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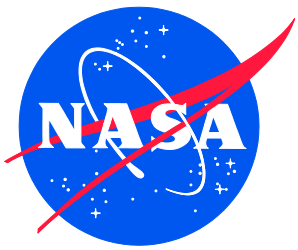
NESC-RP-15-01039



Glenn Extreme Environments Rig (GEER) Independent Review

Robert S. Jankovsky/NESC and Michael D. Smiles/NESC
Langley Research Center, Hampton, Virginia

Mark A. George
Glenn Research Center, Cleveland, Ohio

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Jet Propulsion Laboratory, Pasadena, California

Son K. Le
Stennis Space Center, Mississippi

October 2015

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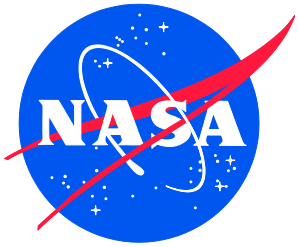

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Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

October 2015

Acknowledgments

The NESC team would like to acknowledge Mrs. Lori Arnett for assuring that the NESC team had access to whomever and whatever information was requested. Her efforts were essential to the efficient completion of this assessment. The NESC team also would like to acknowledge the following individuals for their openness during the facility inspections and tabletop discussion:

- Leah Nakley – Lead Operations
- Ken Gregg – Mechanical Design
- Joe Rymut – Electrical Design
- Alex Sgondea – Electrical Design
- Jim Mullins – Facility Engineer
- Rodger Dyson – Mechanical Design
- Lori Arnett – Facility Manager
- Dan Vento – Project Manager
- Jim Hritz – Safety/Hazard Analysis
- Tim Fiorilli – Industrial Hygienist
- Chuck Druesedow – Pressure Systems Office

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Fax: 757-864-6500

Glenn Extreme Environments Rig (GEER) Independent Review

September 10, 2015

Report Approval and Revision History

NOTE: This document was approved at the September 10, 2015, NRB. This document was submitted to the NESC Director on September 17, 2015, for configuration control.

Approved:	Original Signature on File	9/17/15
	NESC Director	Date

Version	Description of Revision	Office of Primary Responsibility	Effective Date
1.0	Initial Release	Mr. Robert Jankovsky, NESC Chief Engineer, GRC	9/10/15

Table of Contents

Technical Assessment Report

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Technical Assessment Report

1.0 Notification and Authorization

The Chief of the Space Science Project Office at Glenn Research Center (GRC) requested support from the NASA Engineering and Safety Center (NESC) to satisfy a request from the Science Mission Directorate (SMD) Associate Administrator and the Planetary Science Division Chief to obtain an independent review of the Glenn Extreme Environments Rig (GEER) and the operational controls in place for mitigating any hazard associated with its operation.

Mr. Robert Jankovsky, NESC Chief Engineer at NASA GRC, was selected to lead this assessment.

The key stakeholders for this assessment are the NASA SMD, GRC, and the planetary science community.

2.0 Signature Page

Submitted by:

Team Signature Page on File – 9/22/15

Mr. Robert S. Jankovsky Date

Significant Contributors:

Mr. Michael D. Smiles Date

Mr. Mark A. George Date

Ms. Mimi C. Ton Date

Mr. Son K. Le Date

Signatories declare the findings, observations, and NESC recommendations compiled in the report are factually based from data extracted from program/project documents, contractor reports, and open literature, and/or generated from independently conducted tests, analyses, and inspections.

3.0 Team List

Name	Discipline	Organization
Core Team		
Robert Jankovsky	NESC Lead	GRC
Michael Smiles	NESC Chief Engineer	SSC
Mark George	Hazards Analyses	NSC
Mimi Ton	Industrial Hygiene	JPL
Son Le	Pressure Systems	SSC
Linda Moore	MTSO Program Analyst	LaRC
Administrative Support		
Erin Moran	Technical Writer	LaRC/AMA

3.1 Acknowledgements

The NESC team would like to acknowledge Mrs. Lori Arnett for assuring that the NESC team had access to whomever and whatever information was requested. Her efforts were essential to the efficient completion of this assessment. The NESC team also would like to acknowledge the following individuals for their openness during the facility inspections and tabletop discussion:

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- Lori Arnett – Facility Manager
- Dan Vento – Project Manager
- Jim Hritz – Safety/Hazard Analysis
- Tim Fiorilli – Industrial Hygienist
- Chuck Druesedow – Pressure Systems Office

4.0 Executive Summary

Ms. Ann Over, Chief of the Space Science Project Office at Glenn Research Center (GRC), requested this assessment to satisfy a request from the Science Mission Directorate (SMD) Headquarters leadership for an independent review of the Glenn Extreme Environments Rig (GEER) hazards due to its large scale compared to what historically has been done [ref. 1].

The assessment included a review of existing GEER documentation (Section 6.0 Documentation) and a 1-day on-site inspection of the rig/facility (Section 5.0 Rig/Facility Description), including a tabletop review with the project/facility engineering team that designed and built the GEER.

The NASA Engineering and Safety Center (NESC) team found the hazards (high temperature, high pressure, toxic gases) inherent to GEER had been thoroughly and systematically addressed and concurred the transition from commissioning to operations should continue. All other findings were considered minor. Three of the remaining findings were minor discrepancies between documents and the as-built rig, or documented procedures, and those verbally discussed. These discrepancies should be eliminated and changes to procedures reviewed with the operators. Four findings had to do with the main pressure vessel (referred to as TM9001), and maintaining its integrity and history for future recertification. The first of these four findings was that although the facility engineering team considered creep of the TM9001, they did not have a procedure for documenting the cycles, pressure, and temperature to support potential future analyses at different operating conditions.

In the second of the four related findings, the NESC team noted that although the facility engineering team had identified the facility sprinkler system activation while at temperature as a possible hazard, and closed it after testing, the hot vessel could not set off the sprinklers even without the ventilation system operating. The team did not consider other inadvertent sprinkler system activation, and as such have not completely considered the potential for rapid cooling of the TM9001 causing loss of containment.

In the third related finding, the NESC team also found that in at least one instance pressure drop calculations on a pressure relief valve did not consider pipe diameter in accordance with American Society of Mechanical Engineer (ASME) Section VIII, Division 1 allowances.

In the final related finding, the NESC team found that corrosion under the TM9001 insulation was not considered in accordance with American Petroleum Institute (API)-571 and is recommending an inspection/monitoring procedure be added.

Lastly, it was found that the control room had no visual monitoring of the test cell. Although procedures are in place to ensure the area is clear before flowing gases, the NESC team recommends that a video system be installed.

In all cases, the Space Science Project Office and facility engineering team at GRC has accepted all of the findings and NESC recommendations and has either already completed them or they are in work.

5.0 Rig/Facility Description

NASA recently started the commissioning process of the GEER (Figure 5.0-1), located in Building 334 (Figure 5.0-2) at GRC. The GEER is designed to simulate the temperature, pressure, and atmospheric compositions of bodies in the solar system, including those with acidic and hazardous elements.

The GEER consists of a 0.79m^3 (28ft^3), 304 stainless steel pressure vessel with Inconel® sheathed resistance heaters and a Maximum Allowable Working Pressure (MAWP) of 10.47 MPa (1518 psia) at 538ºC (1000ºF) (Figure 5.0-3); four gas cabinets to store up to eight gas cylinders (Figure 5.0-4); a gas mixing cabinet to precisely mix the desired gas chemical composition (Figure 5.0-5); a gas booster to maintain the test conditions over a long period of time with allowable leaks (Figure 5.0-6); a Fourier Transform Infrared (FTIR) Spectrometer to measure chemical composition (Figure 5.0-7); and a vent stack to exhaust gases outside the facility (Figure 5.0-8).

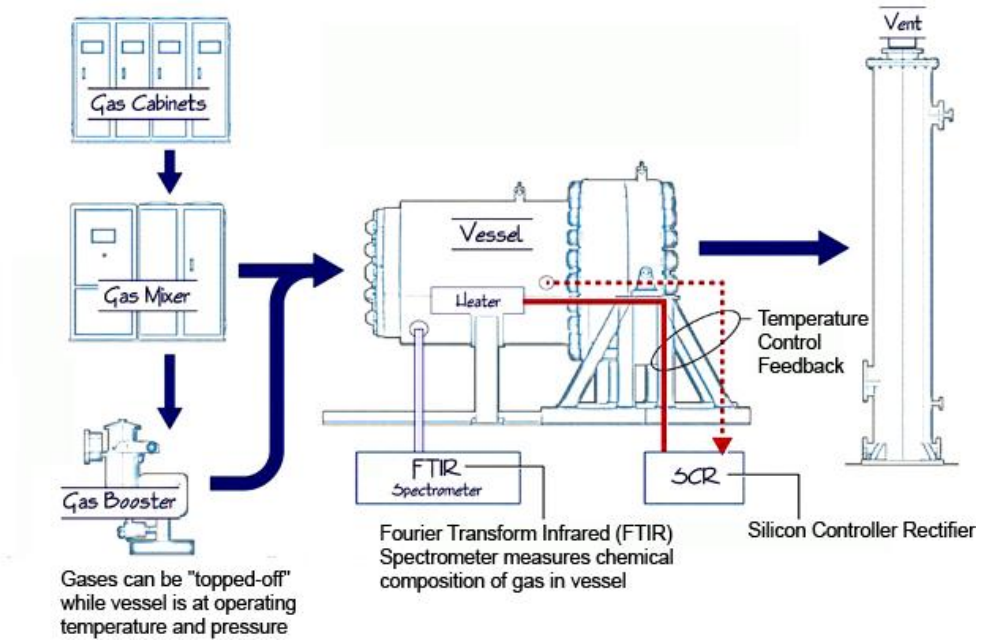

Figure 5.0-1. GRC GEER

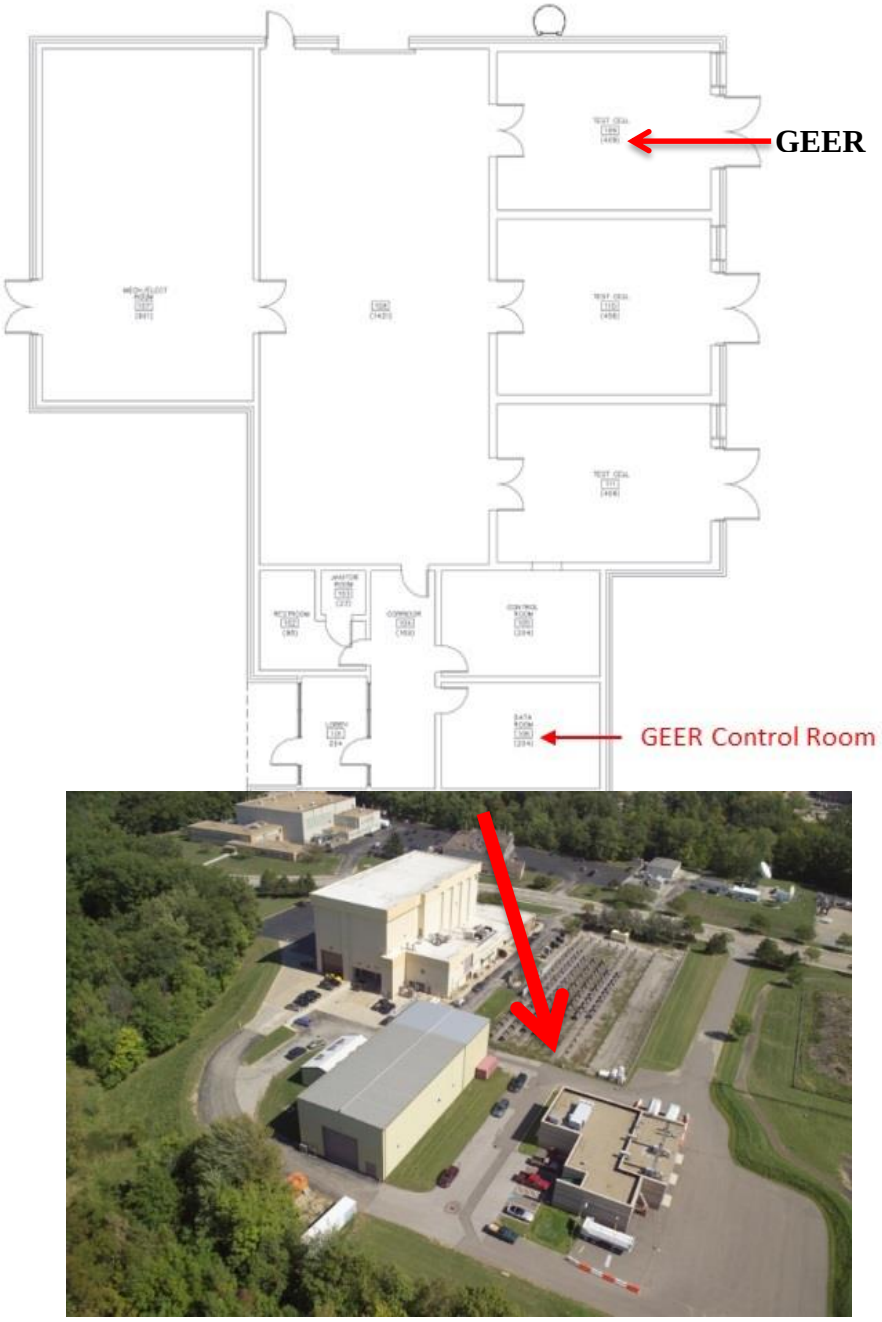

Figure 5.0-2. GRC Building 334

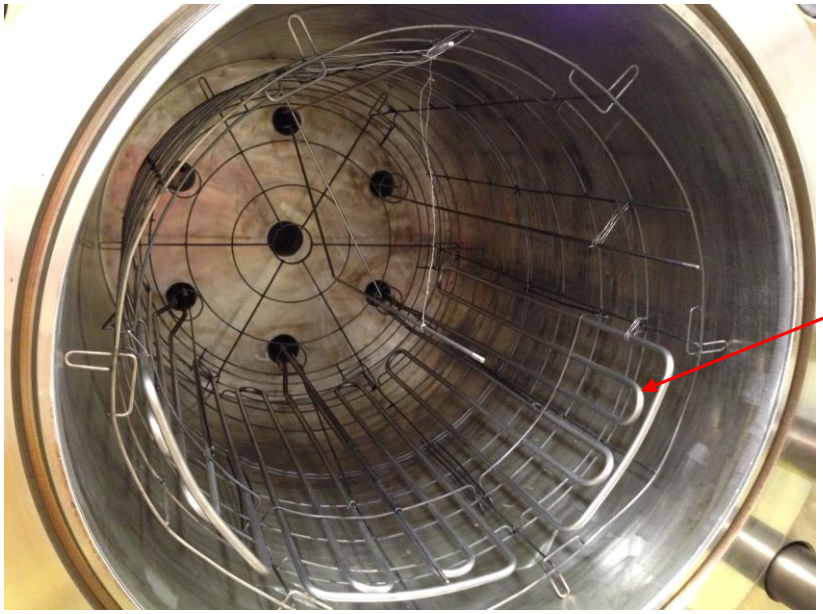

Figure 5.0-3. Pressure Vessel

Figure 5.0-4. Gas Cabinets

Figure 5.0-5. Mixing Cabinet

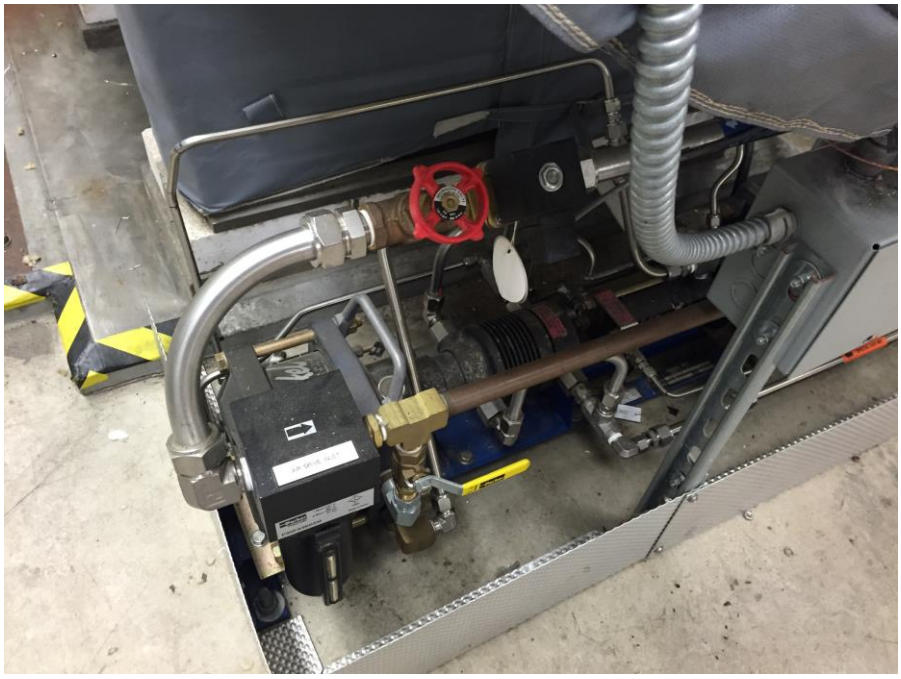

Figure 5.0-6. Gas Booster

Figure 5.0-7. FTIR Spectrometer

Figure 5.0-8. Vent Stack

Currently, GEER is configured for Venus surface conditions (Table 5.0-1) and is in the commissioning phase.

Table 5.0-1. GEER Configuration during Commissioning

Chemical Species	96.5% carbon dioxide (CO_2)
	~3.4% nitrogen (N_2)
	130 ppm sulfur dioxide (SO_2)
	5 ppb hydrogen fluoride (HF)
	0.5 ppm hydrogen chloride (HCl)
	15 ppm carbon monoxide (CO)
	27 ppm carbonyl sulfide (OCS)
	30 ppm water (H_2O)
Temperature	470ºC (878ºF)
Pressure	9.24 MPa (1340 psi)

A simplified outline of operations for the GEER is as follows: 1) the test operations start by purging and evacuating the TM9001; 2) component gasses are then blended using the gas mixer; 3) the TM9001 is filled with the desired gas mixture up to 3.45 MPa (500 psi) (at ambient temperature) for the desired end-state chemistry; 4) heat is applied and controlled autonomously to bring the system to a steady-state operating point; and 5) after testing, chamber and plumbing are vented and purged.

6.0 Documentation

The NESC team was provided access to all project documentation for review. Figures 6.0-1 through 6.0-8 summarize the documentation that was made available to the NESC team. The NESC team selectively reviewed these documents with a focus on the hazards analyses, pressure systems, industrial hygiene, and procedures (e.g., startup, shutdown, and operating/emergency).

Figure 6.0-1. Electronic Folders with All Documentation Provided for Review

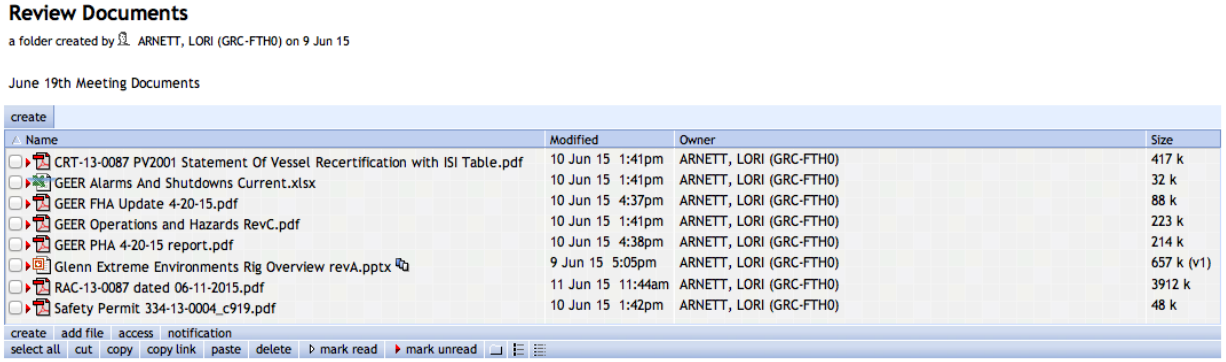

Figure 6.0-2. Review Documents Folder Contents

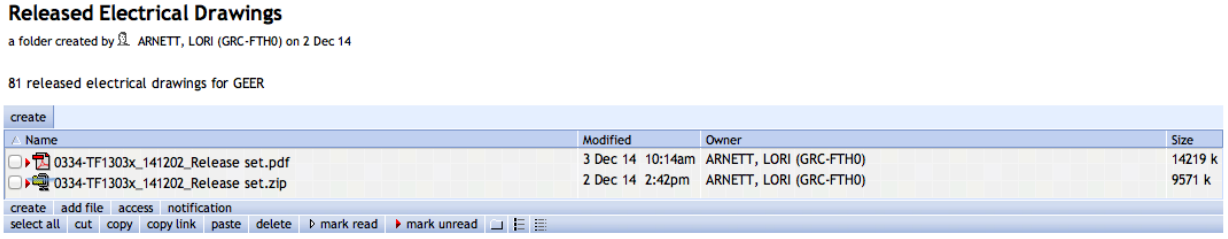

Figure 6.0-3. Released Electrical Drawings Folder Contents

PSO Questions_Answers_Supporting Documentation

a folder created by Nick Lalli on 17 Apr 14

create

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Audit Question Responses 2 - 3-17-14 Final.pdf	18 Apr 14 1:32pm	Nick Lalli	250 k
Audit question responses 3-17-14 Final.pdf	18 Apr 14 1:32pm	Nick Lalli	460 k
GEER Audit Documentation Supplement 1.pdf	18 Apr 14 1:23pm	Nick Lalli	9141 k
GEER Audit Documentation Supplement 2.pdf	18 Apr 14 1:23pm	Nick Lalli	9981 k
MTI 2013 18_PSO_CO2.pdf	18 Apr 14 1:27pm	Nick Lalli	54780 k
MTI 2013 19_PSO_GN.pdf	18 Apr 14 1:27pm	Nick Lalli	49167 k
MTI 2013 20_PSO_HP_GN.pdf	18 Apr 14 1:27pm	Nick Lalli	47158 k
MTI 2013 23_PSO_MGS.pdf	18 Apr 14 1:28pm	Nick Lalli	135379 k
Obsolete Chromalox Heater & New 3 Heater Configuration.pptx	18 Apr 14 1:28pm	Nick Lalli	2154 k
Pressure Vessel PV2001_PSO_GEER.pdf	18 Apr 14 1:28pm	Nick Lalli	150775 k
PSO_B334_MGS_MTI 2013 23.pdf	18 Apr 14 1:29pm	Nick Lalli	135379 k
PSO_PV2004_PV1818.pdf	18 Apr 14 1:29pm	Nick Lalli	17646 k
PV2000_GEER Accumulator.pdf	18 Apr 14 1:29pm	Nick Lalli	33994 k
PV2003_PV1819.pdf	18 Apr 14 1:29pm	Nick Lalli	17971 k

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Figure 6.0-4. PSO Supporting Documentation Folder Contents

PSO Drawings

a folder created by Nick Lalli on 17 Apr 14

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Figure 6.0-5. PSO Drawings Folder Contents

Checksheets

a folder created by ARNETT, LORI (GRC-FTH0) on 10 Jun 15

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Figure 6.0-6. Checksheets Folder Contents

7150 Documents

a folder created by Nick Lalli on 24 Apr 14

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GEER Alarm and Shutdown summary 10242013.docx	24 Apr 14 2:39pm	Nick Lalli	36 k
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Figure 6.0-7. 7150 Documents Folder Contents

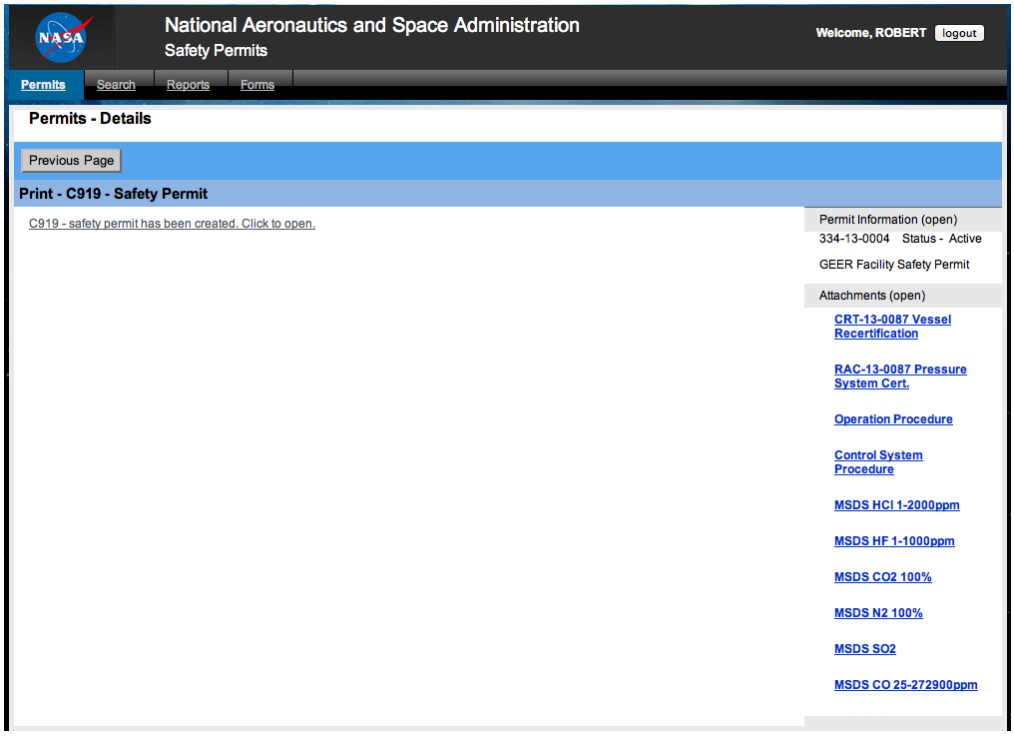

Figure 6.0-8. On-line Safety Permit System with Links to PSO Certifications and Operation Procedures

7.0 Findings and NESC Recommendations

7.1 Findings

The following findings were identified:

F-1. The Process Hazards Analysis (PHA) and Facility Hazards Analysis (FHA) were complete and up to date. The inherent hazards of high pressure, high temperature, and toxic gases were thoroughly and systematically addressed.

F-2. No procedure exists for documenting the operational history (e.g., cycles, pressure, and temperature) of the 304 stainless steel TM9001.

F-3. There is a potential for thermal shock to the GEER TM9001 if the wet fire suppression system in the test cell is inadvertently activated.

F-4. The pressure system relief valve inlet piping pressure drop calculation did not consider changes in pipe diameter.

F-5. The cited MAWP were not consistent across data sources (e.g., Piping and Instrumentation Diagram (P&ID), relief device data sheets, Pressure Systems Office (PSO) data book).

F-6. Corrosion of the TM9001 under the insulation material was not considered in inspection or maintenance planning. In accordance with API-571, for 304-type stainless steel equipment that are insulated, operate intermittently, or operate between 60ºC (140ºF) and 204.4ºC (400ºF), corrosion under insulation is a concern.

F-7. The written procedure for manually drawing a gas sample from the TM9001 was inconsistent with the procedure described by the qualified operator during the rig/facility inspection.

F-8. The relief valve (TM2703/RV6094) from the booster vessel was not installed in accordance with the P&ID.

F-9. Facility engineering's component tags were not secured permanently and were not found in some locations on the rig (Figure 7.1-1).

F-10. Two configuration management systems (PSO and facility engineering) are being used for pressure system components (Figure 7.1-1).

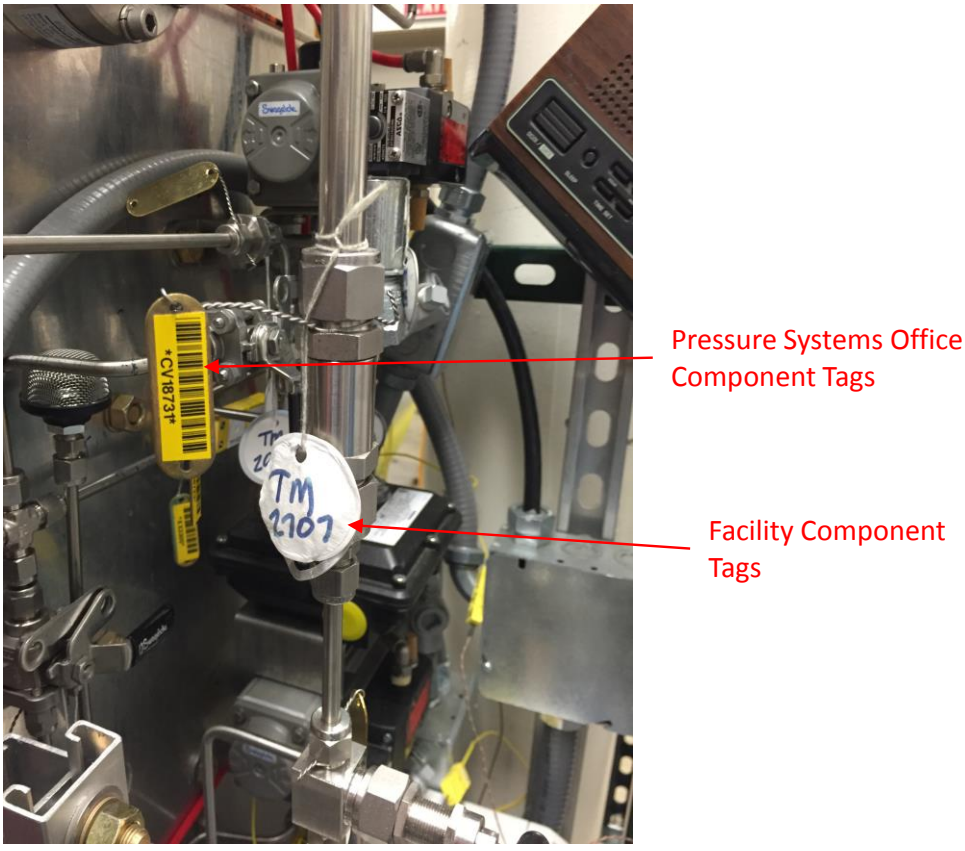

Figure 7.1-1. Pressure System Component Tags

F-11. There is no means to visually monitor the test cell from the control room.

F-12. The test cell ventilation assessment was thorough and included multiple smoke tests.

7.2 NESC Recommendations

The following NESC recommendations were identified and directed toward GRC's Facility, Test and Manufacturing Directorate unless otherwise identified:

R-1. Due to prolonged operation at elevated temperatures, procedures should be modified to include the documentation of the TM9001 operational history (cycles, pressure, and temperature) for consideration of material deformation below yield strength (creep) during future recertification or delta certifications. ***(F-2)***

R-2. Determine the risk associated with rapid cooling of the TM9001 while at temperature by the existing wet fire suppression system. Consider a dry fire suppression system as an alternative if risk is unacceptable as currently installed. ***(F-3)***

R-3. Verify inlet and discharge piping pressure drop do not exceed ASME Section VIII, Division 1 allowances for all relief valves on rig. ***(F-4)***

R-4. Update analyses and any required design, inspection, and monitoring procedures to include consideration of external corrosion over the range of anticipated environments for the TM9001. ***(F-6)***

R-5. Update all documentation to be consistent with present design and operating procedures and review the changes with all qualified operators before the rig is operated each time. ***(F-5, F-7, F-8)***

R-6. Install a video monitoring system between the test cell and the control room as a verification of no personnel in the area before flowing gas and to facilitate compliance with the buddy system requirement. ***(F-11)***

8.0 Alternate Viewpoint

There were no alternate viewpoints identified during the course of this assessment by the NESC team or the NRB quorum.

9.0 Other Deliverables

No unique hardware, software, or data packages, outside those contained in this report, were disseminated to other parties outside this assessment.

10.0 Lessons Learned

No applicable lessons learned were identified for entry into the NASA Lessons Learned Information System (LLIS) as a result of this assessment.

11.0 Recommendations for NASA Standards and Specifications

No recommendations for NASA standards and specifications were identified as a result of this assessment.

12.0 Definition of Terms

Finding	A relevant factual conclusion and/or issue that is within the assessment scope and that the team has rigorously based on data from their independent analyses, tests, inspections, and/or reviews of technical documentation.
Lessons Learned	Knowledge, understanding, or conclusive insight gained by experience that may benefit other current or future NASA programs and projects. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure.
Observation	A noteworthy fact, issue, and/or risk, which may not be directly within the assessment scope, but could generate a separate issue or concern if not addressed. Alternatively, an observation can be a positive acknowledgement of a Center/Program/Project/Organization's operational structure, tools, and/or support provided.
Problem	The subject of the independent technical assessment.
Recommendation	A proposed measurable stakeholder action directly supported by specific Finding(s) and/or Observation(s) that will correct or mitigate an identified issue or risk.

13.0 Acronyms List

API	American Petroleum Institute
ASME	American Society of Mechanical Engineer
FTIR	Fourier Transform Infrared
GEER	Glenn Extreme Environments Rig
GRC	Glenn Research Center
JPL	Jet Propulsion Laboratory
MAWP	Maximum Allowable Working Pressure
MTSO	Management Technical Support Office
NESC	NASA Engineering and Safety Center
NRB	NESC Review Board
NSC	NASA Safety Center
P&ID	Piping and Instrumentation Diagram
ppm	Parts Per Million
psi	Pound Per Square Inch
psia	Pounds Per Square Inch Absolute
PSO	Pressure Systems Office
SMD	Science Mission Directorate
SSC	Stennis Space Center

14.0 References

1. Kremic, Vento, Lalli, Palinski. *Extreme Environment Simulation – Current and New Capabilities to Stimulate Venus and other Planetary Bodies*, (2014).

2. API-571, *Damage Mechanisms Affecting Fixed Equipment in the Refining Industries*, April 1, 2011.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Chief of the Space Science Project Office at Glenn Research Center (GRC) requested support from the NASA Engineering and Safety Center (NESC) to satisfy a request from the Science Mission Directorate (SMD) Associate Administrator and the Planetary Science Division Chief to obtain an independent review of the Glenn Extreme Environments Rig (GEER) and the operational controls in place for mitigating any hazard associated with its operation. This document contains the outcome of the NESC assessment.

15. SUBJECT TERMS
Glenn Extreme Environments Rig; NASA Engineering and Safety Center; Hazard Mitigation

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