

CASE STUDY

TANK FAILURE ANALYSIS

EIS

OVERVIEW

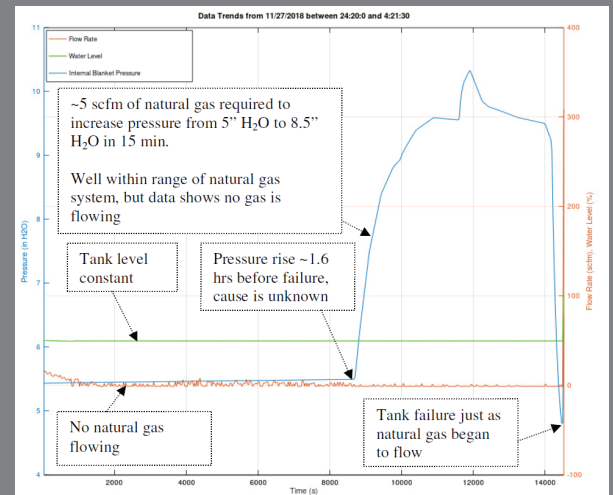
A Cavity Water Collection Tank sustained substantial damage. The roof had become completely detached and its shell to floor joint was broken at several locations. All anchor bolts were either pulled from foundation or broken. Plastic deformation was seen throughout the shell and floor, and buckling was observed in sections of the roof near the roof to shell joint. EIS was tasked to determine if overpressure or deflagration was responsible and identify the root cause.



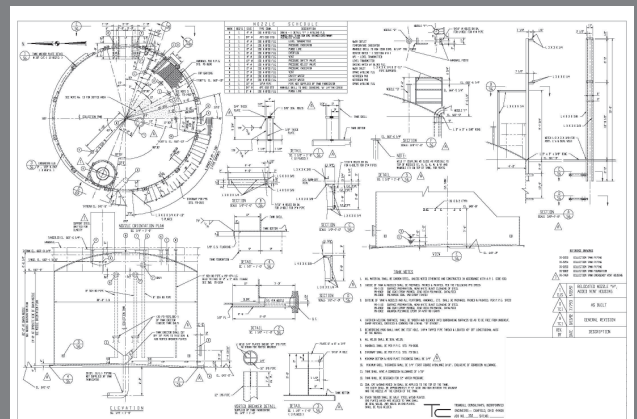
ANALYSIS APPROACH

- 1** PERFORM A FINITE ELEMENT ANALYSIS (FEA) TO DETERMINE THE INTERNAL PRESSURE REQUIRED TO PRODUCE THE LEVEL OF DAMAGE SEEN DURING THE INSPECTION.
- 2** DETERMINE THE AIR TO FUEL RATIO NEEDED TO REACH THE FAILURE PRESSURE PREDICTED BY THE FEA.
- 3** EXAMINE DATA PROVIDED BY CLIENT FOR ANOMALIES THAT COULD BE LINKED TO THE FAILURE.

DATA COLLECTED BEFORE TANK FAILURE



DRAWING USED TO CREATE FEA MODEL



FINITE ELEMENT MODEL

- ▶ Model predicted anchor bolts to fail first. Assuming 1.25"-7 bolts (0.969 in tensile area) with a yield strength of 55 ksi (per ASTM F1554 Gr. 55), maximum tensile load of 53,300 lbs can be achieved before yielding.
- ▶ The FEM showed that the tensile force in the bolt approached this value as internal pressure reached ~4.6 psig.

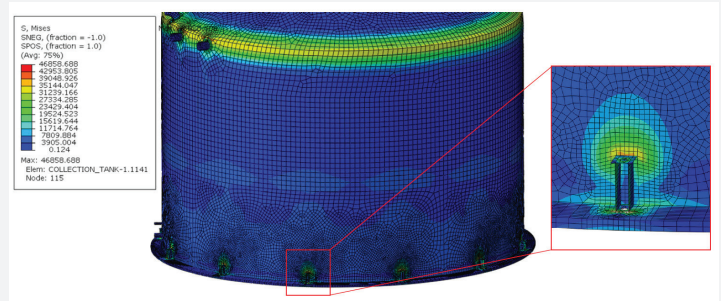


Figure shows a stress contour plot of the tank at ~4.4 psig.

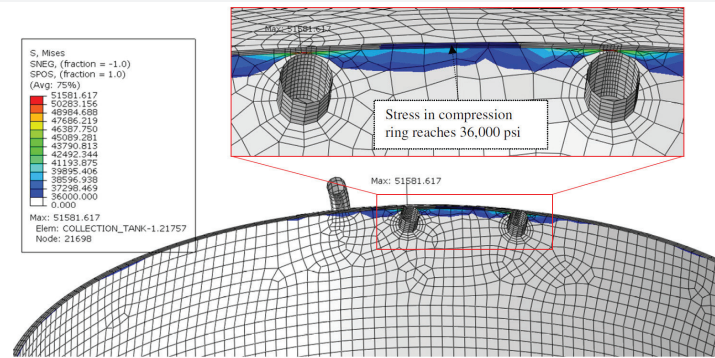


Figure shows the Von Mises stress at roof joint when ~6.5 psig internal pressure was applied. All areas reporting a stress less than 36,000 psi are shown in gray.

- ▶ The floor and floor joint were found to fail at almost the same time as the anchor bolts. Failure pressure ~4.6 psig.
- ▶ Failure not seen at roof joint until internal pressure reached ~6.5 psig.
- ▶ Yielding seen in shell at pressure slightly below this value, but API 650 and test data show roof failure occurs once compression ring yields.
- ▶ Buckling observed around roof joint once internal pressure reached ~8.0 psig.

CONCLUSION

- ▶ Significant amount of air leaked into tank over time. When air reached UFL of methane, mixture ignited causing a rapid pressure increase (deflagration) leading to failure.
- ▶ The flare is believed to be ignition source.
- ▶ Not enough information was presented to determine source of air or how it was introduced. Potentially, it was left over from before start up.
- ▶ Alternatively, air or oxygen could have been present in natural gas line. Failure occurred just as pressure dropped below 5" H₂O and natural gas started flowing into tank. If even a small amount of oxygen/air were present in natural gas, it could have accumulated over time until UFL was reached.

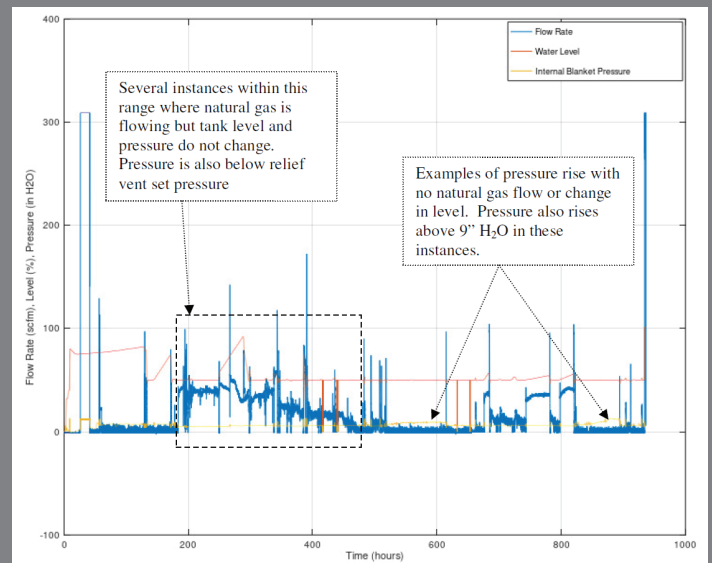


Figure shows additional observations that may not have caused the failure but appear as anomalies.