National Aeronautics and
Space Administration
John C. Stennis Space Center
Stennis Space Center, MS 39529-6000

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Attn: VA60/RKW03003

TO: VA00/Director, Propulsion Test Directorate
QA00/Chief, Office of Safety & Mission Assurance

FROM: VA60/Kern Witcher

SUBJECT: Evaluation of Assistant to the Inspector General Letter dated December 23, 2002

In January of 2003, the PTD Deputy Director assigned a tiger team to evaluate concerns outlined in the above referenced letter from the Assistant to the Inspector General. Please find attached the team's evaluation, findings and recommendations addressing the use of Monel in high-pressure oxygen systems. This evaluation is a culmination of discussions held over the last month with team members and technical advisors. All team members have concurred with this document.

Should you have any questions, please contact any of the team members or myself.

Kern Witcher
Team Lead

Attachment

cc:
RA10/L. deQuay
QA00/D. Moore
VA60/M. Yentzen
USM/H. Haselmeiar

Evaluation of

Assistant Inspector General for Audits
Assignment A-02-020-00
Potential Safety Hazard with the Use of Monel Stem Plugs in High-Pressure Liquid Oxygen Valves

Concurrence:

Larry deQuay

Haynes Haselmaier

Daryl Moore

Michael Yentzen

Kern Witcher

Background

On December 23, 2002 the Director of Stennis Space Center received a letter from the assistant Inspector General (IG) for Audits identifying a potential safety hazard that could adversely affect the Center's propulsion test mission. Specifically, the IG identified the use of Monel stem plugs in stainless steel bodies for liquid or gaseous oxygen service as an area of concern. As a result of that letter, the Deputy Director of the Propulsion Test Directorate assigned a team to evaluate the concern and make specific recommendations if the concern is valid. The team is required to provide a response by February 3, 2003.

Objective

The objective of this effort is to address the concerns expressed by the NASA Inspector General's Office in regard to the use of Monel in severe service oxygen systems. During the review of documentation and drawings associated with an unrelated audit, the IG identified a minority technical opinion indicating a preference of stainless steel over Monel in oxygen service. The technical opinion suggested that the use of a Monel stem plug in a stainless steel body in oxygen service actually represents an increased hazard over using a 300 series stainless steel plug in a stainless steel body.

The context and specific concern noted in the Inspector General letter is generalized. The technical opinion made by the SSC representative concentrated on the following specific configuration and potential use of a valve:

- The valve has experienced galling to the point that the design clearances have been compromised.
- The valve is operated in a deep throttling position (10% or less) and under a closed-loop control scheme at high pressure or highly transient flow conditions in an oxygen system.
- The heat generated from friction (Monel to stainless or stainless to stainless) between the stem/plug and body assemblies may be sufficient to cause an ignition and sustained combustion of the parts.

Findings

As a result discussions with the team and technical advisors, the following findings have been developed:

- Monel is typically reserved for applications where energy levels cannot be otherwise mitigated to a level that allow the use of more sensitive materials such as stainless steel. Based on operational experience and considerable material test data, Monel is frequently the preferred material for severe oxygen service because it is extremely difficult to ignite and is more resistant to combustion at higher pressures and temperatures than stainless steel.

- Stainless steel is used where analysis indicates the actual energy levels are sufficiently low and the risk of a more flammable material is acceptable. Stainless steel, when used within acceptable operating conditions, is often the preferred material due to its lower cost and increased availability.

- The technical opinion concluded (based on standard ASTM gall test data from the manufacturer, selected ASTM oxygen compatibility test data, and observed post-service condition of selected valve stem-plugs and guides) that Monel stem plugs in a specific valve design would experience severe galling whereas stainless plugs in the same application would not. Operational experience shows that valves having stainless plugs with this design have galled to varying degrees as well. Based on this recent experience, galling is likely to be experienced in this design and application regardless of the material. The use of Monel, in this particular design, could offer an increased resistance to ignition and margin of safety above the use of stainless steel.

- The galling issue of the existing plug and liner assemblies (regardless of the stem material issue) is being effectively addressed by adjustments to the clearances, tolerances, and surface finishes as well as an increased level of attention to quality control during parts machining and manufacturing processes. Additional improvements are actively being investigated such as different bronze liner materials or the same material with modified physical characteristics such as increased surface hardness properties. Low-friction plating and coating materials are also being considered as a means to mitigate excessive wear and galling.

- In practice, high-pressure oxygen valves have not been operated in deep throttling (10% or less) positions in closed-loop control.

- To date, SSC test stands have not had a test program nor experienced an event where the conditions outlined in the technical opinion existed. Furthermore, the operation of an oxygen valve in the conditions described in the technical opinion is not anticipated for any future test programs at this time.

Conclusion

The selection of materials for any high pressure oxygen application is a highly specialized process that considers many critical factors including the design of the valve, the design of the system in which it is installed, operating conditions, and other factors as well. Consideration is always given to proven guidelines and standards such as NSS 1740.15 NASA Oxygen Safety Standard, American Society for Testing and Materials (ASTM) G94, G128 as well as others. A credible material selection process always seeks to mitigate the risk and at the same time exercise practicality in achieving a configuration which is safe and reliable. To state that it is inappropriate that any material (i.e. Monel) is universally accepted and necessarily required for oxygen service without considering all the operational conditions and factors is not sound engineering practice. Neither is it appropriate to suggest more sensitive materials (i.e. 300 stainless steel) are never an appropriate choice.

Stennis Space Center has several checks in place, which continuously and effectively address concerns of oxygen safety. The consideration of oxygen safety begins with the design of the system, the specification and manufacturing of oxygen components, and continues through the installation, operation, and maintenance of these critical items in operating systems. Each repair cycle of every valve is carefully scrutinized to ensure that every reasonable precaution toward operating safety has been taken. Additionally, valves are routinely inspected with a borescope to monitor the condition of critical parts and surfaces. The specific design of the valve, its materials of construction, where it is installed and its duty cycle, as well as the growing body of operating experience are always a part of the screening and approval process. One of the many important functions of the safety review board (which authorizes the activation of test systems) is to review each component in a high-pressure oxygen system and ensure the risks associated with its use are reasonable and well understood.

Monel 400 and Monel K500 are recommended to remain primary candidate materials for severe oxygen service at Stennis Space Center as well as other facilities with similar systems. Monel is not the only material, which can be used in high-pressure oxygen systems. Stainless steel, various bronze alloys, and many other metals and nonmetals are appropriate if employed with sufficient design margin and consideration of the operational environment.