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Comparison of Tritium Component Failure Rate Data

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Tritium Fuel Handling is an Important Safety Issue

- *Why collect these data?*
  - *Tritium releases can be a dominant contributor to offsite doses*
  - *Studying reliability can support design and operation of tritium systems and support the safety case for these systems*
  - *Other endeavors have tritium experience, but those facilities are licensed by different governmental branches or agencies*
    - *Military*
    - *Commercial fission*
- *Fusion tritium licensing is expected to proceed in "stair steps"*
  - *JET licensed the PTE at 0.1 g-T, and the DTE at 20 g-T*
  - *TFTR licensed its D-T phase at 5 g-T*
- *JET and TFTR used both traditional safety analysis and probabilistic safety assessment to make the safety case for licensing with tritium*
- *ITER expects < 3 kg-T on site; ITER may follow the path of JET and TFTR, depending on the chosen site. These data can support probabilistic safety assessment for fusion facilities.*

Several Facilities have Collected Operating Experience Data

- *The US Tritium Systems Test Assembly at Los Alamos*
  - *Part of the TSTA mission was to demonstrate safety and reliability; the staff collected data for ~10 years and shared data for analysis*
  - *TSTA is now undergoing final decommissioning*
- *The Tritium Process Laboratory at Naka has collected data and analyzed the data to obtain failure rates*
- *The JET Joint Undertaking collected data on the Active Gas Handling System and shared the data for analysis*
- *The Tritium Laboratory Karlsruhe has collected operations experience data and shared the data for analysis*
- *Data collection is the most difficult aspect of this work, and we are fortunate to have several facilities agreeing to collect and share data*

Data Analysis has Produced Several Failure Rate Data Sets

- *Tritium Systems Test Assembly at Los Alamos*
  - *Tritium Waste Treatment System*
  - *Gloveboxes*
  - *Room Air Monitors*
  - *Room Air Tritium Cleanup System*
- *JET Joint Undertaking*
  - *Active Gas Handling System*
- *Tritium Process Laboratory*
  - *Safety Systems, and an update for the Safety Systems*
- *Tritium Laboratory Karlsruhe*
  - *Tritium-bearing systems*
- *Normally, the data are sparse for fusion systems. The staff at each of these facilities has recognized the value of collecting the operating experience data and allowing the data to be analyzed.*

The 4 Sets of Failure Rate Data Values have been Compared

- *The International Energy Agency in Brussels has a fusion safety task on component failure rate data, these data will be shared with task participants*
- *The IEA data task participants have agreed that when comparing data*
  - *Values agreeing within a factor of 3 are Good agreement*
  - *Values agreeing within a factor of 10 are Fair agreement*
  - *Values differing more than a factor of 10 are Poor agreement*
- *The components that could be compared included compressors, blowers, gloveboxes, tritium monitors, oxygen monitors, valves, and humidity monitors*
- *Of the 12 comparable components and their 17 failure modes, over half were Good, only a few were Fair, and the remainder were Poor*
- *Overall, the result is a reasonably good comparison of the data sets*
- *For facilities of similar size, age and missions, we expect that the failure rates should be within 10x of each other, unless there are*
  - *Differences in operation, that change the stresses placed on components*
  - *Differences in maintenance, preventive vs predictive vs corrective*
  - *Differences in environment, such as humidity or temperature*

The 4 Data Sets were Combined to Give "Generic" Failure Rates

- *The main use for so-called "generic" failure rates is to quantify conceptual designs that require first order estimates of system reliability*
  - *Usually only the type of component or the component function is known in conceptual design studies*
  - *These values can be used to estimate frequencies of off-normal events in tritium systems*
- *To create generic values, the failure rates for comparable components were averaged using a geometric mean*
- *A few values from the generic data results are given below:*

Tritium room air monitor, reads high or reads low

- *$3x10^{-6}$/hour, error factor of 3.3*

Glovebox pressure controller, fails by over- or under-pressure

- *0.1/year, error factor of 3*

Manual valve, fails to operate when required

- *$1x10^{-3}$/demand, error factor of 3*

Conclusions

- *Probabilistic safety assessment and traditional safety analysis have been used together to make the safety case for fusion D-T operations.*
- *Fusion component failure rates are usually sparse; in this case there are 4 data sets. Time and resources have been devoted to record and analyze these data. These data are valuable; they are truly fusion-specific component failure rates. Collecting these data is a part of demonstrating that tritium can be handled safely.*
- *The data compared reasonably well, and these data sets can support probabilistic safety assessment of tritium facilities.*
- *The generic data can support conceptual design studies.*
- *Each of the four data sets will be shared with the IEA participants and with any fusion designs that request data support.*
- *Data work will continue with the facilities still in operation.*