Appendix 3.5.6 Supplemental Thermal Evaluation of Package Contents

As previously stated, the maximum temperature recorded at the payload cavity during the fire event was 552°F at the top of payload cavity, just below the polyurethane plug. Evaluation of the payload vessel wall temperatures extracted from the fire analysis results show that the average temperature of the vessel wall is 360.4°F[1]. However, the actual temperature of the contents will be significantly less due the insulating value of the air within the cavity volume and dunnage materials that is not assumed in the thermal analysis. Fire testing of a similar package also provides supporting evidence for this assumption (see Appendix 3.5.3).

As stated in the Century Industries CI-1 package fire test report, the metallic components of the package "showed no signs of failure or fatigue" at the conclusion of the thermal test. This demonstrated acceptability of the drum design to withstand the fire and post-test cool-down induced thermal stresses. Because the Versa-Pac package is allowed to vent to the atmosphere, pressure stresses are not a concern.

Examination of the CI-1 contents following the test series shows that the O-ring gaskets were unaffected by the fire event (Figure 3.5.6-1). This provides further evidence that the contents remained below 400°F since the gasket material is rated to 400°F (Silicone Rubber AMS 3304-F).

A simplified transient thermal conduction analysis using ANSYS[2] is performed assuming paint can sized steel cylinder surrounded by perlite. The model is shown in Figure 3.5.6-2. Physical properties used in the analysis are presented in Table 3.5.6-1. The inner steel cylinder is modelled with a diameter of 6.5 inches. The perlite layer surrounding the steel cylinder has a diameter of 15 inches. The total length of the model is 24 inches with the end perfectly insulated. To simulate the fire event, an initial temperature of 100°F is applied to the outer surface and an internal heat generate of 20 W/m^3 applied uniformly to the steel cylinder. At 30 minutes, the peak fire temperature of 552°F is applied to the outer surface of the model. The analysis is allowed to run for an additional 80 minutes to bound the cool-down phase of the fire. The result of the analysis suggests that the internal temperature of the contents remains below 300°F during the fire and cool-down period. Figure 3.5.6-2 shows the analysis results. The inner cylinder surface temperature reaches a maximum temperature of 125.44°F.

Based upon the thermal averaging of the containment vessel temperatures, test results from similar packages and simplified thermal conduction analysis, the contents of the Versa-Pac payload vessel will not cause chemical or galvanic reactions with either the contents or packaging materials. As a result, no adverse reactions are predicted during NCT and HAC.

[1] Averaging analysis report
[2] ANSYS Version 13.0, SAS IP, Inc., 2010.

Table 3.5.6-1 Applied Heat Loads, Heat Transfer Coefficients and Initial Conditions

Material	Density (Kg/m^3)	Thermal Conductivity ($W/m•K$)	Specific Heat ($J/kg•K$)	Heat Generation Rate (W/m^3)	Reference
Structural Steel	7850	60.5	434	20	ANSYS Material Library
Perlite	32	0.1	387	N/A	The Engineer ToolBox[3]

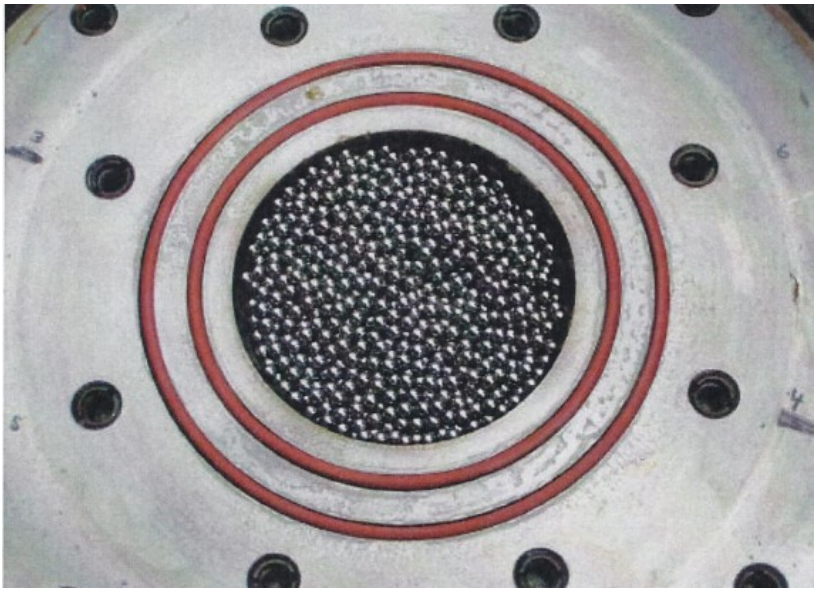

Figure 3.5.6-1 CI-1 Inner Vessel and Gasket Post Fire Test

[3] http://www.engineeringtoolbox.com/perlite-insulation-k-values-d_1173.html

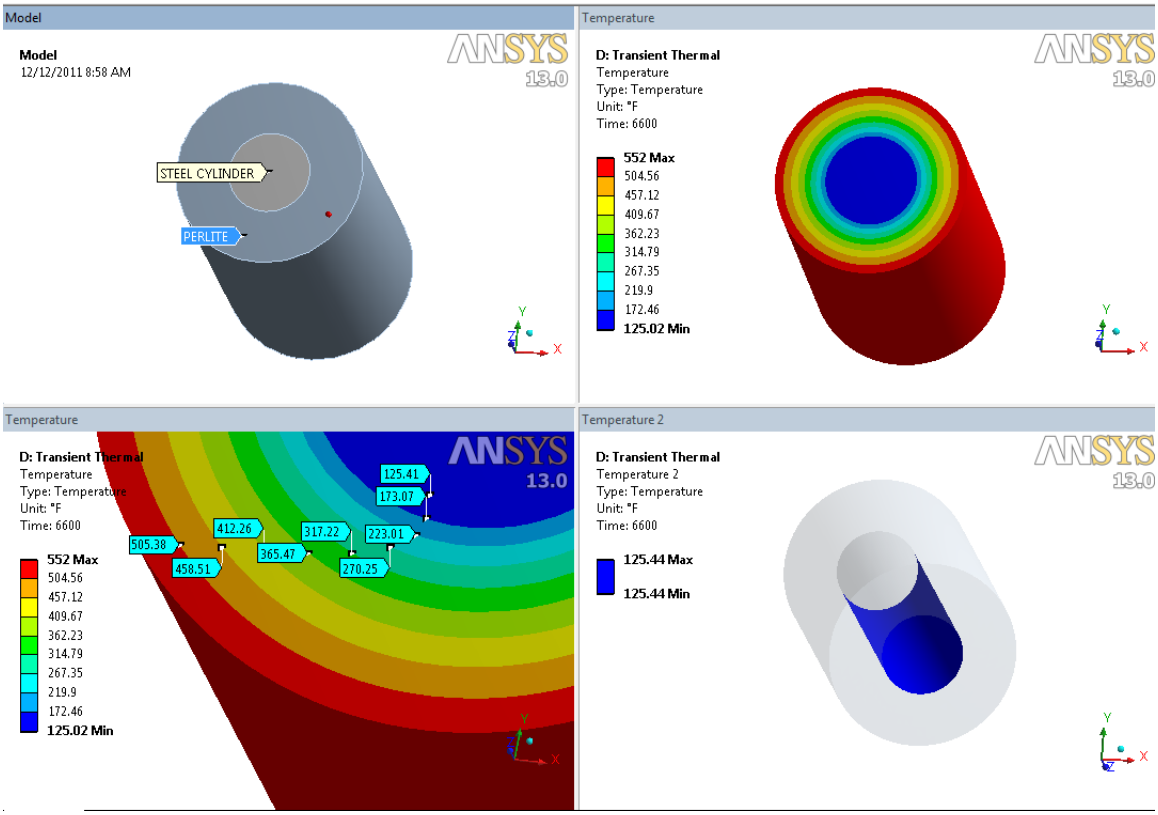

Figure 3.5.6-2 Results of ANSYS Analysis of Payload Vessel Contents Region