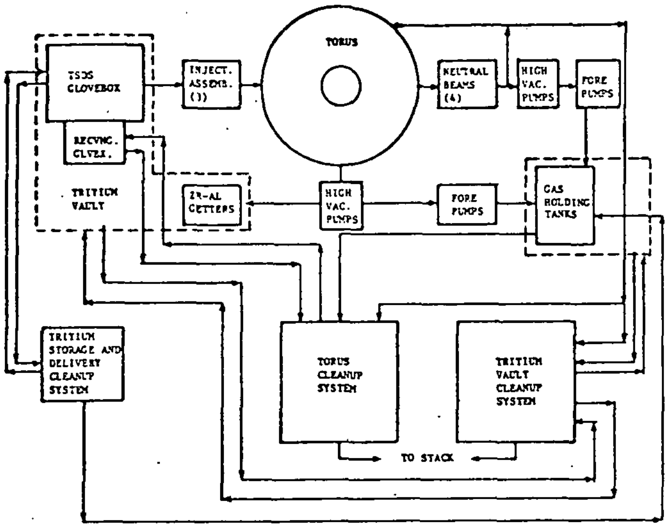

FIGURE 2. TFTR TRITIUM SYSTEMS

PITR - TRITIUM CONTROL AND PROCESSING SYSTEMS

The proposed PITR Tritium Source and Handling Complex will consist of the folowing spaces: Tritium Source and Getter Room; Tritium Recycle Room; Gas Holding Tank Room; Clean-up Systems Room; Waste Handling Room; Tritium Control Room; Uninterruptible Power Supply Room.

The entire Tritium Source and Handling Complex and the Test Cell will be designed to structurally withstand the most intense natural phenomena defined for the TFTR site. The natural phenomena criteria to be applied to individual systems, subsystems and components within the Tritium Source and Handling Complex and the balance of the PITR facility will depend upon the potentially releaseable tritium inventory located in that specific system, subsystem, or component and/or whether or not it is needed to perform some critical radiation safety function. All of the major systems within the Tritium Source and Handling Complex will be designed to operate through the most intense natural phenomema. Those systems in the Tritium Source and Handling Complex not required to operate through such an event will maintain structural and pressure boundary integrity. Appropriate uninterruptible power and emergency power systems for the Tritium Source and Handling Complex will be provided.

The proposed PITR Tritium Cleanup systems will be capable of being operated from either the main facility control room or from a local control room located outside of the tritium seal boundary. Figure 3 is a schematic representation of the proposed tritium cycle for PITR.

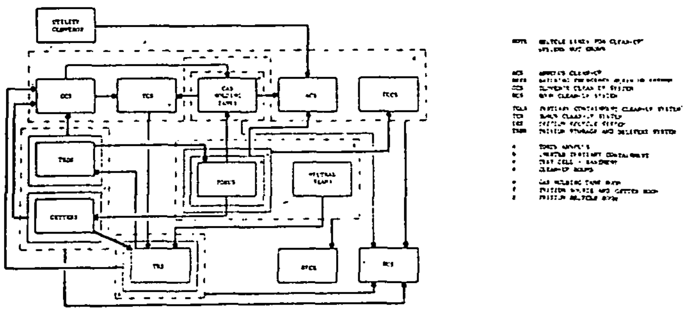

FIGURE 3. PITR PROPOSED TRITIUM CYCLE

The substantially larger tritium inventory in the proposed PITR will necessitate a more conservative design philosophy providing for a greater degree of redundancy. All high tritium concentration activities will be confined to the Tritium Source and Getter Room, the Tritium Recycle Room, and the Gas Holding Tank Room.

Tritium recycle capability is proposed in order to reclaim the gettered tritium, the Torus/Neutral Beam waste gases and as much of the remaining inventory as practicable. On site recycle will minimize the shipment of source tritium to and packaged tritium waste from the PITR site. Demonstration of the safe and routine functioning of the D-T fuel cycle at near prototypical conditions will also be realized.

Delivery of tritium gas to the Torus will be accomplished by a dedicated Tritium Storage and Delivery System (TSDS). The TSDS will store tritium and automatically deliver measured quantities of tritium to the Torus on demand from the control systems. The PITR TSDS will essentially be a larger version of the system used for TFTR. Only small replenishment shipments will be required to make up for losses in the on-site use and recycle process. Some losses will inevitably occur due to burning in the D-T reaction, diffusion into facility components and piping, and very small amounts through component or system leakage.

The Storage and Delivery Glove Box will be maintained at low humidity and a negative pressure by the Glove Box Cleanup System (GCS). When not in use all glove ports in both the Tritium Storage and Delivery Glove Box and the Receiving Glove Box will be sealed and evacuated. The glove pump exhaust will be monitored and processed by the Annulus Cleanup System (ACS). The atmosphere of all glove boxes will be monitored and may be cleaned up when necessary by the GCS. Under failure conditions the atmosphere of either or both glove boxes may be directed to the gas holding tanks and/or processed directly by the Torus Cleanup System (TCS).

All TSDS piping outside of the glove boxes will be of double walled, welded pipe with the annular space between the pipe walls kept under vacuum. The vacuum pump exhaust will be directed to a second set of gas holding tanks for processing by the ACS. For physical protection, all TSDS piping outside of the Tritium Source and Handling Complex will be run through a protected pipe chase. Separate delivery systems will be provided for tritium and for non-tritium gases.

Two identical all-purpose systems, each providing total system redundancy for the other, are proposed to clean up the Torus/Neutral Beam Lines - the Torus Cleanup System (TCS) - and for the containment between the double walls of the Torus - Annulus Cleanup System (ACS). A third system will provide cleanup for the Tertiary Containment located within the Secondary Shield - the Tertiary Containment Cleanup System (TCCS). Emergency cleanup capability will be provided by the Room Cleanup System (RCS) for the Tritium Source and Getter Room, the Gas Holding Tank Room, the Tritium Recycle Room and Tritium Cleanup Systems Room. The Test Cell will have a dedicated cleanup system. All of these systems will catalytically oxidize the tritium and adsorb the resultant water on molecular sieve beds.

The purpose of the Torus Cleanup System, will be to : 1) Maintain a negative pressure and clean up leaks in the Torus or Neutral Beam Vacuum Pumping Systems; and 2) serve as a back up system to the Glove Box Cleanup System. The TCS will be able to operate in a direct process mode or in a holdup process mode which will take suction from the gas holding tanks.

The purpose of the Tertiary Containment Cleanup System, will be to cleanup the inert atmosphere within the tertiary containment volume. The TCCS will be essentially identical in design to the TCS described earlier and will be backed up by the Annulus Cleanup System (ACS).

The purpose of the ACS will be to: 1) Clean up any tritium released to the Torus annulus; 2) clean up any tritium released to TSDS piping vacuum jacket annuli; 3) clean up glove box port pump exhaust; 4) back up the Torus Clean Up System; 5) clean up the Utility Glove Box; and 6) back up the TCCS.

The purpose of the RCS will be to provide the capability to clean up the atmosphere of the

Tritium Source and Getter Room, the Tritium Recycle Room, the Gas Holding Tank Room, and the Tritium Cleanup Room in the event of an accidental release of tritium from either the TSDS, the Gas Holding Tanks, or any of the cleanup systems, while maintaining the area being processed at a negative pressure. The RCS will be backed up by the Building Emergency Cleanup System (BECS).

The purpose of the proposed Building Emergency Cleanup System will be to clean up the Test Cell and Test Cell Basement atmosphere so that in the unlikely event of a tritium release into these spaces, resultant exposures are "as low as practicable."

The purpose of the Tritium Recycle System is to recover as much tritium as possible from other PITR tritium systems. The TRS will condense vapor from the on-site regeneration of the high activity molecular sieves in the Tritium Cleanup Systems as well as processing condensate from the various tritium system cold traps. The condensate will be electrolyzed and isotopically separated by cryogenic distillation. Hydrogen gases recovered without conversion to water will be purified and reprocessed directly by the cryogenic distillation columns. T_2 and DT collected in the separation process will be returned to the uranium beds for re-use in the TSDS. D_2 separated during the process will be recycled to the Non-Tritium Gas Delivery System.

The use of the Tritium Recycle System will reduce tritiated waste to a small fraction of total tritium inventory, but there may still be considerable quantities of low specific activity waste (water, tritiated vacuum pump oil, contaminated consumables, etc.) generated in the operation of PITR tritium systems. In addition, the maintenance of these systems may generate materials such as tritium-contaminated machining waste that must also be handled.

Facilities for the handling, processing (solidification of liquids, etc.) and packaging of all such materials will be located in the Waste Handling Room. All radioactive waste generated at PITR will be shipped off site for disposal.

REFERENCES

1. C. W. Pierce, H. J. Howe, L. Yemin and K. Lind, "The Handling of Tritium at TFTR", Seventh Symposium on the Engineering Problems of Fusion Research, Knoxville, Tennessee, October 1977.