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CONCEPTUAL DESIGN OF AN EMERGENCY TRITIUM CLEAN-UP SYSTEM

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The Los Alamos Scientific Laboratory (LASL) has been selected by the Department of Energy (DOE) to design, build, and operate a facility to demonstrate the operability of the tritium-related subsystems that would be required to successfully develop fusion reactor systems. An emergency tritium clean-up subsystem (ETC) for this facility will be designed to remove tritium from the cell atmosphere if an accident causes the primary and secondary tritium containment to be breached. Conceptually, the ETC will process cell air at the rate of 0.65 actual m^3/s and will achieve an overall decontamination factor of 10^6 for tritium oxide (T_2O). Following the maximum credible release of 100 g of tritium, the ETC will restore the cell to operational status within 24 h without a significant release of tritium to the environment.

I. INTRODUCTION

The Tritium Systems Test Assembly (TSTA) Program is dedicated to the development, demonstration, and integration of technologies related to the deuterium-tritium fuel cycle of fusion reactor systems. Included in the objectives of TSTA are development and testing of environmental and personnel protective systems, study of systems response to abnormal and emergency situations, and demonstration of long-term reliability of components.

A basic requirement for all fusion reactor tritium systems will be an emergency tritium clean-up subsystem (ETC) for atmospheric detritiation if there is an accidental release of tritium to the reactor building. The ETC provided for the TSTA is a small-scale prototype of this required subsystem. The experimental area (cell) will provide tertiary containment of the tritium systems and storage containers used in TSTA. The TSTA cell contains 3000 m^3 of building atmosphere that would become contaminated with tritium if an accident caused the primary and secondary tritium containment to be breached. The primary function of the ETC is to prevent tritium release to the environment from the TSTA cell after such an accident. The secondary function of the ETC is to provide the capability to carry out experiments on various aspects of room air detritiation under controlled conditions.

This document specifies the functional design criteria for the TSTA version of the ETC and presents the conceptual design description of a system that satisfies these criteria.

II. FUNCTIONAL DESIGN CRITERIA

A. General

The basic ETC process shall include oxidation of the tritium to tritiated water in a catalytic reactor and then removal of the tritiated water from the air with an air dryer system. A minimum of 1% of the cell air is to be processed each minute, and the components are to be designed so that the system can be operated continuously for a minimum of 30 h without any contact maintenance or regeneration. Valving is to be provided so that the air exiting the system can be either routed directly to the building exhaust stack or a portion (up to 100%) recirculated to the cell. The ETC

is to be designed to permit evaluation of the following:

- Emergency and experimental operating modes that involve detritiation of the air in the cell;
- Experimental operating modes that involve detritiation of the air in a test room, at reduced flow rates; and
- An operating mode in which regeneration of a molecular sieve dryer would be demonstrated.

Key design considerations of the system are personnel safety, ease of maintenance, and operational flexibility. All systems shall be designed for "fail-safe" operation if air or electrical failure occurs.

F. Instrumentation

The ETC is to be controlled by the Master Data Acquisition and Control System (MDAC) and is to be automatically actuated in the emergency tritium clean-up mode if a significant tritium release to the cell is detected. The MDAC is not covered by these criteria; the interface between the MDAC and the ETC shall be at the signal conditioners and controllers as shown in Fig. 1. The ETC is to be located in the cell with principal instrument readouts and alarms in the control room. For experimental and operational simplicity, some duplicate local controls will be located in the cell.

C. Catalytic Reactor

The catalytic reactor shall be designed to reduce the concentration of elemental hydrogen isotopes in air from 1000 ppm to 1 ppb by volume with one pass at a flow rate of 0.5 standard m^3/s, an inlet pressure of 0.35 MPa, and an inlet temperature of 450 F.

D. Air Dryer System

The air dryer system shall be designed to provide a minimum T_2O decontamination factor across the system of 10^6, based on inlet air containing 100 ppm T_2O and 15 000 ppm H_2O. Both refrigerated- and desiccant-absorber-type air dryers are to be considered for use in the system. Redundancy is to be provided in the air-dryer system so that the ETC can be used to demonstrate detritiation of air

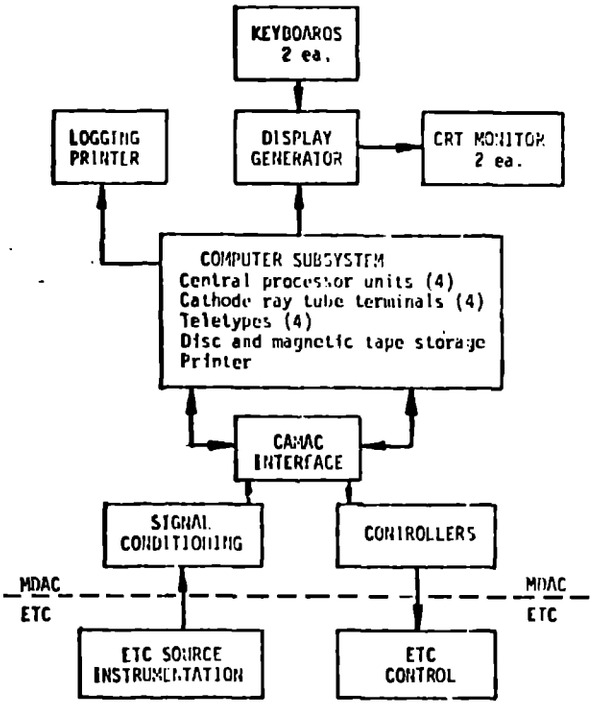

FIGURE 1. MDAC-ETC interface.

in a test room or to demonstrate regeneration of a molecular sieve bed. These tests are to be conducted without compromising the capability of the dryer system for emergency tritium cleanup.

E. Interfaces

The ETC shall interface with the building ventilation system so that air in the ventilation exhaust duct can be routed to the ETC, if necessary. The exhaust air from the room housing the experimental clean-up system shall have alternate ducting to the ETC available so that experiments involving the release of small amounts of tritium to the air in this room can be conducted safely without interfering with activities in the main TSTA cell.

F. Containment

Major components of the ETC are to be provided with valving so that isolation from other ETC components is possible for maintenance or removal. Piping ports to these components shall be provided to allow in-place tritium decontamination by purging the components with inert gas and then evacuating them.

These criteria do not require double containment of the ETC, but the design shall minimize leakage of process gas from the system. Piping joints are to be welded or made using a compression seal against a metal gasket.

G. Materials

The materials of construction used in the ETC shall be chosen to provide long-term reliability and minimum tritium release over the system's working life. Wherever practicable, austenitic stainless steels, aluminum alloys, and copper alloys shall be used for piping and equipment that will be in direct contact with the process stream.

H. Regulations, Codes, and Standards

The quality assurance program establishes measures, procedures, and instructions for accomplishing the activities to assure the requisite quality of the system and components. In general, the "national consensus" codes and standards as developed by such organizations as the American Society of Mechanical Engineers (ASME), American Chemical Institute (ACI), American National Standards Institute (ANSI), and Institute of Electrical and Electronics Engineers (IEEE) are to be used where applicable. The latest editions of all codes and standards shall be used.

Design and construction of the ETC will be in accordance with the following regulations, codes, and standards:

American National Standards Institute (ANSI):
- ANSI B2.1, "Pipe Threads"
- ANSI B13.1, "Codes for Pressure Piping"
- ANSI B16.5, "Steel Pipe Flanges and Flanged Fittings"

American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code:
- Section II, "Material Specifications"
- Section VIII, Division 1, "Rules for Construction of Pressure Vessels"
- Section IX, "Welding and Brazing Qualifications"

Military Standards (MS):
- MS-3116, "Connector, Plug, Electric, Series 1, Solder Type, Straight, Bayonet Coupling"
- MS-33649, "Boss, Fluid Connection-Internal Straight Thread"

National Electrical Manufacturers Association (NEMA), ICS-1970, "Industrial Controls and Systems"

National Fire Protection Association (NFPA), NFPA-70-1975, "National Electric Code"

Los Alamos Scientific Laboratory (LASL), "Quality Assurance Program Plan for the Tritium System Test Assembly," TTA-QP-C3-1

I. Natural Forces

The ETC equipment and piping shall be classified as seismic category I and, as such, shall be designed and analyzed to withstand the design basis earthquake (DBE), sometimes referred to as the safe shutdown earthquake (SSE). The DBE shall be assumed to produce a maximum horizontal ground acceleration of 0.33 g's. The independent, simultaneous vertical ground motion shall be assumed to be two-thirds of the horizontal DBE acceleration level. The ETC shall be designed to remain functional during and immediately following the DBE event. The facility is to be restored to operational status within a reasonable period of time, thus preventing a significant release of tritium to the environment if a tritium release coincides with the DBE.

All components of the ETC and adjacent equipment that could cause collateral damage if an earthquake occurred shall have anchorage designed to the DBE criteria.

III. CONCEPTUAL DESIGN DESCRIPTION

A. System Description

1. General. Three typical modes of operation have been identified for the ETC: (a) an emergency clean-up cycle, (b) a test room clean-up cycle, and (c) a molecular sieve dryer regeneration demonstration cycle. The ETC will be an experimental

facility so many variations of these basic cycles can be expected. The following assumptions have been made to establish a basis for the emergency clean-up cycle:

- One hundred grams of tritium are released to the cell.
- The ETC processes room air at a rate of 0.65 actual m^3/s.
- The exit air stream from the ETC is split with 0.26 actual m^3/s being routed to the building stack and the remainder recirculated to the cell.
- The normal cell ventilation air, 2.36 actual m^3/s, is bypassed to the ventilation stack, where it is mixed with the ETC exit air stream.
- A decontamination factor of 10^6 is achieved for tritium oxide (T_2O) across the ETC.
- The concentration of tritium (T_2) in the room air is reduced by a factor of 10^6 across the catalytic reactor.
- All T_2 leaving the catalytic reactor exits the air dryer system unchanged.

After a 100-g release of T_2, the initial average cell concentration would be 3.23×10^8 $\mu Ci/m^3$. Assuming complete mixing with the air in the cell, the ETC would reduce the concentration of tritium to 40 $\mu Ci/m^3$ in 20.1 h, at which concentration normal cell ventilation would be restored. The tritium concentration in the stack, averaged over the next 24-h period would be 0.58 $\mu Ci/m^3$ for a release of 0.12 Ci. Tritium oxide release during the clean-up phase would average 2.0 $\mu Ci/m^3$ from the stack over the 20.1 h, for a T_2O release of 0.38 Ci during this phase. The tritium released as T_2 would add an additional 0.38 Ci. These calculations neglect any tritium that could be lost to the stack before the ventilation exhaust dampers could be closed and any tritium that diffuses through or otherwise interacts with the cell walls. The TSTA ventilation system will be designed to minimize these effects.

2. Emergency Clean-Up Cycle. If a release of 100 g of tritium into the TSTA cell occurred, the tritium monitors located in the cell exhaust duct would alert the MDAC, which would activate both the cell ventilation isolation sequence and the ETC in the emergency clean-up mode. Tritium-contaminated air in the exhaust duct would be routed to a nonlubricated compressor where it would be compressed to 0.35 MPa at a rate of 0.65 actual m^3/s. Inlet ducts to the compressor would also be available to pick up the contaminated air from specific areas in the cell. The heat of compression would raise the air temperature to 450 K, because neither an intercooler nor an aftercooler would be employed in the compressor. The room air is assumed to be at 293 K and 50% relative humidity. After compression, a mixture of hydrogen and an inert gas would be added to the compressed air to bring the hydrogen isotope concentration to 1000 ppm. The air would then be routed to the catalytic reactor to reduce the hydrogen isotope concentration to less than 1 ppb. A shell and tube air cooler would then be used to reduce the air temperature to near its dew point. The next step would be a refrigerated condenser designed to reduce the air temperature to 275 K and thus condense most of the H_2O and T_2O. This condensate would be drained to the tritiated water storage tanks and segregated according to tritium concentration. After the cell was returned to normal conditions, the tritiated water could be either loaded onto molecular sieve and sent to disposal or transferred to a tritium recovery unit.

A heat recovery unit in the condenser would reheat the exit air by indirect contact with the inlet air to reduce the refrigeration load and to eliminate "sweating" on the exit air line. The reheated air would leave the condenser at 286 K and be routed to the first-stage molecular sieve dryer, reducing the water content from 2500 ppm to 31.2 ppm. The heat of absorption associated with this drying step would raise the dry air exit temperature to 310 K. Swamping water, as steam, would be added at this point to bring the water content up to 1200 ppm and thus make possible a further decontamination factor of 1000 across the second-stage molecular

sieve dryer. During the last phase of the emergency clean-up cycle, the second-stage dryer might not be necessary, and dry air from the first-stage dryer could be stacked directly or returned to the cell. Dry air would exit from the second-stage dryer at 320 K with a water content of 1.2 ppm. Depending upon the particular clean-up mode employed, this air could be sent to the stack or recirculated to the room. Current estimates are that 0.26 actual m^3/s will have to be stacked to balance infiltration to the cell, which will be maintained at a slightly negative pressure with respect to the atmosphere.

This mode of emergency cleanup would be expected to reduce the cell air tritium content to 40 $\mu Ci/m^3$ in 20.1 h. During this time, 130 liters of condensate would be collected in the tritiated water storage tanks, and 100 liters of water would be collected in the molecular sieve dryers. After the cell returned to normal conditions, the molecular sieve in the dryers would be loaded out to lined drums, and fresh molecular sieve would be loaded into the dryers.

3. Test Room Clean-Up Cycle. The test room clean-up cycle would be used to demonstrate various modes of air detritiation under controlled conditions and would be employed only for experimental purposes. The cycle would operate exactly as the emergency clean-up cycle except that the flow rates could be 1/4, 1/2, or 3/4 of full scale, and separate molecular sieve dryers would be provided to save the other dryers for use during an accidental tritium release to the cell.

4. Regeneration Demonstration Cycle. The regeneration demonstration cycle would be designed to demonstrate in-place regeneration of a molecular sieve dryer. This cycle would be for test purposes only, because normal regeneration would be by replacement of the bed. After initial pressurization of the system, the cycle would operate as a closed loop with no gaseous effluent. The compressor would provide the motive power to move the air through the loop at a nominal flow rate of 0.24 standard m^3/s and would provide preheating of the regeneration air. A 100-kW electric heater would be used to provide hot air for regeneration of the molecular sieve. The nominal regeneration temperature would be 478 K, but the incoming regeneration air would have to be at a higher temperature, 700 K, to preheat the bed and to supply the heat of absorption required to remove the water from the molecular sieve. After preheating of the molecular sieve bed, the regeneration air leaving the dryer would be at 478 K and would contain 23 200 ppm of water. This steam would be cooled to near its dew point, 315 K, in the air cooler and then routed to the refrigerated condenser, where 85% of the water would be condensed and collected in the tritiated water storage tanks. The condenser exit air would be routed to one of the test-cycle molecular sieve dryers, where it would be dried to a dew point of 205 K. The dried air at 310 K would be returned to atmospheric pressure and recycled to the compressor.

B. Configuration

The ETC will be located in the southeast corner of the TSTA cell. Both the pit area and the mezzanine will be used to minimize the cell floor space dedicated to the ETC. A new concrete foundation will be poured in the pit area to provide support for the compressor. To facilitate loadout of the molecular sieve beds and the tritiated water, the air cooler, refrigerated condenser, dryers, and tritiated water storage tanks will be located at the mezzanine level. Additional support, as required, will be provided. Containment boxes, as shown in Fig. 2, will be installed beneath the dryers to assure that loadout of the molecular sieve beds will not result in a tritium release.

C. Components, Parts, and Materials

1. Compressor. A compressor will be used to provide both the pressure differential required to move the air through the ETC and additional compression of the air to reduce the size of the downstream components. This compressor will be a double acting reciprocating type with one or two stages and have isolation seals between the cylinders and crankcase to minimize contact of the air and crankcase

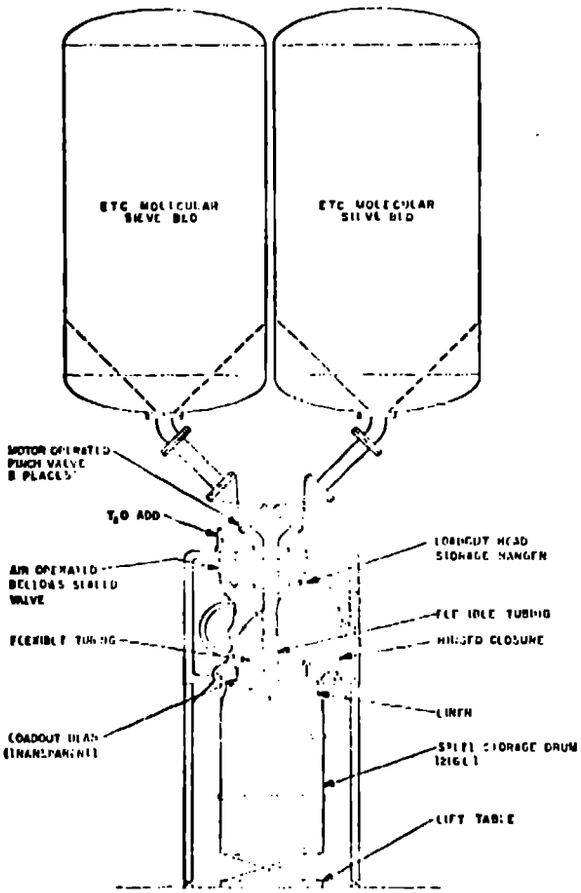

FIGURE 2. ETC molecular sieve bed loadout.

lubrication oil. Inert-gas-pressurized seal chambers between the cylinders and the crankcase will also be considered. The crankcase will be vented to the tritium waste treatment system to assure containment of any tritium that may leak past the isolation seals. The compressor will be of a nonlubricated design with Teflon-honed cylinders and filled-Teflon piston rings. The suction valves will be equipped with five-step clearance control to allow operation at 1/4, 1/2, and 3/4 of full scale. Neither an intercooler nor an aftercooler will be used to take advantage of the heat of compression for heating the air before the catalytic reactors. Automatic unloading of the compressor for starting to reduce the required driver torque will be provided. The cooling water to the crankcase oil cooler will be controlled by a thermal modulating valve to assure that condensation will not take place when the compressor is on standby.

The nominal free air capacity of the compressor will be 0.65 m^3/s with inlet conditions of 0.077 MPa and 293 K and outlet conditions of 0.35 MPa and 450 K. A 150-kW motor will be required to drive the unit. A foundation containing 3.8 m^3 of concrete will be poured in the pit to support the compressor.

2. Catalytic Reactor. A catalytic reactor is required to oxidize the tritium in the air to tritium oxide, which can be removed downstream by conventional air drying techniques. It is critical to effect a very high conversion of T_2 to T_2O in the reactor because T_2 that is not oxidized in the reactor will not be removed from the air by the downstream components. To assure this high conversion, hydrogen will be added to the air stream before the reactor at a rate sufficient to maintain a minimum hydrogen isotope concentration of 1000 ppm by volume. The reactor will be designed to reduce this level to 1 ppb at the nominal inlet conditions of 0.5 m^3/s, 450 K, and 3.5 MPa. To achieve this conversion will require approximately 0.225 m^3 of catalyst. The catalyst will be in the form of 3-mm-diam by 3-mm-long pellets and will be composed of a blend of precious metals on a high surface area substrate. The reactor vessel and the inlet and exit piping will be constructed of Type 316 stainless steel and, to allow a wide variety of experimental operation modes, will be designed to withstand a maximum temperature of 755 K and a maximum pressure of 0.7 MPa. The reactor vessel will be designed for manual loading and unloading of the catalyst through access ports and will have a limited number of ports to minimize the potential for system leakage. The reactor vessel is expected to be about 0.76-m diam by 1.52-m tall with 0.15-m-diam inlet and exit ports. The reactor vessel will be freestanding and will be located on the pit floor adjacent to the compressor.

3. Air Cooler. The air cooler will be used to cool the hot exit gases from the catalytic reactor to near their dew point. Conceptually, this unit

will be a water-cooled shell and tube heat exchanger with two tube passes and baffled shell pass. Nominally, the unit will be designed to cool 0.5 m^3/s of air at a pressure of 0.31 MPa from 460 to 294 K. Actually, the cooler will be oversized to allow experiments involving higher air temperatures and pressures, but lower flow rates. The maximum design pressure and temperature will be 0.7 MPa and 775 K, respectively. The extent to which the air is cooled will be controlled by varying the water flow rate through the tubes. The entire unit will be fabricated of Type 316 stainless steel and will have 140 15-mm-diam tubes in a 25-cm-diam shell. The tubes will be spaced on a 1.9-cm equilateral triangle pitch, and the baffles will be spaced at 15-cm intervals along the shell length. Conceptually, the tubes will be 1.5 m long. The air cooler will be located in the mezzanine area over the pit and will be on the same support structure as the condenser unit. Insulation will be required around both the air cooler and the piping leading to it from the catalytic reactor.

4. Condenser. The function of the condenser will be to remove as much water as possible from the air before it reaches the molecular sieve dryers to minimize the water loading of these units. Refrigeration-type compressed-air dryers that have the capability to cool compressed air to 275 K are available commercially and it is expected that an "off-the-shelf" unit can be purchased and modified for this service.

The condenser must be capable of cooling 0.5 m^3/s of air containing 31 000 ppm of water from 320 to 275 K at a pressure of 0.31 MPa. This represents the maximum projected heat load for the condenser; nominal conditions would be the same flow rate, pressure, and exit temperature, but the water load would be 6570 ppm and the inlet temperature would be 294 K. The condenser will be equipped with a moisture separator to remove any water mist that may be entrained in the air stream. This unit will incorporate a wire mesh de-entrainment pad to enhance its effectiveness. A precooler/reheater will be incorporated into the condenser unit to reheat the exit air from the separator by using it to precool the inlet air. This will reduce the load on the refrigeration unit and will prevent condensation from forming on the outside of the exit gas line. The refrigerant condenser of the refrigeration unit will be water cooled.

The condenser unit will be located in the mezzanine area over the pit and will be high enough above the mezzanine floor to allow the condensate to drain by gravity to the storage tanks. Secondary containment will be provided for the condenser unit to prevent leakage of tritiated water into the cell.

5. Tritiated Water Storage Tanks. The tritiated water storage tanks will be used to provide containment of the water and T_2O that is removed from the air by the condenser. Three storage tanks will be used to allow segregation of the condensate based upon T_2O content. At nominal flow rates, the tritium concentration in the cell will be reduced by a factor of 10 every 3 h of ETC operation. At this rate, 99% of the tritium will be removed from the cell in the first 6 h. Condensate formed during this time period will be collected in the two smaller tanks that will be sized to contain 68 liters each. The third tank will be sized to contain 757 liters of condensate. These sizes are based on the projected maximum condensate generation rates and, as such, provide a margin of safety as compared with the nominal condensate generation rates. The two smaller tanks will overflow to the larger tank, and all three tanks will be vented to the tritium waste treatment system. The tanks will be located so that each tank top is flush with the mezzanine floor. From this location, the condensate can be transferred to either disposal or storage containers. The tanks will be fabricated of Type 316 stainless steel with double walls to assure containment of the T_2O.

6. Dryers. Molecular sieve dryers will be used to provide the final separation of water and T_2O from the air. Two complete molecular sieve

dryer systems will be provided, one to be used for room clean-up experiments and the other to be on standby for emergency clean-up situations. Each system will have two dryer stages with provisions for adding swamping water (as steam) between stages. Both systems will be designed to process 0.5 m^3/s of air at 286 K and 3 atm pressure containing 2500 ppm of water. Conceptually, each dryer will have a top air inlet with a bottom exit and will be 1.06 m in diam with a 1.4-m-deep bed of molecular sieve. This size has sufficient capacity to allow completion of an emergency clean-up operation without saturating a dryer to the point where regeneration of the bed is required. Since normal regeneration will be accomplished by replacement of the bed, the dryers will be designed so that the bed can be loaded out by gravity. The molecular sieve will be equivalent to LINDE Type 4A and will be in the form of 1.5-mm-diam spheres. A conceptual design for a molecular sieve dryer and its associated bed loadout containment box is shown in Fig. 2. The dryers and associated piping will be fabricated of stainless steel and will be designed to withstand a maximum internal pressure of 0.68 MPa and a maximum temperature of 644 K. The piping system connecting the dryers will be designed to provide sufficient flexibility so that various modes of dryer operation and regeneration can be evaluated.

7. Heater. The air heater will be used to heat the air used to demonstrate in-place regeneration of the molecular sieve beds. During regeneration, the air must supply the heat to raise the dryer and bed to 478 K, plus the heat of absorption required to vaporize the water and separate it from the molecular sieve. This heat is provided by heating the regeneration air above the nominal regeneration temperature of 478 K. The heater will be designed to heat 0.24 m^3/s of dry air at 3.5 atm from 472 to 755 K. Conceptually, a 100-kW electric heater with internal heating cables will be used. The heater housing will be fabricated of Type 316 stainless steel and will be an in-line unit with flanged ends. Both the heater and the inlet and outlet piping will be insulated.

8. Volume Bottle. A metal volume bottle will be installed at the compressor intake to limit upstream pressure pulsation. The bottle will be connected to the compressor by a flexible metal connection and will be equipped with a nitrogen addition port to permit replacement of system leakage during operation in the dryer-regeneration-demonstration mode.

9. Intake Air Filter. A replaceable, pipeline-type, air filter will be provided at the inlet to the volume bottle to prevent dirt particles from entering the compressor. The filter will be capable of removing 95% of entrained particles down to 5-μm diam. The filter will be the dry type and will be designed to permit replacement of the filter element without breaking the pipe connections.

10. Pulsation Damper. A pulsation damper will be installed on the compressor discharge to limit the residual pulse in the compressed air stream to less than ±1% of the absolute stream pressure. The damper will be connected to the compressor discharge by a flexible metal connection.

D. Instrumentation and Controls

The ETC will be controlled and monitored remotely with some duplicate local controls. The local control and monitoring panels to facilitate manual control will be located adjacent to the ETC. The remote control/monitor operation will be performed from the TSTA control room. In the remote control/monitor mode, all process-oriented functions of the ETC will be under computer control. The amount and type of computer control will vary for each function as the design dictates. The exact type of control required for each process is yet to be established. The amount of redundancy within the ETC control system will be addressed after a more detailed design study.

The interface between the ETC instrumentation and controls and the computer subsystem will be made by CAMAC modules per IEEE Standards 583-1975 and 596-1976. A bipolar interface will be used, and analog voltage channels will be scaled within

the range of -5 Vdc to +5 Vdc. Digital channels will be similarly scaled.

The minimum end-to-end absolute accuracy for each measured ETC parameter that interfaces with the MDAC will be ±2% of full scale or range, as applicable. However, the moisture content and tritium level measurements will be an exception. An attempt will be made to keep the accuracy of these two measurements to within ±5% of full scale or range, as applicable.

All of the temperature transducers in the ETC will be platinum resistance type. The sensing element is reference-grade (99.999 + purity) platinum wire, mounted on a mandrel in a strain-free manner. The sensing element is hermetially sealed in a stainless steel housing to meet the environmental and mechanical requirements and to insure highly reliable performance. The temperature transducer will form one leg of a Wheatstone bridge. The bridge will be provided with 10-Vdc excitation, and the output signal will be 0 to 50 mV, corresponding to zero and full scale, respectively.

There will be two types of pressure transducers used on the ETC, bonded strain gauge and variable reluctance types. Each type of transducer was chosen for its individual advantages to a particular application. The bonded strain-gauge-type pressure transducer will be used to measure pressures within the ETC up to 0.68 MPa. The transducer will be excited with 28 Vdc and will have a 0- to 5-Vdc output, corresponding to zero and full scale, respectively.

The variable reluctance-type pressure transducer to be used in the ETC will be completely self-contained, that is, the input and output of the transducer is dc and all ac networks are contained within the transducer. This feature eliminates the need for an ac excitation source and a demodulator located in the MDAC. Another feature is that no high-frequency ac signals are placed on the instrumentation cables, thus eliminating the possibility of noise because of crosstalk. Variable reluctance-type pressure transducers will be used to measure pressures over the range of 0 to 0.07 MPa. The excitation applied to the transducer will be 28 Vdc and the output will be 0 to 5 Vdc, corresponding to zero and full scale, respectively. The output for differential pressure measurements will be -5 to +5 Vdc, with 0 Vdc corresponding to 0 differential pressure and the -5 and +5 Vdc corresponding to minus and plus full-scale differential pressure, respectively.

Flow rate parameters will be measured with turbine- and thermal-type flow meters for liquid and gaseous flow, respectively. The signals from the turbine-type flow meters will be conditioned with frequency to dc converters contained within the CAMAC section of the MDAC. The output signal will be 0 to 5 Vdc, corresponding to zero and full-scale flow, respectively. The signal from the thermal-type flow meters will be conditioned to 0 to 5 Vdc before being interfaced to the CAMAC equipment.

The exact method to measure liquid level has not been decided yet. Those techniques being considered are: sonic, capacitance, pressure, and float-type liquid level transducers. The instruments to measure the moisture content and the tritium level of the effluent have not been selected to date.

The position indicators depicting value position will be linear potentiometer types. The signal from these units to the MDAC will be 0 to 5 V for corresponding closed and open positions, respectively.

Specific controllers have not been selected yet; however, it is anticipated that the solenoid valves will be excited with a control voltage of 24 Vdc. Where possible, all other control valves interfaced to the MDAC will be electrically operated. The accuracy of the control system will be identical to that described above for the measured parameters.

An emergency generator set with the capacity to furnish full power to the MDAC and its control functions and the ETC will be provided. Therefore, if a loss of commercial power occurs, the ETC will remain functional.