Finite Element Analysis
PredictiveEngineering

ASME

Section VIII, Division 2 Stress and Fatigue Analysis

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Over the last 20+ years, Predictive Engineering has tackled some of the most complex applications of the ASME BPVC Section VIII, Division 2 "Design-by-Analysis" specifications.

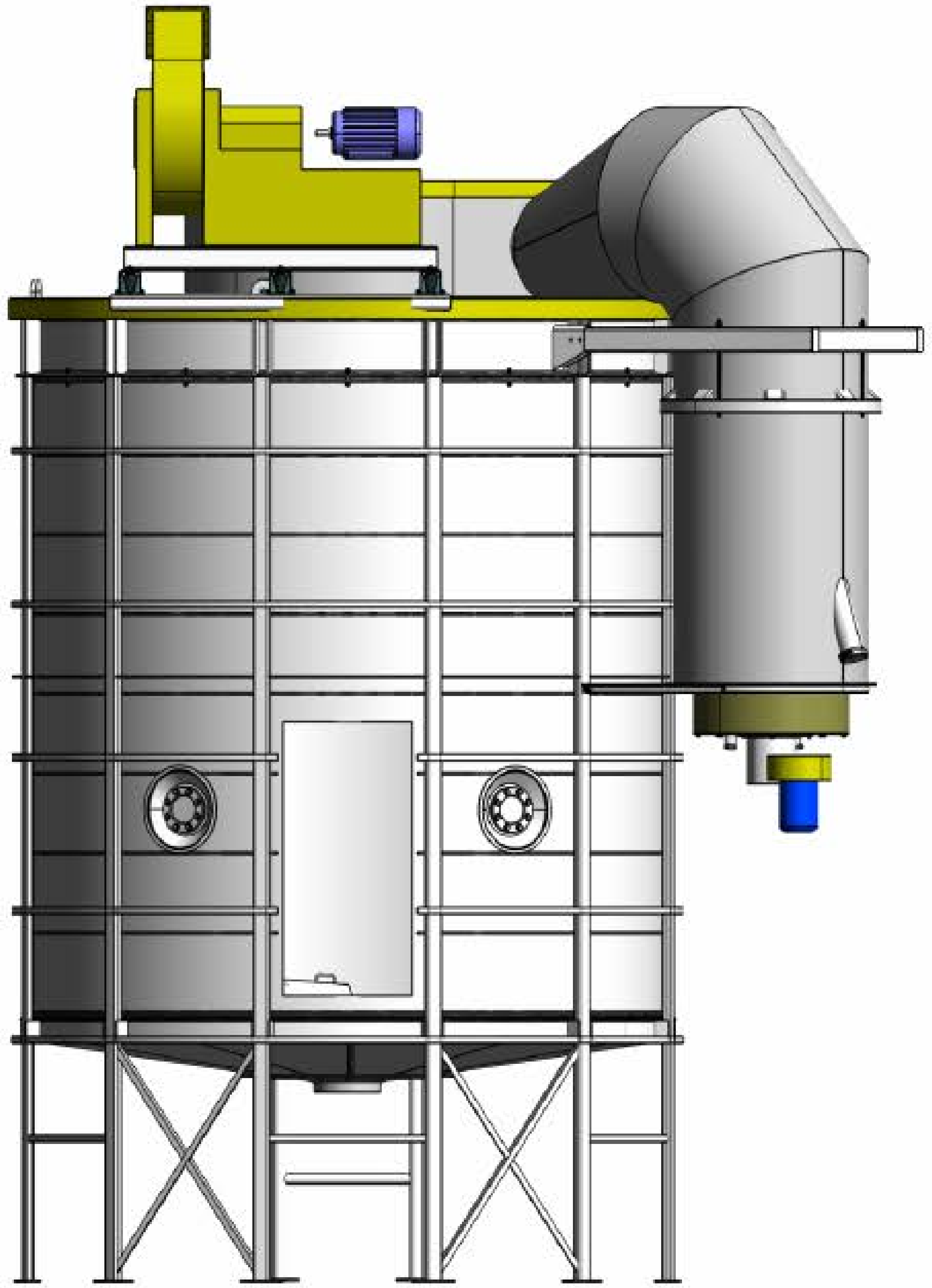
- Stress and fatigue analysis of large-diameter nuclear waste recycling vessels under NQA-1 requirements.
- Vessels with internal piping and structures subjected to sloshing, seismic and added-mass effects.
- Transient thermal-fatigue of thick-walled tanks.
- Lifting and transportation analyses.
- Buckling analysis via ASME formulas, Eulerian and Nonlinear methods.
- Differential thermal-stress analysis of heat exchanges having mixed materials.

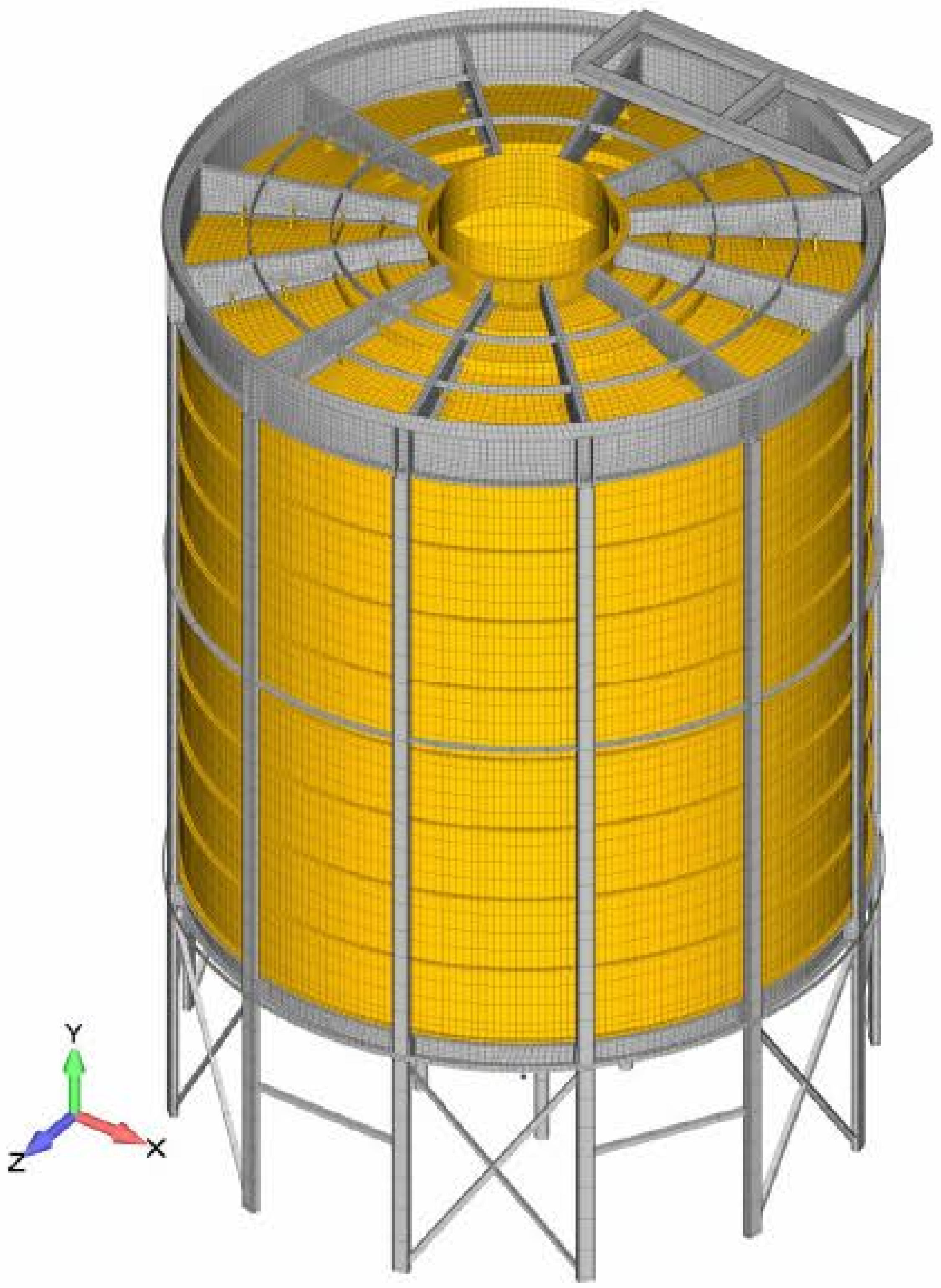
Within this body of pressure vessel consulting work, we have applied the following codes:

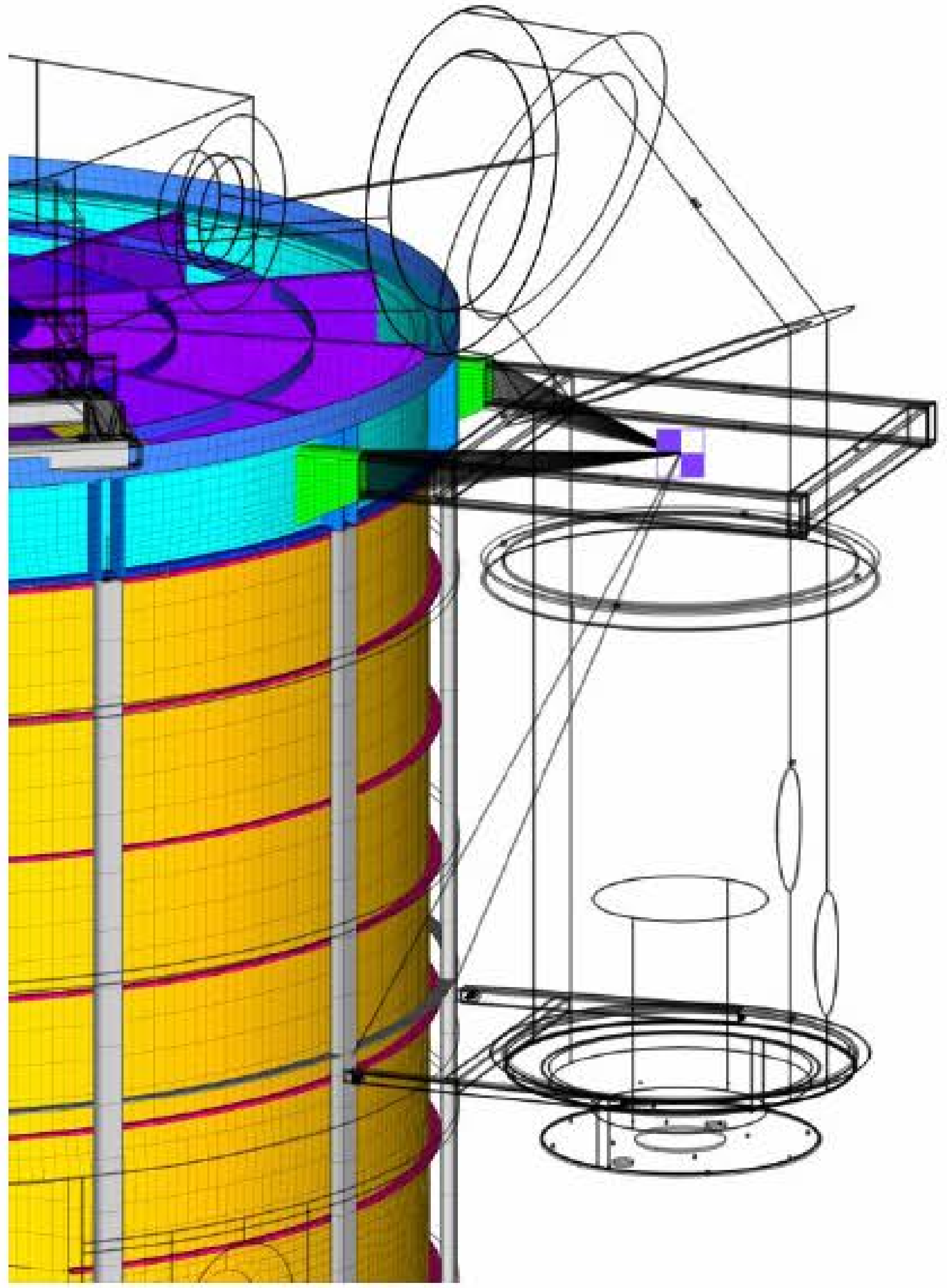
- ASME BPVC Section VIII, Division 2 stress and fatigue
- ASCE 4-98 with added-mass applications for normal modes analysis
- ASCE 7-02, AISI N690 and ABS

To take our engineering work to the next level, our pressure vessel consultants have written custom software for stress and fatigue evaluation of thin and thick-walled pressure vessels and when needed been able to perform optimization studies on vessels via Excel spreadsheet via our FEA software's application programing interface.

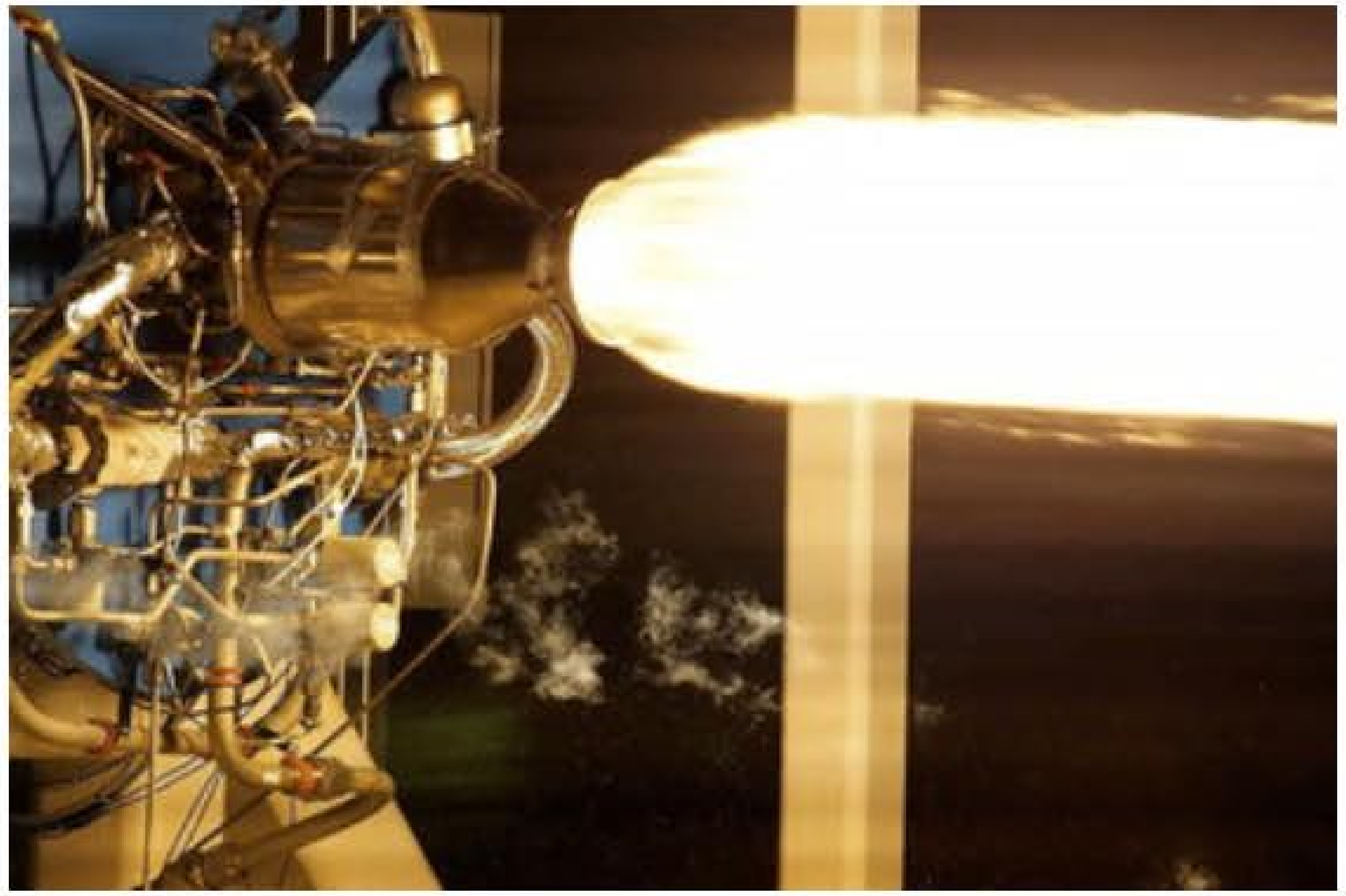
In summary, our careful and meticulous analysis work has allowed us to classify tanks and vessels as "fit-for-service" that would typically have required extensive rework by hand-calculations. Clients come to us when they need high-quality work executed and documented to withstand the most rigorous reviews whether DOE, Bechtel, GE Water and Gas or SpaceX.

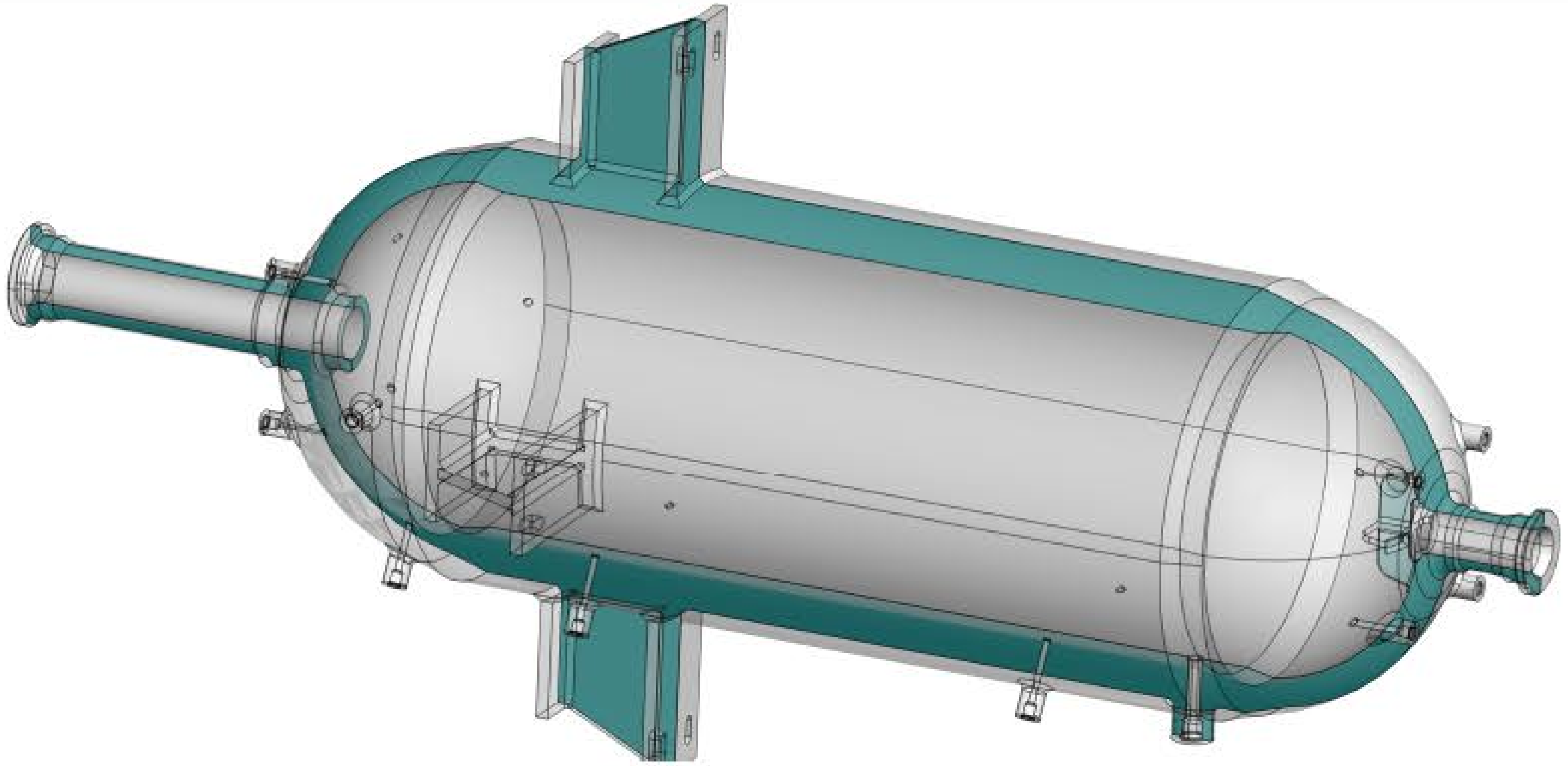


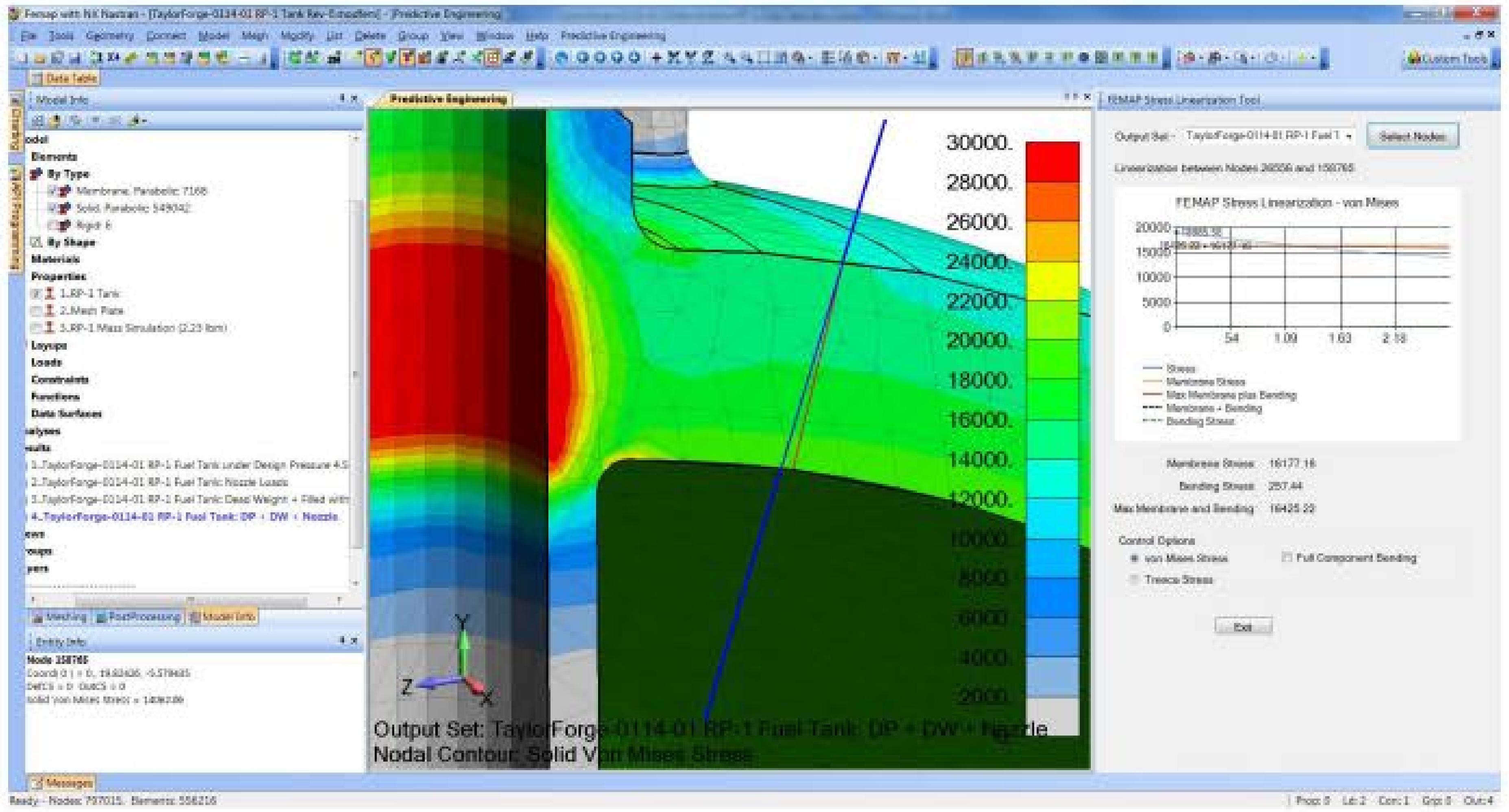


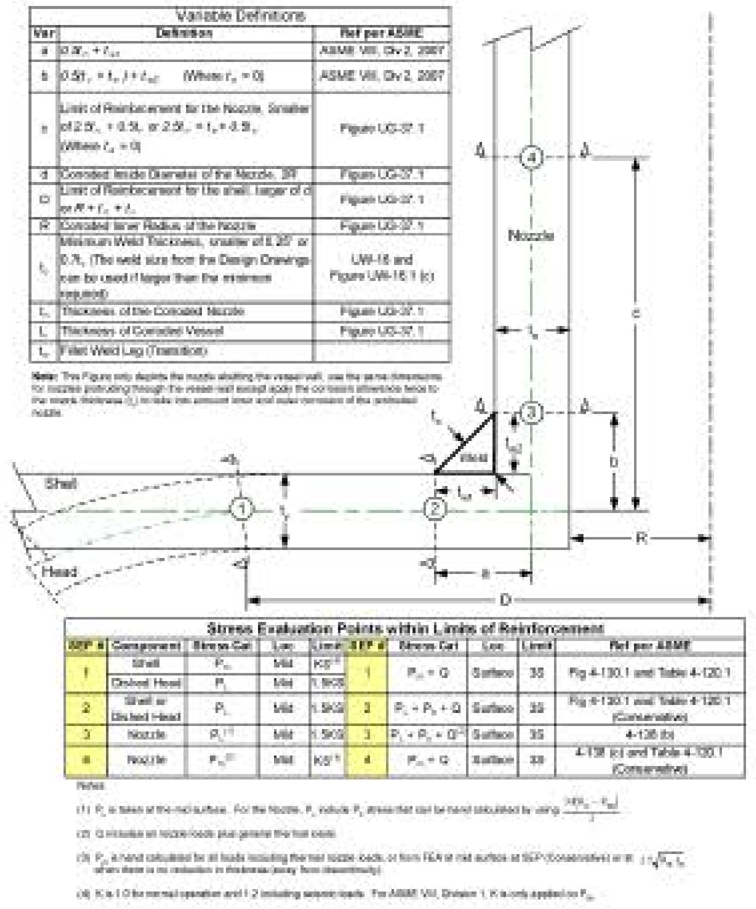


A large diameter spray-drying chamber was analyzed for seismic, wind and lifting. Applicable codes were ASCE 7-02 with reference to the UBC and ANSI A58.1. The lifting stress requirements were borrowed from ASME, Section VIII, Division 2. The model was highly idealized and allowed sections to be optimized for seismic and lifting.

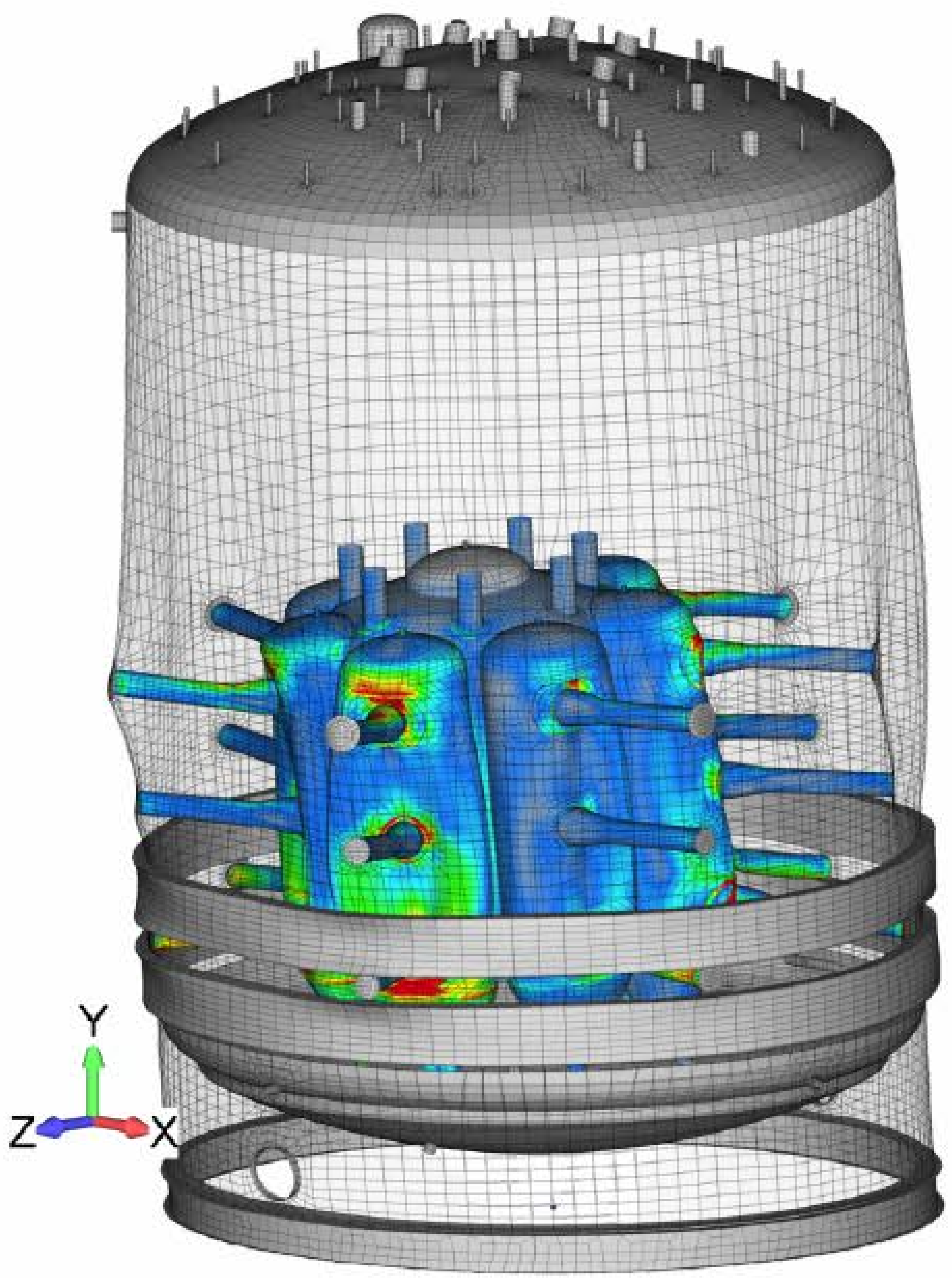


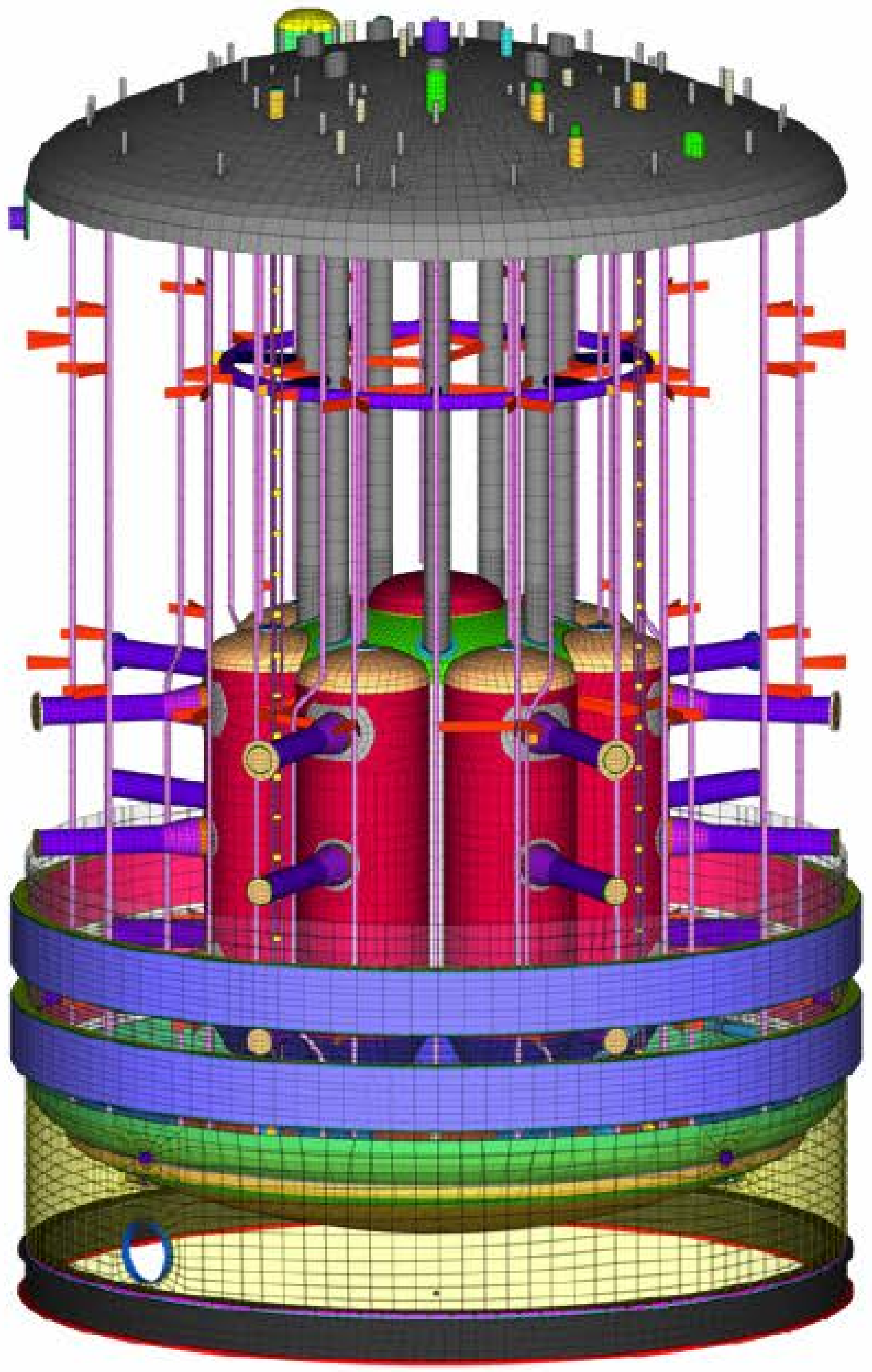




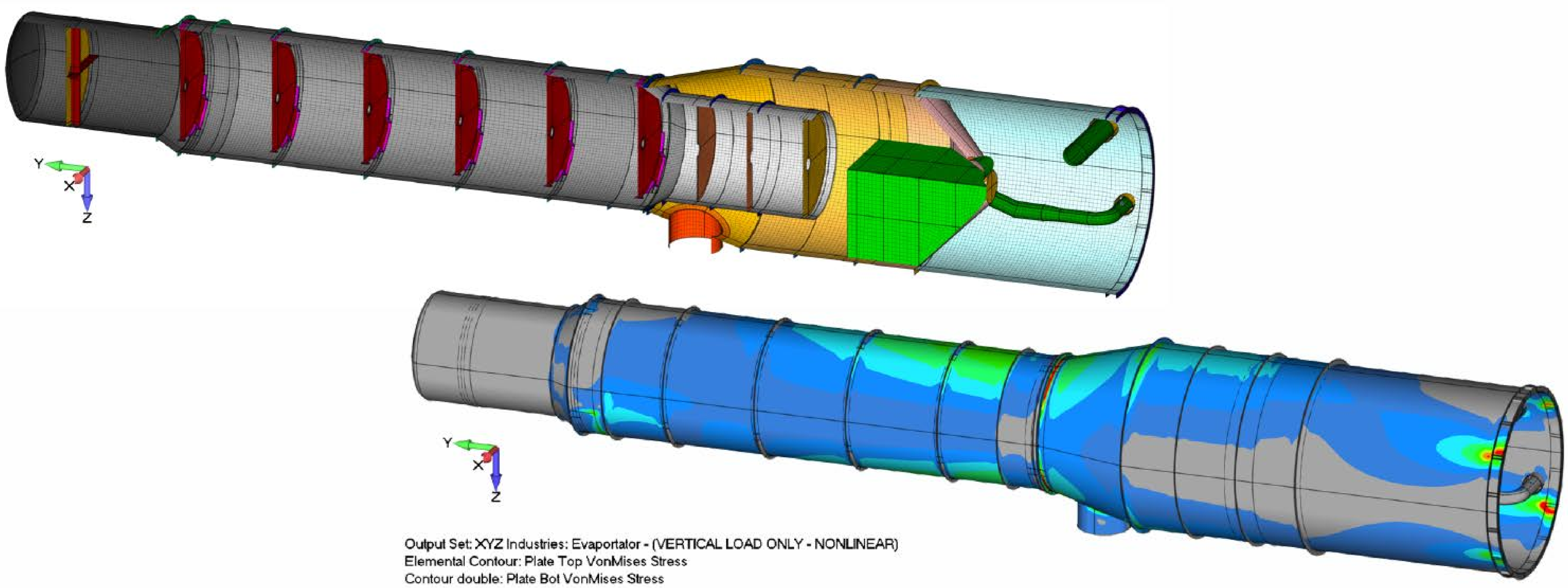


Thick-wall, high-pressure liquid oxygen (LOX) tanks experience thermal fatigue conditions not rarely seen in normal pressure vessels. Stress classification required our complete ASME software arsenal. Membrane stresses were calculated using standard ASME stress linearization.

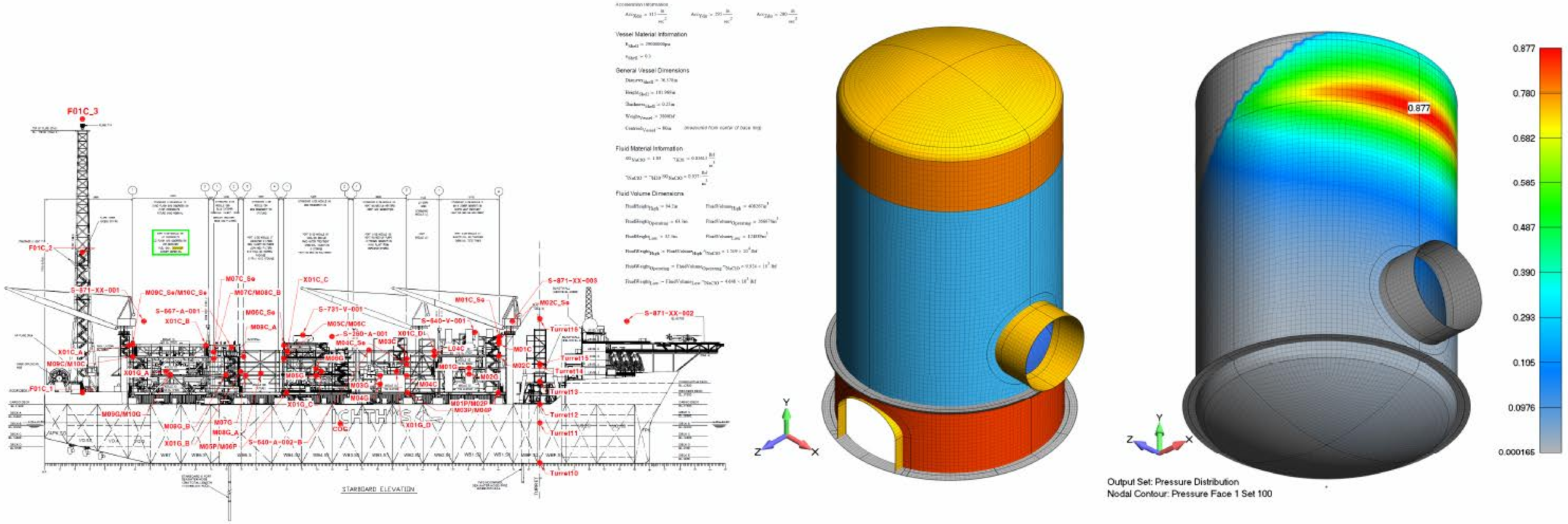




Seismic, thermal, dead weight, nozzle and pressure analyses were performed on a series of large-scale (e.g., 300" diameter) nuclear waste processing vessels for the DOE. Engineering work was approved under ASME Section VIII, Div. 2, ASCE 4-98 for Seismic Analysis of Nuclear-Related Equipment and associated NQA-1 requirements.

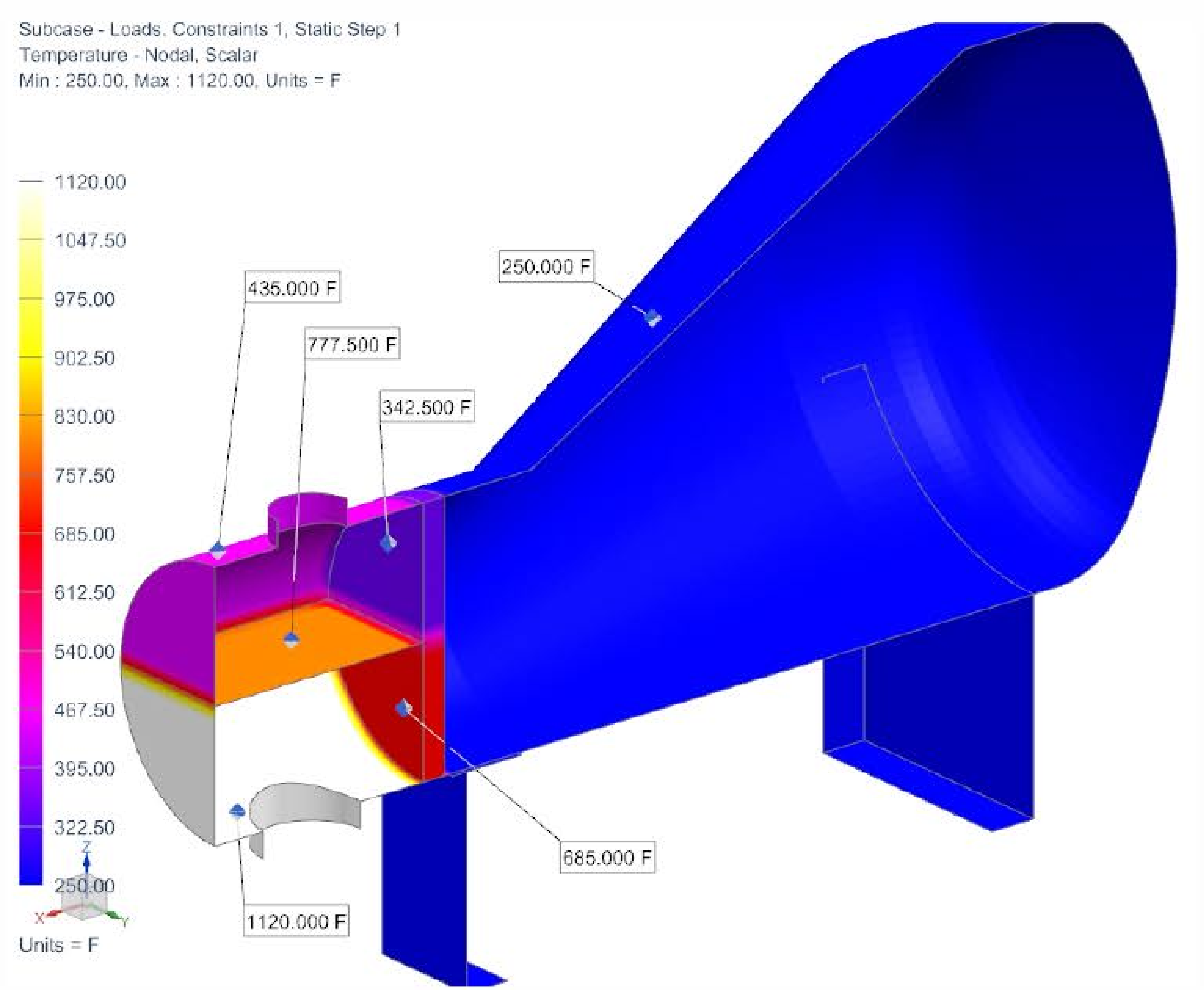


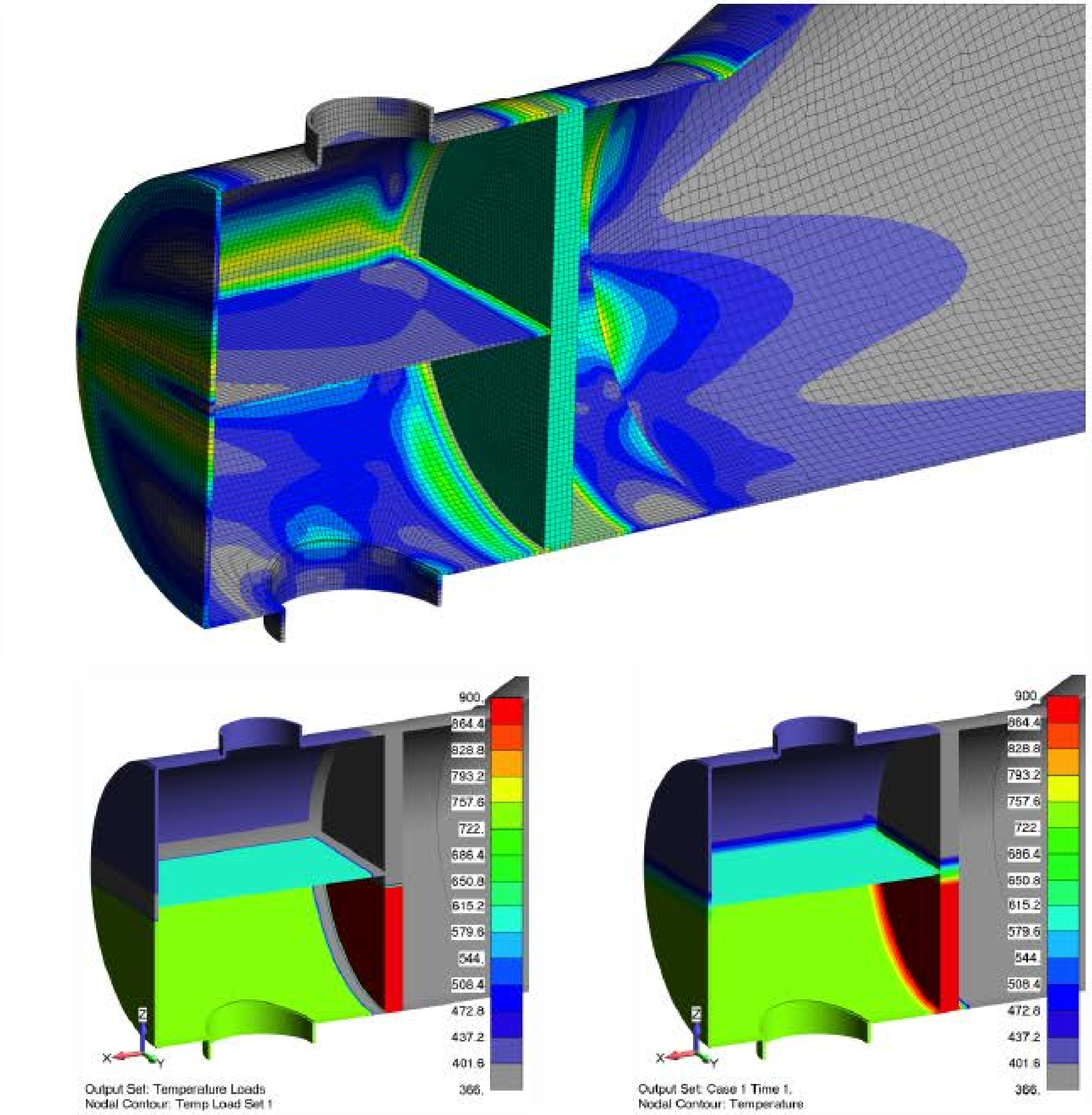
A 100 foot-long tube and shell evaporator was analyzed for stress and deflection based on jointly developed transportation loads. Stresses were classified according to ASME Section VIII, Div. 2. The evaporator was fabricated with several different material types, each with different ASME Division 1 material allowables. The vessel was constrained with a saddle support near the top tubesheet with a Schnabel connection at the base of the skirt.



Off-Shore Processing Platform: Sloshing Analysis

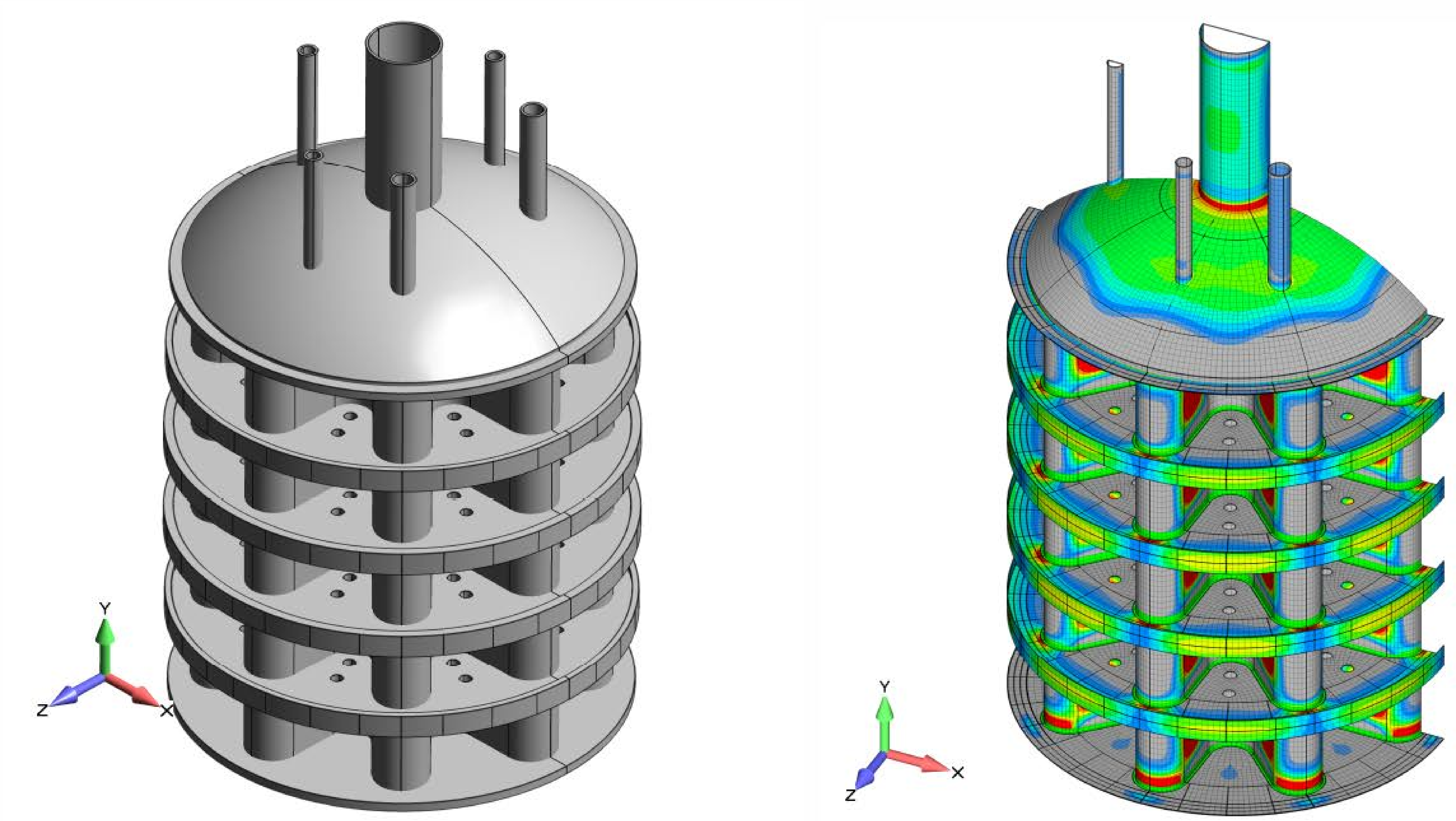
The sloshing loads for this vessel were calculated per ASCE 4-98, Seismic Analysis of Safety-Related Structures. From these calculations, three loading conditions were derived: Horizontal Impulsive Mode, Horizontal Sloshing (Convective Mode) and Vertical Fluid Response Mode (Breathing). Hand calculations were done along with Smooth Particle Hydrodynamics (SPH) to simulate the sloshing event. Analytical and numerical results correlated and the vessel was classified “fit-for-service”.



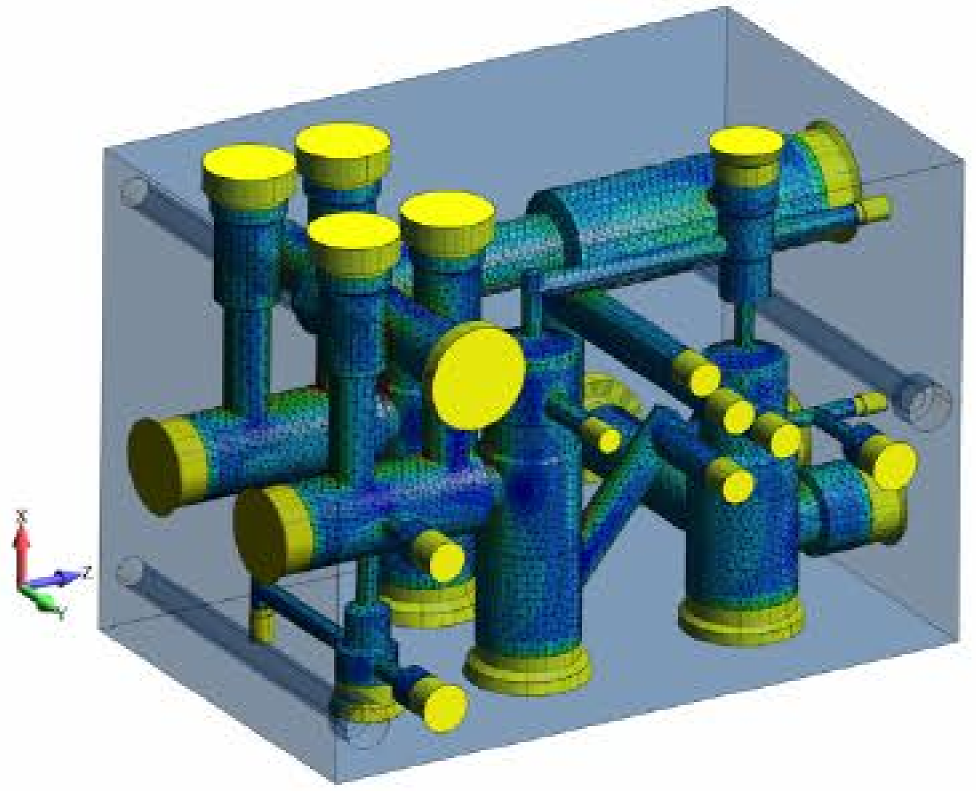


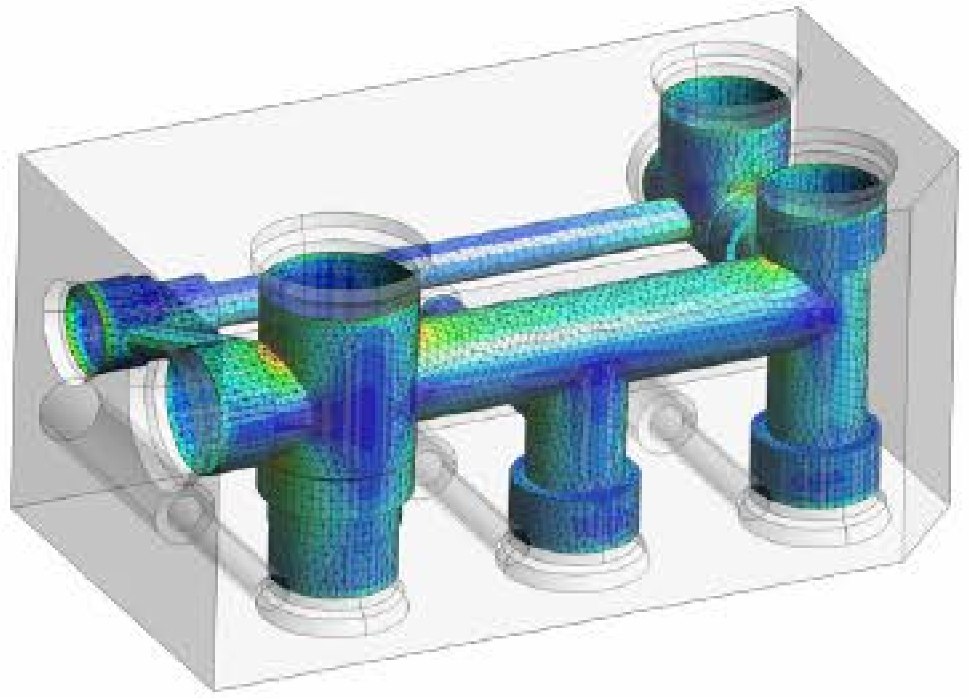
Thermal-Stress Fatigue Analysis of Boiler

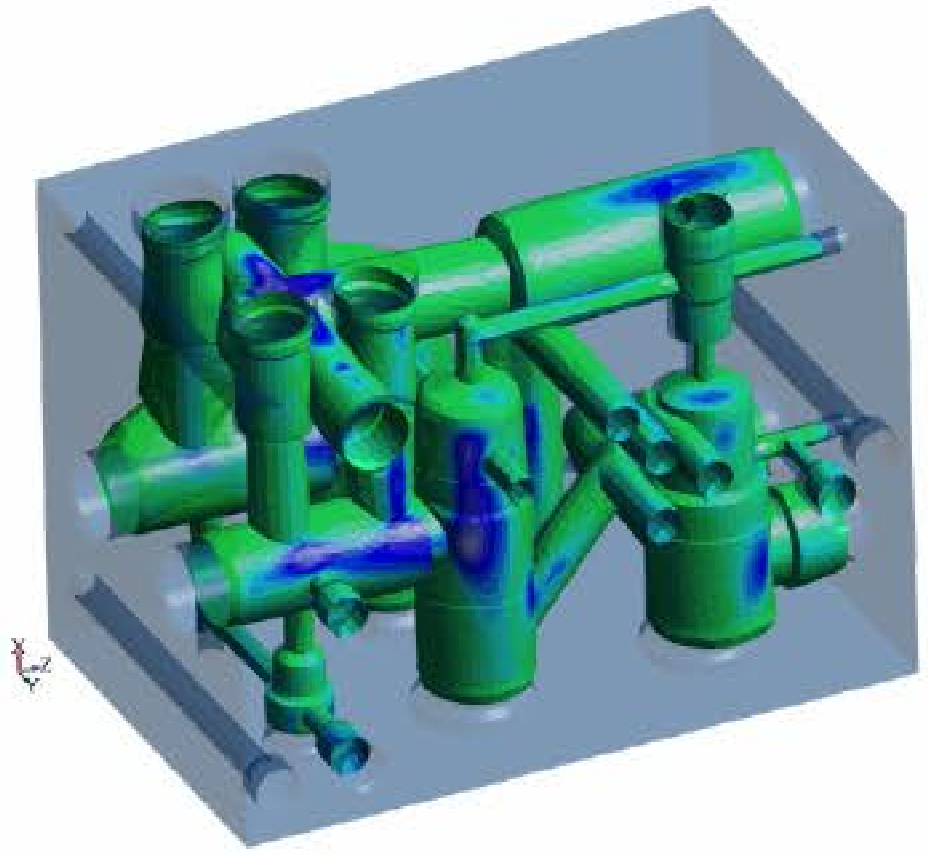
An ASME thermal fatigue analysis was performed on a high-temperature flue gas steam generator (i.e., boiler). Given the large thermal gradients between the flue gas inlet and outlet, the thick tube sheet presented a particular thermal-stress challenge. The vessel passed based on peak alternating stress (Sa) per Figure 5.110.2.1.

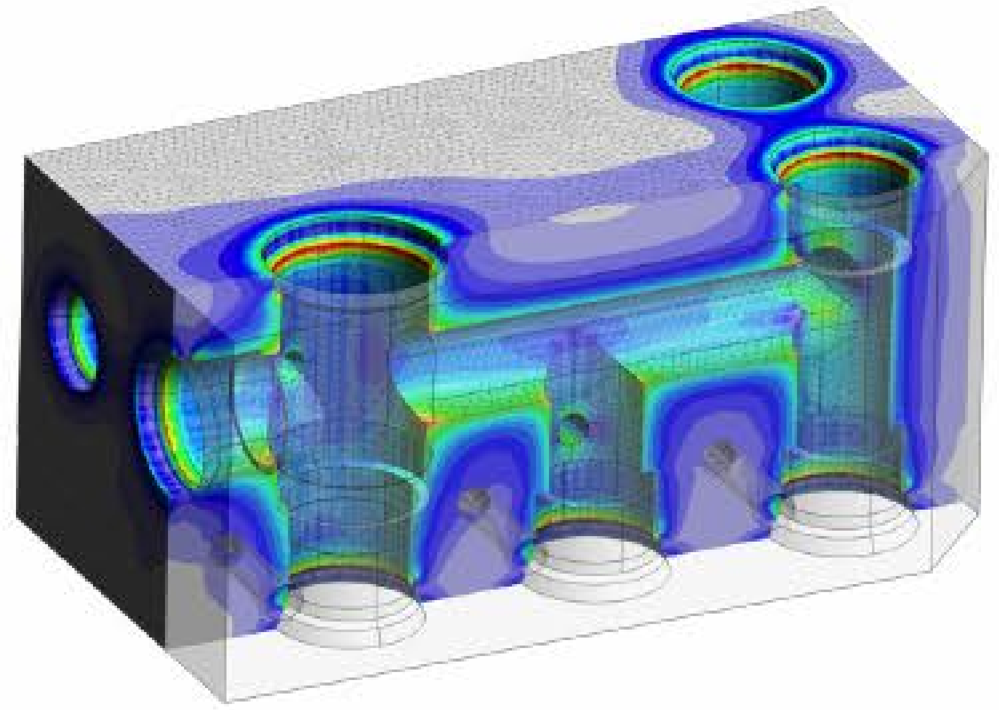


Sometimes our best work is to optimize a design into something compact, efficient and robust. The above model represents a unique type of ASME pressure vessel that must withstand high pressures while simultaneously having a large surface area for heat transfer requirements.

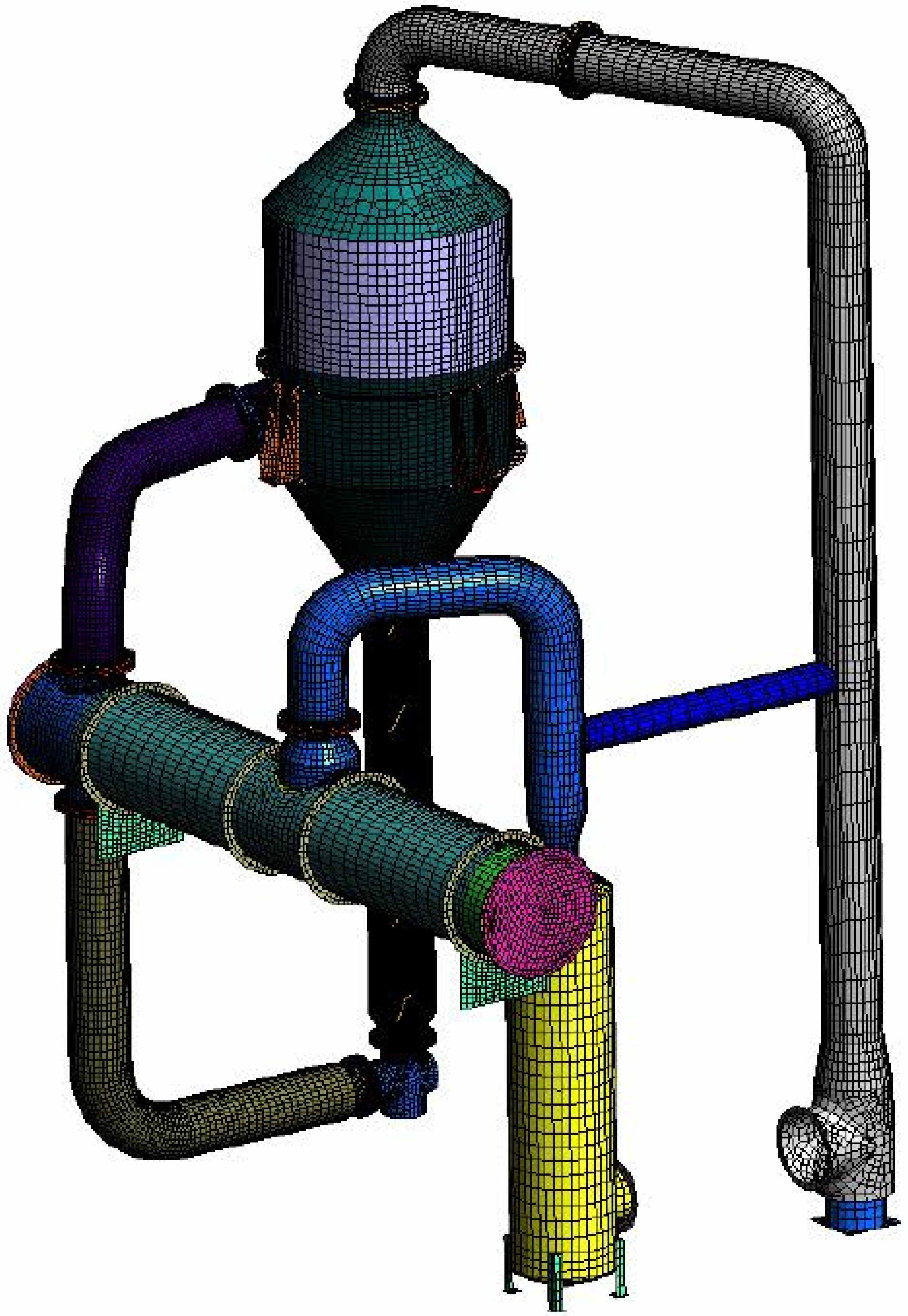


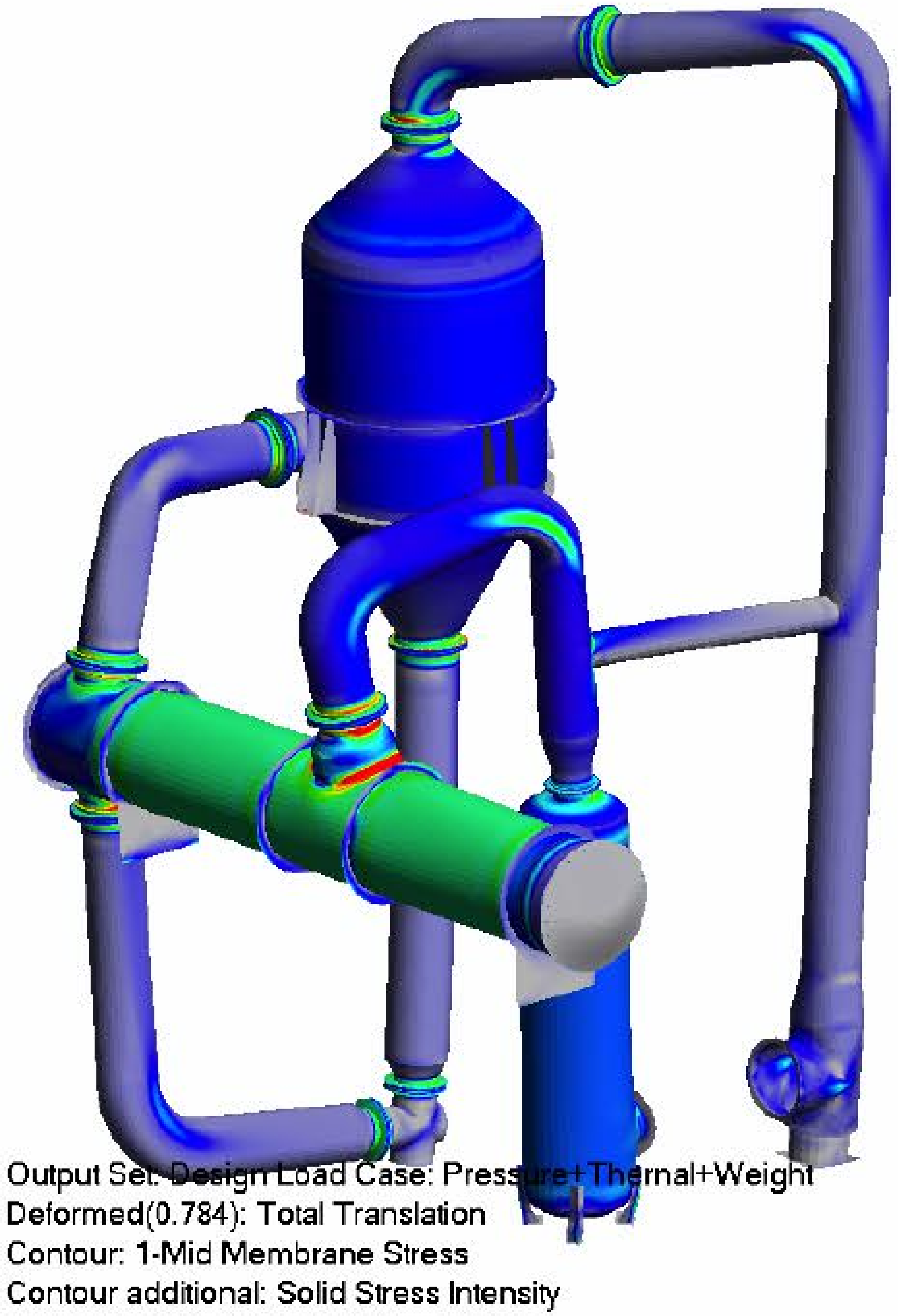




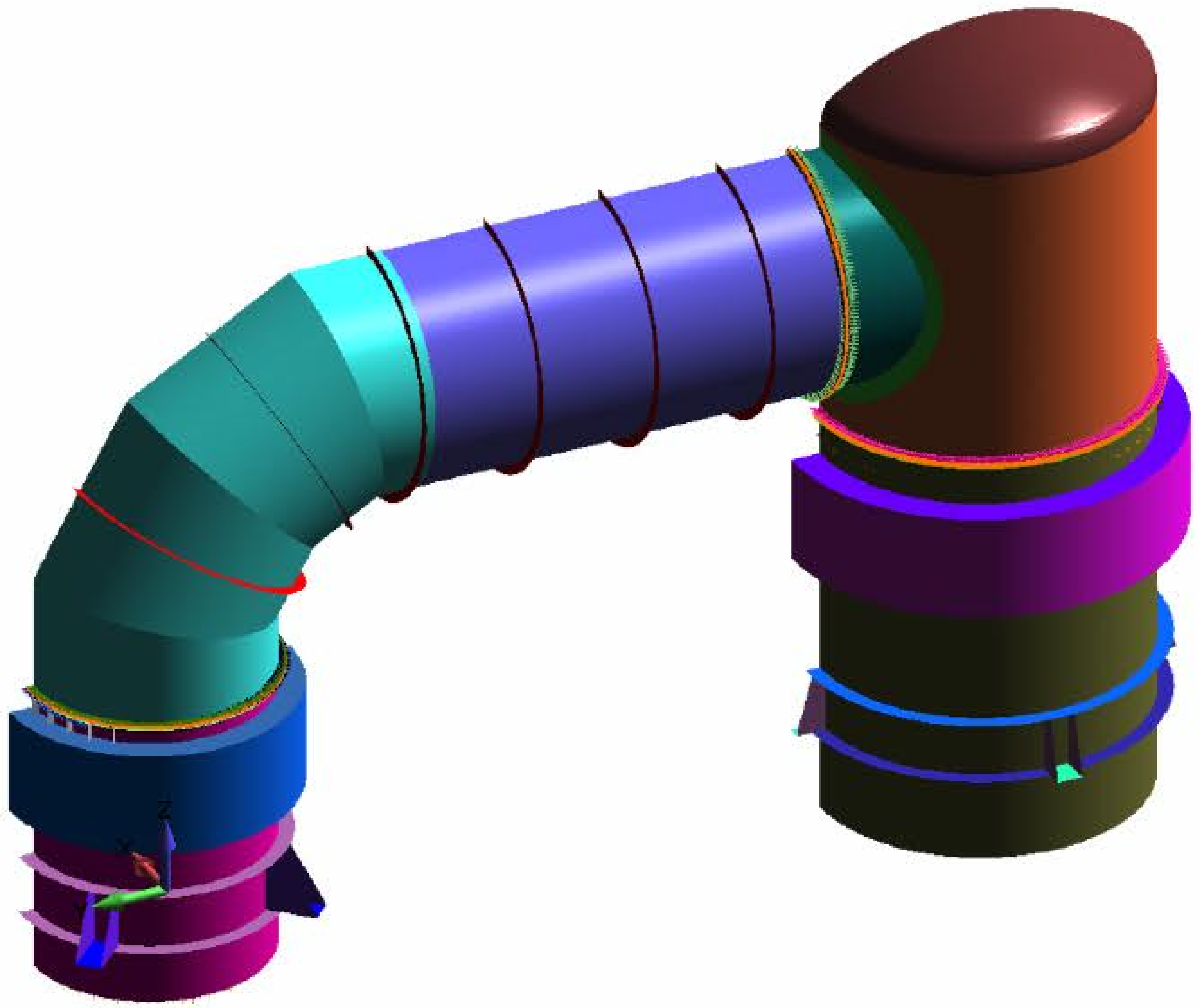


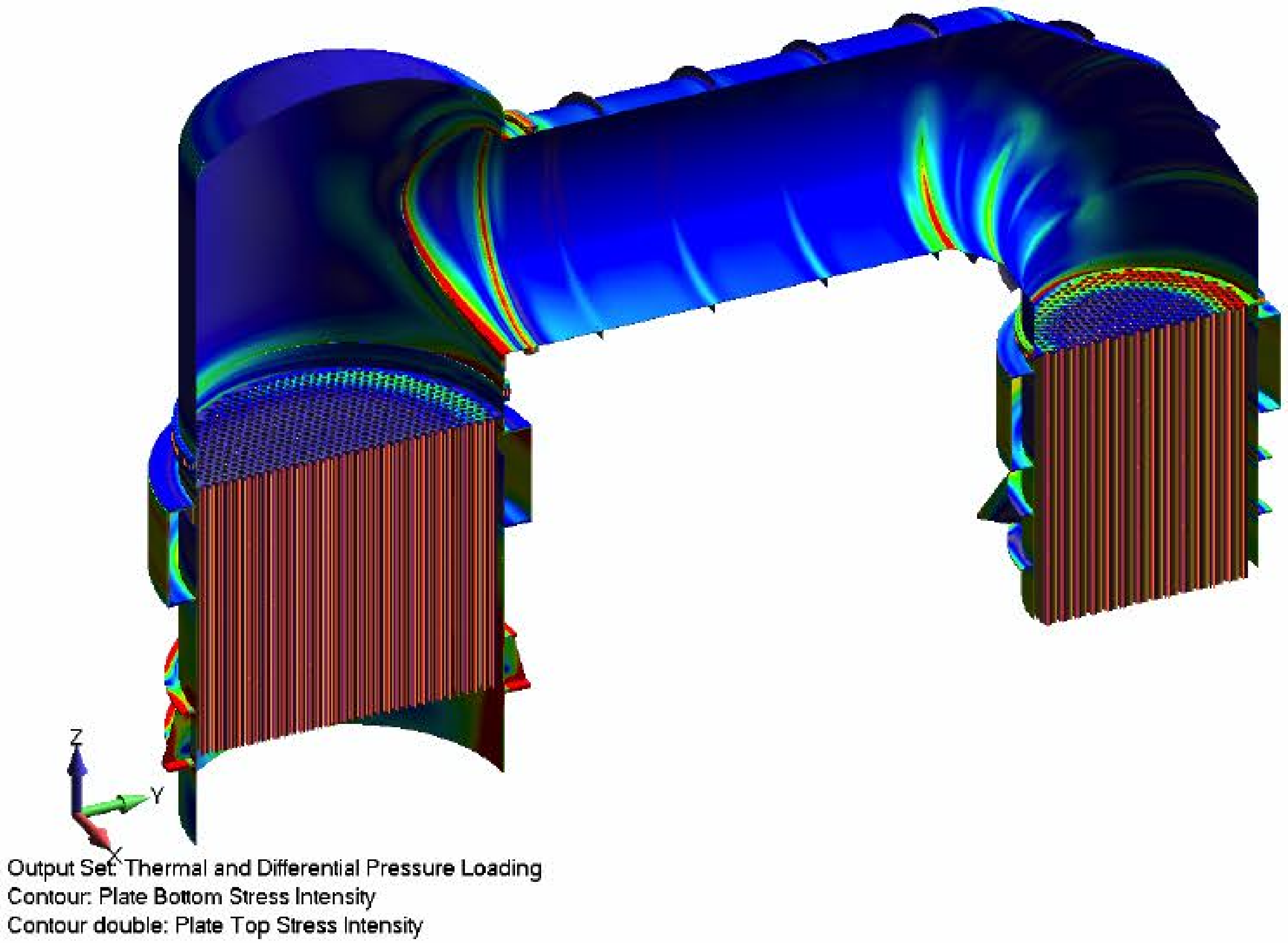
High-pressure manifold castings are not uncommon in marine and chemical processing applications. Usually, it is enough to perform a standard hydrostatic test (UCD-99) at twice the maximum allowable pressure but in this case, our client's client (US Government) requested that their high-pressure hydraulic manifold castings also meet ASME Design-by-Analysis specifications including protection against plastic collapse. Standard ASME Section VIII, Division 2 rules can be met with linear static analysis but plastic collapse assumes that the casting must hold together under 2.4x the design load. This last requirement was met by performing a complete nonlinear stress analysis using LS-DYNA.



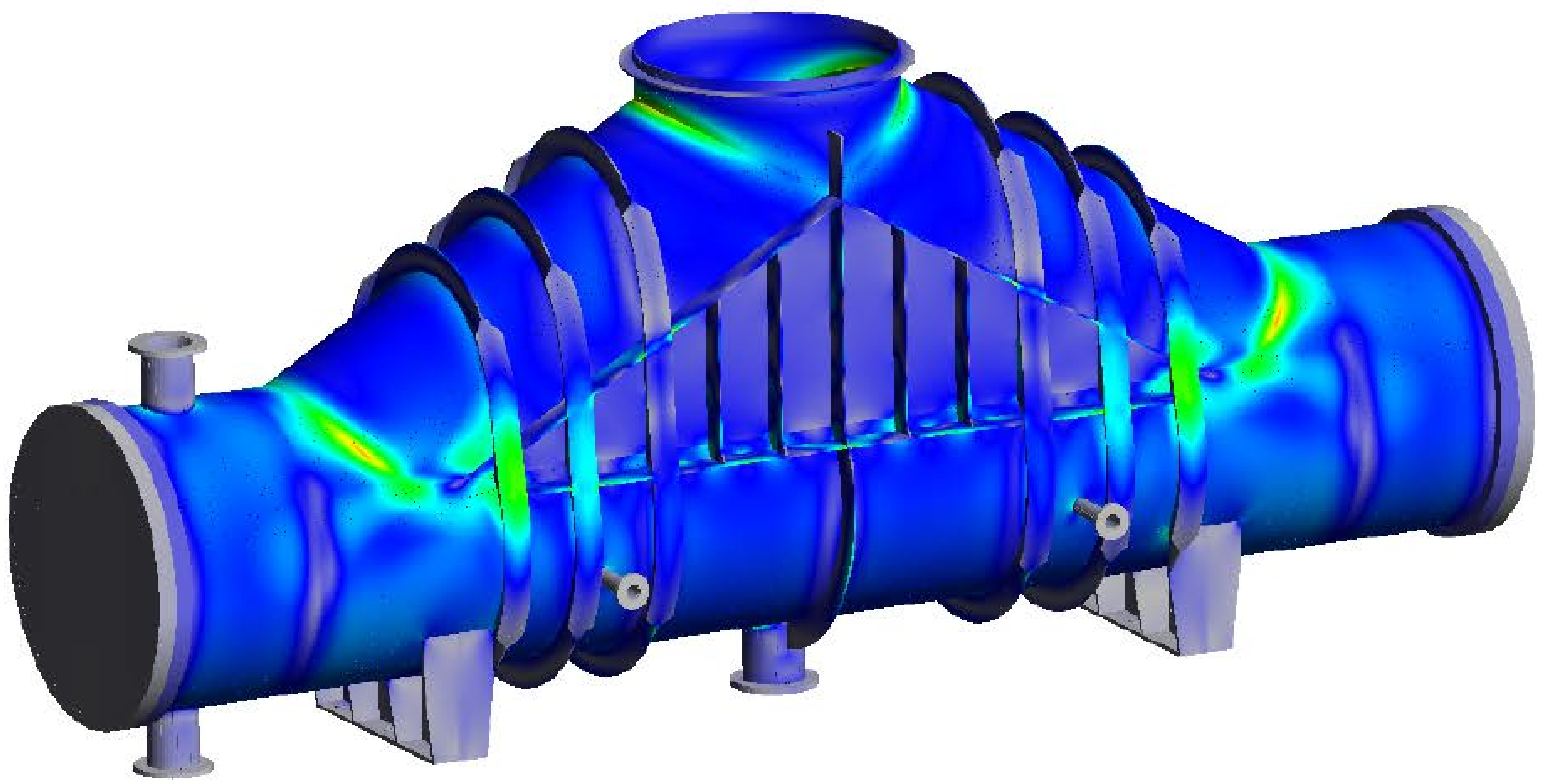


Shown above is a tube and shell heat exchanger coupled to piping system. The system is mounted on a structure steel frame (not shown). Thermal and stress analysis calculations were performed per ASME VIII, Div. 2 to determine thermal and stress margins. Some optimization work was done on the lower piping system due to wind loading effects per ASCE 7-02.



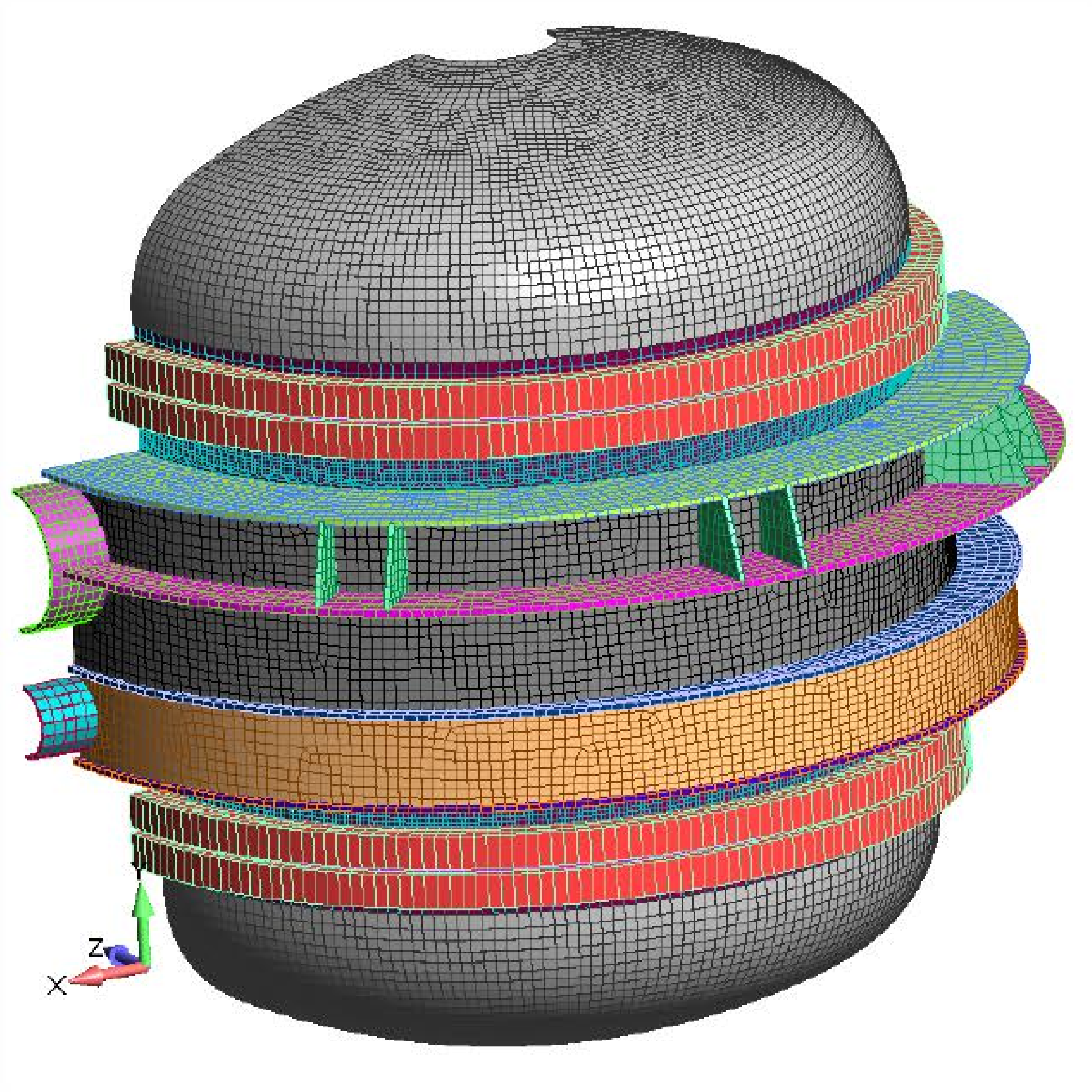


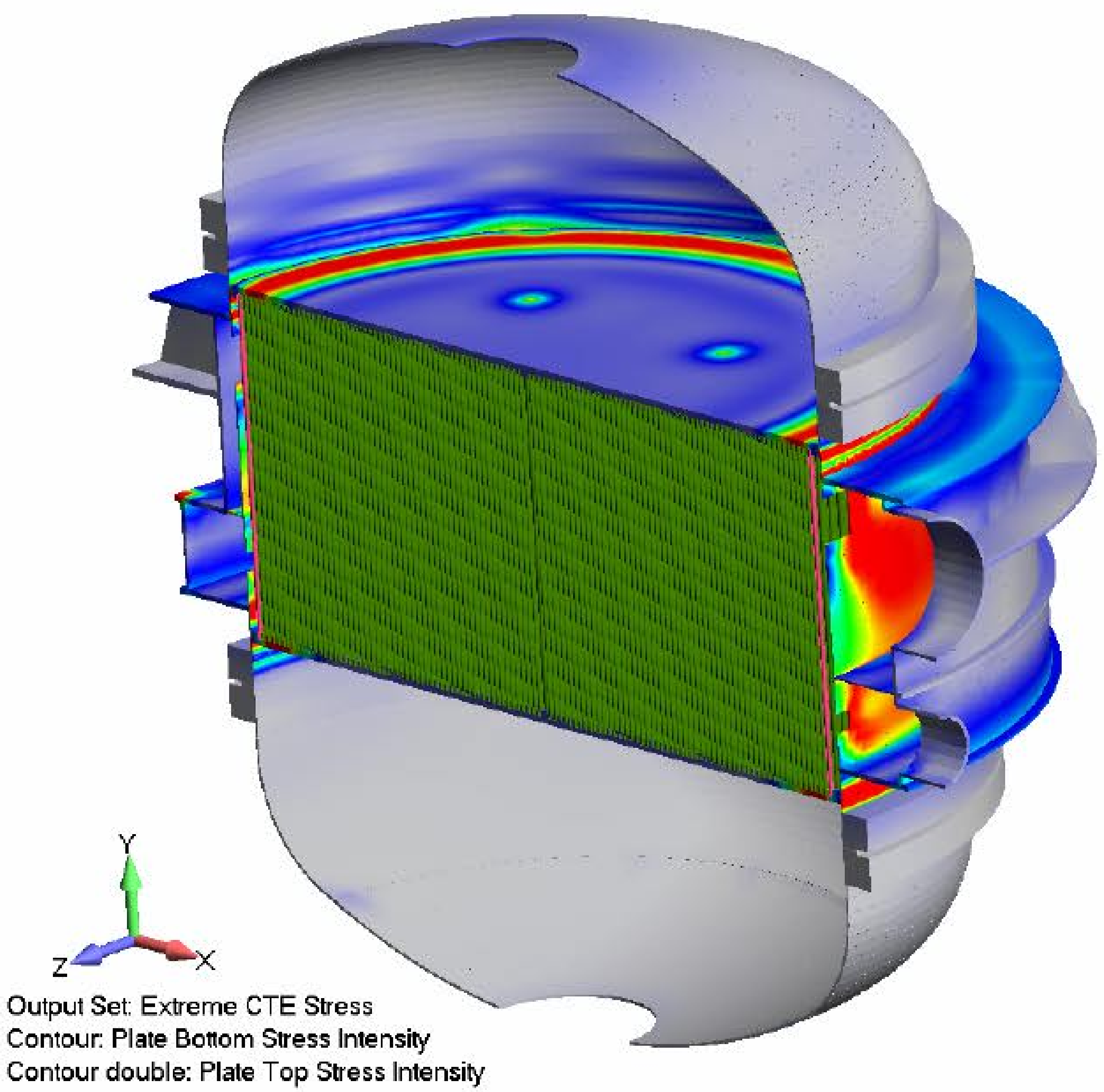
Shell and tube heat exchanger for a boiling tube, dual-vessel evaporative system. The main shell was titanium with the tubing of SA-240. Design and analysis work performed for the Dedert Corporation.



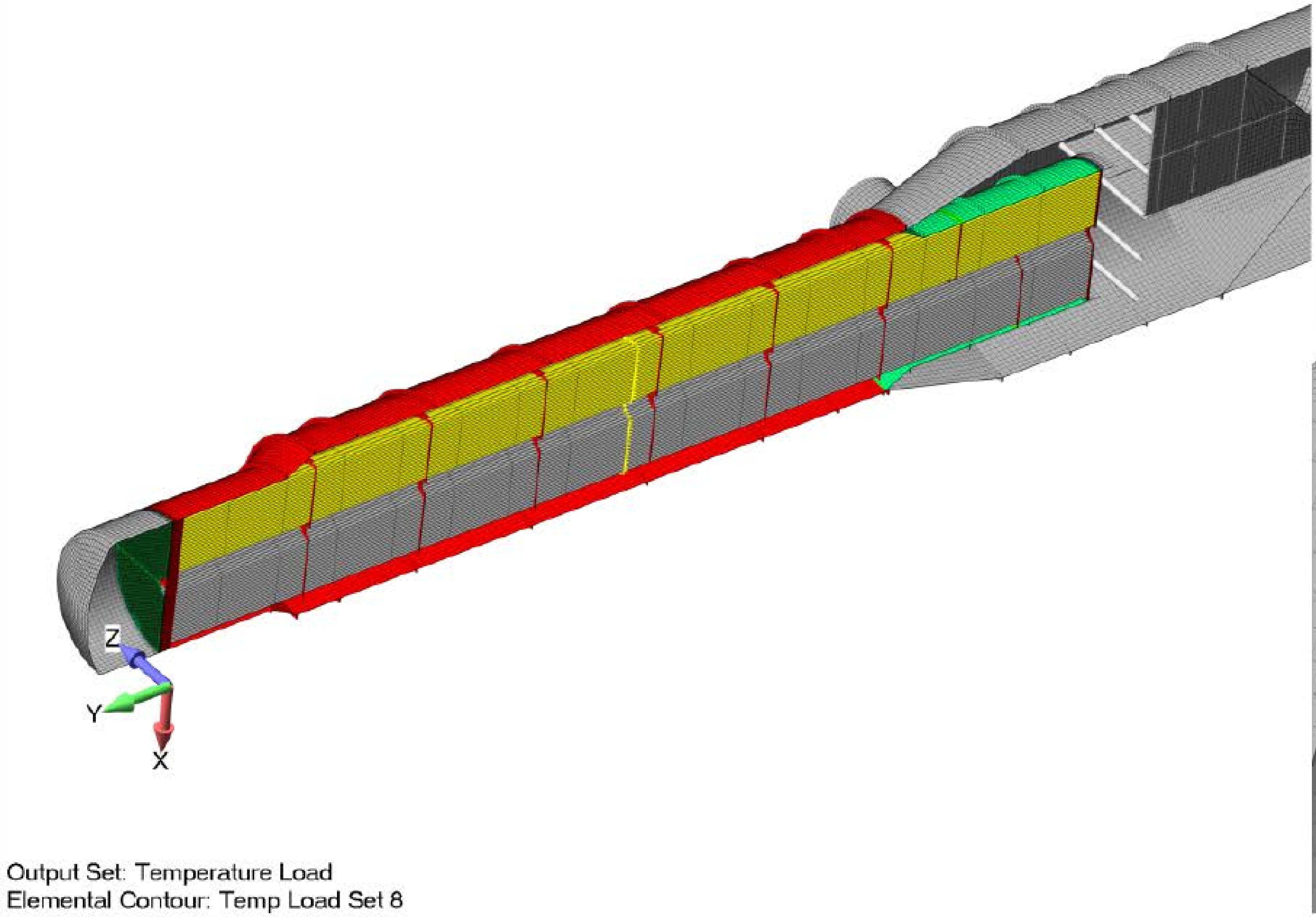
Output Set: ASME Section VIII, Div 2 Design and Analysis of Shell and Tube Heat Exchanger
Contour: SI-Mid Membrane Stress

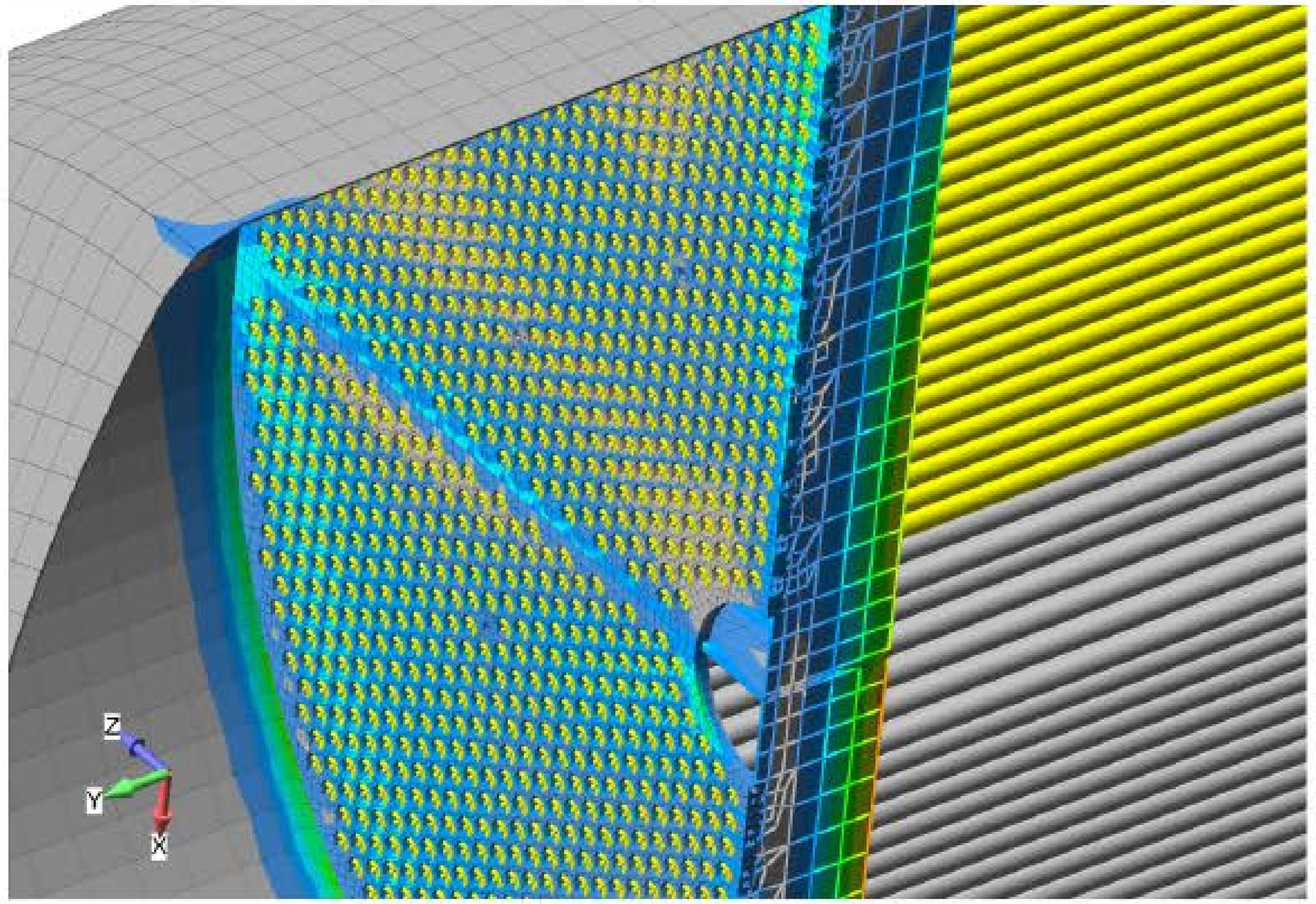
Shell and tube heat exchanger per ASME Section VIII, Div. 2 analyzed for design, operating, buckling and seismic loading. The final design of the vessel required 14 design iterations due to internal baffle constraints to prevent buckling. The final buckling analysis was done by geometric, nonlinear analysis to confirm safety margins.



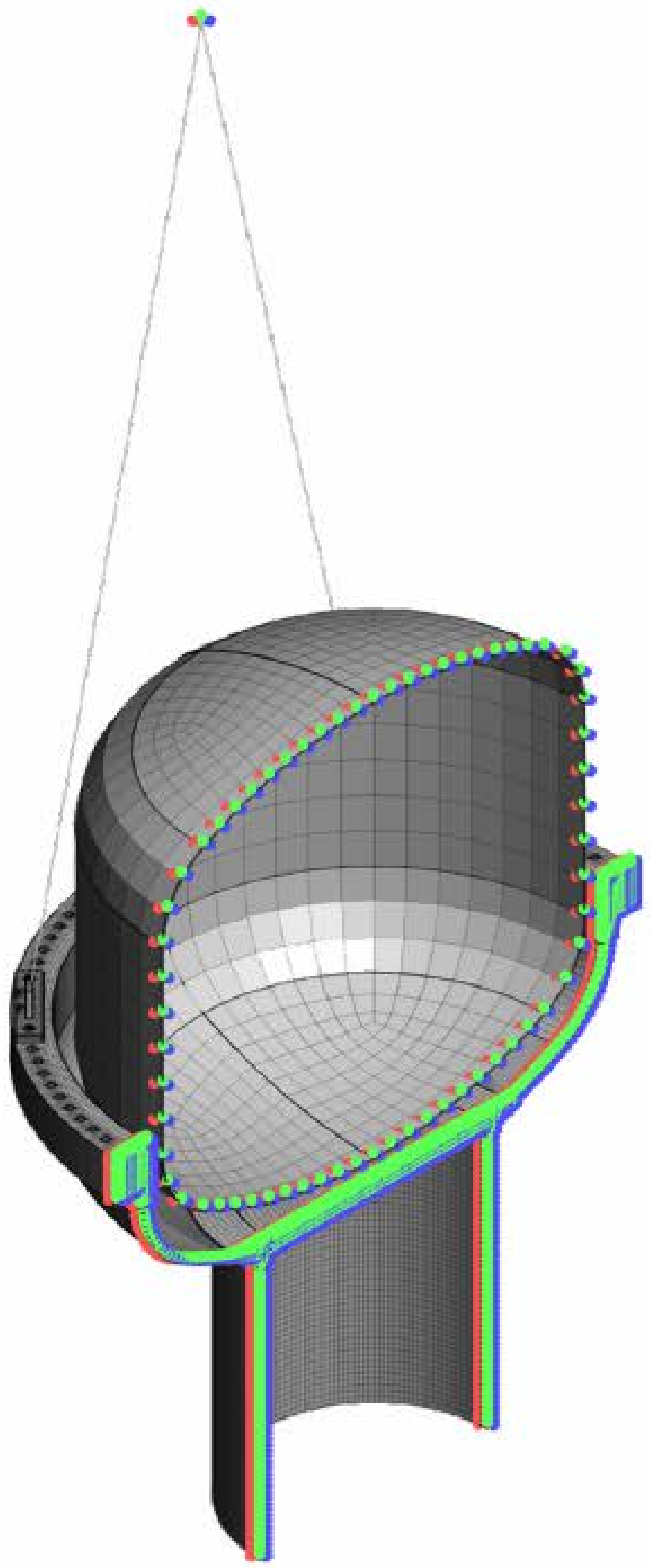


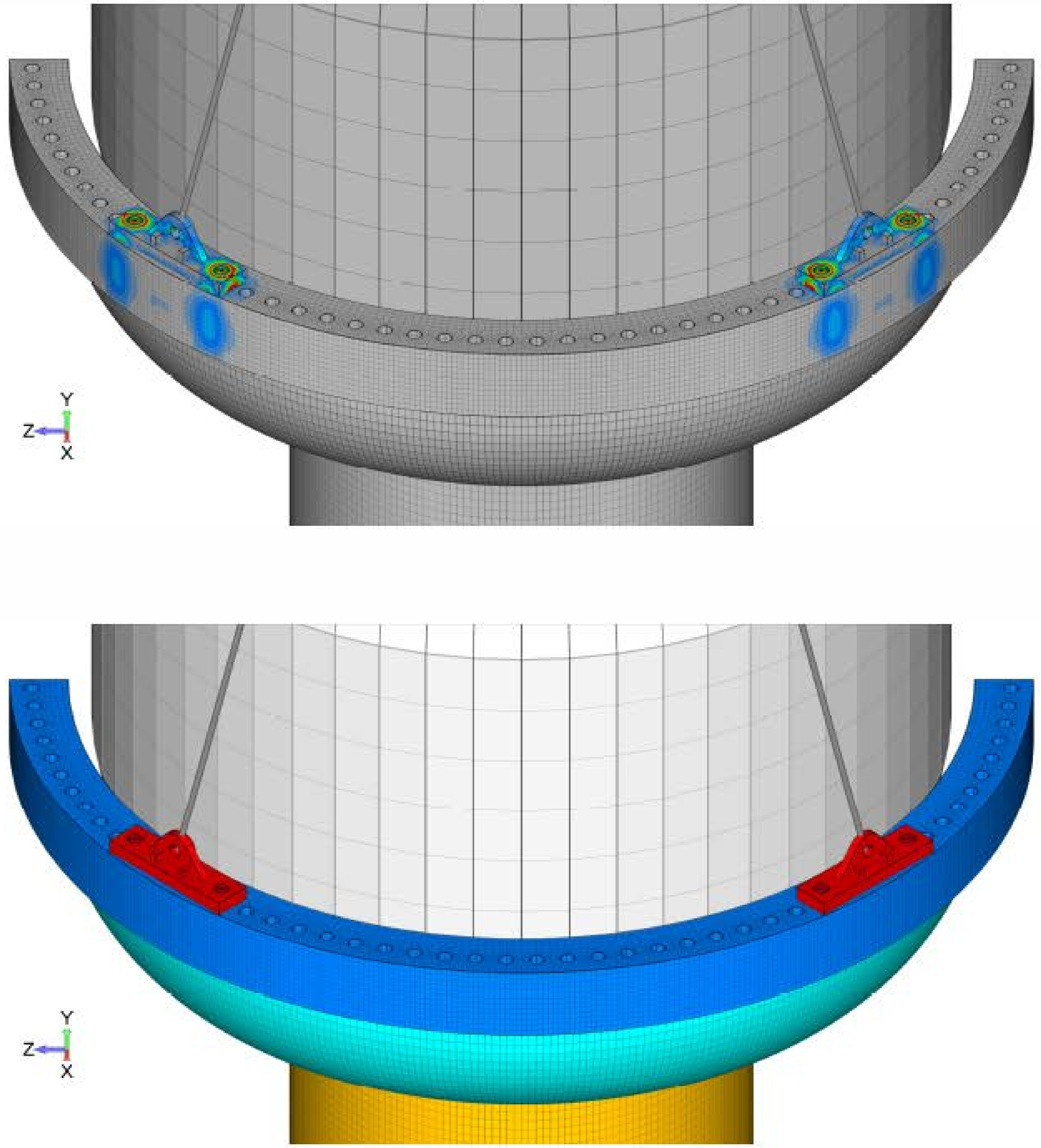
Formaldehyde reactor analyzed for thermal and mechanical performance. ASME Section VIII, Div. 2 code requirements on internal shell and tube heat exchanger.



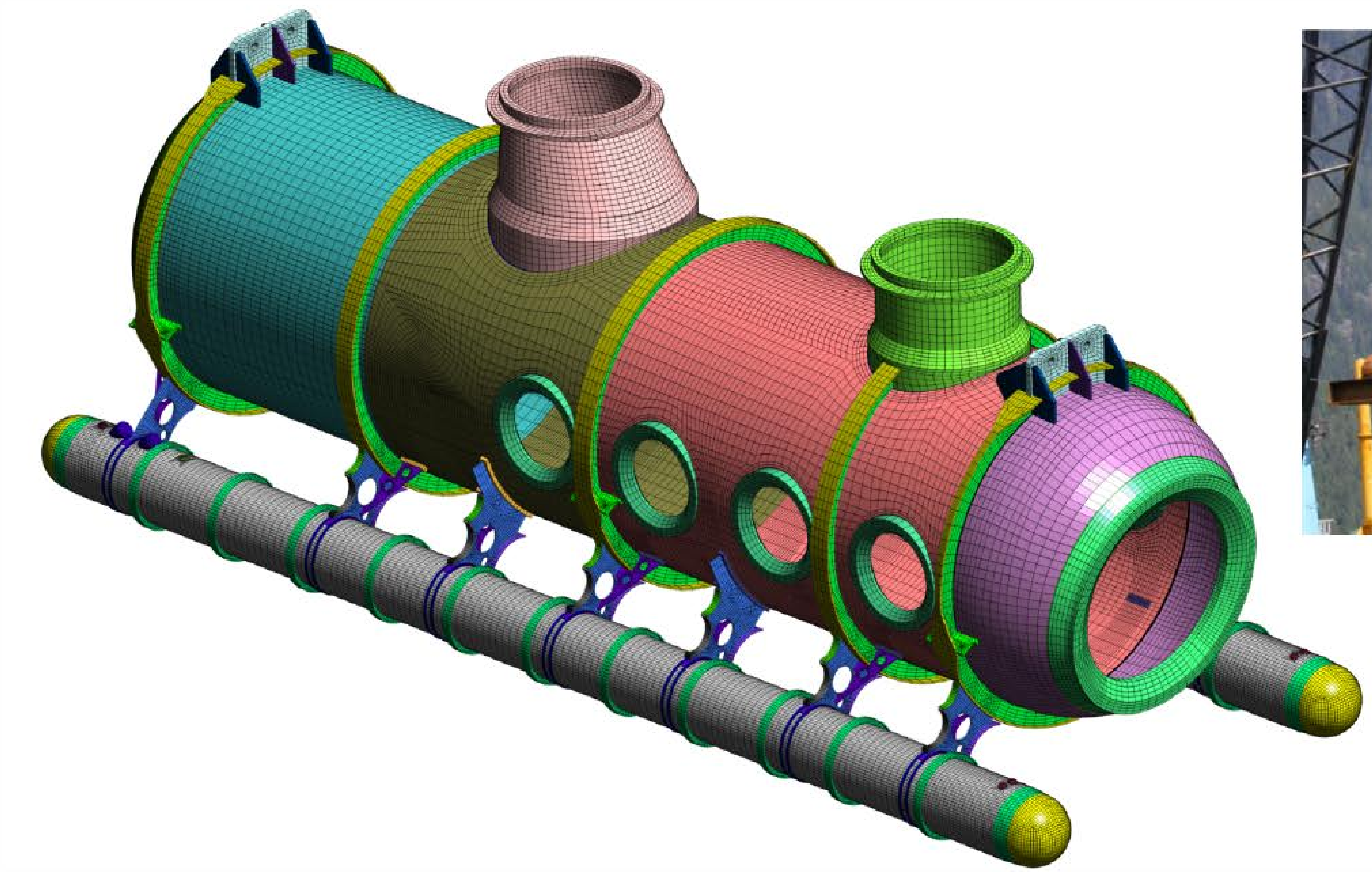


Very large ASME vessel analyzed for tube-sheet stresses arising from dual-material tube-bundle with likewise dual material shell. Thermal-stress analysis was performed to classify system under ASME stress and fatigue requirements.





A complex lifting analysis was performed to verify that an already built vessel system would not exceed ASME Section VIII, Div. 1 allowables. The slings and spreader bar were idealized with beam elements and pinned connections.



Shown above is a FEA model of an eight passenger, deep-diving (depth 1,200') luxury submarine. Stress results were verified by strain gauging of the submarine during its submersible proof-test. Given the close correlation of the stress results to the dive test, it become the first human occupancy submersible certified by the American Bureau of Shipping (ABS) via the finite element method.

About Predictive Engineering

- Based in Portland, Oregon
- 20+ years experience with FEMAP, NX Nastran and LS-DYNA.
- Focused on simulation of complex structures and systems where the right answer is fundamental.

- References can be obtained at our website: **www.PredictiveEngineering.com.**