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TRITIUM WASTE TREATMENT SYSTEM
COMPONENT FAILURE DATA ANALYSIS
FROM JUNE 18, 1984 TO DECEMBER 31, 1989

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ABSTRACT

This document gives the failure rates for the major tritium-bearing components in the Tritium Waste Treatment System at the Tritium Systems Test Assembly, which is a fusion research and technology facility at the Los Alamos National Laboratory. The failure reports, component populations, and operating demands/hours are given in this report, and sample calculations for binomial demand failure rates and poisson hourly failure rates are given in the appendices. The failure rates for tritium-bearing components were on the order of the screening failure rate values suggested for fusion reliability and risk analyses. More effort should be directed toward collecting and analyzing fusion component failure data, since accurate failure rates are necessary to refine reliability and risk analyses.

SUMMARY

The failure data from the Tritium Waste Treatment System (TWT) at the Tritium Systems Test Assembly (TSTA) was analyzed to produce demand and/or hourly failure rates, as appropriate, for major tritium-bearing components. The TWT removes tritium from all gaseous wastes before the gases are released through the TSTA vent stack. The TWT must be reliable for successful facility operation, and the failure data collected show that the TWT had no total system outages over the 5.5 years considered in this analysis. This failure data analysis was made possible due to the collection and collation of several types of data: failure reports, component populations in the TWT, and TWT operating times (and demands). The TSTA staff was very supportive in their tasks to collect, complete, and store these data. Binomial distributions were used for calculating demand failure rates on gas chromatographs, motor operated ball valves, manual valves, and compressors (failure to start). Poisson distributions were used for calculating hourly failure rates on moisture, radiation, and pressure monitors, running compressors, and the recombiner. A TWT system breach failure rate was also estimated. The motor operated valve failure rates were much lower than those suggested for screening failure rates, which is significant since the screening value has sometimes been used as a refined value of last resort in some quantitative risk analyses. This illustrates that actual fusion failure rate data is necessary to support accurate fusion facility reliability and risk analyses.

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We wish to thank the staff, particularly the operations staff, at the Tritium Systems Test Assembly for their diligence and help in collecting and interpreting these failure data. Without them and their efforts, this report would not have been possible. Ms. Kathleen Gruetzmacher, of Los Alamos National Laboratory, developed the failure/maintenance computer code and entered TWT component engineering information into the code. This computer code was used to sort the TWT failure and engineering data reports. Finally, Dr. Cory Atwood and Mr. Mark DeHaan, statisticians in the EG&G Idaho Statistics and Reliability Engineering Group, performed the calculation of failure rates from the reduced data set.

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ACRONYMS

CI	Confidence interval
CIT	Compact Ignition Tokamak
CREDO	Centralized Reliability Data Organization
FAWG	Fusion Availability Working Group
FSP	Fusion Safety Program at EG&G Idaho
FTCTR	Failure to continue to run
FTOAR	Failure to operate as required
GC	Gas chromatograph
H ₂	Hydrogen
IBM	International Business Machines, Inc.
INEL	Idaho National Engineering Laboratory
ITER	International Thermonuclear Experimental Reactor
LANL	Los Alamos National Laboratory
LCP	Large Coil Project
LPR	Low Pressure Receiver
MDAC	Master Data Acquisition Computer
MMI	Man-machine interface
MOV	Motor operated valve
NC	Normally closed
NO	Normally open
ORNL	Oak Ridge National Laboratory
O ₂	Oxygen
PC	Personal Computer
QA	Quality Assurance
TSTA	Tritium Systems Test Assembly
TWT	Tritium Waste Treatment system
SV	Screening value
UB	Upper bound
USDOE	United States Department of Energy

TRITIUM WASTE TREATMENT SYSTEM
COMPONENT FAILURE DATA ANALYSIS
FROM JUNE 18, 1984 TO DECEMBER 31, 1989

1. INTRODUCTION

This report is a summary of data collected at the Tritium Systems Test Assembly (TSTA), at Los Alamos National Laboratory (LANL), between June 18, 1984 and December 31, 1989 that pertain to the Tritium Waste Treatment System (TWT). Failure data work such as this is performed to support fusion design studies and device construction; therefore, an ongoing effort to collect and analyze failure data for active and passive fusion components is conducted by TSTA and the Idaho National Engineering Laboratory (INEL) Fusion Safety Program (FSP).

Generally, fusion experiment failure data is not rigorously collected. At this stage in fusion research, there are more pressing concerns at experimental facilities. However, as these experiments begin to use radioactive tritium fuel, fusion community concerns for safe fuel storage and cleanup arise, and government regulations regarding these safety concerns also apply.¹ This concern causes a need for facility risk assessment to show that the public is protected from undue radiation hazards by facility design and prudent operation. Investment protection, guaranteed by careful design and reliability analyses, is also a concern to experimentalists and facility managers.

Risk, safety, and reliability analyses need the support of failure rate data to quantify results.² Fortunately, experiment programs such as TSTA, the Large Coil Program (LCP) at Oak Ridge National Laboratory (ORNL), and General Atomics Doublet III-D experiment at San Diego have collected experience data that can be analyzed for failure rate values.

This report describes the TSTA TWT failure experience, which is immediately applicable to the Compact Ignition Tokamak (CIT) and International Thermonuclear Experimental Reactor (ITER) design studies. Failure rates for equipment are calculated and presented here. These

calculations are possible because component populations, failures and operating times are known. These necessary values are collected and stored in a computer searchable format at TSTA.

TSTA's event data collection system has been in place for over six years and is administered by the Quality Assurance Specialist, M. A. Stolpe- Gavett, assigned to the program. A failure report form is filled out by the responsible operator or system designer whenever a component of the TWT or of another TSTA system fails or needs major adjustment. A second part of the form, detailing the corrective action taken, is completed during or immediately after the repair/replacement of the failed component. All of this information is placed into the failure/maintenance data base as it is received.²

This personal computer-based data collection program has been installed at INEL, with the intent of collecting data from other facilities and building a core of a fusion component failure data base. With the appropriate engineering data and operating times (or demands), failure rates can be calculated from this data base. As the data base collects more information, the component failure rates will become more generic and can be applied to fusion facilities in general.

The TWT essentially removes tritium and tritiated compounds from waste gases by converting them to water, traps the tritiated water on molecular sieve material, and allows the purified gases to be stacked. The TWT was chosen for this initial failure data analysis for several reasons: similar systems are used in many fusion designs, the component engineering data had already been collected, the number of operating hours was easily estimated, and the system operates almost continuously (meaning the chance for statistically significant results was greater over the time period of interest). The TWT sees a modest amount of tritium over a significant portion of the calendar year, therefore the components are considered to be well-exposed to tritium. Other systems, such as the Emergency Tritium Cleanup system and the room air radiation monitoring system, will be investigated in the future.

2. TSTA FAILURE/MAINTENANCE DATA BASE

The failure/maintenance data system at TSTA is based on the Centralized Reliability Data Organization (CREDO),^{3,4} a system developed at ORNL for fast reactor failure data. CREDO's development as a national reliability data base and data analysis center for advanced fission reactors was initiated in 1978 and is funded by the U.S. Department of Energy (USDOE). CREDO was selected as the basis for a failure/maintenance data system for fusion after consideration by the informal Fusion Availability Working Group (FAWG). CREDO is a component-oriented data base which was implemented at TSTA using an IBM PC. The original objectives of the CREDO project at TSTA included:

- Adapting CREDO for use in fusion availability/reliability programs
- Programming the data base on the IBM PC with KnowledgeMan software
- Collecting the appropriate data on the TWT
- Testing the adapted data base with the TWT data

Only minor changes in the original CREDO data collection forms were made to make them more applicable for fusion systems.

The IBM PC was programmed using logical tables to contain the data.^{4,5} Three types of data are entered into the data base. These are: engineering data, event data, and component operating data. The engineering data describes each component of a system as fully as possible by involving a one-time submission of data, such as component type, model number, and operating parameters. The engineering data report uses a unique identifying number to track the component through its lifetime. The event data describes each reportable event or failure in any TSTA system, and uses a unique event report number for each event. Reportable events include component failures, events that lead to unscheduled repair or maintenance, and unanticipated changes in normal operating conditions

due to a component failure. The operating data is a quarterly report that gives the operating time for the entire facility. Component operating time estimates are obtained from these overall facility values.

After the engineering data are collected on the major components in a system, event data reports become the focus of the effort for collection of failure/maintenance data. At TSTA, two-part event data forms are strategically placed in holders throughout the facility, so that when a reportable event occurs, the forms are easily accessible by the operator involved in the event. Part I of the form (example forms are given in Appendix D) is filled out whenever a component of the TWT or a component of another TSTA system fails or needs major adjustment. When the initial report is completed as much as possible, it is put back in a holder. The Quality Assurance (QA) specialist, M. A. Stolpe Gavett, inspects the holders periodically and retrieves any completed forms. Part II of the form details the corrective action taken on the problem. The QA specialist routes the completed Part I forms to appropriate personnel. The corrective actions are documented by either the operator or the system designer during or immediately after the repair/replacement of the failed component. Then, the QA Specialist picks up Part II of the form and enters this new information into the data base and assigns a sequential report number. If the information is complete, the report is termed "closed". If it is incomplete, the report is termed "open" and it is returned to the appropriate personnel for completion.²

3. TRITIUM WASTE TREATMENT SYSTEM DESCRIPTION

TSTA construction was completed in 1983, and pretritium introduction testing was performed in 1983 and early 1984. The facility loaded tritium in June 1984.⁶ The TSTA mission is testing and evaluating the processes and equipment for handling the deuterium and tritium fuel, and the exhaust gases from a magnetic fusion reactor.^{6,7} TSTA is a fully-integrated, full-sized, computer-controlled fusion fuel processing loop. The main process loop block diagram and the auxiliary systems list are shown in Figure 1.⁴

Within the main flow loop of TSTA, gases which simulate the effluent from a magnetic fusion reactor are sent through the Vacuum System to be processed in the Fuel Cleanup Unit and the Isotope Separation System. The waste gases from loop operation and from non-loop experiments are handled by the Tritium Waste Treatment System, which removes tritium from all gaseous waste before the gases are released through the vent stack. Tritium removal is accomplished by catalytic oxidation of the tritium and tritiated compounds to water and then collecting the water on molecular sieve.⁸ The TWT is a mature technology based on similar systems that have operated for nearly two decades. The TWT needs to maintain and has maintained a high availability in its continuous operation target demand of 24 hours per day, 365 days per year.⁴ High availability is also evidenced by the fact that none of the failure reports show that the entire system was incapacitated in the 5.5 year time span of this study. The TWT contains many components that are identical to those being used in tritium systems at other fusion facilities. Therefore, this report should be of value to multiple facilities and design teams.

The system description is taken from reference 5, unless otherwise stated. Component operating times were estimated by R. S. Dahlin, the TSTA operator responsible for the TWT at the time.⁹ The TWT consists of the following major components:

Input gas filters	Low pressure gas storage tanks
Catalytic converter system	Compressors
High pressure gas storage tanks	Molecular sieve beds
Molecular sieve bed regeneration system	Gas analysis system
Radiation monitoring system	Computer control system

Figure 1. Tritium Systems Test Assembly Process Loop.
(taken from reference 4)

Figure 2 shows a schematic of the system (without the 151 valves).⁸ Except for the catalytic reactor, all components of the TWT are redundant. The piping is one inch (25.4 mm) diameter copper lines which have been joined using soft solder. Process valves are motor actuated ball valves, referred to here as motor-operated valves (MOVs), and their positions are monitored by the Master Data Acquisition and Control System (MDAC). Each major component can be isolated by a series of manual ball valves, referred to as non-MOVs, that allow for maintenance isolation and component evacuation. The position of each cluster of manual valves is monitored by a single signal to the MDAC.

TWT Filters

The gas to be processed is first passed through two filters. The first is an oil separator and the second is a charcoal filter. They remove the majority of vacuum pump oil and other hydrocarbon vapor residues present in the effluent gas system. Each of these filter sets is operated half of the calendar year. Vacuum pump oil is no longer an added source of contamination. Therefore, these filters are only used to remove any residual oil in the lines.

TWT Input Gas Storage Tanks

Three 262 ft³ (7.4 m³) stainless steel tanks can be used to store input gas. Normally only one tank is on-line with the other two tanks used to provide additional storage as required. The primary input receiving tank, the low pressure receiver (LPR), operates between 4 and 8 psia (27 and 54 kPa). Important instrumentation on the LPR is: two redundant gas chromatographs, redundant pressure transducers and a tritium monitor. Dry air can be added to the LPR if either the oxygen concentration is too low to achieve efficient conversion of tritium to the oxide or if the hydrogen/oxygen concentration in the LPR approaches the combustible range. A noncombustible mixture of hydrogen/argon can be added to the LPR to achieve better tritium conversion by increasing the total hydrogen isotope concentration at the input to the catalyst bed.

Note: Valves and regeneration paths are not shown.

Figure 2. Schematic diagram of the Tritium Waste Treatment System.
(taken from reference 8)

The other two input tanks are kept at a vacuum [0.5 psia (3.5 kPa)]. If the pressure in the LPR rises above 10 psia (69 kPa), these tanks are opened to the LPR to reduce the pressure and increase the gas storage capacity. If the pressure rises above 11 psia (76 kPa), these tanks are pumped to 50 psia (0.34 MPa) using the small compressor.

The system operates in a batch mode, with input gas collected in the Low Pressure Receiver.⁸ During early TSTA operations the LPR was pumped down once every two hours. This time depended on the number of gloveboxes which were purging and the use of the house vacuum pump, effluent line and the Process Evacuation System. This compressor demand every two hours was used for failure rate calculations over the first two years of operation. Over the next three years, the compressor operation increased to starting every twenty minutes, and in 1989, the compressor ran almost continuously, where one demand per week was considered typical.⁹

Catalytic Reactor

The catalytic reactor consists of three stainless steel units: a gas-to-gas heat exchanger, catalyst bed, and a water cooled gas aftercooler. The catalyst bed contains approximately 0.5 cubic feet (0.014 m³) of catalyst in the form of 3 mm diameter by 3 mm long alumina pellets, which are coated with a blend of precious metals (Englehard catalyst A-16825). This system was designed and built by the Englehard Company. The bed is designed to operate in the temperature range of 500 to 1000° F (533 to 810 K). With an input concentration of hydrogen isotopes of up to 40,000 ppm, the bed was designed to have a residual unconverted hydrogen isotope concentration of less than 1 ppm at the exit. The bed is operated in the high range to assure conversion of tritiated hydrocarbons to nonradioactive gases and water. The catalytic reactor runs continuously throughout the calendar year.

The catalyst bed is the only major component of the TWT that is not redundant. Two factors entered into the decision not to have a second bed. First, operating experience with a similar system at Los Alamos National Laboratory has shown that it has not had problems resulting from catalyst poisoning. Second, the cost of a backup system was high,

approximately \$70,000.00. The catalyst bed was designed so that the catalyst itself could be replaced and a spare charge was purchased. The TWT also was designed so that, if necessary, a second bed could be easily added in the future. (note: in September 1990, a redundant catalytic reactor bed was installed at TSTA.)

Compressors

One of two compressors is used to move the gas through the TWT and to pressurize the gas to 45 psia (0.3 MPa). The compressors are reciprocating, nonlubricated two stage units with an inert-gas-pressurized sealed chamber between the compression chamber and the crankcase. The pumping speeds of the two compressors are 15 scfm (25 m³/hour) and 53 scfm (90 m³/hour). With the larger compressor (unit B) running continuously, the TWT can process the gas load from all 13 TSTA gloveboxes purging at the same time. The smaller compressor (unit A) is normally used to process the gas, however if the pressure rise in the LPR is greater than 0.33 psi/minute (2.3 kPa/second), the large compressor will start. If the input gas capacity of the LPR is exceeded, the small compressor can be used to pressurize the input storage tanks to 50 psia (0.34 MPa) while the large compressor is used to process the gas from the LPR through the TWT.

High Pressure Gas Storage Tanks

Two stainless steel tanks [40 cubic feet (1.13 m³) each], located after the compressors, are used to provide additional gas storage during processing. The normal flow is through only one tank, and the other tank is normally evacuated. These tanks have staggered operating periods, such that each tank operates half of a year.

Molecular Sieve Beds

Tritiated water is removed by passing the process gas through one of four molecular sieve beds. These dryers are arranged in pairs. One set contains approximately 80 pounds (36.4 kg) per bed of Linde type 13X molecular sieve while the second pair is filled with 120 pounds (54.4 kg) per bed of Linde type 4A molecular sieve. The beds are cylinders, 16

inches (0.4 m) in diameter by 29 inches (0.74 m) high. The beds are in pairs so that one bed can be rearranged while the second bed is still processing gas. The process gas is first passed over the bed containing 13X sieve. This is done so that in addition to water, hydrocarbons which may not have been converted in the catalyst bed can be collected in a sieve with a capacity for larger molecules. The 4A bed is used only if the first bed does not remove the tritiated water efficiently.

Each molecular sieve bed will hold approximately 3 to 4 pounds (1.4 to 1.8 kg) of water before breakthrough occurs. The actual capacity depends on the water content of the input gas and the total flow through the system. The beds were initially sized for three month operating cycles.

Radiation Monitoring

The dried gas is passed through one of three ion chambers (designated RMA, RMBY, and RMC) to measure the tritium concentration. If the tritium level after the 13X bed is less than the administrative limit (225 microCuries per cubic meter), the gas is routed to the stack. If the tritium level after the 13X bed is greater than the administrative limit, the process gas is routed through the water swamp path to the 4A molecular sieve bed. If the level in the exhaust stream from the 4A bed is still above the administrative limit, the gas is recycled to the LPR. When the level in the exhaust line is reduced below the administrative limit, the gas is again routed to the stack. The gas is then run through a pressure regulator to drop the gas pressure to ambient pressure. A fourth radiation monitor (designated RMEX) is in the exhaust stream to provide final radiation monitoring before the gas is released to the stack. If this monitor detects a tritium level greater than the administrative limit, the gas is recycled back to the LPR. These monitors operate continuously throughout the year.

Molecular Sieve Bed Regeneration System

Regeneration of a molecular sieve bed is accomplished by passing heated dry nitrogen through the saturated sieve in a direction opposite to the flow of process gas through the bed. The output of the bed is heated to approximately 200°F (455 K). The moist nitrogen is cooled and then dried by passing the gas through one of two moisture collectors, which each contain approximately 80 pounds (36 kg) of type 4A molecular sieve. The dried regeneration gas is then routed to the TWT LPR to remove any residual water. Regeneration of a bed takes approximately eight hours. This time is dependent on the amount of water initially on the bed. The moisture collectors will hold approximately 12 pounds (5.44 kg) of water. When breakthrough (at about 30% water loading) occurs, the collectors are replaced and the tritium contaminated sieve and container are sent to waste disposal. This operation is now performed six to eight times per year, but for the majority of operating history four times per year was typical, so this value was used in the failure rate calculations.

Gas Analysis

Gas composition analysis in the TWT is performed using gas chromatographs (GCs), humidity detectors, and ion chambers. GCs are used to measure the composition of the gas in the LPR and the input storage tanks. Nitrogen, hydrogen, oxygen, and methane are detected and measured. The GC uses a packed molecular sieve column with helium as the carrier gas. Tritium is monitored both in the input to the TWT and the exhaust stream. A 0.11 liter ion chamber is used to monitor the radiation in the LPR while two of four 1.7 liter chambers are used to monitor the exhaust gases. The humidity sensors monitor the moisture content in the process gas flowing from the molecular sieve beds and the regeneration gas stream. The GCs are operated roughly one full week per quarter year.

TWT System Control

The operation of the TWT is controlled by a continuously operating program which is run on the TSTA control computer. Operators are not needed for normal processing of tritiated effluent. If the computer

system fails, the TWT can be operated locally, with critical instrumentation also read locally. The program performs the functions necessary for the automatic processing of tritiated waste gases. It handles pump down of the LPR, the reporting of abnormal conditions or operating modes to the control displays, the monitoring of the health and state of the components in the system, the switching to backup components when failure is detected, the appropriate actions to be taken when abnormal tritium levels are detected at the output of the TWT, and the gas analysis and system parameter monitoring functions.

Some functions are not automatically performed by the program. The regeneration of a saturated bed is not started automatically. The system operator must initiate this task.

The system operators can also input commands from the man-machine interface (MMI) and override the automatic operation of the TWT if necessary. For example, the operator can take a component off-line and force the system to use the redundant or backup system.

The control program also interacts with other programs which control other TSTA systems. When the TWT is in the recycle mode because of high tritium levels at the output, the purges of the gloveboxes are halted to reduce the load to the LPR. If necessary, the purges can be restarted by the duty operator while the system is in recycle.

Valve Exercising

Some of the most used components in the TWT are the valves that control process flow. Typically, the compressor valves are the most used units in the entire TWT system. These valves can change state two times per day, while most of the remaining valves in the system typically change state two times per month.¹⁰ For this reason, the compressor valve MOV CA1 was examined separately in the failure rate data analysis. Some manual valves in the TWT have never been transferred, but serve as pressure boundary components meant for major component isolation if there is a need for extended major component maintenance or replacement. These valves and other components that have not been exercised over the operating time period cannot be given a failure rate.

4. TWT FAILURE DATA ANALYSIS

This section presents the failure rate estimates for several TSTA TWT component types. These component types under study are motor operated ball valves, tritium monitors, non-nuclear monitors, compressors, and gas chromatographs. The system failure rate for pressure boundary breaches is also presented.

From January 1, 1984 to December 31, 1989, 491 failure reports were collected at TSTA. Sixty of these reports pertained to the TWT. Brief summaries of these 60 reports are given in Appendix B. Table 1 contains abbreviated counts of the failures in terms of the components, their failure modes, and failure causes assigned from a root cause list.¹¹

Since the TWT is a continuously operating system, most of the 60 failures were detected by either the operators noticing a deviation from normal operation, or a control room alarm. A few of the failures were noticed during routine operator walkdown inspection tours.

The system operating hours are an important consideration for failure rate calculations. The TWT continues to run even during a TSTA shutdown, to provide glove box gas sweep for other, smaller experiments that are unaffected by the status of the overall TSTA operating loop. Even with this system requirement, the TWT is not always operating. The total operating hours were estimated from the maintenance/failure data program and from TSTA operating logs, as well as from conversations with TSTA operators. This information, with estimated errors, is given in Table 2.

Failure rates for individual component types and for system integrity are listed in Table 3. These failure rates were calculated using the means described in Appendix A and the component information that is listed in Appendix C. These failure rates are assumed to be random failure rates, with no common cause contributions. The component failure reports typically do not suggest any common cause concerns. In the case of tritium monitors and computer control software errors, the system outage reports were not used for failure rate calculations.

TABLE 1. SUMMARY OF 1984-1989 TSTA TRITIUM WASTE TREATMENT SYSTEM FAILURE REPORTS

Number of Failures	Component of Interest/Report No	Component Failure Mode	Failure Cause
1	MOV CA1 [report 63]	Fail to open	Electrical Failure
3	MOV CA1 [rpts 67,116,119]	Fail to open	Unclassifiable cause
1	MOV CA1 [report 124]	Fail to open	Loose connections
1	MOV CA1 [report 262]	FTOAR (a)	Unclassifiable cause
0	MOV CA1 [report 449]	Disconnected on August 12, 1988	Approved Maintenance Action
1	MOV MSA1 [report 97]	FTOAR	Unclassifiable cause
1	MOV MSA4 [report 97]	FTOAR	Unclassifiable cause
1	MOV MSABY [report 229]	Fail to open	Electrical Failure
1	MOV MSB3 [report 361]	Fail to open	Unclassifiable cause
2	MOV LPR3 [rpts 301, 448]	Fail to close	Unclassifiable cause
1	MOV MCA1 [report 447]	FTOAR	Unclassifiable cause
1	MOV MCA6 [report 447]	FTOAR	Unclassifiable cause
1	MOV RMA1 [report 314]	Fail to open	Unclassifiable cause
1	MOV IS6 [report 337]	FTOAR	Unclassifiable cause

a. Fail to operate as required

b. Fail to continue to run

note: report summaries are listed by report number in appendix B.

TABLE 1. (continued)

<u>Number of Failures</u>	<u>Component of Interest/Report #</u>	<u>Component Failure Mode</u>	<u>Failure Cause</u>
2	Sampling valve CBGA1 [rpts 147, 149]	Fail to open	Foreign material intrusion (oil, dirt)
1	manual valve RECA2 [report 391]	Spurious transfer	Accidental maintenance action
2	Compressor A [rpts 231, 236]	Fail to start	Electrical failure
1	Compressor A piping, [rpt 165]	Breach	Corrosion
1	Compressor A, [report 24]	FTCTR (b)	Electrical failure
1	Tritium monitor, [report 17]	Incorrect reading	Short circuit
13	Tritium monitor, [rpts 25,53,53.1, 55,56,57,64,65, and 393]	Incorrect reading	Unclassifiable cause
2	Tritium monitor [rpts 17, 75]	No reading	Short circuit
1	Tritium monitor [report 242]	No reading	Broken wire

TABLE 1. (continued)

<u>Number of Failures</u>	<u>Component of Interest/Report #</u>	<u>Component Failure Mode</u>	<u>Failure Cause</u>
1	Humidity indicator MSAEX [report 230]	High reading	Unclassifiable cause
1	Humidity indicator MSAEX [report 452]	Low reading	Foreign material intrusion (oil)
1	Humidity indicator H-HPRA [report 450]	High reading	Corrosion
1	Humidity indicator H-MCIN [report 451]	High reading	Corrosion
2	Pressure transducer HPRB3 [rpts 107.1, 372]	Incorrect reading	Unclassifiable cause
1	Pressure transducer HPRA3 [report 127]	Incorrect reading	Unclassifiable cause
2	Gas chromatograph [rpts 120, 146]	Loss of function	Unclassifiable cause
1	Gas chromatograph [report 367]	Loss of function	Accidental operations activity
2	Recombiner [rpts 46, 252]	Loss of function	High temperature degradation, and mechanical vibration

TABLE 1. (continued)

<u>Number of Failures</u>	<u>Component of Interest/Report #</u>	<u>Component Failure Mode</u>	<u>Failure Cause</u>
1	Tubing [report 185]	Leakage	Unknown
1	Filter case [report 136]	Leakage	Unknown (note c)
3	Small compressors [rpts 148, 261]	FTCTR	Diaphragms broken

There were 58 failures listed in the 53 TWT failure reports used. The reports on software faults (reports 049, 121, 244, 268, and 107) and two tritium monitor reports (205 and 391) were not considered since actual failures were not clearly defined.

- c. Pinhole leak due to rusting, J. E. Nasise and R. S. Dahlin, from a conversation on January 31, 1970.
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TABLE 2. TRITIUM WASTE TREATMENT SYSTEM OPERATING HOURS ESTIMATES

<u>Year</u>	<u>Operating hours</u>	<u>Assumed Error (in hours)</u>
1984	4728 (a)	± 8
1985	7905	± 8
1986	8690	± 8
1987	8712	± 8
1988	8784 (b)	± 8
1989	8712	± 8
Total	47,531	

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- a. The TWT achieved full-time operation on June 18, 1984, as noted in the TWT log book kept by R. S. Dahlin, the TSTA operator responsible for the TWT system at the time of this data compilation.
- b. Leap years in 1984 and 1988

Note: The error rate is low, but the staff is very confident that the facility log books are accurate and these operating hours errors are considered to be very conservative.

TABLE 3. ESTIMATED FAILURE RATES FOR TRITIUM WASTE TREATMENT SYSTEM
COMPONENTS

Component Type	Failure Mode	Failure rate (a)	95% Confidence
			Interval, UB
Gas chromatograph	Fail to function	6.3E-05/d	1.6E-04/d
Motor Operated Valve ^b	Fail to open	5.0E-04/d	8.5E-04/d
MOV CA1	Fail to open	1.6E-03/d	3.2E-03/d
Compressor	Fail to start	3.1E-05/d	9.5E-05/d
Manual Valve (non-MOV)	Fail to operate	1.8E-03/d	4.8E-03/d
Humidity indicator	Incorrect reading	1.7E-05/h	3.9E-05/h
Compressor	Fail to run	6.3E-05/h	1.6E-04/h
Tritium monitor	Incorrect reading	8.9E-05/h	1.3E-04/h
Pressure transducer	Incorrect reading	5.3E-06/h	1.4E-05/h
Recombiner	Fail to function	4.2E-05/h	1.3E-04/h
Gas chromatograph small compressors	Fail to run	6.3E-05/h	1.6E-04/h
Piping/filter case	Breach	(c)	

a. /d stands for per demand, /h stands for per operating hour

b. Not including motor operated valve CA1

c. Report numbers 136, 165, and 185 are all of the TWT system breach events over the 5.5 year time period. Using a Chi-square distribution for $2 \times 3 + 1 = 7$ degrees of freedom gives $6.35/(2)(5.5) = 0.6$ events/yr. The 95% upper bound is $14.1/(2)(5.5) = 1.3$ events/year. All of these events were minor in-building release events in the microCurie range.

For the TWT system overall, there have been no unscheduled total system outages in the 5.5 years covered in this report (this statement does not include loss of offsite power events: however, there is an emergency diesel generator dedicated to TSTA). This exemplary record is due to the redundancy built into the system. There have been instances that the system capacity was reduced to 50%, but no total system outages have been reported. Therefore, using a Chi-square distribution on zero failures in 5.5 years, this gives 1 degree of freedom and the 50% mean value failure rate is $0.455/(2)(5.5) = 0.04/\text{year}$, with a 95% upper bound as $3.84/(2)(5.5) = 0.35/\text{year}$. The average TWT failure rate, 0.04/year, corresponds to that assumed in earlier work on fusion fuel reprocessing risk.¹¹ This failure rate will reduce as the highly available TWT continues to operate in the future.

The component failure rates summarized in this report should be interpreted as tentative gross indicators of true fault trends for the Tritium Waste Treatment System. Because subjective judgements had to be made regarding the pertinence of recorded events and the system boundaries, because some components may have been changed out, and because some system modifications have altered the basic system configuration and the mode of operation over the data recording period, individual fusion analysts and designers should confirm the applicability of the component failure rates cited in Table 3 for their own specific uses.

It is interesting to note that the failure rates for the TWT components were sometimes higher than those reported for fusion screening data.¹³ The first approach to obtaining failure rates for tritium-bearing components was to arbitrarily increase the existing nuclear fission power plant component failure rates by a factor of ten to provide conservative overestimates.¹³ Results from this study indicate that this action may have led to overconservatism in some instances, and to small underconservatism in others. Table 4 gives a comparison of several actual TWT tritium component failure rates versus the suggested screening values from reference 13. The motor operated valve failure to transfer and the compressor failing to start values are the most divergent, and show that the screening data values may be overly conservative. The motor-operated valve values were overconservative in

TABLE 4. ACTUAL POINT ESTIMATE COMPARISONS WITH SCREENING DATA VALUES
FOR SELECTED TWT COMPONENTS

<u>Component</u>	<u>Failure Mode</u>	<u>Point Estimate</u>	<u>Screening Value (a)</u>	<u>Comments on Differences (b)</u>
MOV (c)	Fail to transfer	5E-04/d	1E-02/d	SV larger, *20
Compressor	Fail to start	3.1E-05/d	3E-03/d	SV larger, *100
Manual valve	Fail to transfer	1.8E-03/d	1E-03/d	SV smaller, *2
Moisture monitor	Incorrect reading	1.7E-05/h	8.9E-06/h [note d]	SV smaller, *2
Compressor	Fail to run	2.2E-05/h	4.17E-05/h [note d]	SV larger, *2
Radiation monitor	Incorrect reading	8.9E-05/h	1.43E-05/h [note d]	SV smaller, *4
Pressure monitor	Incorrect reading	5.3E-06/h	3E-06/h [note d]	SV smaller, *2

- a. Screening values are taken from the tritium section of reference 13.
- b. These screening value (SV) differences are multiplicative factors expressed in round numbers only for a coarse comparison.
- c. Without MOV CA1 included. A lower value for the factor of difference is obtained, roughly a factor of *15, when the total TWT MOV failure rate is used for comparison.
- d. This is an all failure modes value. For conservatism, the all modes value would be used for one failure mode, thus comparisons are reasonable.

the screening data report. The compressor failure to start value is puzzling, until conversation with TSTA operator R. C. Wilhelm¹⁴ yielded the information that compressor A, the on-line unit with a high number of demands per year, is watched carefully, has frequent operator inspections and preventive maintenance intervals, and is kept cool through the use of fan-forced air flow. When a component is given such care and attention, it is reasonable to find that the actual failure rate is significantly lower than the conservative screening value.

The rest of the data compare closely, within a factor of two in almost all of the remaining cases. In the cases where the screening failure rate is the lower value, such as the manual valves, moisture monitors, radiation monitors, and pressure monitors, reference 13 will be updated to show that actual data provides somewhat higher values, and new screening values will be suggested. True screening values should provide overestimates to set failure rate upper bounds in the screening stage, so that when actual failure rate data is applied in the refinement stage the accident scenario frequencies (or fault tree branch values) decrease for those accident scenarios (or fault tree branches) that are still found to be probabilistically significant.

The finding that some screening values were on the order of the actual failure rate data for the TWT was surprising. Since the TWT had several trial runs during preoperational testing prior to June, 1984, the system is considered to be mature, and the failure rates calculated here are random, constant values. The margin of difference between these actual rates and the screening values is not great enough in this case to warrant complacency. Some screening values will be adjusted to provide conservative upper bounds for these true failure rates. Since the screening values were not always conservative overestimates, it is obvious that more work should be done to produce actual failure rates. Accurate failure rates are necessary for producing accurate safety, risk, and reliability analyses. More data must be collected on actual fusion systems, so that these systems and future facility designs can be accurately treated for reliability and safety.

5. CONCLUSIONS AND RECOMMENDATIONS

As noted in Table 1, roughly half of the failure reports did not contain enough information to discern the failure cause. Feedback from field experience is extremely valuable to system designers when planning for new designs. For example: does the failed component need to be replaced or does it require minor repair while in place? The failure cause and the corrective action may provide this answer, and the answer will affect spare parts inventories as well as design considerations for maintenance access (i.e., is an airlock warranted, is working through gloves sufficient for most work, will the glovebox need to be opened frequently, is there enough room to disassemble a component in the space provided, will this work well the way that it has been designed?, etc.).

Failure causes are also important because they indicate component acceptability. A component that has frequently recurring failures may be replaced by another brand or even another type of component (such as pneumatic operated valves versus motor operated valves). Conversely, the failures may be tolerable and the field tested component is suggested for use in future designs. Failure cause information is needed to make these judgements. Inherent traits of a particular type of component may make it unacceptable in future designs. As an example, the operations staff would like to see ball valve use discontinued, since if the valve has any type of failure, it is possible to fail in an unknown position. Discussions with the TSTA staff have been helpful in providing information on typical and unique human failures. Even though detailed records are kept at TSTA, more information would support determination of failure causes. Improved record keeping would provide a better opportunity to disseminate and analyze the data for fusion community use and support. For these reasons, continued effort on consistent record keeping is recommended. TSTA personnel agree with this recommendation and are complying.

The failure rates were calculated based on independence of failure causes. Common cause failures were not indicated in the failure reports used for failure rate calculations. Standard beta method approaches¹⁵ to common cause failure rates are suggested for situations requiring common cause treatment.

Failure repair times were typically not given for these failure reports. These times to repair would greatly support system availability calculations for systems configured differently than the TWT. Since the TWT never experienced an unscheduled outage from internal causes (i.e., power outages are not included) over the data reporting period of 5.5 years, this system's availability is 100%. This is due to the wise use of redundant components in parallel trains, and good component maintenance/operations practices. It should also be noted that the total tritium emissions from the entire TSTA facility over the time period of this report were less than 100 Ci. The TWT is responsible for less than 2% of this total.

Overall, the failure rates have reasonable confidence intervals, thus lending credibility to the mean values. The TWT is considered to be a mature system, therefore, these failure rates are constant, random values. The mean values lying so close to the screening values was surprising, but also informative. Screening values will be adjusted to regain conservatism, and the actual failure rates themselves can be applied to a variety of analyses. The Chi-square calculations for the TWT system are very conservative and represent order of magnitude indicators at best. As the TWT continues to operate, the Chi-square failure rates will decrease accordingly.

Other fusion components should be examined for their actual failure rates to verify that the screening data values are truly conservative estimates of failure rates. As more information on component failures is collected, the screening data can be replaced with actual values. Generic failure rates for fusion-specific components can serve the purpose of screening data, and the generic data can be adjusted by multiplicative factors to account for extreme environments outside the typical fusion design usage, such as high temperature, etc. In this way, the actual failure rate data can be highly versatile and useful to the fusion community.

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TITLE TRITIUM WASTE TREATMENT SYSTEM COMPONENT FAILURE DATA ANALYSIS
FROM JUNE 18, 1984 TO DECEMBER 31, 1989

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APPENDIX A

STATISTICS FOR FAILURE RATES

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STATISTICS FOR FAILURE RATES

The failure rates for two different types of failures were calculated. For components that are required on operational demand, the failure rate per demand was calculated. For components that may fail while running, the failure rate per hour running was calculated.

Table A-1 shows the data used in the calculations.

The demand type failures were modeled as binomial random variables. The binomial distribution results from counting the number of failures in a fixed number of trials, when the outcomes of the trials are independent. The binomial distribution is well suited for demand failure rates. The run-time (hourly) failures were modeled as poisson random variables. The poisson distribution results from counting the number of failures in a fixed operating time period, when the numbers of failures in non-overlapping time intervals are independent. This distribution is well suited for hourly failure rate calculations.

Several notes should be made about the calculations:

- The total number of operation hours of the Tritium Waste Treatment System used in the calculations was 47531 hours covering the time period from June 18, 1984 through the end of 1989.
- For motor operated valves (MOV's) there was a total of 23515 demands for the 5.5 years duration of this study. Valve CA1 was disconnected in mid-August, 1988 because it had a high failure rate. It accounted for a total of 3660 demands during the 5.5 years. The failure rate for MOV's was also calculated with and without valve CA1 included.
- Moisture collectors were run for approximately 100 hours per year.

- In calculating the demand type failure rate (fail to start) for compressors, the two compressors were treated individually. Compressor A had $(4728 \text{ hrs})(0.75)(1 \text{ d}/2 \text{ hrs}) + (7905 \text{ hrs})(0.75)(1 \text{ d}/2 \text{ hrs}) + (8690 \text{ hrs})(0.75)(3 \text{ d/hr}) + (8712 \text{ hrs})(0.75)(3 \text{ d/hr}) + (8784 \text{ hrs})(0.75)(3 \text{ d/hr}) + (8712 \text{ hrs})(1 \text{ day}/24 \text{ hrs})(1 \text{ week}/7 \text{ days})(1 \text{ d/week}) = 63,708$ demands, and the compressor B total is: $(47531 \text{ hrs})(0.20)(1 \text{ day}/24 \text{ hrs})(1 \text{ week}/7 \text{ days})(1 \text{ demand/week}) = 283$ demands. Then the total compressor start demands are = 63,991.
- The number of demands for all of the non-MOVs (manual valves) was 296 demands/year * 5.5 years for a total of 1628 demands.
- Some components were never used or demanded during the time period of this study, and thus their failure rates are inestimable.

Sample Calculation for a Demand Type Usage

The point estimate for the probability of a failure upon demand is,

$$p = (\text{total number of failures})/(\text{total number of demands}).$$

Confidence bounds for p are based on formula (28) found in reference A-1.

$$\text{Lower 95\% Confidence Bound on } p = X*FL/(n-X+1+(X*FL))$$

$$\text{Upper 95\% Confidence Bound on } p = (X+1)*FU/(n-X+(X+1)*FU)$$

where: X = total number of failures for the set of components
 n = total number of demands for the set of components
 FL = Lower F-statistic = $F(.05, 2X, 2(n-X+1))$
 FU = Upper F-statistic = $F(.95, 2(X+1), 2(n-X))$

For example, the calculations for the gas chromatography components are:

$X = 3$ failures of gas chromatographs

(report numbers 120, 146, and 367)

$n = 44$ demands over the time period of this study, 5.5 years

$p = X/n = 3/44 = 0.068$ failures per demand, or f/d

The F-statistic values can be found in tables in reference A-2.

Lower 95% Confidence Bound = $(3 \cdot 0.269) / ((44 - 3 + 1) + 3 \cdot 0.269) =$
0.019 f/d

Upper 95% Confidence Bound = $((3 + 1) \cdot 2.053) / ((44 - 3) + (3 + 1) \cdot 2.053) =$
0.167 f/d

Sample Calculation for an Hourly Type Usage

The point estimate for the failure rate per hour usage is,

$\text{Lambda} = X/t = (\text{total number of failures}) / (\text{total number of hours operated}).$

Confidence bounds for lambda are based on formulas (28.1) and (28.2) found on page 96 of reference A-1.

Lower 95% Confidence Bound on $\text{Lambda} = CL/(2 \cdot t)$

Upper 95% Confidence Bound on $\text{Lambda} = CU/(2 \cdot t)$

where X = Total number of failures for the set of components
 t = Total hours of operation for the set of components
 CL = Lower Chi-squared statistic = $\text{chi-squared}(.05, 2 \cdot X)$
 CU = Upper Chi-squared statistic = $\text{chi-squared}(.95, 2 \cdot (X + 1))$

For example, the calculations for the moisture monitors are:

$X = 4$ failures of moisture monitors

(report numbers 230, 450, 451, 452)

$t = 237655$ accumulated hours of moisture monitor operation
over 5.5 years

$\text{Lambda} = X/t = 4/237655 = 1.68\text{E-}5$ failures/hour or f/h

Lower 95% Confidence Bound = $2.734/(2*237655) = 5.8\text{E-}6$ f/h

Upper 95% Confidence Bound = $18.307/(2*237655) = 3.9\text{E-}5$ f/h

The Statistical Analysis System (SAS) computer code suite^{A-3} was used to generate the failure rates and confidence intervals for the TWT components. Table A-2 lists the results of the analysis. Note that the confidence bounds are one-sided 95% confidence limits (i.e., $\alpha = 0.05$ in each tail).

A chi-squared test found the failure rate for the motor-operated ball valve CA1 (MOV CA1) was fairly significantly divergent from the failure rate for the set of TWT motor operated ball valves without MOV CA1 included (chi-squared=3.64, degrees freedom=1, probability that chance alone would produce such a difference in the observed failure rates is about 0.06). MOV CA1 was in a high usage position in the system, with the possibility of debris buildup in the valve body. This valve's service life was extremely atypical prior to its removal from service in August 1988. Therefore, keeping this valve's failure rate separate from the failure rate for the rest of the valves is prudent.

TABLE A-1. COMPONENT DATA FOR THE TSTA TRITIUM WASTE TREATMENT SYSTEM

COMPONENT	USAGE TYPE	NUMBER OF THIS TYPE IN SYSTEM	USAGE RATE	TOTAL NUMBER HOURS/DEMANDS	NUMBER OF FAILURES
ELECT. HEATERS	DEMAND	2	4/YR	44 d	0
MOL. SIEVE BEDS	DEMAND	4	1/YR	22 d	0
GAS CHROMATOGR.	DEMAND	2	4/YR	44 d	3
MOV (all)	DEMAND	69	23815 TOTAL	23815 d	16
MOV (w/o CA1)	DEMAND	68	19855 TOTAL	19855 d	10
MOV CA1	DEMAND	1	3690 TOTAL	3690 d	6
MOIST. COLLECT.	DEMAND	2	4/YR	44 d	0
COMPRESSOR (start)	DEMAND	2	63991 TOTAL	63991 d	2
NON-MOVs	DEMAND	82	1628 TOTAL	1628 d	3
OIL SEPARATORS	HOURLY	2	50%	47531 h	0
LEVEL MONITORS	HOURLY	2	100%	95062 h	0
MOISTURE MONITORS	HOURLY	5	100%	237655 h	4
TEMP. MONITORS	HOURLY	11	100%	522841 h	0
HIGH PRES. TANK	HOURLY	2	50%	47531 h	0
MOV (leak)	HOURLY	69	100%	3279639 h	0
PRES. REGULATOR	HOURLY	9	100%	427779 h	0
FLOW INDICATOR	HOURLY	1	100%	47531 h	0
INPUT STOR. TANK	HOURLY	2	100%	95062 h	0
PAIRED FILTERS	HOURLY	6	190124 TOTAL	190124 h	0
MOIST. COLLECT.	HOURLY	2	1100 TOTAL	1100 h	0
COMPRESSORS (run)	HOURLY	2	47%	45154 h	1
RAD. MONITORS	HOURLY	4	100%	190124 h	17
MANOMETER	HOURLY	1	100%	47531 h	0
PRES. MONITORS	HOURLY	12	100%	570372 h	3
ORIFICES	HOURLY	5	100%	237655 h	0
RECOMBINER	HOURLY	1	100%	47531 h	2
L. P. RECEIVER	HOURLY	1	100%	47531 h	0
NON-MOV (leak)	HOURLY	82	100%	3897542 h	0
CHROMATOGRAPH COMPRESSORS	HOURLY	2	50%	47531 h	3

TABLE A-2. TWT COMPONENT FAILURE RATE ESTIMATES AND ONE-SIDED 95% CONFIDENCE BOUNDS

<u>Demand Failure Rates</u>			
<u>COMPONENT</u>	<u>POINT ESTIMATE p</u>	<u>95% CONFIDENCE LIMITS</u>	
		<u>LOWER BOUND</u>	<u>UPPER BOUND</u>
ELECTRIC HEATERS	0.00E+00	0.00E+00	6.58E-02
MOLECULAR SIEVE BEDS	0.00E+00	0.00E+00	1.27E-01
GAS CHROMATOGRAPHS	6.82E-02	1.88E-02	1.67E-01
MOVs	6.72E-04	4.21E-04	1.02E-03
MOVs (w/o valve CA1)	5.04E-04	2.73E-04	8.54E-04
MOV CA1	1.63E-03	7.08E-04	3.21E-03
MOISTURE COLLECTORS	0.00E+00	0.00E+00	6.58E-02
COMPRESSORS, FTS (a)	3.13E-05	1.55E-06	9.84E-05
NON-MOVs (manual valves)	1.84E-03	5.02E-04	4.76E-03

<u>Hourly Failure Rates</u>			
<u>COMPONENT</u>	<u>LAMBDA ESTIMATE</u>	<u>95% CONFIDENCE LIMITS</u>	
		<u>LOWER BOUND</u>	<u>UPPER BOUND</u>
OIL SEPARATORS	0.00E+00	0.00E+00	6.30E-05
LEVEL MONITORS	0.00E+00	0.00E+00	3.15E-05
MOISTURE MONITORS	1.68E-05	5.75E-06	3.85E-05
TEMPERATURE MONITORS	0.00E+00	0.00E+00	5.73E-06
HIGH PRESSURE TANKS	0.00E+00	0.00E+00	6.30E-05
MOV (leakage)	0.00E+00	0.00E+00	9.13E-07
PRESSURE REGULATOR	0.00E+00	0.00E+00	7.00E-06
FLOW INDICATOR	0.00E+00	0.00E+00	6.30E-05
INPUT STORAGE TANK	0.00E+00	0.00E+00	3.15E-05
PAIRED FILTERS	0.00E+00	0.00E+00	1.58E-05
MOISTURE COLLECTORS	0.00E+00	0.00E+00	2.72E-03
COMPRESSORS	2.21E-05	1.14E-06	1.05E-04
RADIATION MONITORS	8.94E-05	5.70E-05	1.34E-04
MANOMETER	0.00E+00	0.00E+00	6.30E-05
PRESSURE MONITORS	5.26E-06	1.43E-06	1.36E-05
ORIFICES	0.00E+00	0.00E+00	1.26E-05
RECOMBINER	4.21E-05	7.48E-06	1.32E-04
LOW PRESSURE RECEIVER	0.00E+00	0.00E+00	6.30E-05
NON-MOV (leakage)	0.00E+00	0.00E+00	7.59E-07
CHROMATOGRAPH COMPRESSORS	6.31E-05	1.72E-05	1.63E-04

Note: One-sided confidence bound means that the alpha tail is 0.05 on each side of the distribution

a. FTS stands for fail to start

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APPENDIX B

SUMMARY DESCRIPTIONS OF
TRITIUM WASTE TREATMENT SYSTEM
FAILURE REPORTS FROM
JUNE 18, 1984 TO DECEMBER 31, 1989

TABLE B-1. TRITIUM WASTE TREATMENT SYSTEM FAILURE REPORT SUMMARIES

Report Number	Event Date	Component of Interest	Failure Description and Cause	Failure Effect	Method of Detection
063	10/03/84	Valve CA1	Power circuit spade lugs degraded, valve failed to open	TWT capacity reduced 50%	Operational Occurrence
067	10/10/84	Valve CA1	Cause unknown, valve failed to open	TWT capacity reduced 50%	Operational Occurrence
116	05/28/85	Valve CA1	Cause unknown, valve failed to open	TWT capacity reduced 50%	Alarm
119	06/03/85	Valve CA1	Cause unknown, valve failed to open	TWT capacity reduced 50%	Alarm
124	06/07/85	Valve CA1	Connections loose, valve failed to open	Compressor A is isolated, TWT capacity reduced 50%	Operational Occurrence
262	09/03/86	Valve CA1	Cause unknown, valve stuck	TWT capacity reduced 50%	Alarm
449	08/12/88	Valve CA1	Valve is open, actuator is disconnected	Modified system operation to allow this action	Maintenance Action
097	02/26/85	Valve MSA1, Valve MSA4	Cause unknown, valves transferred inadvertently	Isolated Molecular Sieve Bed A	Operational Occurrence
147	08/05/85	Sampling Valve	Oil on connectors, valve failed to open	Chromatograph B would not analyze	Operational Occurrence
149	08/19/85	Sampling Valve	Dirt in air actuator, valve failed to open	Specimen sampling out for two hours	Operational Occurrence
229	03/13/86	Valve MSABY	Solid state relay failed, valve failed to open	TWT capacity reduced 50%	Operational Occurrence
361	03/11/88	Valve MSB3	Cause unknown, valve failed to open, ganged to MSB2	MSB not regenerated	Operational Occurrence

TABLE B-1. TRITIUM WASTE TREATMENT SYSTEM FAILURE REPORT SUMMARIES (continued)

Report Number	Event Date	Component of Interest	Failure Description and Cause	Failure Effect	Method of Detection
301	01/08/87	Valve LPR-3	Cause unknown, valve did not close	Unknown	Operational Occurrence
448	05/17/89	Valve LPR-3	Cause unknown, valve did not close	Re-exercised valve, and it closed	Operational Occurrence
447	05/22/89	Valve MCA1, Valve MCA6	Cause unknown, valves showed 'between' on MMI, did not transfer as required	Computer switched from from MSBA to MCB	Operational Occurrence
314	01/14/87	Valve RMA1	Cause unknown, valve failed to open	Unknown	Alarm
337	12/16/87	Valve IS6	Bad 'close' relay, valve cycled continuously	Unknown	Alarm
391	07/09/88	Recombiner A manual valve	PAWS cleaning crew bumped valve, placed it off line	Unknown	TWT went into recycle
024	03/12/84	Compressor A	Transformer in motor controller failed, compressor stopped running	TWT capacity reduced 50%	Alarm message
165	10/03/85	Compressor A	Corrosion on vibration eliminator, lost integrity	Tritium gas leaked into room, unknown quantity	Alarm
231	03/14/86	Compressor A	Protective heaters in start circuit too hot to restart after emergency power test	TWT capacity reduced 50%	Operational Occurrence
236	04/23/86	Compressor A	Control transformer failed, compressor wouldn't restart after a power glitch	TWT capacity reduced 50%	Operational Occurrence

TABLE B-1. TRITIUM WASTE TREATMENT SYSTEM FAILURE REPORT SUMMARIES (continued)

Report Number	Event Date	Component of Interest	Failure Description and Cause	Failure Effect	Method of Detection
148	08/14/85	Small compressor	Compressor diaphragm failed, analyzing inleak air, not LPR	Unknown	Operational Occurrence
261	08/28/86	Small compressors	Sampling compressors from LPR to gas chromatographs not working, diaphragms worn and ruptured	No LPR gas samples, possible explosive H ₂ mixture formed in LPR	Indication of High O ₂ level in LPR
049	06/18/84	Software	Incorrect software change blocked start of Compressor B	TWT capacity reduced 50%	Operational Occurrence
121	06/01/85	Software	Manual defeat of software to purge saturated Molecular Sieve Bed A	Forced system to ignore high radiation readings	Alarm at high radiation
244	07/15/86	Software	Software actuated TWT recycle mode inadvertently Change software to lag the current operations	No significant effect	Alarm
268	09/11/86	Software	Software controlling TWT caused inadvertent TWT configuration change	TWT configuration erratic	Operational Occurrence
107	04/01/85	TWT system	Shutdown for new computer parameter entry. Pressure in Solid Waste Disposal and Inventory GBs increased.	Small amount of untreated GB atmosphere sent thru bubblers and up the stack	Operator MMI inspection
136	07/23/85	Filter A	Pinhole leak in Cuno filter case	Leaked contaminated gas into room	Hissing heard during operator walkdown tour

TABLE B-1. TRITIUM WASTE TREATMENT SYSTEM FAILURE REPORT SUMMARIES (continued)

Report Number	Event Date	Component of Interest	Failure Description and Cause	Failure Effect	Method of Detection
185	12/19/85	tubing	Leak in flexible connector between valve MCA1 and moisture collector A	Tritium concentration around tube was 100 microCi/m ³	Radiation alarms
238	04/09/86	piping	Oil weep from elbow solder connection, no breach found.	No significant effect	Operator walkdown tour
120	06/01/85	Gas Chromatograph #A	Cause unknown, failed to report cause or results	Potential explosive H2 mixture in LPR	Operational Occurrence
146	07/29/85	Gas Chromatograph #A	Cause unknown, failed to analyze	Unknown	Operational Occurrence
367	04/06/86	Gas Chromatograph Sys.	Operator error in loading the data space for GC output	Potential explosive H2 mixture in LPR	Alarm
046	06/08/84	Recombiner	Cable on recombiner charred from high temp operation	Recombiner degraded	Operational Occurrence
252	07/29/86	Recombiner	Microswitch on recombiner shifted due to vibration, sent false signal	TWT isolated, GBs not purged adequately	Alarm
450	06/06/89	Humidity Indicator H-HPRA	Corrosion, humidity reading was off scale high	Loss of one instrument channel	Alarm
451	06/07/89	Humidity Indicator H-MCIN	Corrosion, humidity reading was out of calibration (high)	Loss of one instrument channel	Alarm
452	06/07/89	Humidity Indicator	Oil intrusion, humidity read out of calibration (low)	Loss of one instrument channel	Alarm

TABLE B-1. TRITIUM WASTE TREATMENT SYSTEM FAILURE REPORT SUMMARIES (continued)

Report Number	Event Date	Component of Interest	Failure Description and Cause	Failure Effect	Method of Detection
230	03/13/86	Humidity Indicator MSAEX	Unknown cause, humidity reading pegged	Loss of one instrument channel	Control instrumentation readout
107.1	04/01/85	Pressure transducer HPRB3	Aging of signal conditioning card, caused low reading	2 of 3 system, no immediate effect	Control instrumentation readout
127	06/18/85	Pressure Transducer HPRA3	Unknown cause, HPRA3 read low on actuation	2 of 3 system, no immediate effect	Operational Occurrence
372	04/18/88	Pressure Transducer HPRB3	Transducer failed, reading 0 output	2 of 3 system, no immediate effect	Alarm
017	12/22/83	T monitor	Short circuit prevented ion chamber from correct reading	No significant effect	Operational Occurrence
025	03/28/84	T monitor	Keithley model 616 T monitor electrometer unstable, cause is unknown	No significant effect	Operational Occurrence
053.1	06/24/84	T monitor	Ion chamber reads excessively high	Unknown	Operational Occurrence
053	07/23/84	T monitors (all units)	Spurious voltage transient, four units, unknown origin	Unknown	Operational Occurrence
055	06/07/84	T monitor RMBY	Keithley 616 unit read low during calibration, cause unknown	No significant effect	Maintenance testing

TABLE B-1. TRITIUM WASTE TREATMENT SYSTEM FAILURE REPORT SUMMARIES (continued)

Report Number	Event Date	Component of Interest	Failure Description and Cause	Failure Effect	Method of Detection
056	06/10/84	T monitor	Keithley 616 unit alarm is always on, cause unknown	Unknown	Alarm
057	07/20/84	T monitor RMBY	Cannot zero electrometer, cause unknown	Unknown	Operational Occurrence
064	09/26/84	T monitor RMBY	Keithley unit 616 would not zero, cause unknown	Unknown	Maintenance testing
065	10/04/84	T monitor RMBY	Keithley 616 unit from report #064 above still malfunctioning, cause unknown	Unknown	Operational Occurrence
075	12/21/84	T monitor	Short circuit prevented ion chamber from sending reading	No significant effect	Control instrumentation readout
126	06/14/85	T monitor RMBY	Possible short circuit, RMBY failed to indicate	Reduced T monitor redundancy	Control instrumentation readout
205	01/27/86	T monitors	Manual range changes cause monitor system to move into and out of automatic control	No significant effect	Operational Occurrence
242	07/15/86	T monitor RMEX	Wire broken during bias resistor modification, caused improper voltage	RMEX was inoperative	Alarm
391	07/09/88	T monitors	Room monitors began rising with a room alarm during MSB A was being regenerated	Potential that incorrect signals were existing in the system or that MCA A was leaking	Alarm

TABLE B-1. TRITIUM WASTE TREATMENT SYSTEM FAILURE REPORT SUMMARIES (continued)

Report Number	Event Date	Component of Interest	Failure Description and Cause	Failure Effect	Method of Detection
393	07/24/88	T monitor	When monitor goes thru a range change, wrong value is registered with MDAC	Potential for MDAC to act on wrong info	Operational Occurrence
* REPORTS ON TRITIUM LEAKAGE EVENTS AT TSTA *					
107	04/01/85	TWT system	Shutdown for new computer parameter entry. Pressure in Solid Waste Disposal and Inventory GBs increased	Small amount of untreated GB atmosphere sent thru bubblers and up the stack	Operator MMI inspection
136	07/23/85	Filter A	Pinhole leak in Cuno filter case	Leaked contaminated gas into room, unknown amount	Hissing heard during operator walkdown tour
165	10/03/85	Compressor A	Corrosion on vibration eliminator, lost integrity	Tritium gas leaked into room, unknown amount	Alarm
185	12/19/85	tubing	Leak in flexible connector between valve MCAI and moisture collector A.	Tritium concentration around tube was 100 microCi/m ³	Radiation alarms
362	05/29/87	T Monitor	Wrong monitor signal sent to MDAC, MDAC responded correctly to incorrect signal Cause is unknown. Monitor is left in constant range mode now to solve problem.	TSTA stacked about 1.5 Ci of T2 to the atmosphere The largest T2 release from the TWT.	Radiation alarm

APPENDIX C

TRITIUM WASTE TREATMENT SYSTEM
COMPONENT POPULATIONS AND DEMANDS

APPENDIX C
TRITIUM WASTE TREATMENT SYSTEM COMPONENT POPULATIONS AND DEMANDS

This appendix gives the Tritium Waste Treatment (TWT) system component identifiers, the total counts of the types of equipment found in the TWT, and the typical operational demands or operating hours that the components undergo on a yearly basis. The demand estimates were best estimates made by the TSTA operations staff, particularly by R. S. Dahlin, the TSTA operator responsible for the TWT, on February 12, 1990.

In the Tritium Waste Treatment System, there are:

2 electric heaters	6 filters
2 oil separators	2 moisture collectors
4 molecular sieve beds	2 compressors
2 gas chromatographs	4 radiation monitors
2 level monitors	1 manometer
5 moisture monitors	12 pressure monitors
11 temperature monitors	5 orifices
2 high pressure tanks	1 recombiner
4 check valves	1 low pressure receiver tank
69 motorized ball valves	10 safety valves
9 pressure regulators	1 flamestop
1 flow indicator	82 nonmotorized valves
2 input storage tanks	

Note that piping and fittings are not included in this appendix.

TABLE C-1. TSTA TWT COMPONENTS AND THEIR OPERATIONAL DEMANDS

<u>TWT Component Name & Identifier</u>	<u>Yearly Operational Demands</u>
Electric Heater 2	100 hours throughout year
Electric Heater 3	100 hours throughout year
Charcoal Filter A	50% of the year continuous operation
Charcoal Filter B	50% of the year continuous operation
Filter A	50% of the year continuous operation
Filter B	50% of the year continuous operation
Molecular Sieve Filter A	100% of the year
Molecular Sieve Filter C	100% of the year
Oil Separator A	50% of the year continuous operation
Oil Separator B	50% of the year continuous operation
Moisture Collector A	100 hours throughout the year
Moisture Collector B	100 hours throughout the year
Molecular Sieve Bed A	25% of the year continuous operation
Molecular Sieve Bed B	25% of the year continuous operation
Molecular Sieve Bed C	25% of the year continuous operation
Molecular Sieve Bed D	25% of the year continuous operation
Compressor A	75% of the year (0.33 hour time intervals per demand, see page A-3)
Compressor B	20% of the year continuous operation (note 5% of the year neither A or B run)
Gas Chromatograph A	4 weeks per year continuous operation
Gas Chromatograph B	4 weeks per year continuous operation
Sample Pump CAGA	50% of the year continuous operation
Sample Pump CAGC	50% of the year continuous operation
Radiation Monitor A	100% of the year
Radiation Monitor Bypass	100% of the year
Radiation Monitor C	100% of the year
Radiation Monitor EX	100% of the year
Level Monitor MCA	100% of the year
Level Monitor MCB	100% of the year
Manometer	100% of the year
Moisture Monitor HPRA	100% of the year
Moisture Monitor HPRB	100% of the year
Moisture Monitor MSAEX	100% of the year
Moisture Monitor MSCEX	100% of the year
Moisture Monitor MSCIN	100% of the year
Pressure Monitor CGA	100% of the year
Pressure Monitor HPRA1	100% of the year
Pressure Monitor HPRA2	100% of the year
Pressure Monitor HPRA3	100% of the year
Pressure Monitor HPRB1	100% of the year
Pressure Monitor HPRB2	100% of the year
Pressure Monitor HPBR3	100% of the year
Pressure Monitor ISAB	100% of the year
Pressure Monitor LPR1	100% of the year
Pressure Monitor LPR2	100% of the year
Pressure Monitor LPR3	100% of the year
Pressure Monitor RMEX	100% of the year
Temperature Monitor SGXA	100% of the year
Temperature Monitor GWXA1	100% of the year
Temperature Monitor GWXA2	100% of the year
Temperature Monitor GWXA3	100% of the year

TABLE C-1. (continued)

TWT Component Name & Identifier	Yearly Operational Demands
Temperature Monitor MSA	100% of the year
Temperature Monitor MSB	100% of the year
Temperature Monitor MSC	100% of the year
Temperature Monitor MSD	100% of the year
Temperature Monitor RECA1	100% of the year
Temperature Monitor RECA2	100% of the year
Temperature Monitor RECA3	100% of the year
Orifice 1	on-line all year
Orifice 2	on-line all year
Orifice 3	on-line all year
Orifice 4	on-line all year
Orifice STKOR	100% of the year
High Pressure Receiver A	50% of the year, 40 psia unit
High Pressure Receiver B	50% of the year, 1 psia standby unit
Input Storage A	Standby 100% of the year
Input Storage B	Standby 100% of the year
Low Pressure Receiver	100% of the year continuous operation
Recombiner A	100% of the year continuous operation
Check Valve 1 (stack exhaust)	Standby (no demands per year)
Check Valve 2 (comp outlet)	Standby (no demands per year)
Check Valve 3 (comp outlet)	Standby (no demands per year)
Check Valve 4 (stack exhaust)	Standby (no demands per year)
Motorized Valve CA1	720 valve transfer demands per year
Motorized Valve CA6	720 valve transfer demands per year
Motorized Valve CB1	720 valve transfer demands per year
Motorized Valve CB6	720 valve transfer demands per year
Motorized Valve CFA4	2 transfer demands per year
Motorized Valve CFB4	2 transfer demands per year
Motorized Valve FA1	2 transfer demands per year
Motorized Valve FA6	2 transfer demands per year
Motorized Valve FB1	2 transfer demands per year
Motorized Valve FB6	2 transfer demands per year
Motorized Valve HPRA1	2 transfer demands per year
Motorized Valve HPRB1	2 transfer demands per year
Motorized Valve HPRB6	2 transfer demands per year
Motorized Valve IS1	10 transfer demands per year
Motorized Valve IS2	2 transfer demands per year
Motorized Valve IS3	2 transfer demands per year
Motorized Valve IS4	2 transfer demands per year
Motorized Valve IS5	Removed from the system
Motorized Valve IS6	80 transfer demands per year
Motorized Valve LPR3	144 transfer demands per year
Motorized Valve LPR4	4 transfer demands per year
Motorized Valve MCA1	24 transfer demands per year
Motorized Valve MCA6	24 transfer demands per year
Motorized Valve MCB1	24 transfer demands per year
Motorized Valve MCB6	24 transfer demands per year
Motorized Valve MSA1	24 transfer demands per year
Motorized Valve MSA2	12 transfer demands per year
Motorized Valve MSA3	12 transfer demands per year
Motorized Valve MSA4	24 transfer demands per year

TABLE C-1. (continued)

TWT Component Name & Identifier	Yearly Operational Demands
Motorized Valve MSB1	24 transfer demands per year
Motorized Valve MSB2	12 transfer demands per year
Motorized Valve MSB3	12 transfer demands per year
Motorized Valve MSB4	24 transfer demands per year
Motorized Valve MSC1	24 transfer demands per year
Motorized Valve MSC2	12 transfer demands per year
Motorized Valve MSC3	12 transfer demands per year
Motorized Valve MSC4	24 transfer demands per year
Motorized Valve MSD1	24 transfer demands per year
Motorized Valve MSD2	12 transfer demands per year
Motorized Valve MSD3	12 transfer demands per year
Motorized Valve MSD4	24 transfer demands per year
Motorized Valve MSAB1	48 transfer demands per year
Motorized Valve MSABY	48 transfer demands per year
Motorized Valve MSCD2	48 transfer demands per year
Motorized Valve MSFA1	1 transfer demand per year
Motorized Valve MSFA6	1 transfer demand per year
Motorized Valve MSFC1	1 transfer demand per year
Motorized Valve MSFC6	1 transfer demand per year
Motorized Valve OSA1	2 transfer demands per year
Motorized Valve OSB1	2 transfer demands per year
Motorized Valve RCY1	80 transfer demands per year
Motorized Valve RCY2	80 transfer demands per year
Motorized Valve RECA1	2 transfer demands per year
Motorized Valve RECA6	2 transfer demands per year
Motorized Valve RECB1	0 transfer demands per year (NC)
Motorized Valve RECB6	0 transfer demands per year (NC)
Motorized Valve RMA1	80 transfer demands per year
Motorized Valve RMA6	80 transfer demands per year
Motorized Valve RMABY	2 transfer demands per year
Motorized Valve RMCBY	2 transfer demands per year
Motorized Valve RMBY5	2 transfer demands per year
Motorized Valve RMBY6	2 transfer demands per year
Motorized Valve RMC1	80 transfer demands per year
Motorized Valve RMC6	80 transfer demands per year
Motorized Valve Scram	0 transfer demands per year
	(safety valve is not tested)
Motorized Valve STK1	80 transfer demands per year
Motorized Valve STK2	80 transfer demands per year
Motorized Valve WS1	0 transfer demands per year
Motorized Valve WS6	0 transfer demands per year
Safety Valve RLF1	Standby operation
Safety Valve RLF2	Standby operation
Safety Valve RLF3	Standby operation
Safety Valve RLF4	Standby operation
Safety Valve RLF5	Standby operation
Safety Valve RLF6	Standby operation
Safety Valve RLF7	Standby operation
Safety Valve RLF8	Standby operation
Safety Valve RLF10	Standby operation
Safety Valve RLF11	Standby operation

TABLE C-1. (continued)

TWT Component Name & Identifier	Yearly Operational Demands
Pressure Regulator BPR1A	100% of the year continuous operation
Pressure Regulator BPR1B	100% of the year continuous operation
Pressure Regulator BPR2A	100% of the year continuous operation
Pressure Regulator BPR2B	100% of the year continuous operation
Pressure Regulator BPR4	100% of the year continuous operation
Pressure Regulator PRV1	100% of the year
Pressure Regulator PRV2	100% of the year
Pressure Regulator PRV3	100% of the year
Pressure Regulator PRV4	100% of the year
Flamestop FS1	100% standby passive operation
Flow Indicator F1	100% of the year
Nonmotorized Valve CA2	24 transfer demands per year
Nonmotorized Valve CA3	24 transfer demands per year
Nonmotorized Valve CA4	24 transfer demands per year
Nonmotorized Valve CA5	24 transfer demands per year
Nonmotorized Valve CA7	24 transfer demands per year
Nonmotorized Valve CAGA1	4 transfer demands per year
Nonmotorized Valve CAGA2	4 transfer demands per year
Nonmotorized Valve CBGA1	4 transfer demands per year
Nonmotorized Valve CBGA2	4 transfer demands per year
Nonmotorized Valve CFA3	0 transfer demands per year (NC)
Nonmotorized Valve CFB3	0 transfer demands per year (NC)
Nonmotorized Valve FA2	0 transfer demands per year (NC)
Nonmotorized Valve FA5	0 transfer demands per year (NC)
Nonmotorized Valve FB2	0 transfer demands per year (NC)
Nonmotorized Valve FB5	0 transfer demands per year (NC)
Nonmotorized Valve CABY	0 transfer demands per year (NO)
Nonmotorized Valve HPRA2	8 transfer demands per year
Nonmotorized Valve HPRA3	0 transfer demands per year (NO)
Nonmotorized Valve HPRA4	0 transfer demands per year (NO)
Nonmotorized Valve HPRA5	8 transfer demands per year
Nonmotorized Valve RMEX1	0 transfer demands per year (NO)
Nonmotorized Valve RMEX2	0 transfer demands per year (NC)
Nonmotorized Valve RMEX3	0 transfer demands per year (NO)
Nonmotorized Valve RMEX4	0 transfer demands per year (NO)
Nonmotorized Valve RMEX5	0 transfer demands per year (NC)
Nonmotorized Valve RMEX6	0 transfer demands per year (NO)
Nonmotorized Valve WS2	0 transfer demands per year (NC)
Nonmotorized Valve WS3	0 transfer demands per year (NC)
Nonmotorized Valve WS4	0 transfer demands per year (NC)
Nonmotorized Valve WS5	0 transfer demands per year (NC)
Nonmotorized Valve IG2	0 transfer demands per year (NO)
Nonmotorized Valve IG5	0 transfer demands per year (NO)
Nonmotorized Valve IG6	0 transfer demands per year (NO)

TABLE C-1. (continued)

TWT Component Name & Identifier	Yearly Operational Demands
Nonmotorized Valve HPRA7	8 transfer demands per year
Nonmotorized Valve HPRB2	8 transfer demands per year
Nonmotorized Valve HPRB3	0 transfer demands per year (NO)
Nonmotorized Valve HPRB4	0 transfer demands per year (NO)
Nonmotorized Valve HPRB5	8 transfer demands per year
Nonmotorized Valve HPRB7	0 transfer demands per year (NC)
Nonmotorized Valve MCA2	6 transfer demands per year
Nonmotorized Valve MCA5	6 transfer demands per year
Nonmotorized Valve MCAB1	0 transfer demands per year (NO)
Nonmotorized Valve MCAB2	0 transfer demands per year (NC)
Nonmotorized Valve MCAB3	0 transfer demands per year (NO)
Nonmotorized Valve MCB2	6 transfer demands per year
Nonmotorized Valve MCB5	6 transfer demands per year
Nonmotorized Valve MSAB2	0 transfer demands per year (NC)
Nonmotorized Valve MSAB3	0 transfer demands per year (NO)
Nonmotorized Valve MSCD2	0 transfer demands per year (NC)
Nonmotorized Valve MSCD3	0 transfer demands per year (NO)
Nonmotorized Valve MSFA2	0 transfer demands per year (NC)
Nonmotorized Valve MSFA5	0 transfer demands per year (NC)
Nonmotorized Valve MSFA7	0 transfer demands per year (NC)
Nonmotorized Valve MSFC2	0 transfer demands per year (NC)
Nonmotorized Valve MSFC5	0 transfer demands per year (NC)
Nonmotorized Valve MSFC7	0 transfer demands per year (NC)
Nonmotorized Valve GA1	0 transfer demands per year (NO)
Nonmotorized Valve GA2	0 transfer demands per year (NO)
Nonmotorized Valve GA3	0 transfer demands per year (NO)
Nonmotorized Valve GB1	0 transfer demands per year (NO)
Nonmotorized Valve GB2	0 transfer demands per year (NO)
Nonmotorized Valve GB3	0 transfer demands per year (NO)
Nonmotorized Valve OSA2	0 transfer demands per year (NC)
Nonmotorized Valve OSB2	0 transfer demands per year (NC)
Nonmotorized Valve RCY3	0 transfer demands per year (NO)
Nonmotorized Valve RECA2	0 transfer demands per year (NC)
Nonmotorized Valve RECA5	0 transfer demands per year (NC)
Nonmotorized Valve RECB2	0 transfer demands per year (NC)
Nonmotorized Valve RECB5	0 transfer demands per year (NC)
Nonmotorized Valve RMA2	0 transfer demands per year (NC)
Nonmotorized Valve RMA3	0 transfer demands per year (NO)
Nonmotorized Valve RMA4	0 transfer demands per year (NO)
Nonmotorized Valve RMA5	0 transfer demands per year (NC)
Nonmotorized Valve RMBY1	0 transfer demands per year (NC)
Nonmotorized Valve RMBY2	0 transfer demands per year (NO)
Nonmotorized Valve RMBY3	0 transfer demands per year (NO)
Nonmotorized Valve RMBY4	0 transfer demands per year (NC)
Nonmotorized Valve RMC2	0 transfer demands per year (NC)
Nonmotorized Valve RMC3	0 transfer demands per year (NO)
Nonmotorized Valve RMC4	0 transfer demands per year (NO)
Nonmotorized Valve RMC5	0 transfer demands per year (NC)

Note: NC means normally closed, NO means normally open

APPENDIX D

TRITIUM SYSTEMS TEST ASSEMBLY

FAILURE/MAINTENANCE DATA FORMS

APPENDIX D

TRITIUM SYSTEMS TEST ASSEMBLY FAILURE/MAINTENANCE DATA FORMS

This appendix shows examples of the data collection forms that are placed in strategic locations around the facility. The part I and part II forms are shown. More information about these forms is found in the main report and its references.

TSTA FAILURE AND CORRECTIVE MAINTENANCE REPORT FORM 1

Subsystem _____ Originator _____ Report Date ____/____/____

TSTA Parameter No. or Name _____ Event Date ____/____/____ Event Time ____:____:____

Subsystem Parameters at Time of Failure _____

Subsystem Configuration at Time of Failure _____

Method of Detection _____ Occurrence Title _____

Event Narrative _____

Initial (Immediate) Action _____

.....

COMPONENT FAILURE DATA (Originator - complete the remainder of this form as fully as possible)

Component Description _____

Cause: Software ____ Personnel ____ Material ____ Design ____ Procedure ____ Other (Specify) _____

Failure Cause Narrative _____

Failure Effects: Subsystem: _____ Hours Lost _____

Unit: _____ Hours Lost _____

Other Items Affected: _____

Proposed Long-Term Corrective Action _____

Remarks _____

TSTA Report Number (filled in by QA) _____

TSTA FAILURE AND CORRECTIVE MAINTENANCE REPORT FORM 2

TSTA Report Number (filled in by QA) _____ Corrective Action Taken: Corrected by TSTA Operational Personnel _____

Corrected by TSTA Repair/Design Personnel _____

Other (Specify) _____

Failed Component _____ Serial Number _____ Model Number _____

Critical Part (s) _____

Problem with Component: Electrical _____ Mechanical _____ Software _____ Other (Specify) _____

Describe Corrective Maintenance Taken to Correct Failure _____

Special Maintenance Equipment Required _____

Time Required for Component Repair/Replacement (hours/manhours) (i) Total ____/____ (ii) Administrative ____/____

(iii) Logistics ____/____ (iv) Indirect Repair ____/____ (v) Direct Repair ____/____ (vi) Retest ____/____

(vii) Restart ____/____

Time Since Last (1) Maintenance _____ (ii) Testing _____

Unusual Circumstances Causing Long or Short Repair/Replacement Time:

Assessability _____ Size and Weight of Component _____ Connections _____ Contamination _____ (Level _____)

Other (Specify) _____

Method Used for Verification of System Operational Status _____

Corrective Action Completed On ____/____/____ By _____

-END-

DATE FILMED

01 / 28 / 91