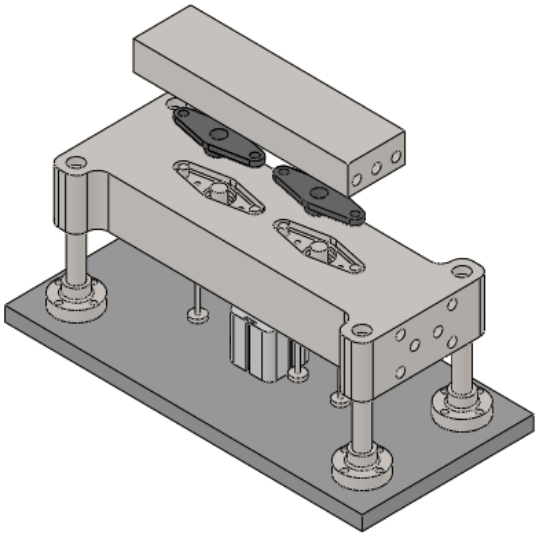
Design Conditions

Die Temp:	**400**	°F
Warm Up Time:	**15**	min
Process Mtl Temp:	**400**	°F
Tolerance:	**±10**	°F
Process Time:	**6**	min

Finite Element Analysis Report

File: **PVEfea-4437-0-0**
Desc: **Die and Heater Assembly**
Dwg: **PVEdwg-4437-0-0**
Date: **August 18, 2010**



Author: Ben Vanderloo
Reviewer: Laurence Brundrett

Conclusion: The die assembly is capable of warming up to a constant temperature of 400°F in 15 min. The process medium can reach the required temperature of 400°F (±10°F) in approximately 360 sec.

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Revision(s)			
Rev	Description	Date	By
0	Release	18-Aug-10	BTV

Executive Summary ver 4.00

Goal:

The die assembly PVE-4437 is required to warm up to 400°F in a 15 minute window and heat the process medium to 400°F (±10°F) during operation. Due to the complexities of the die setup the thermal aspects of this problem will be analyzed using FEA to determine if the design is acceptable.

Summary Conclusions:

Materials

The material thermal properties used in this analysis have been obtained from material data sheets from suppliers. See material page for more details

Model Information

The model used in this report represents one quarter the die assembly. Items not affecting the thermal study have been removed to simplify the analysis. A 3/8" second order, tetrahedral solid mesh is used for this analysis. The process medium is further refined based on geometry.

Boundary Conditions & Thermal Loads

Heat power is applied to all heating element surfaces and an ambient non-forced air convection is applied to all outer faces of the die assembly. Section plane surfaces are treated as thermally isolated.

Results

The FEA shows that the die assembly has enough heat power to warm up to 400°F in approximately 11 minutes. The setup is capable of heating the process medium to 400°F in approximately 6 minutes.

Analysis Conclusion:

The die assembly has sufficient heating to achieve the required warm up time of 15 minutes. The die setup is capable of heating the process medium to 400°F (±10°F) with a 6 minute window.

Material Properties ver 4.00

Element 1 (Process Medium)

Thermal Conductivity = 25 W/m-K
Source: Material Data Sheet
Specific Heat = 710 J/kg-K
Source: Material Data Sheet

Element 2 (Process Medium)

Thermal Conductivity = 1 W/m-K
Source: Material Data Sheet
Specific Heat = 1000 J/kg-K
Source: Material Data Sheet

Element 3 (Process Medium)

Thermal Conductivity = 35.3 W/m-K
Source: Material Data Sheet
Specific Heat = 130 J/kg-K
Source: Material Data Sheet

Process Medium

Thermal Conductivity = 5.12 W/m-K
Source: See Following Page
Specific Heat = 578 J/kg-K
Source: See Following Page

S7 (Die Components)

Thermal Conductivity = 28.9 W/m-K
Source: See Following Page
Specific Heat = 460 J/kg-K
Source: See Following Page

Thermal Conductivity ver 4.00

Process Medium Description

Element 1

Cp_1 =	710	J/kg-K
k_1 =	25	W/m-K
Comp_1 =	0.6	%
Rho_1 =	1.95	g/cc

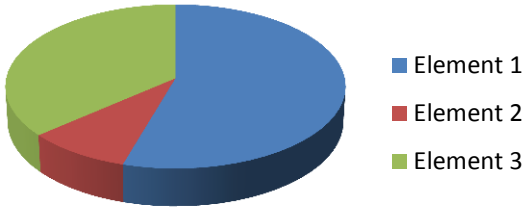
Element 2

Cp_2 =	1000	J/kg-K
k_2 =	1	W/m-K
Comp_2 =	0.1	%
Rho_2 =	1.5	g/cc

Element 3

Cp_3 =	130	J/kg-K
k_3 =	35.3	W/m-K
Comp_3 =	0.4	%
Rho_3 =	11.34	g/cc

	Mass (g)	Vol. (cc)	% Vol.	
Element 1	600	307.692	0.751	V_1
Element 2	100	66.667	0.163	V_2
Element 3	400	35.273	0.086	V_3



Estimated Composite Material

Cp_t = Cp_1 * Comp_1 + Cp_2 * Comp_2 + Cp_3 * Comp_3

Cp_t = 578.0 J/kg-K

k_t = 1/((1 / k_1) * V_1 + (1 / k_2) * V_2 + (1 / k_3) * V_3)

k_t = 5.12 W/m-K

Displacement

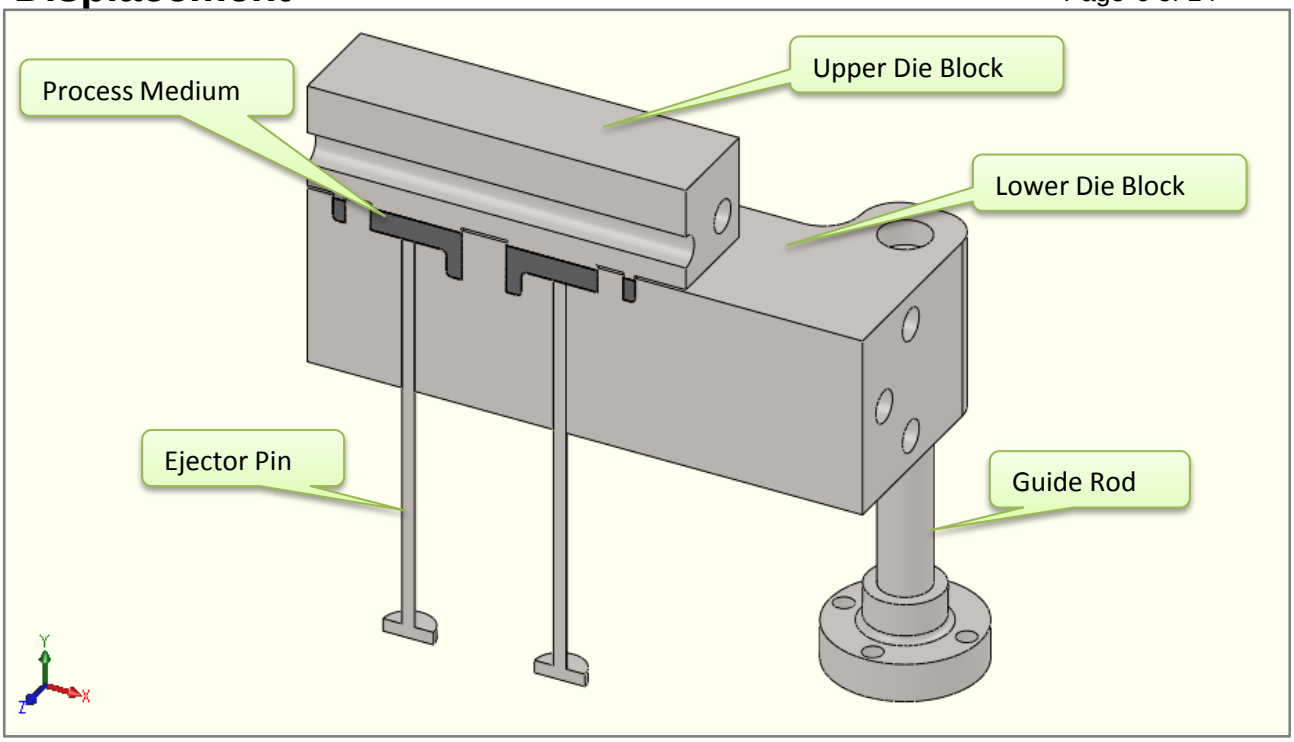


Fig-A A view of the quarter die assembly used for the analysis. Items not affecting the thermal study have been removed to simplify the analysis.

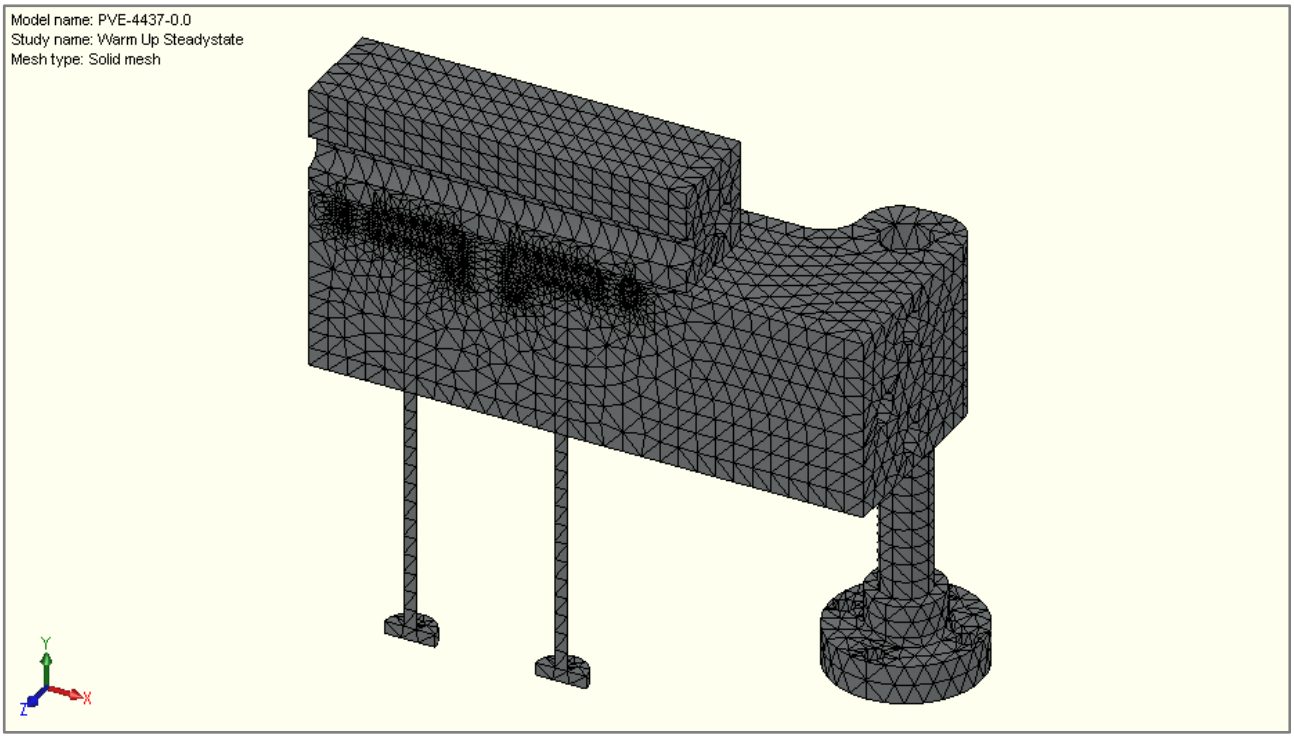


Fig-B A view of the global 3/8" mesh used for the analysis. The process medium has a 1/16" refinement applied.

Boundary Conditions and Thermal Loads

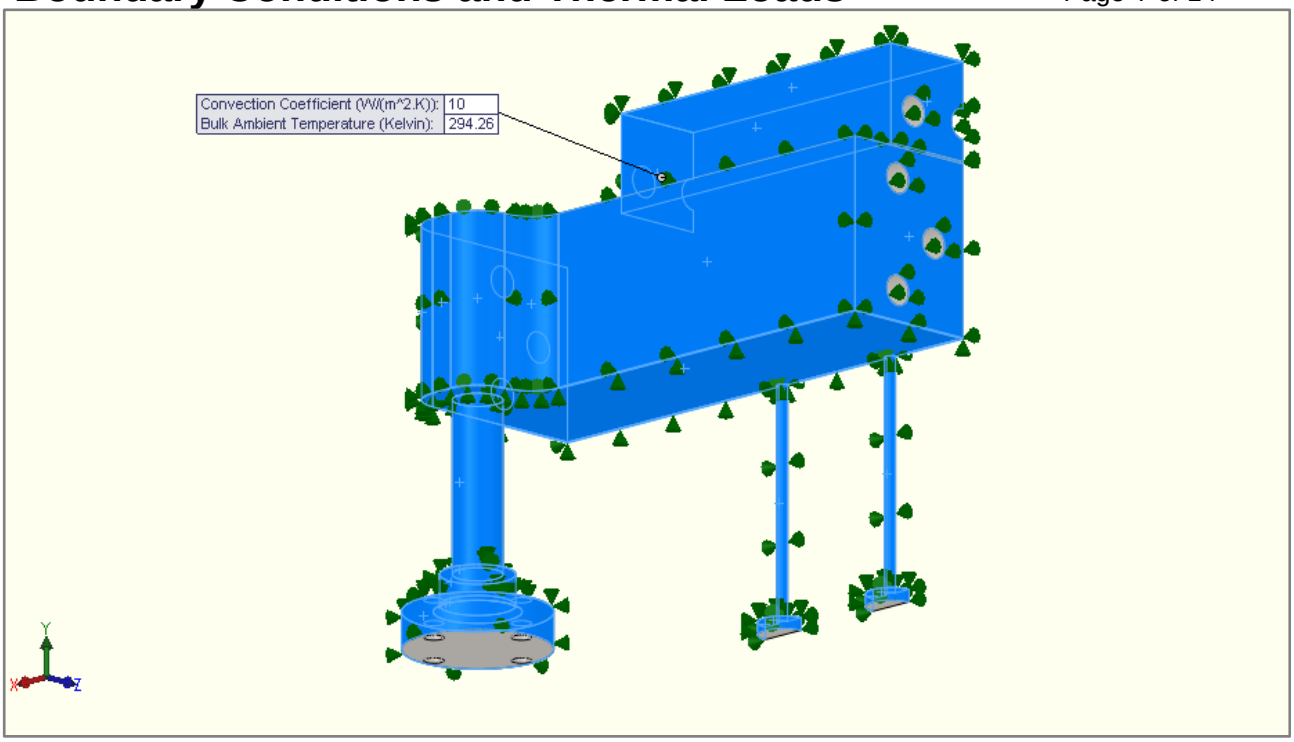


Fig-A An ambient (70°F) non-forced air convection of 10 W/m^2-K is applied to all outer surfaces of the die assembly. This convection coefficient is critical to the die block and ejector pins. These items may need to be shielded from moving air to obtain uniform temperatures.

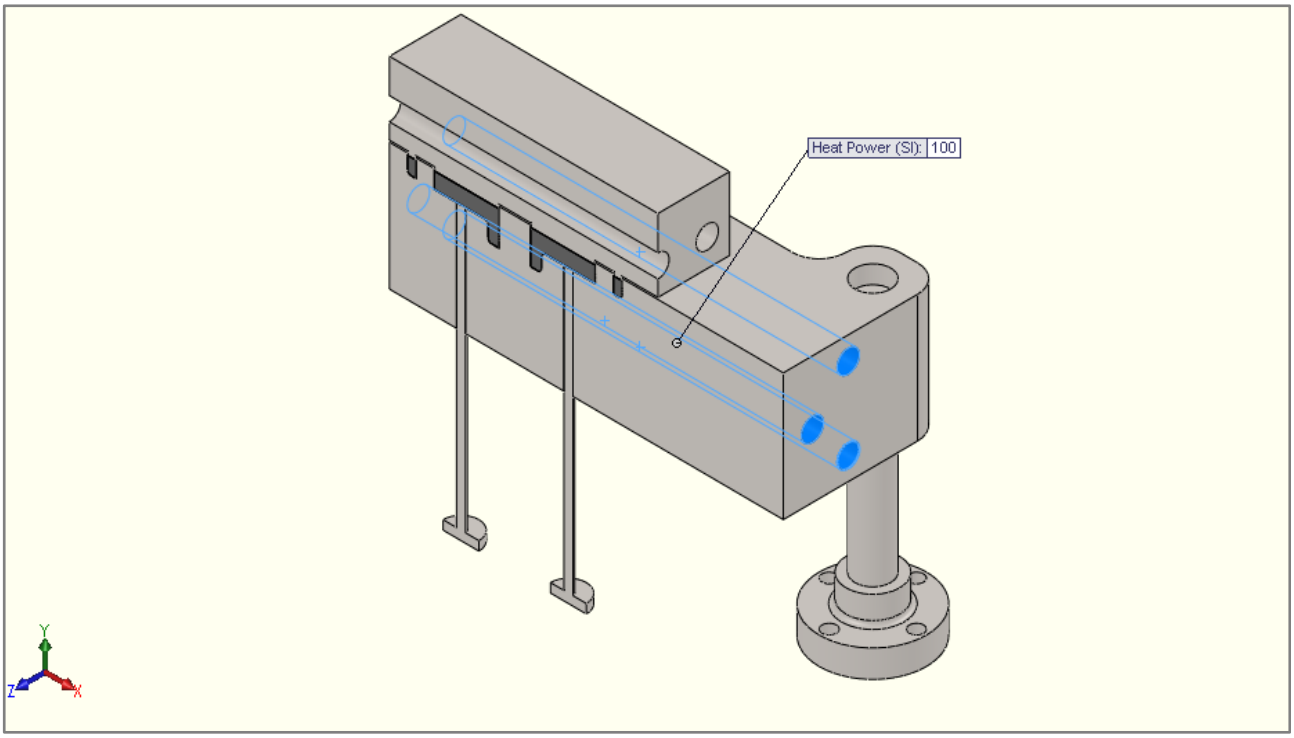


Fig-B A view of the heat power applied to the lower die. Total heat power for each heater is 200 W. Half of a heater is shown with 100 W applied. During the warm up cycle these heaters need to drop to 40% power after 11 minutes to sustain 400°F.

Boundary Conditions and Thermal Loads

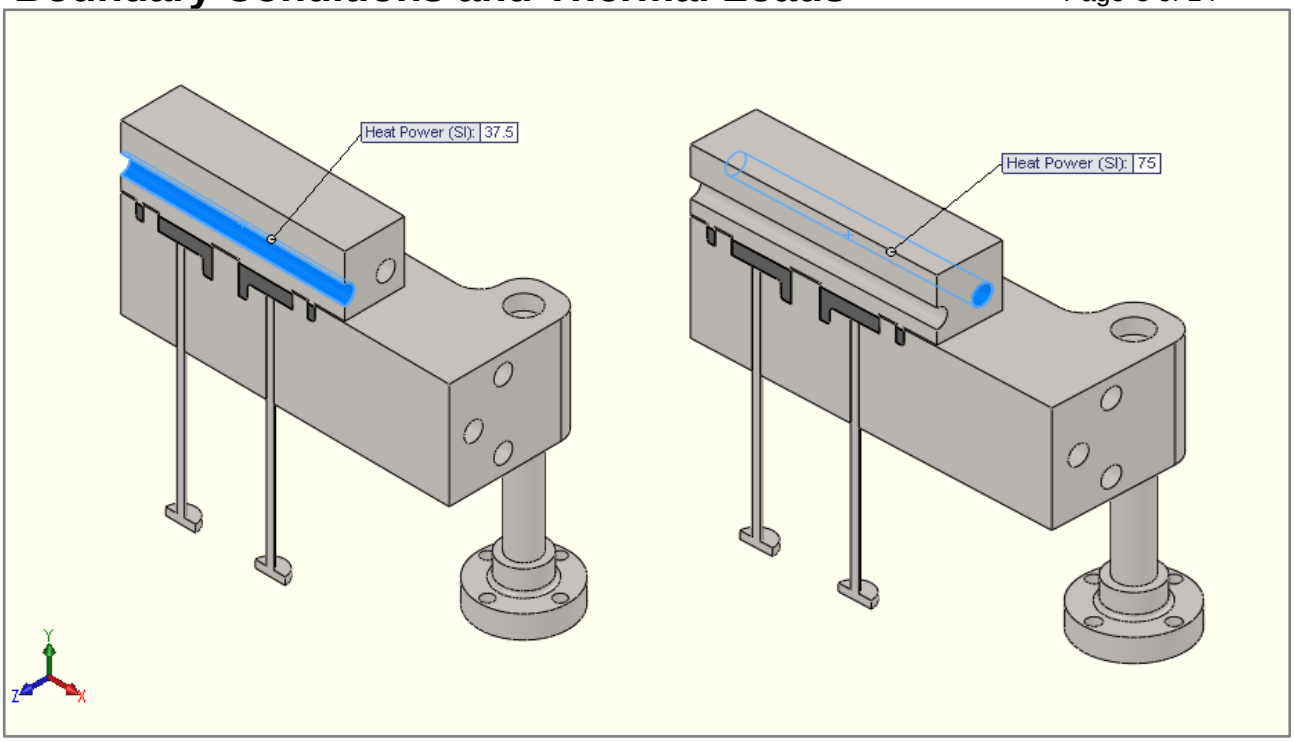


Fig-A A view of the heat power applied to the upper die. Total heat power for each heater is 150 W. A quarter and half heater are shown with 37.5 W and 75 W applied. During the warm up cycle these heaters need to drop to 34.7% power after 6.6 minutes to sustain 400°F.

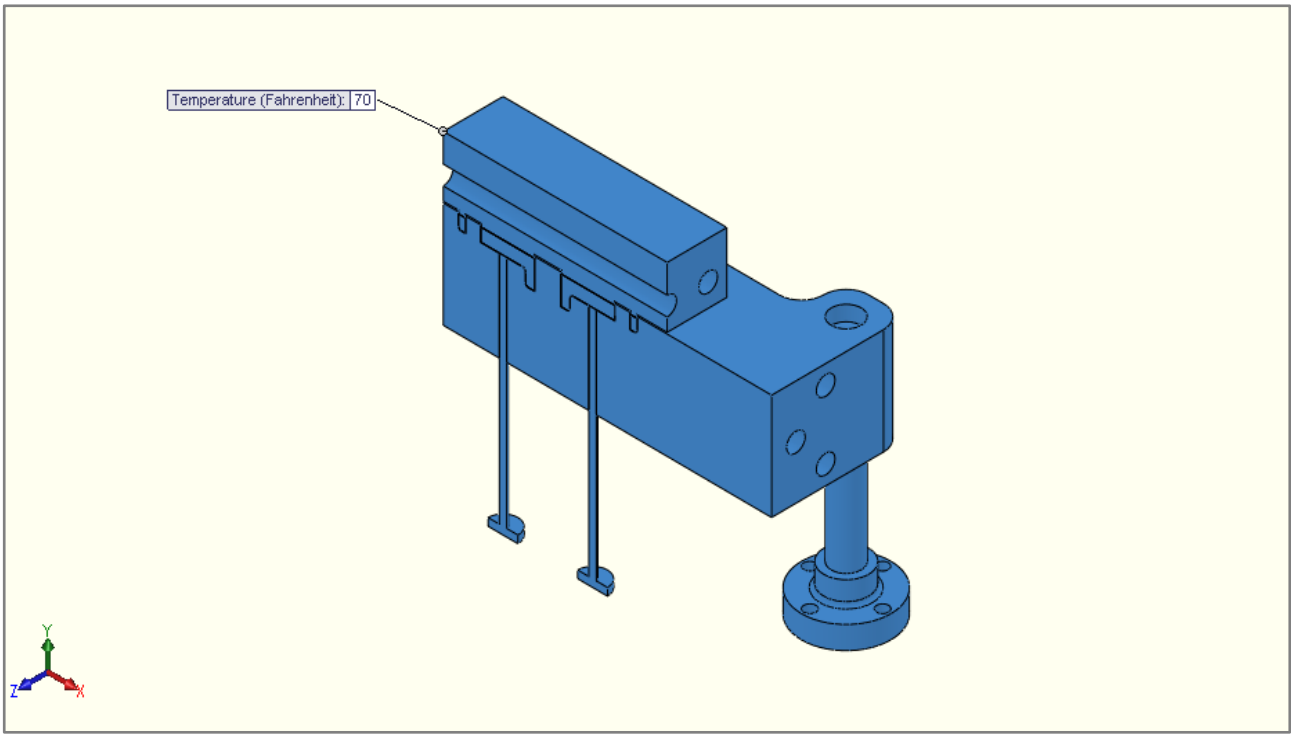


Fig-B All components are set with a 70°F initial temperature.

Section - Warm Up Results

Study Summary:

This section of the report will analyze the die assembly's capabilities during the warm up cycle. The die is required to warm up to a stable 400°F in 15 minutes.

Results:

From the FEA thermal study results, it is observed that the die setup can reach a stable temperature of 400°F in 11 minutes. This warm up time is quicker than the required 15 minutes. The warm up time is acceptable.

Displacement

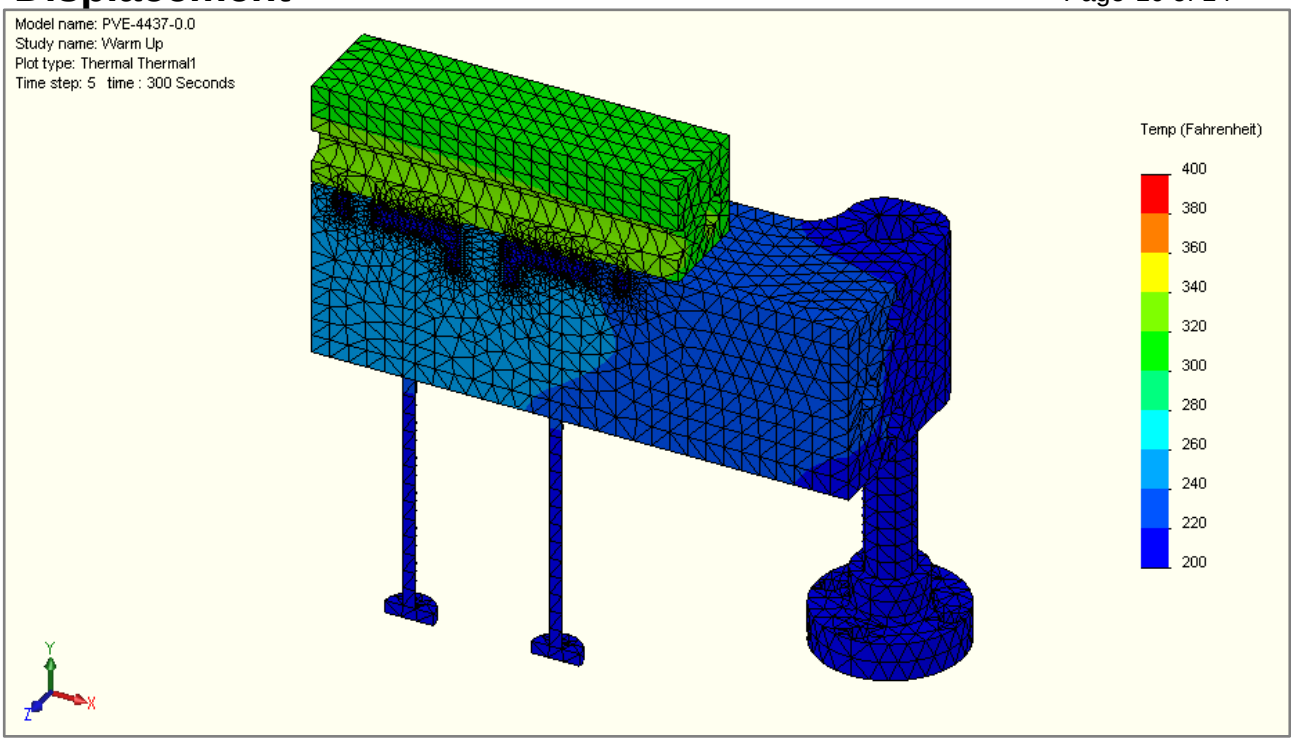


Fig-A A view of the temperature plot scaled at 200-400°F. This plot represents the die warm up cycle after 300 seconds (5 minutes).

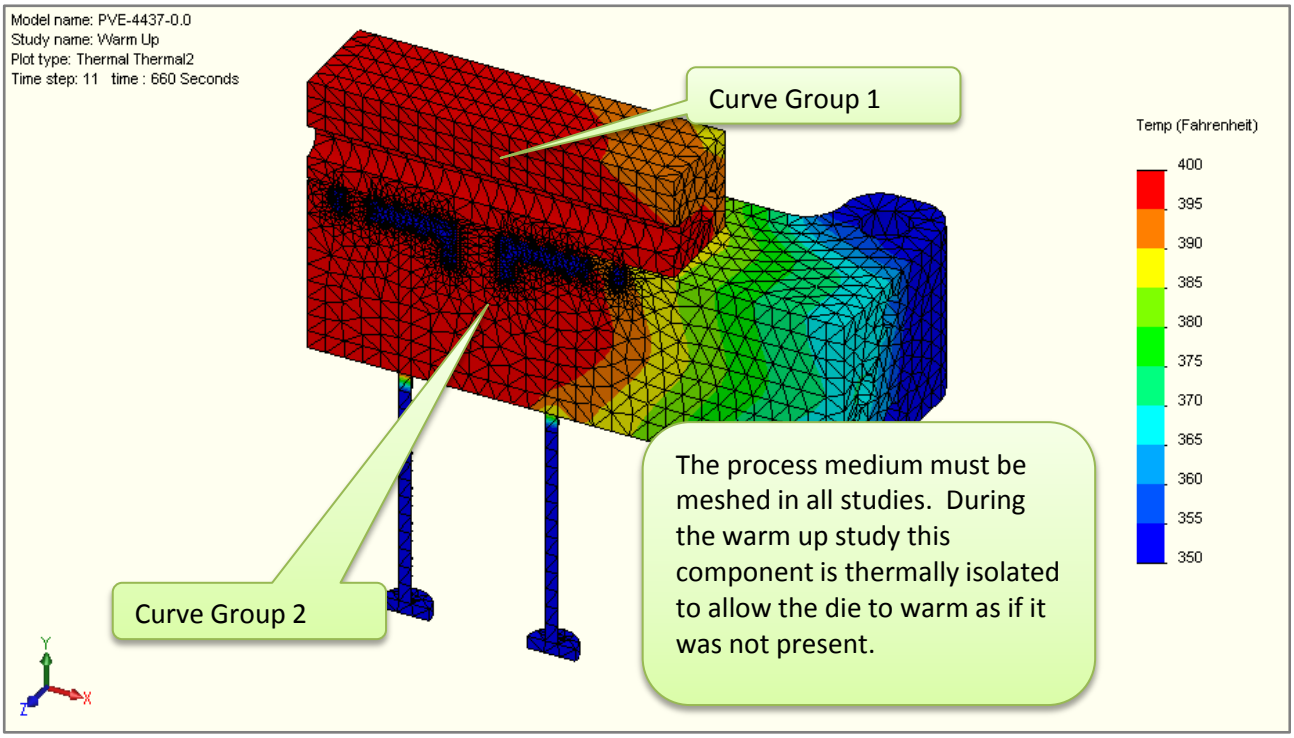


Fig-B A view of the temperature plot scaled at 350-400°F. This plot represents the die warm up cycle after 660 seconds (11 minutes). The die is a uniform 400°F in the process area and is ready for operation. See warm up curves for more temperature details.

Displacement

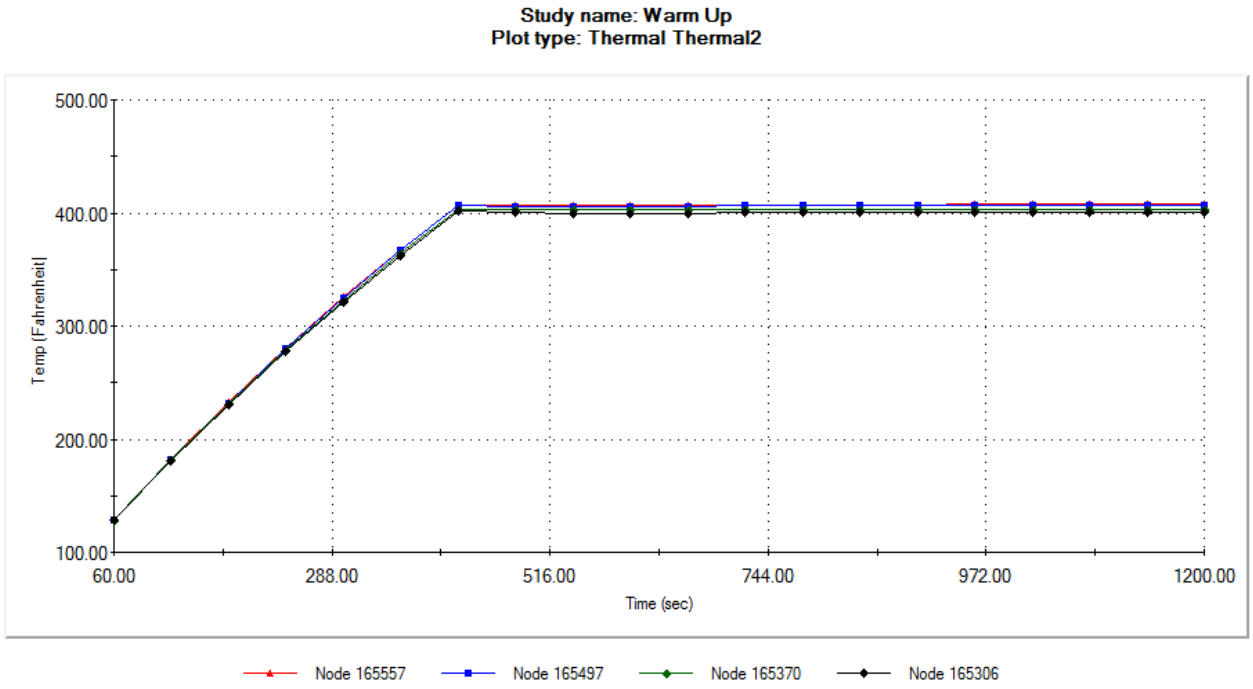


Fig-A Curve Group 1 - A graph of the temperatures along the upper die where the process medium contacts. A stable 400°F is reached at 400 seconds.

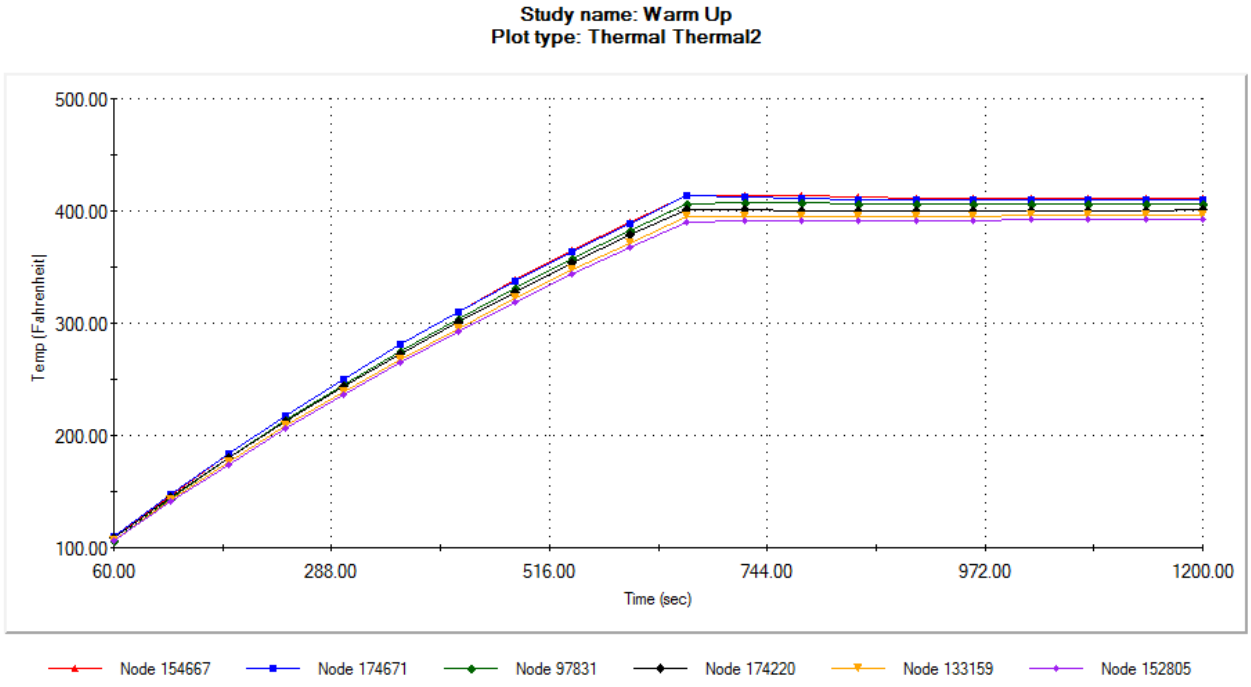


Fig-B Curve Group 2 - A graph of the temperatures along the lower die where the process medium contacts. A stable 400°F is reached at 660 seconds.

Section - Process Results

Study Summary:

This section of the report will analyze the die assembly's capabilities during the process cycle. The die is required to warm up the process medium to a stable 400°F ±10°F in 6 minutes.

Special Setup:

The process study in solidworks simulation will be linked with the warm up study. The last time step of the warm up study will become the process studies' initial temperature for all components. This study requires the thermal isolation on the process medium to be removed allowing heat to flow in. To avoid excessive heat loss from the die to the process medium the heaters are required to run at 100% for the first 240 seconds of the process cycle. After this they can drop to the original percentages for sustaining constant temperature.

Results:

From the FEA thermal study results, it is observed that the die setup can heat up the process medium to a stable 400°F ±10°F in approximately 360 seconds (6 minutes). The process cycle time is acceptable.

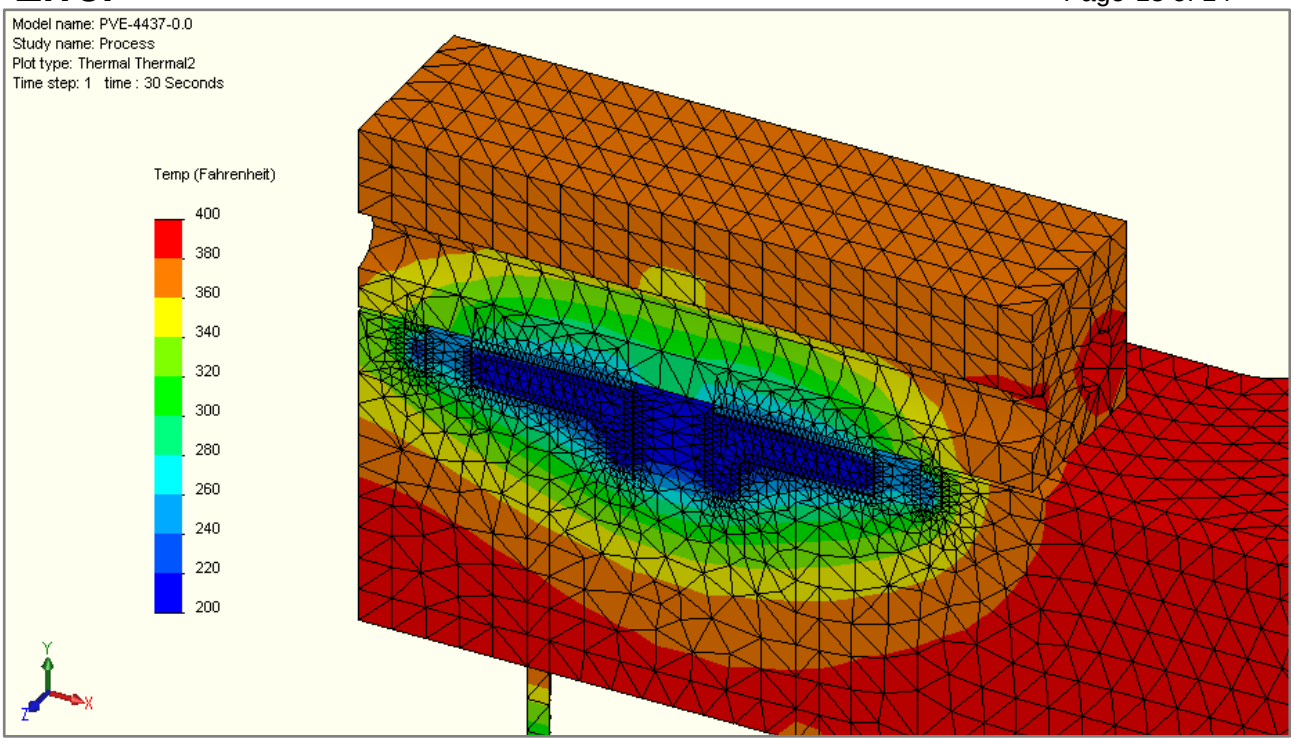


Fig-A A view of the temperature plot scaled at 200-400°F. This plot represents the die process cycle after 30 seconds (0.5 minutes). A this time a noticeable temperature drop occurs in the die as energy begins flowing into the process medium.

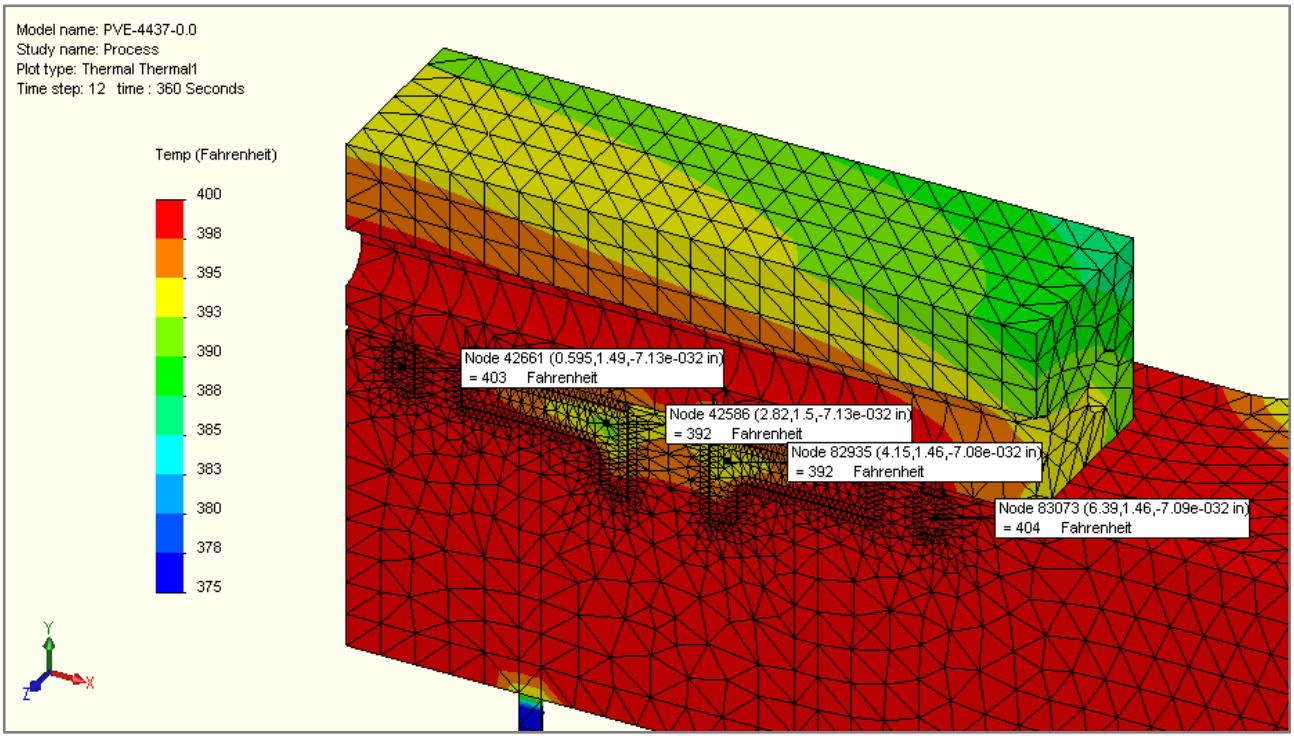


Fig-B A view of the temperature plot scaled at 375-400°F. This plot represents the die process cycle after 360 seconds (6 minutes). At this time the core of the process medium has reached 400°F ±10°F. See temperature curves for the probed location's temperature throughout the cycle.

Error

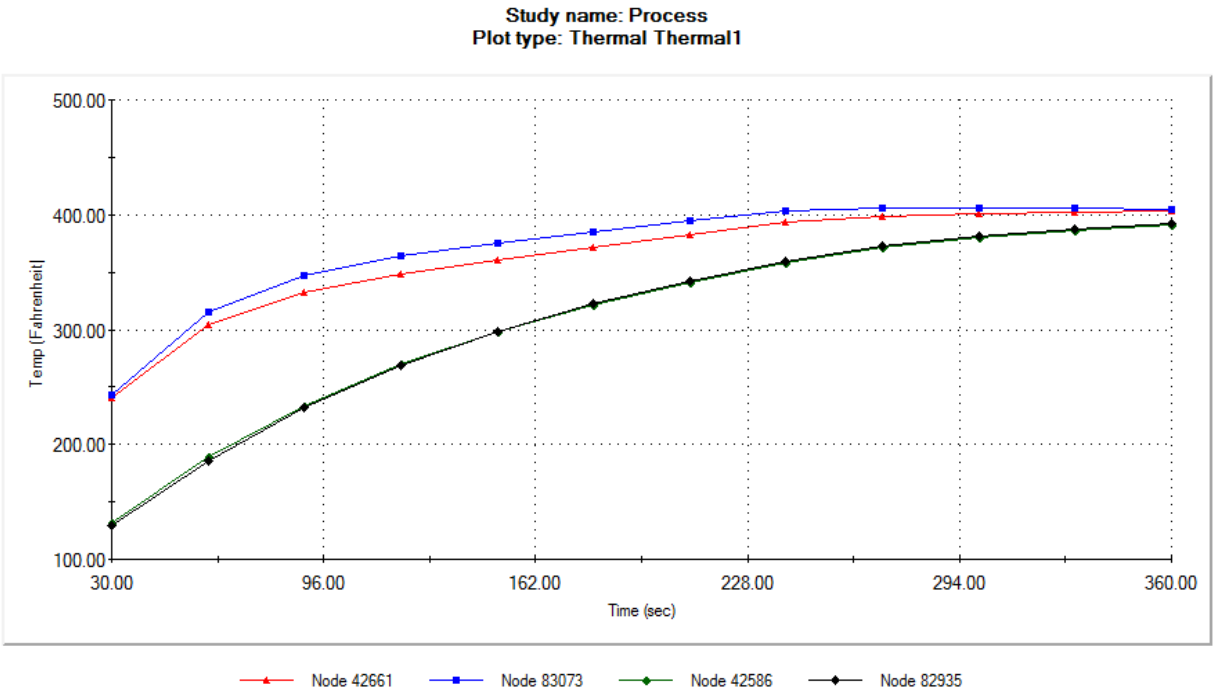


Fig-A A graph of the temperatures throughout the process medium. Temperature has reached 400°F ±10°F after 360 seconds (6 minutes)