**RISK BASED Certification/Recertification**

The following document (SEAL-SSD-020) is provided as an example of a Risk Based Recertification (RBR) approach to certification/recertification of metallic pressure vessels in service on USSF/USAF installations. Specific details on required content are dependent on the particulars of the vessel in question including, but not limited to: commodity, pressure, temperature, vessel history and supporting documentation.

Risk Based Certification/Recertification is an acceptable alternative to standard recertification approaches per the latest revisions of the USSFMAN 91-710. This document was largely developed from the EMSC-TR-88-1: A Guide for Recertification of Ground Based Pressure Vessels and Liquid Holding Tanks. The data required to complete a Risk Based Inspection (RBI) for recertification of a vessel will need to be generated using the applicable industry standards:

* ASME Boiler and Pressure Vessel Code
* ASME PCC-3, Inspection Planning Using Risk Based Methods
* National Board of Boiler and Pressure Vessel Inspectors (NBBI) Inspection Code (NBIC) 23, Part 2, Inspections
* For non-code pressure vessels, NASA-STD 8719.17, Requirements for Ground-Based Pressure Vessels and Pressurized Systems, applies.

If the Range User chooses to use this template as a deliverable format, it is recommended that USSFMAN 91-710 (2019) Volume 3, Sections 11.3.2 through 11.3.2.6, be used as a reference/checklist for populating the template or adding new sections or subsections to the document, as needed. This template example is by no means complete; therefore, the Range User should use USSFMAN 91-710 Volume 3, Section 11.3.2 as the reference for addressing the intent of the recertification effort.

[*If USSFMAN 91-710 and/or SEAL-SSD-020 required information is already covered in another deliverables document, then only a reference to that document and section is recommended.*]

**Pressure Vessel Recertification: Risk Based Assessment Template**

**NOTE:** Prior to filling out this form, please read the information (attached Page 7) for Range Safety intent when assessing Range User RBR requests. This form should be completed with detailed rationale. Rationale and assessment should be supported by documentation and analysis (either attached or a link to source)

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| --- |
| Document Number – SEAL-SSD-022 |
| Revision | Date | Comments |
| 0 | 8/7/20 | Initial |
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| --- |
| Pressure Vessel ID and/or other identifier: * U-1A Form
* NB#
* U-Stamp Nameplate
* Manufacturer
* Year of construction
* Serial number, ID, distinguishing physical characteristics, nicknames, etc.
* Volume
* Other…
 |
| Vessel History: (e.g. – owned/operated since new ->well documented history, repurposed with history and prior assessment, etc….)\*If the vessel has never been recertified and does not have original ASME calculations, then a new design analysis will be required |
| Date of last Certification/Recertification:Link to Last Report or Previous Report(s) |
| Attachment B: Photo/Drawing/Other showing Pressure Vessel location on site with measurements to relevant locations of discussion; to be referenced in supporting analyses (e.g. fence lines, points of controlled entry/exit, operational safety clear zones, etc.)  |
| Vessel Code Stamped for current use? | Yes: \* When taking credit for charpy v-notch testing based on similar pressure vessels, there must be material traceability for the material in question being of the same heat as provided by ASME B&PVC Section VIII, Division 1, UG-84.  |
| No:\* Non-Code vessels must meet ASME rules for construction. In particular traceability to meet MDMT per UCS-66 |
| Service Commodity and Use Profile: (if previously used, that service must be accounted/dispositioned)* Commodity
* Temperature Range
* Pressure Range (standby, nominal, MOP, cycles per relevant time period)
* Hazard Analysis per USSF 91-710
 |
| Remaining Safe Life Analysis Summary:*I.A.W - ASME B&PVC Section VIII, Division 1**91-710 drives factor of safety (FS) of 4:1 against calculated safe life*  |
| Fracture Mechanics Service Life: The API-579 fracture mechanics approach is the preferred method of analysis, using API’s method of determining fracture toughness, residual stress, and flaw growth using the fracture assessment diagram. |
| FAILURE MODES ASSEMENT TABLE |
| Failure Mode: | Applicable | Mitigations |
| Over pressurization | N | Overpressure not credible. Triple RVs maintained via company hardware/asset management program and ISI Program. |
| External Loading | N | External loading not credible. * Tank(s) are minimally constrained
* barricaded from vehicular traffic
* appropriate strain relieving plumbing install and inspected via maintenance and ISI
 |
| Pressure Cycling | Y | Pressures are tightly controlled in narrow range via procedure; standard safe life analysis applies  |
| Vibration | N | Tank(s) are appropriately isolated from pumps |
| Thermal Cycling | N | Tank commodity in constantly held in narrow temperature range. Strain across the temp range has been assessed and does not impact safe life.  |
| Mechanical Shock | - | …… |
| Dissimilar Metal Welds | - | …… |
| High Temp Creep | - |  |
| General Corrosion | - |  |
| Galvanic Corrosion | - |  |
| Local Corrosion | - |  |
| Intergranular Corrosion | - |  |
| Crevice Corrosion | - |  |
| Stress-Corrosion Cracking | - |  |
| Stress Enhanced Corrosion | - |  |
| Refurbishment Activities | - |  |
| Modification/Repair deficiencies | - |  |
| Operation beyond allowable limits | - |  |
| Maintenance deficiencies | - |  |
| Other | - |  |
| NOTE: The above list of failure modes may not be comprehensive for your vessel. NOTE: The mitigations provided are only examples |
| INSPECTIONS/NDE  |
| Internal | N | No internal inspections performed on this cryo vessel. We do not wish to bring the tank up to ambient. Corrosion concerns are negligible, outlet filters do not show concern. Stress and Fracture mechanics + procedure controlled operating procedures mitigates fatigue and crack growth concerns.Tank is holding pressure and annulus is holding vacuum |
| External | Y | Visual – 100% visually inspectedDye Pen – Mag Part – Etc…  |
| Volumetric | Y | Radiography, Volumetric shear wave…….. 100% welds… |
| Other | - |  |
| PRESSURE/OPERATIONAL TESTS |  |  |
| Proof Tests | - |  |
| Leak | - |  |
| Vacuum | - |  |
| Other | - |  |
| CONCLUSION |
| Pressure Vessel X.XXX is recommended to be reassessed : * Additional Narrative
* links to supporting documentation
* list of supporting attachments
* Other
 | 10 years | X |
| 15 years |  |
| 20 years |  |
| Other |  |
|  |  |
|  |

**ABSTRACT:** This document provides a brief history of Space Force pressure vessel recertification requirements development, purpose of recertification, change in requirements to allow risk based recertification, discussion of damage mechanisms, and inspection, and analysis associated with the recertification process.

1. **Brief History**

The AFSPCMAN 91-710 Range Safety Requirements Volume 3, Chapter 11, 2004 release contained specific and prescriptive pressure vessel recertification requirements. These requirements provided for recertification intervals were based on the level of inspection and testing. These requirements were heritage from the Eastern-Western Range Safety Requirements, EWR 127-1. Prior to the release of EWR 127-1, there were no specific requirements for recertification.

In the 1980s, it was determined that aerospace requirements for pressurized systems did not include guidance on the evaluation of pressure systems’ mechanical integrity for personnel and resource protection. There were fleets of hazardous-commodity pressure vessel assets with no traceability on historical use or state of mechanical integrity.

Two referenced documents from the time, WSMCR 127-1 (Dec 1989) and the WRR 127-1 (Jun 1993), showed design requirements for pressure systems, but did not contain guidance or methodology for recertification, or mechanical integrity evaluation.

In the late 80s, the Eastern Space and Missiles Center (ESMC) commissioned an effort, in response to a recommendation of NASA’s Kennedy Space Center, to develop guidance for the recertification of ground based pressure vessels. This became ESMC-TR-88-1, A Guide for Recertification of Ground Based Pressure Vessels and Liquid Holding Tanks (Dec 1987). The TR-88-1 was incorporated as a guidance document into EWR 127-1, with certain specific recommendations of the TR-88-1 included as prescriptive requirements. The EWR 127-1 requirements were then adopted into AFSPCMAN 91-710.

1. **ESMC-TR-88-1**

The objective of TR-88-1 was to present a step-by-step methodology for the evaluation of the condition of pressure vessels that had been in operation for a number of years in a wide variety of service environments. It was geared toward hazardous service vessels containing high-pressure gases, cryogenics, hypergols, or other hazardous fluids. The methodology addressed four major areas attributable to service-related failures / root causes (damage mechanisms): (1) Corrosion, (2) Stress and fatigue, (3) Design, fabrication and installation, and (4) Operation and maintenance.

The recertification process was broken down into five phases:

* Phase I Documentation Retrieval and Review
* Phase II: Engineering Assessment
* Phase III: Inspection/Test Plan
* Phase IV: Inspection/Test Implementation
* Phase V: Final Evaluation and ISI Initiation

Phases I through III were primarily geared toward vessels of unknown, or not well-known, pedigree. Similar approach for pedigree determination is used in API-579 Fitness for Service technologies code. In particular, Phase II of TR-88-1 evaluated vessel design and construction against ASME Boiler and Pressure Vessel Code, Section VIII, Divisions 1 and 2, to verify or determine the design factor of safety and the maximum allowable working pressure (MAWP).

In Phase III, the inspection/test plan was developed to resolve concerns identified in Phases I and II, which were particular to the vessel being recertified.

Phase IV, the implementation of inspections/testing also characterized and analyzed any issues found during inspection/test, provided for follow up engineering assessment of inspections, and finalized disposition, or removed assets from service.

Phase V provided for final evaluation and in-service inspection (ISI) initiation by providing analysis for safe life determination, setting recertification period up to 20 years, remaining safe life, and developing the ISI plan.

1. **AFSPCMAN 91-710**

AFSPCMAN 91-710 (and its predecessor EWR 127-1) took the five phases from TR-88-1 and incorporated them into firm requirements captured in the Volume 3 (2004), Chapter 11 sections for Ground Support Pressure Systems (GSPS):

* 11.2.4. GSPS Analysis and Documentation Requirements
* 11.3.1. GSPS Recertification Test Requirements
* 11.3.2. GSPS General Recertification Requirements
* 11.3.3. GSPS Certification
* 11.3.4. GSPS Analyses
1. **Risk Based Alternative to Pressure Vessel Recertification**

One aspect of the boilerplate approach to recertification incorporated into Space Force requirements was the inapplicability of requirements in all cases on various types of pressure vessel configurations. In 2019, the AFSPCMAN 91-710 requirements committee agreed to expand the prescriptive requirements to include a risk based approach to recertification. The limits on recertification intervals were retained to-not exceed a 20 year period. The recertification requirements were updated and relocated from AFSPCMAN 91-710Volume 3 July 2004, 11.3. Ground Support Systems Certification and Recertification to USSFMAN 91-710 Volume 6 February 2020, 11.5.5. General Recertification Requirements

The specific purpose of a risk based pressure vessel recertification alternative is to provide an approach that is not prescriptive, which implements the intent of the TR-88-1 to develop inspection and testing requirements around the failure or specific damage mechanisms of the pressure vessel asset that is being recertified.

A Risk based approach to recertification is not associated with API-580, Risk Based Inspection; therefore, no probabilistic analysis against failure shall be accepted to reduce inspection and test requirements.

1. **Damage Mechanisms**

TR-88-1 included (1) Corrosion, (2) Stress and fatigue, (3) Design, fabrication and installation, and (4) Operation and maintenance as damage mechanisms. Table 1 discusses each and their applicability.

**Table 1. TR-88-1 Damage Mechanism**

|  |  |
| --- | --- |
| **Damage Mechanism** | **Comment** |
| Corrosion | Corrosion is one of the most prevalent damage mechanisms that leads to material loss in the pressure boundaries. |
| Stress and Fatigue | These were credible damage mechanisms for TR-88-1 when evaluating assets with limited documentation. For vessels with limited, or no traceability, design and construction evaluations had to be determined and assumptions on use developed. In many cases, conservative cycle usage was assumed in analysis for safe-life evaluation. Note: this section also includes creep. |
| Design, fabrication and installation | As with stress and fatigue, these were considered credible damage mechanisms for TR-88-1 when evaluating assets with limited documentation, or for non-code vessels. Man non-code vessels are still in use at many aerospace installations. |
| Operation and Maintenance | These were credible damage mechanisms for TR-88-1 when evaluating assets with limited documentation, or non-code vessels.  |

A review of TR-88-1, Section 1.1, Figure 1, is recommended to understand the importance of each one of these damage mechanisms when evaluating pressure vessels with little to no design, construction, and/or service history.

The USSF 91-710 damage mechanism list in Volume 3 May 2019, section 11.3.4, spreads across several paragraphs. These are captured in Table 2, maintaining the same categorization as Table 1, with a discussion on their applicability with the perspective in mind that they apply only to pressure vessels with no, or limited traceability. In other words, most of these damage mechanisms should not apply to:

* new pressure vessel acquisitions (for whose design and construction must meet ASME and installation and commissioning must meet other sections of Volume 3),
* existing pressure vessels currently under recertification (with appropriate documentation and service history), and
* care-taker, or relocated status vessels (with appropriate documentation and service history prior to being put in care-taker status).

Credible damage mechanisms on Vandenberg AFB and Cape Canaveral fall under four primary categories; corrosion, mechanical damage, fatigue, and temperature embrittlement (for vessels not meeting UCS-66). However, it is up to the Range User to determine what the specific damage mechanisms are for the specific pressure vessels undergoing recertification.

**Note:** Some vessels under current recertification intervals may not be compliant with ASME UCS-66 MDMT requirements for the environmental service temperatures that may be experienced. This will need to be addressed and dispositioned via USSFMAN 91-710 Tailoring, Establishing Equivalent Level of Safety, and/or Waiver.

**Table 2. AFSPCMAN 91-710 Damage Mechanism**

|  |  |
| --- | --- |
| **Damage Mechanism** | **Comment** |
| Corrosion | External corrosion is a primary damage mechanism on both coasts due to proximity to the coast and presence of salt in the near-marine environment. Internal corrosion for the majority of aerospace propellants is not a concern, but for some specific commodities, i.e., H2O2 can present degradation. |
| Stress and Fatigue | When a pressure vessel is designed, constructed and operated within Code requirements, stress and fatigue are not a concern within the certification period. As noted in Table 1, these are considered damage mechanisms for evaluating assets that do not have a documented service record. Stress conditions should be controlled by the inhibit strategy of Volume 3, the design stress requirements of ASME, and documented fatigue life analysis (safe-life and fracture mechanics, including Factor of Safety (FS) that comes with the original certification requirements of Volume 3. |
| Design, fabrication and installation | These would not be considered damage mechanisms for evaluation for vessels already in service undergoing recertification. The reasons are similar as those for “Stress and Fatigue” above. Also, operation would need to follow Volume 3 and Volume 6 requirements. |
| Operation and Maintenance | These would not be considered damage mechanisms for evaluation for vessels already in service undergoing recertification. The reasons are similar to those for “Stress and Fatigue” above. Also, operation would need to follow Volume 3 and Volume 6 requirements. Based upon operational requirements, there should not be either any operation or destabilizing conditions and maintenance should never lapse. The incidence of either would violate the recertification period and trigger a new assessment. |

For additional guidance, 91-710 has adopted reference ASME PCC-3, Inspection Planning Using Risk Based Methods and National Board of Boiler and Pressure Vessel Inspectors (NBBI) Inspection Code (NBIC) 23, Part 2, Inspections, which provide inspection technique guidance for various damage mechanisms and guidance on inspections and frequency.

**Note:** The30th Space Wing will no longer recertify A.O. Smith or similar non-code layered pressure vessels. The only exception to layered pressure vessels is Code Stamped ASME vessels constructed to B&PVC, Section VIII.

1. **AFSPCMAN 91-710 Requirements Period Determination**

The prescriptive recertification period requirements (Volume 6, sect 11.5.5.3) list the following:

11.5.5.3. The **recertification period for vessels** and systems shall not exceed the shortest period resulting from or determined by the following criteria:

11.5.5.3.1. The shortest service life shall be determined based on the system and components design performance parameters, operational requirements, and inspection and test results.

11.5.5.3.2. Twenty years for systems and vessels that can be 100% inspected both internally and externally.

 11.5.5.3.3. Ten years for systems and vessels that cannot be 100% inspected internally but can be 100% inspected externally.

11.5.5.3.4. Five years for systems and vessels that cannot be 100% inspected either internally or externally.

11.5.5.3.5. Manufacturer recommendations.

11.5.5.3.6. Recertification of cryogenic vessels shall be accomplished, at a minimum, every 20 years with an internal inspection every 10 years.

The alternative risk based methods (not to exceed 20 years) allow for the following, but must be weighed against the Recertification Test and Analysis requirements of Volume 6, section 11.5.5.1:

11.5.5.3.7. As an alternative to the above criteria, pressure vessel recertification intervals, not to exceed 20 years, may be established using alternative inspection methods (e.g., risk-based methods), with Wing Safety approval.

11.5.5.3.7.1. The determination of recertification intervals using alternative methods shall identify all credible failure mechanisms and associated risks, and define appropriate inspections, tests, and analyses to address the mitigation of pressure vessel failure.

11.5.5.3.7.2. Implementation of a risk-based method approach shall include justification for any deviations from paragraph **11.5.5.1** (Recertification Test and Analysis Requirements).

1. **How should recertification requirements be determined?**

The Range User can either apply the prescriptive requirements of 11.5.5.3, or evaluate each individual asset against the test and analysis requirements of 11.5.5.1, taking into consideration which test and inspections can be implemented and to what degree. The following *brief* examples are included to provide insight. (Examples are only brief discussions, and actual rationale would require substantiating, detailed documentation, Code references, analysis, inspection alternatives, and mitigation strategies, etc.).

**Example 1: Cryogenic Liquid Storage Tank Recertification.**

Requirements:

* Internal inspection at 10 years
* Pressure test at cryogenic temperatures
* 100% volumetric inspection

Risk based approach:

* Internal inspection at 10 years: not required based on material of construction, LBB determination, fracture mechanics analysis, level of inspections that would identify a containment breach.
* Pressure test at cryogenic temperatures: not required by ASME. In lieu use cryoshock after pressure testing.
* 100% volumetric inspection: not feasible based on construction. Equivalent level of safety (ELS) based on material of construction, LBB determination, fracture mechanics analysis, and level of inspections that would identify a containment breach.

**Example 2. Hazardous Commodity Storage Tank Recertification**

Requirements:

* Internal inspection
* 100% volumetric inspection

Risk based approach:

* Internal inspection: ELS determined by near 100% volumetric inspection, surface thickness mapping, material of construction, LBB determination, fracture mechanics analysis, level of inspection and mitigations that would identify a containment breach. Additionally, commodity sampling is used to determine the presence of internal corrosion.
* 100% volumetric inspection: 100% volumetric inspection is not feasible, but ELS is maintained by near-100% volumetric inspection and fracture mechanics evaluation.

**Example 3. Brittle Failure High-Pressure Vessel in Gaseous Service**

Requirements:

* Fracture mechanics analysis with flaw shapes (a/2c) ranging from 0.1 to 0.5
* Engineering assessment of the design, fabrication, material, service, inspection, and testing shall be evaluated against the latest codes

Risk based approach:

* Fracture mechanics analysis with flaw shapes (a/2c) ranging from 0.1 to 0.5: ELS by performing a fracture mechanics evaluation using API-579 postulate flaw guidance and residual stress to determine flaw growth and fracture mechanics service life predictions.
* Engineering assessment of the design, fabrication, material, service, inspection, and testing shall be evaluated against the latest codes: not required, newer Codes use lower factors of safety and change the nozzle area for reinforcement calculations. Comparison does not add value. Assessment will be against Code in force at time of construction.
1. **Fatigue**

Each pressure vessel asset must be assessed for safe-life, including new construction. With respect to ASME B&PVC Section VIII, Division 1, safe life determination is not a code requirement. Therefore, it is the vessel operator’s responsibility to determine safe life and track it against in-service cyclic use. This safe life carries a factor of safety (FS) of 4:1 against calculated maximum in-service cyclic use.

1. **Safe-Life Analysis**

The fracture mechanics service life is a required analysis that postulates a flaw exists at a critical junction and reaches critical size during the pressure test. This flaw size is then evaluated for growth at the expected cycle use to determine at what point in its cycle life it will reach a critical size at nominal operating pressures. The analysis results shall be reduced by a factor of 4 in conjunction with assuming the most conservative bounds on material properties and crack growth data for the vessel environment.

Commentary on Fracture Mechanics: The implementation of fracture mechanics is critical for pressure vessel assessment. In particular, the identification of material fracture toughness, as a function of the lowest operating temperature, and the critical locations where the analysis is performed, must be assessed. What the primary operating stress is, what the residual stresses are (if any), and their contribution to flaw propagation, are all critical factors to assess. The API-579 fracture mechanics approach is the preferred method of analysis, using API’s method of determining fracture toughness, residual stress, and flaw growth using the fracture assessment diagram.