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90/95 POD Radiography Concern for COPVs and Metal Tank Welds

Radiographic inspections of welds in all-metal tanks and composite overwrapped pressure vessel (COPV) liners that are used to establish initial crack size in damage tolerance assessments are not as rigorous as previously understood. As a result, the 90/95 percent probability of detection (POD) requirements in S-080[1] and S-081[2] are not met when this inspection method is used. Development of new inspection methods will require about three years. During that time, additional review and assessment of the fracture margin may be needed to support waivers and provide a better understanding of weld cracking risk associated with an individual tank design.

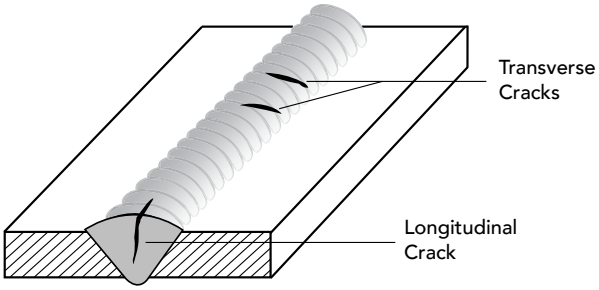

Illustration of metal weld cracks

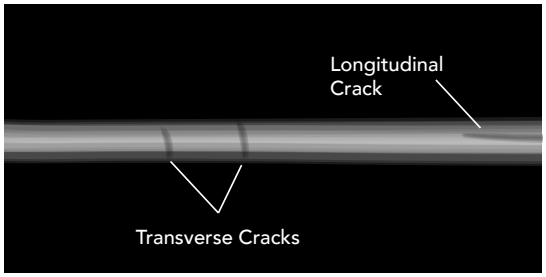

Illustration of notional radiographic inspection of metal weld cracks

Discussion

Damage tolerance life (safe-life) for COPVs and metallic tanks is a deterministic damage tolerance approach required by S-081 and S-080. It assumes the existence of cracks of a size that can be reliably detected by an established nondestructive evaluation (NDE) method used to inspect the liner/tank prior to service. The intent of damage tolerance life is to demonstrate that cracks at or below this size will not grow to failure during the service life. S-081 and S-080 require that this initial crack size be determined from the sensitivity limit of the 90% POD at a 95% confidence level.

For volumetric inspections of tank welds and domes, tank manufacturers typically use radiography. The majority use a crack depth of 60% of the thickness (0.6t, identified as special radiography) and specific inspectors and processes have been certified by NASA to be able to detect cracks of that size with POD of 90/95 in accordance with NASA-STD 5009[3]. The larger, 0.7t crack depth is occasionally used and requires less rigor under NASA-STD 5009.

Recent radiography studies have concluded that 0.6t and 0.7t cracks are not as consistently detectable as previously understood. Detectability of cracks on the film (or digital radiography) is sensitive to several parameters: the need for double-wall inspection on close-out welds, separation distance of the tank walls, incidence angle, wall thickness, and exposure time. These parameters have not been included in certification tests in the past, but were found to be important in crack detection. Implementation of more stringent certification tests that capture these parameters will take about three years since new image quality aids will need to be developed, qualified, and implemented. It is understood that these planned improved double-wall radiography methods may not be achievable in all tank designs. In the near term, certifications will continue in the current protocol to establish that heritage capability has not changed.

As a result, manufacturers that are currently certified to 0.6t or 0.7t radiography may not be able to detect cracks of that size with 90/95 POD, so the risk of missing a crack larger than 0.6t or 0.7t is higher than previously understood. This risk has been present in previous flights, but was not appreciated until recent studies of radiography techniques were completed.

Since the damage tolerance analysis or test assumes crack sizes associated with radiography, additional analysis and tests may be needed to understand fracture risks associated with cyclic and sustained load crack growth. Tests of larger initial crack sizes or better understanding of analytically-derived fracture margin and critical initial flaw size analysis may be needed to support waivers against the 90/95 POD requirements in S-081 and S-080 and provide a better understanding of the risks associated with individual tank designs.

References

1. American Institute of Aeronautics and Astronautics (AIAA) S-080 Space Systems - Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
2. AIAA S-081, Pressure Vessel Standards Implementation Guidelines
3. NASA-STD-5009 Nondestructive Evaluation Requirements for Fracture-Critical Metallic Components

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