

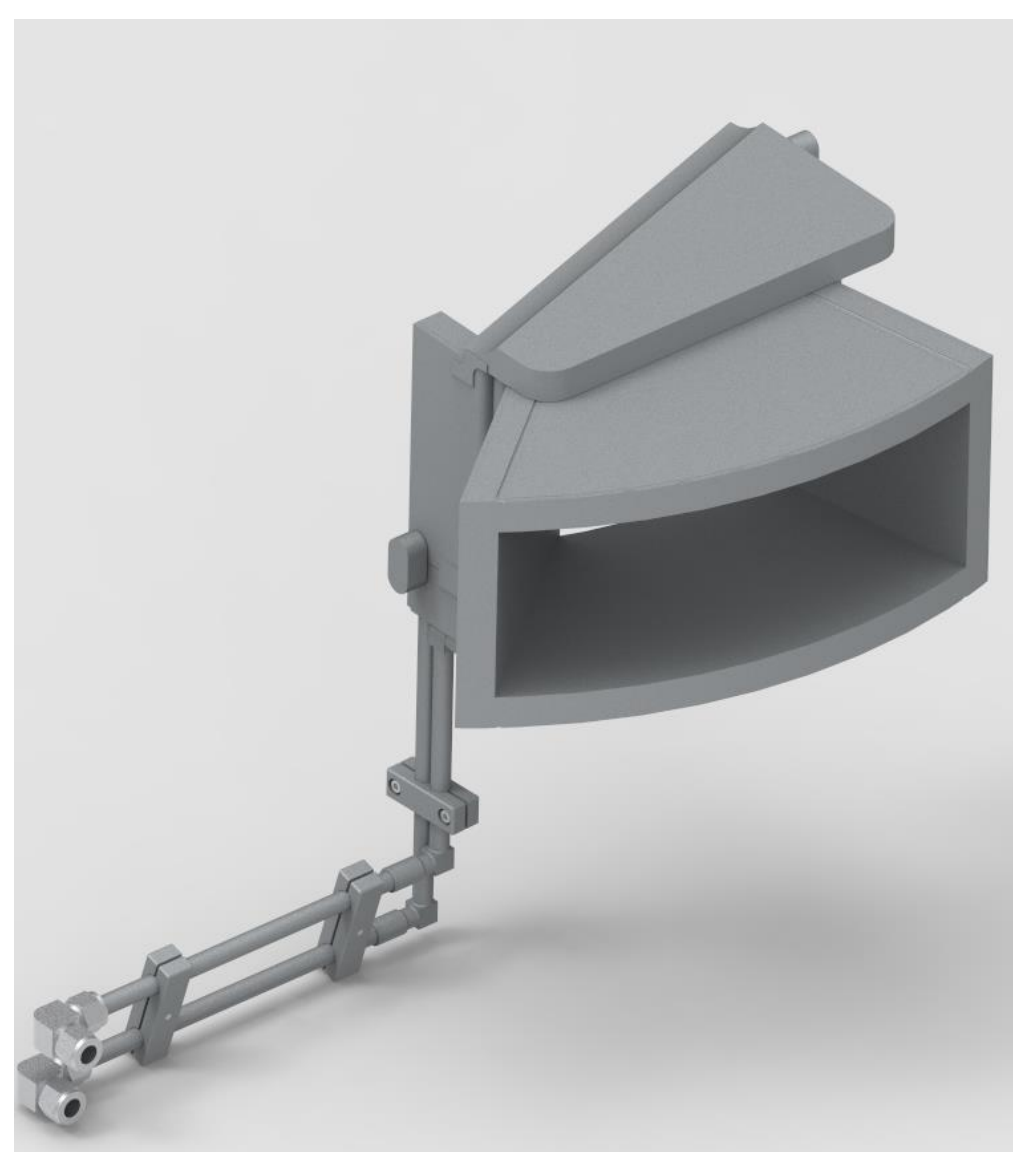
ISIS Target Station 2 – Horn Water Pre-Moderator Failure, Investigation, and Redesign

ISIS Neutron and Muon Source

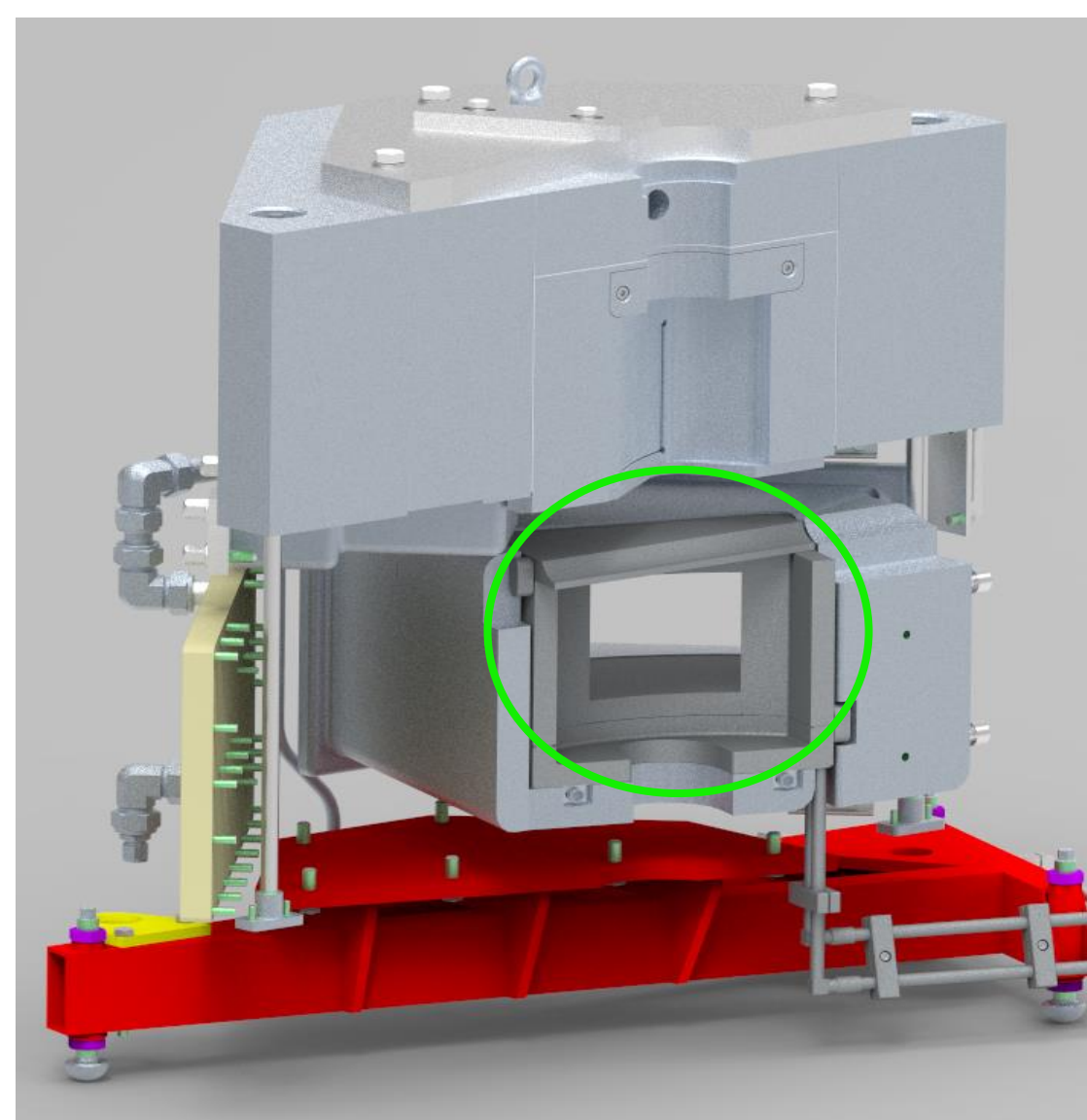
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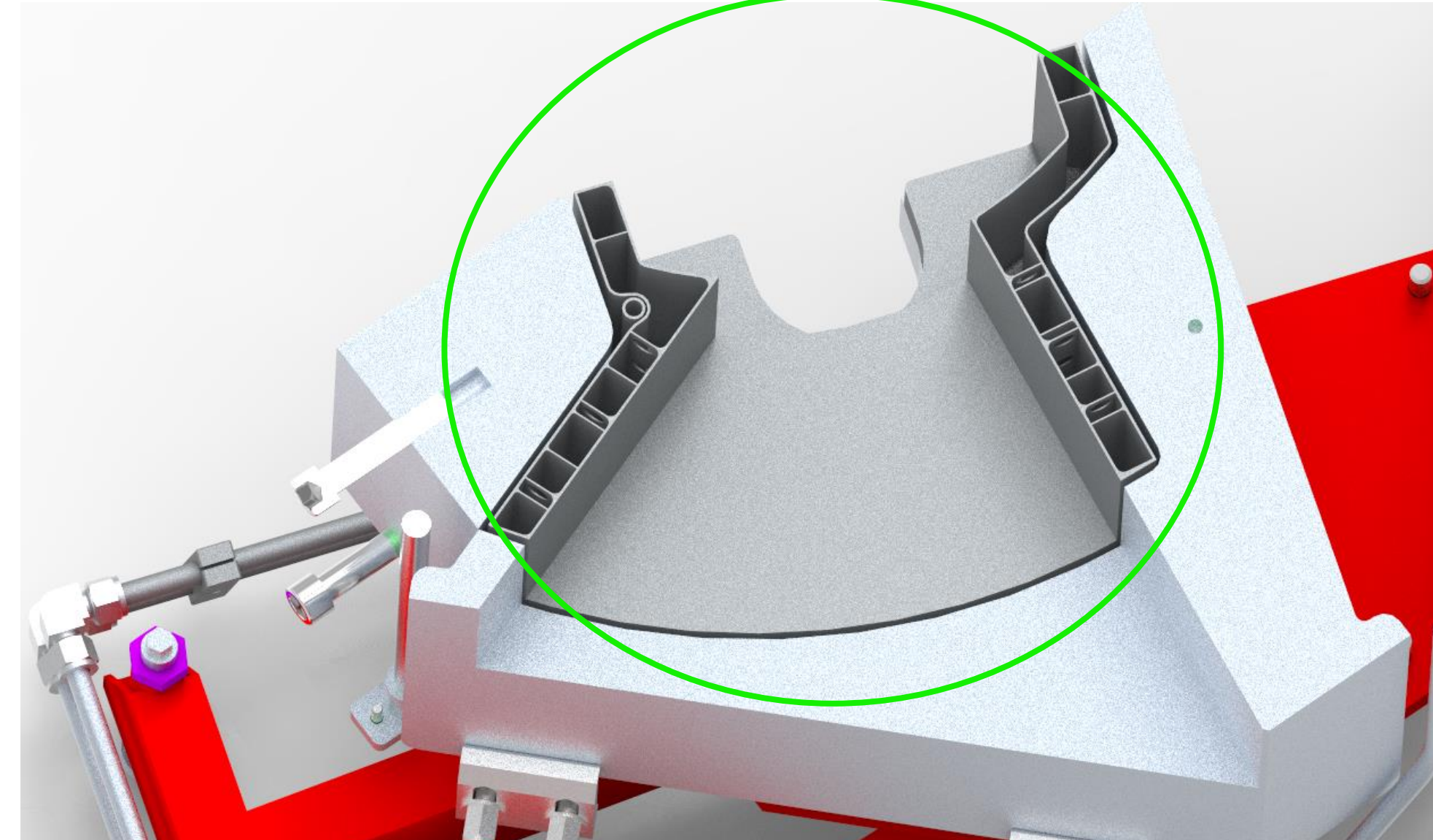
The ISIS Target Station Two (TS2) Horn (water) Pre-Moderator is a vital component in the process of moderating neutrons. Neutrons are slowed down here before entering the cryogenic hydrogen moderator, where they become thermal neutrons for instruments on the west side of the Target Station. The original pre-moderator, made from a 2000 series aluminium alloy, failed within the first year due to corrosion. The replacement was manufactured from the 5083-aluminium alloy for improved corrosion resistance and ran for six years before being replaced during a reflector upgrade in 2013.



Newly designed horn pre-moderator

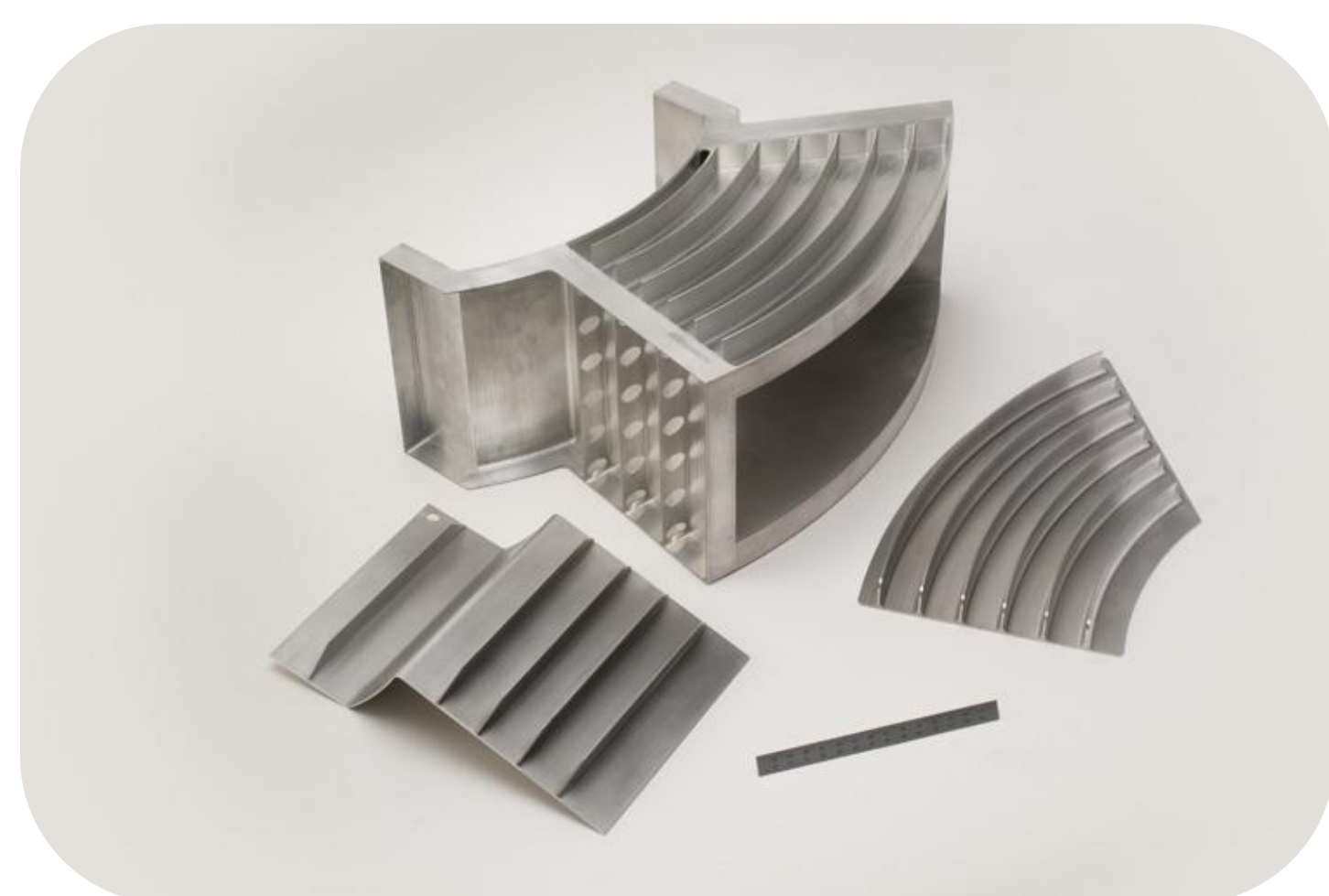


Pre-moderator inside reflector



Cut-through of pre-moderator inside reflector showing water channels

(1) Original Design



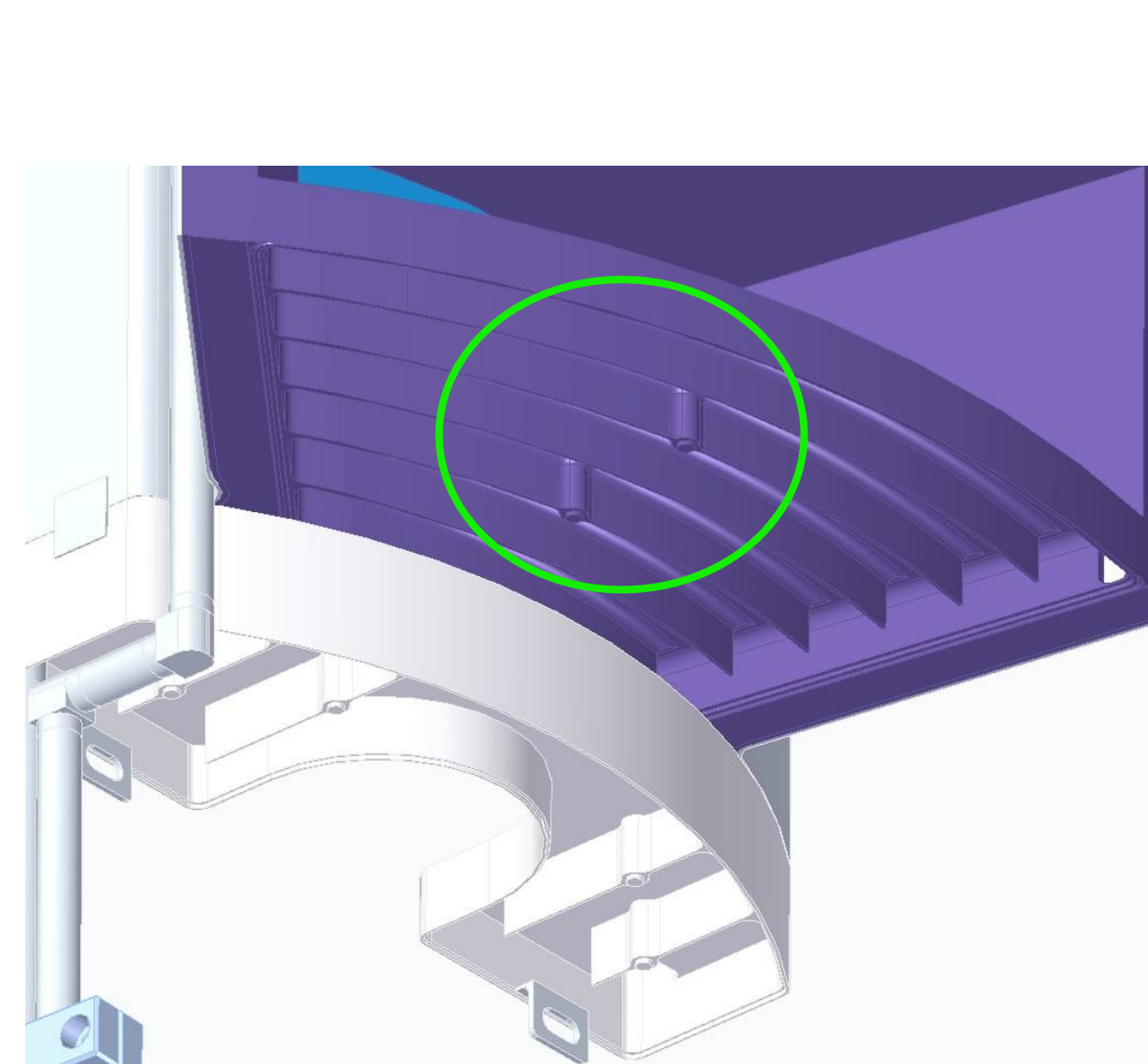
(a) Original manufacture parts of the horn pre-moderator first iteration



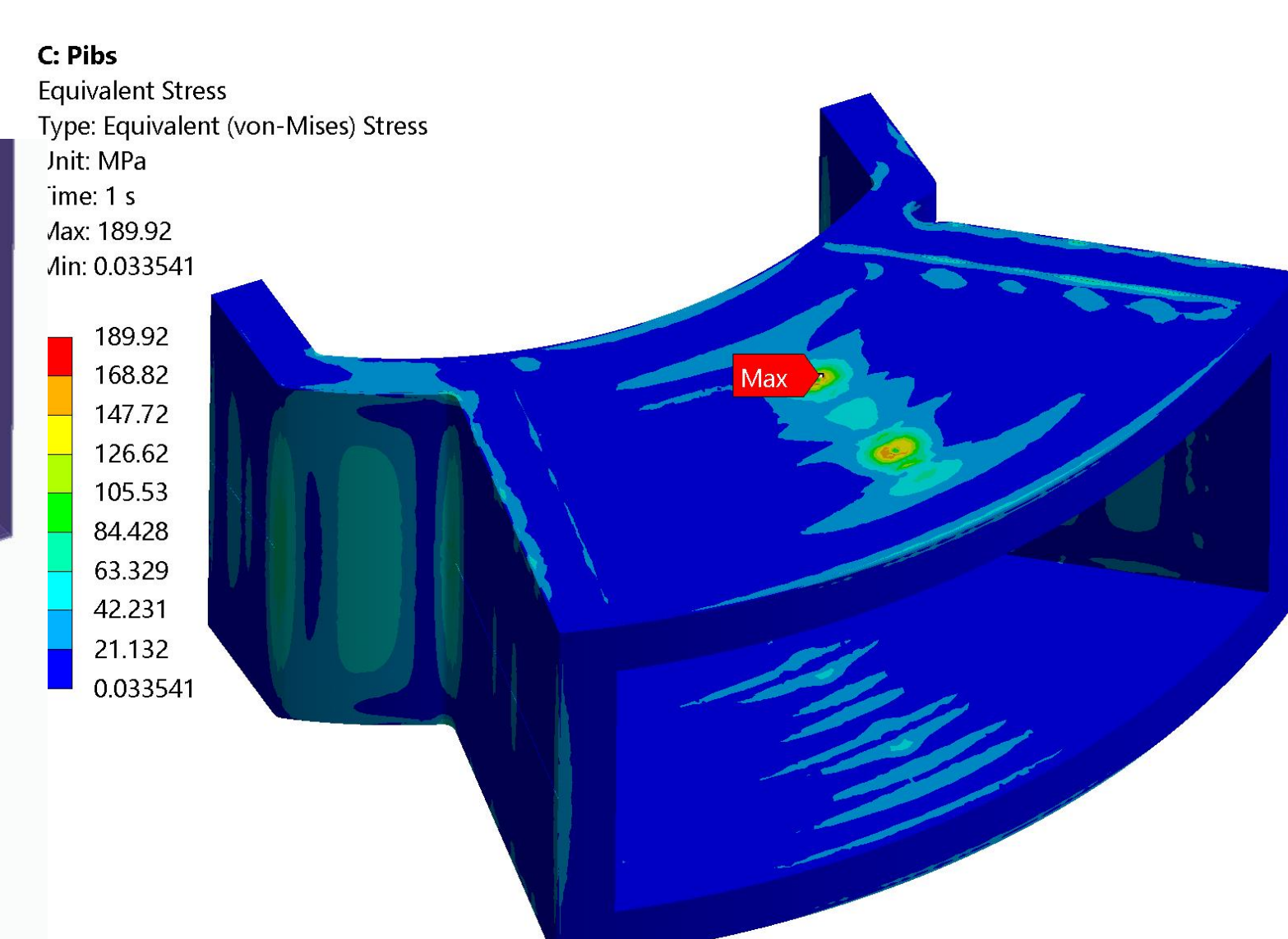
(b) Second iteration with the additional welded "pips" for structural rigidity.

- Design parameters:
 - 3.5 L/min
 - Negatively pressurised
 - Water "pulled" through
- The original Horn pre-moderator in 2009 was manufactured using Aluminium 2014-T6 due to its high strength. However, a leak was discovered, and the hypothesised fault was pitting corrosion; 2014-T6 has poor corrosion resistance.
- This led to a redesign using aluminium 5083-O and increasing the wall thickness from 1mm to 1.5mm.
- Electron beam welded "pips" were added to the lid for increased strength.
 - Circular weld profile
- The new pre-moderator was installed in 2013 and ran for eight years.

(3) Investigation



(a) Highlighting where the pip welds are located



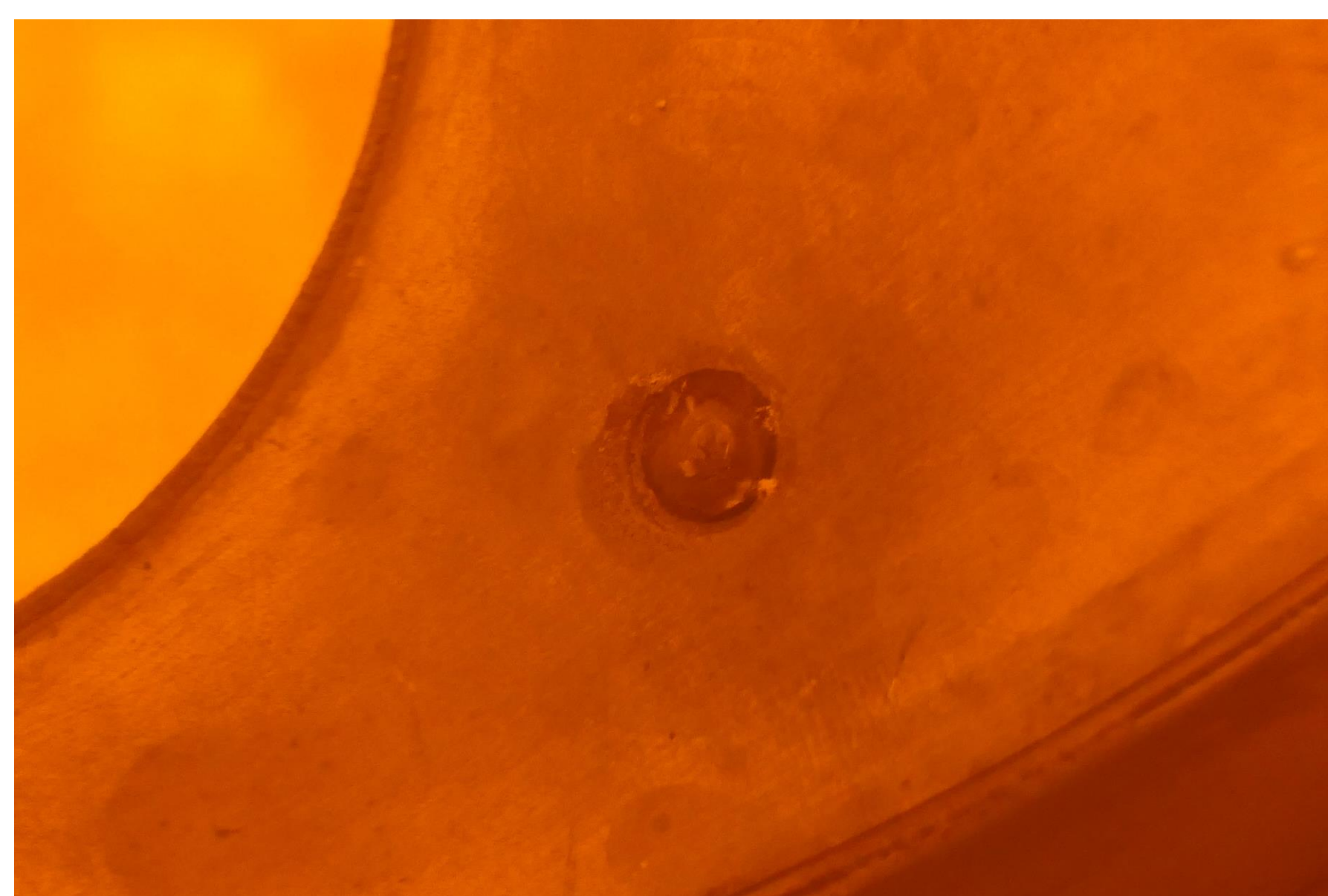
(b) FEA structural analysis highlighting stress concentrations at the pip welds.

How do you investigate a radioactive component without a Post Irradiation Examination (PIE) setup?

Stress concentration around the electron beam welded "pip" joints? Finite Element Analysis was performed to demonstrate where stress concentrations would be. A maximum stress of 190 MPa was seen in these highly stressed areas, much higher than the yield strength of Aluminium 5083-O (125 MPa). Pressure regulations set the limit for Al5083-O at 83 MPa (safety factor of 1.5).

This was to be redesigned using rib stake welds.

(2) Failure

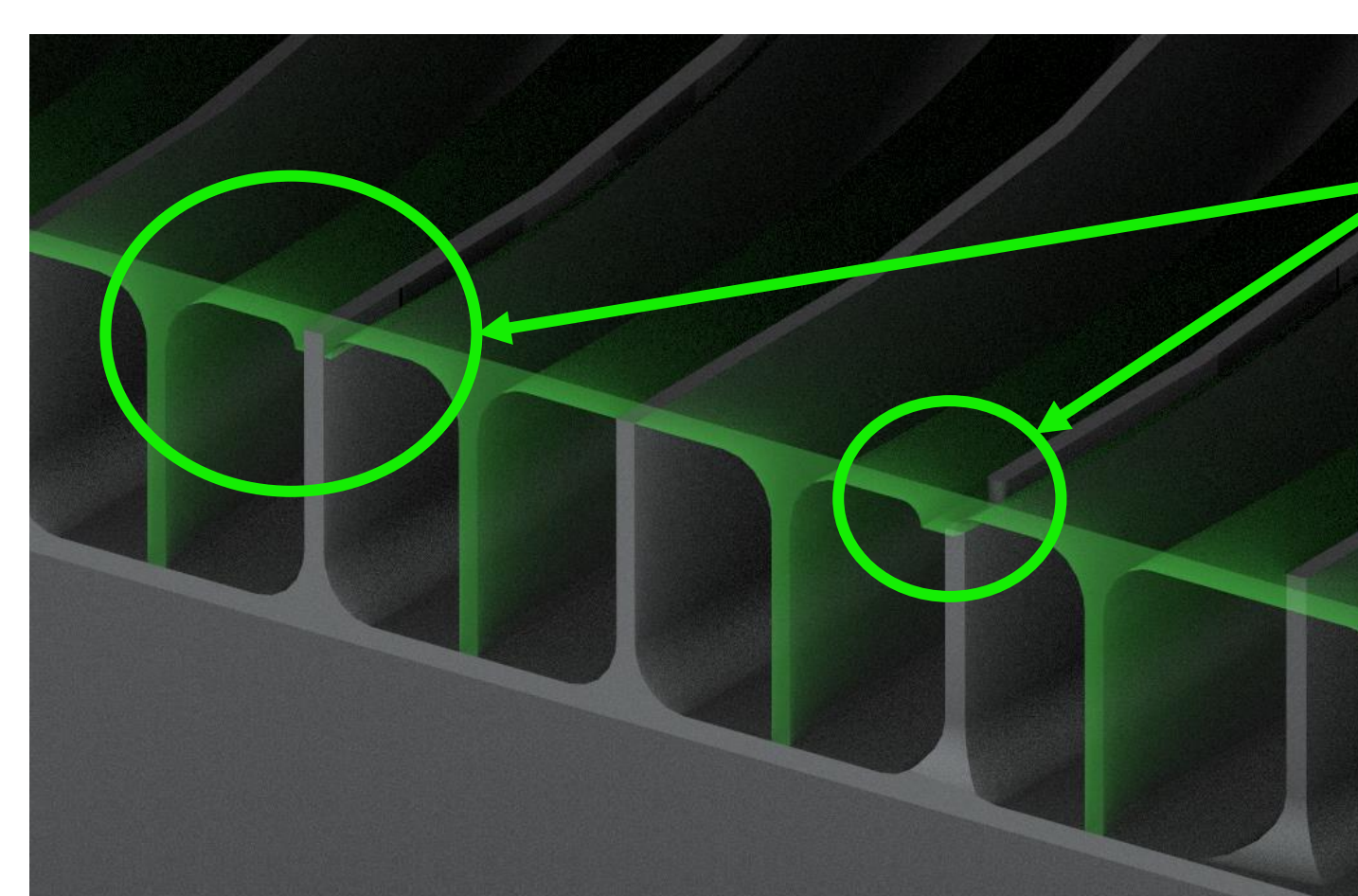


(a) Visual leak spotted on the vertical pipework below the pre-moderator (left). (b) Remote handling visual inspection showing a small amount of corrosion around electron beam welded pip weld (right).

After eight years, a leak was detected in 2021. On visual inspection, water could be seen dripping from the bottom of the pipework elbow (2a). Once the reflector was opened, discolouring of the reflector block from the water block was also seen.

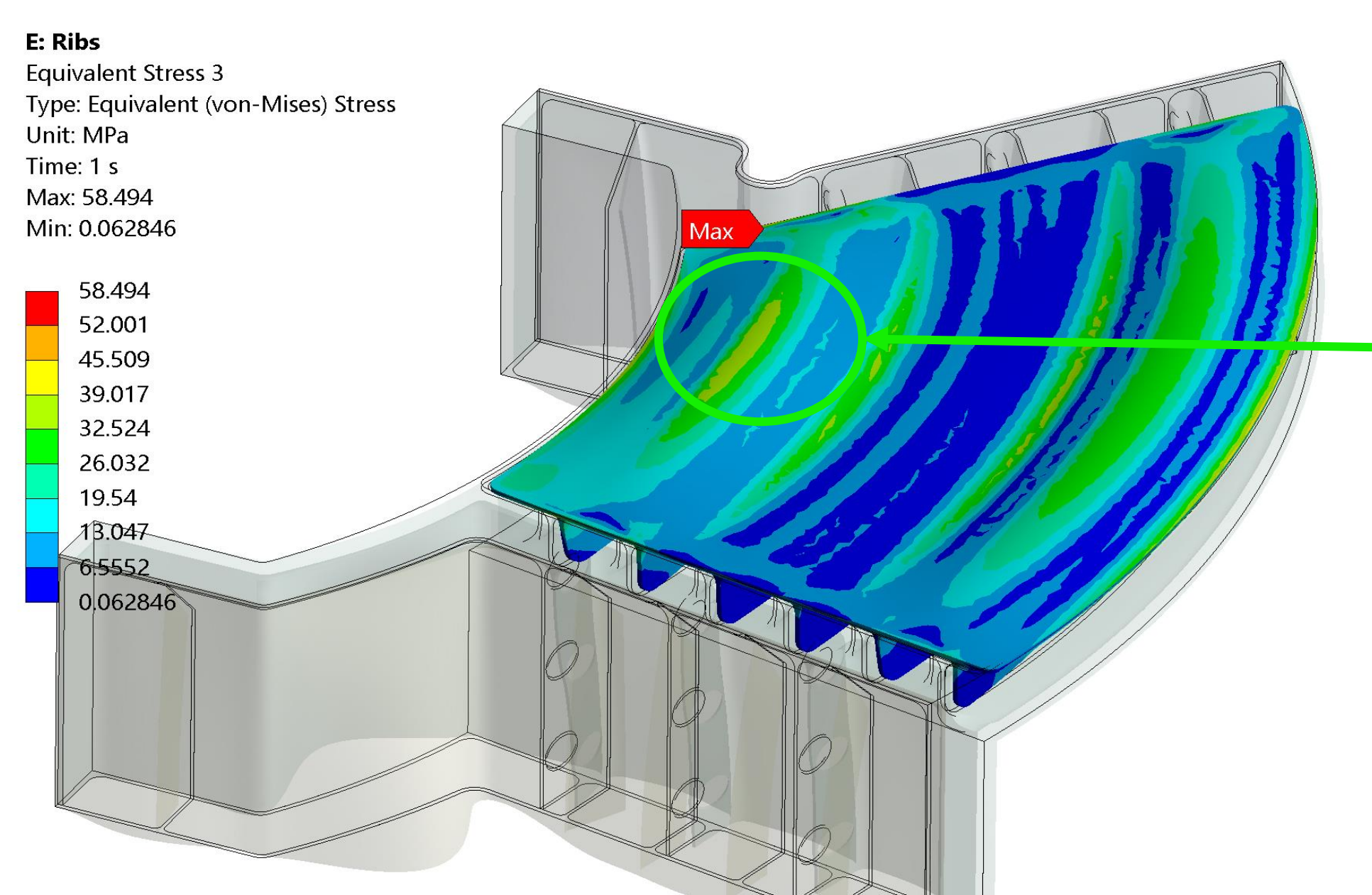
The spare pre-moderator of the same design was installed. Analysis was performed to identify the fault and develop out the problem before manufacturing another spare pre-moderator.

(4) Redesign



(a) Cut through image of the CAD model showing the rib stake weld

- The pips were replaced with long ribs to distribute the stress along the weld line, thus removing the stress concentrations.
- Thin scribe line to indicate the location of the stake weld through the lid.
- Rib inserts into lid by 1.5 mm to improve the contact for electron beam welding. Less power required and therefore smaller weld profile.



(b) ANSYS Structural analysis showing a lower maximum stress of 58.5 MPa.

Stress at the welds reduced from 189 MPa to approximately 45 MPa. Maximum stress located at perimeter (58.5 MPa).