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memorandum

LANSCE Division
Group LANSCE-1

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Symbol: LANSCE-1:00-91
Date: October 2, 2000
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SUBJECT: Structural / Thermal Analysis of SNS Chopper

Introduction:

As requested, a combined structural / thermal analysis has been performed on the SNS chopper ground plane. This memo summarizes the model predictions for temperatures and deflections using the material properties listed in Table 1 and boundary conditions listed below. The results shown in Figures 4 - 9 summarize the model predictions for the various boundary conditions and geometries considered. From the point of view of temperature distribution and deformation of the upper surface, the three coolant passage configurations discussed here are identical.

Models:

Models of the SNS chopper ground plane have been constructed for COSMOS/Works and represent a simplified version of the ground plane geometry as shown in LA-UR-00-3088 which is reproduced in Figure 1. In addition to the geometry as defined in the drawing, the addition of a 0.25 inch diameter cooling passage was included. The coolant flow rate will be 0.5 GPM flow through the 0.25 inch diameter channel, giving a bulk velocity of 3.3 ft/sec, and a Reynolds number of 6416 making the flow turbulent. At this flow rate and 10W of input power the temperature rise in the coolant will be less that 0.15°F. The orientation of this cooling passage was considered to be one of the following:

a) Horizontal, down the long direction of the ground plane.

b) Horizontal, down the short direction of the ground plane.

c) Horizontal and diagonally across the ground plane.

Figures 2a, 2b, and 2c show the geometry for each of the respective cases listed above.

Material properties were taken as the ambient temperature aluminum properties listed in Table 1.

Table 1: Room Temperature Properties of 6061-T6 Aluminum

Property	Value	Units
Thermal Conductivity, K	8.7	btu/hr-in-°F
Modulus, E	$1.1X10^{7}$	lb/in^{2}
Thermal Expansion Coeff. α	$13.1x10^{-6}$	$(°F)^{-1}$
Poisson's Ratio, ν	0.33	none

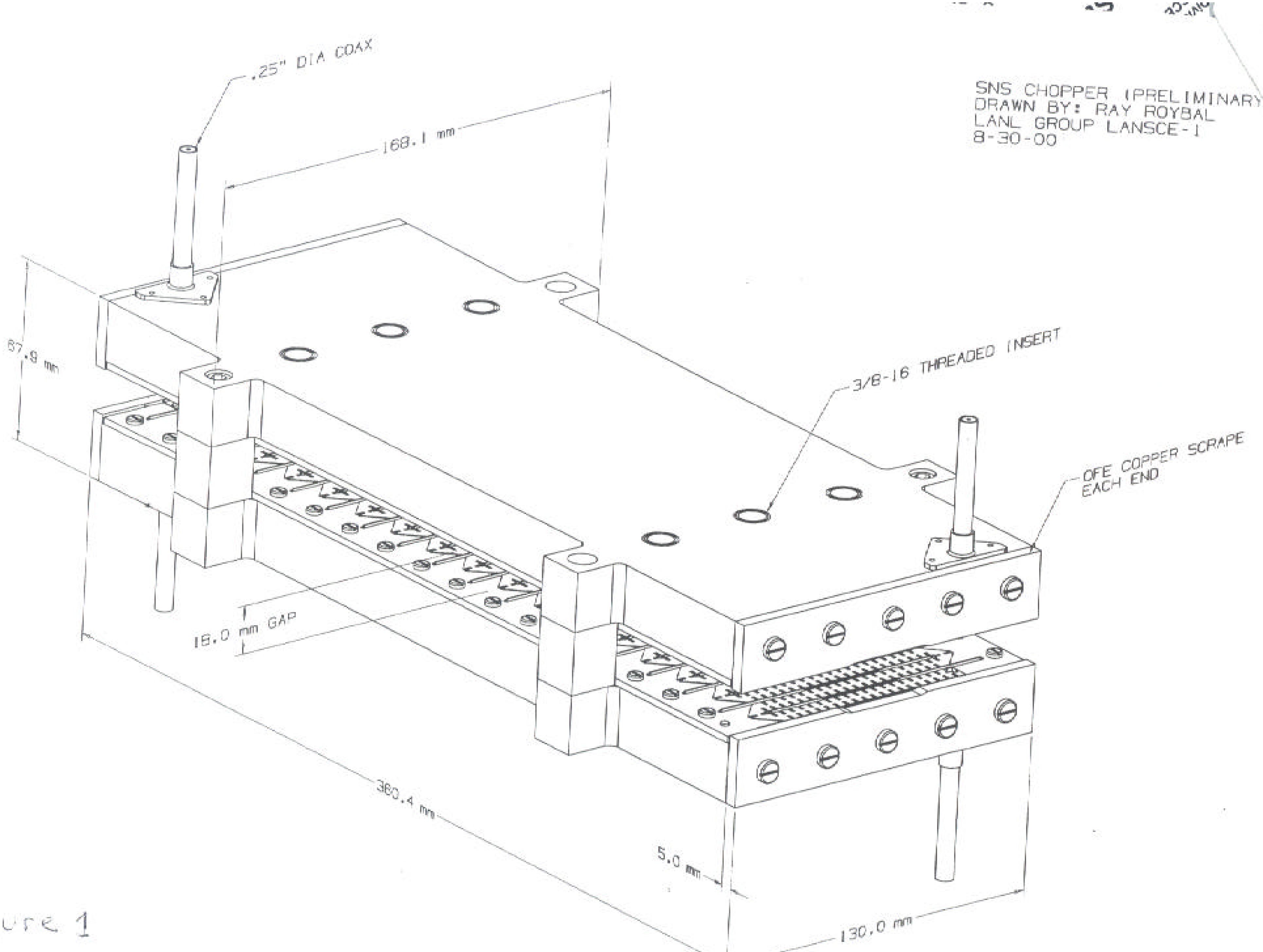
.25" DIA COAX
168.1 mm
SNS CHOPPER (PRELIMINARY
DRAWN BY: RAY ROYBAL
LANL GROUP LANSCE-1
8-30-00
87.9 mm
3/8-16 THREADED INSERT
OFE COPPER SCRAPE
EACH END
18.0 mm GAP
380.4 mm
5.0 mm
130.0 mm

Figure 1

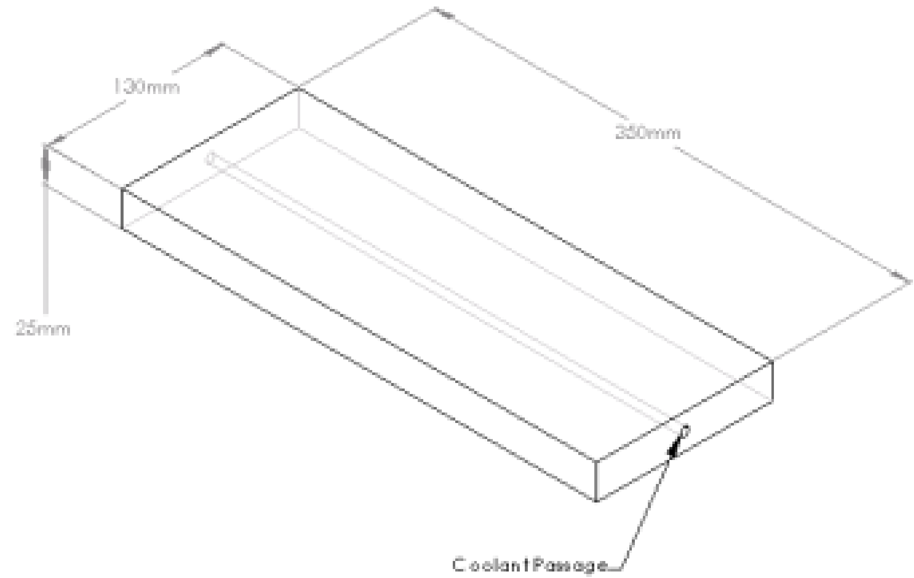

Figure 2a; Coolant Passage Configuration ‘A’

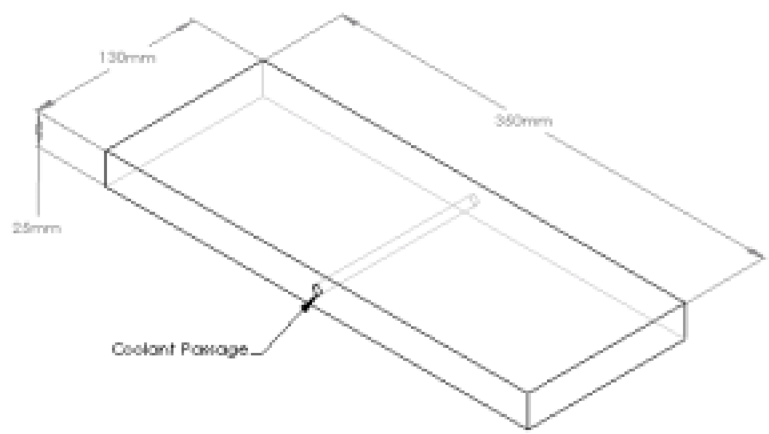

Figure 2b; Coolant Passage Configuration ‘B’

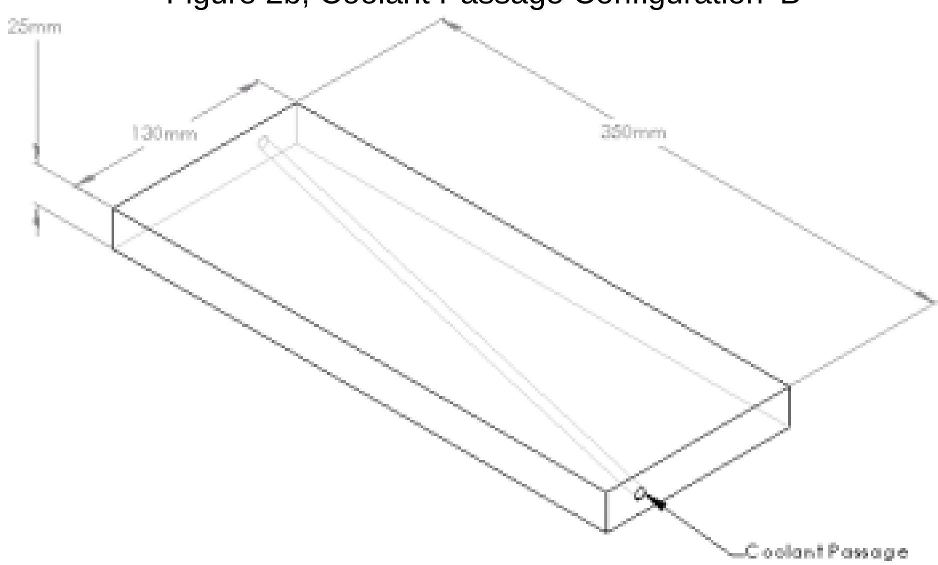

Figure 2c; Coolant Passage Configuration ‘C’

The models were meshed with four node tetrahedral elements resulting in problems with approximately 17,000 degrees of freedom (DOF). Figure 3 shows the mesh generated for coolant passage configuration 'A'.

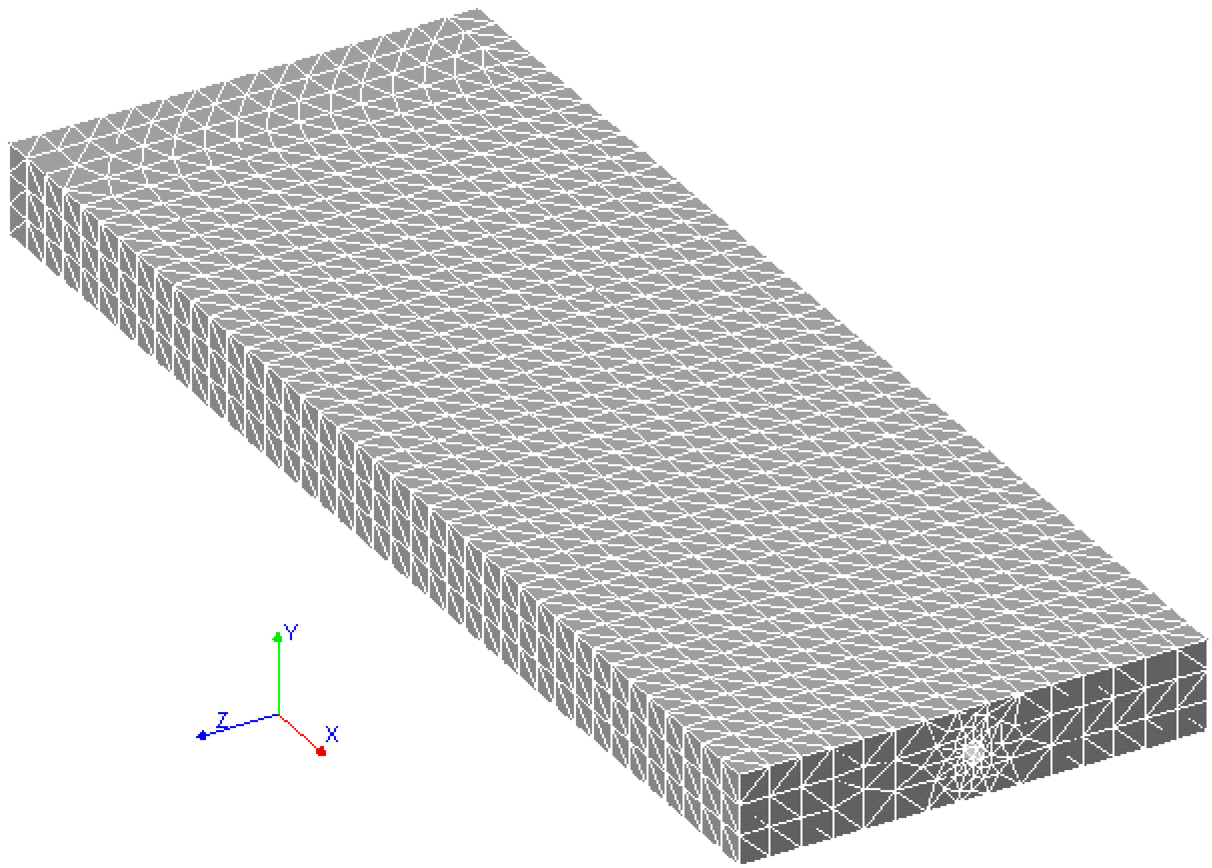

Figure 3; Mesh Generated for Coolant Passage Configuration 'A'

Boundary Conditions:
The following boundary conditions were imposed on all the models:

a) Three bolt holes constrained. These are the design constraints as shown in LA-UR-00-3088.

b) A uniform heat flux of 10 W (34 Btu/hr) on the uppermost surface of the model.

c) A convective heat transfer coefficient of 6.5 Btu/hr-in^2-°F between the aluminum and the coolant.

d) Coolant temperature of 70°F, assumed constant between inlet and outlet.

Results and Discussion:

Results for each of the cases considered are shown in figures 4 - 9. Figures 4 and 5 show temperature and displacement results for configuration 'A', while figures 6 and 7 show similar results for case 'B', and figures 8 and 9 refer to case 'C'. The highest temperature difference in any of the cases was 2.7°F and the largest vertical displacement was 3.5x10^{-5} inches.

Model Verification:

Model verification was performed with hand calculations. As an example consider coolant passage configuration 'A'.

- To estimate the coolant passage wall temperature rise above the coolant temperature use:

$\Delta T = Q/hA$

$Q = 10\ W = 0.0095$ btu/sec

$H = 6.5$ Btu/hr-in^2-°F = 0.0018 btu/sec-in^2-°F

$A = \pi DL = \pi * 0.25in * 13.8in = 10.8\ in^2$

Calculating gives $\Delta T = 0.48°F$, so $T_{wall} = 70.48°F$

Reviewing the results shown in figure 4 gives the models predicted T_{wall} of 70.47°F.

- To estimate the maximum material temperature above the wall temperature use:

$\Delta T = (Q/2)(L/2)/KA$

$L = 5.12in$

$A = 13.8in * 1in = 13.8in^2$

$K = .0024$ btu/sec-in-°F

Calculating ΔT gives $\Delta T = 0.36°F$ so $T_{max} = T_{wall} + .36°F = 70.83°F$.

Reviewing the results shown in figure 4 gives the models predicted T_{max} of 70.70°F.

- Estimating the maximum vertical displacements can be done once the temperature limits are known.

  $\Delta L = \alpha \Delta T L$

  $\Delta T_{max} = 0.7°F$

  $\alpha = 13.1 \times 10^{-6}\ (°F)^{-1}$

  $L = 1$ inch

  So calculate $\Delta L_{max} = 9.2 \times 10^{-6}$ in.

Reviewing the results shown in figure 5 gives the models predicted ΔL_{peak} of 1.1×10^{-5} in. Similar calculations have been performed for configuration 'B' and 'C' and also give good agreement.

Summary:

The thermal / structural analysis of the SNS Chopper has been completed and indicates satisfactory performance under all of the cases considered. The addition of a coolant channel in any of the configurations considered in this document limits the maximum temperature difference to less than 3°F and the maximum vertical displacement to less than 3.5×10^{-5} inches.

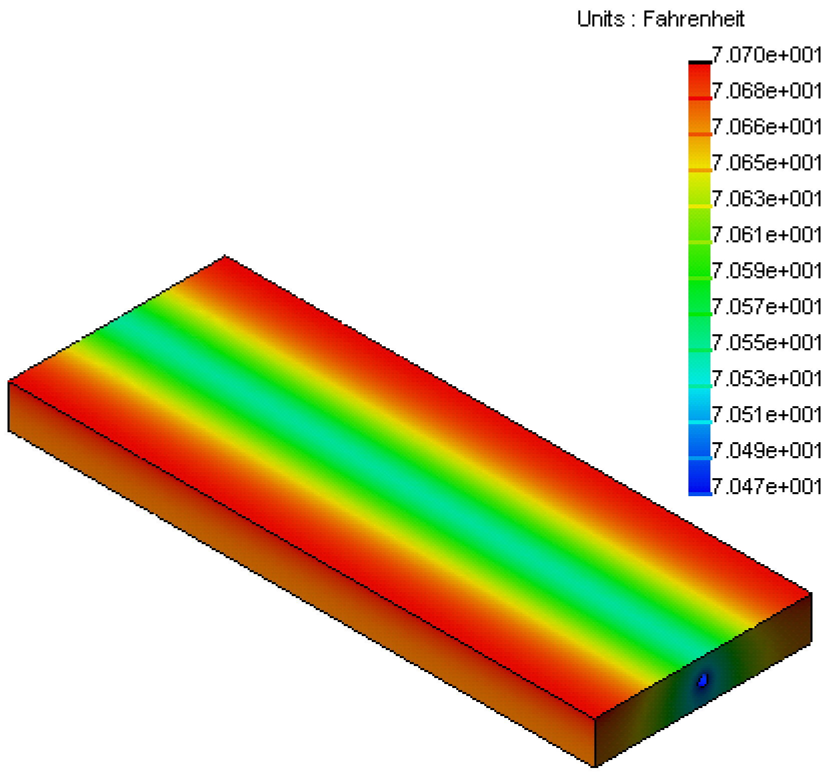

Figure 4; Temperature Plot, Configuration 'A'

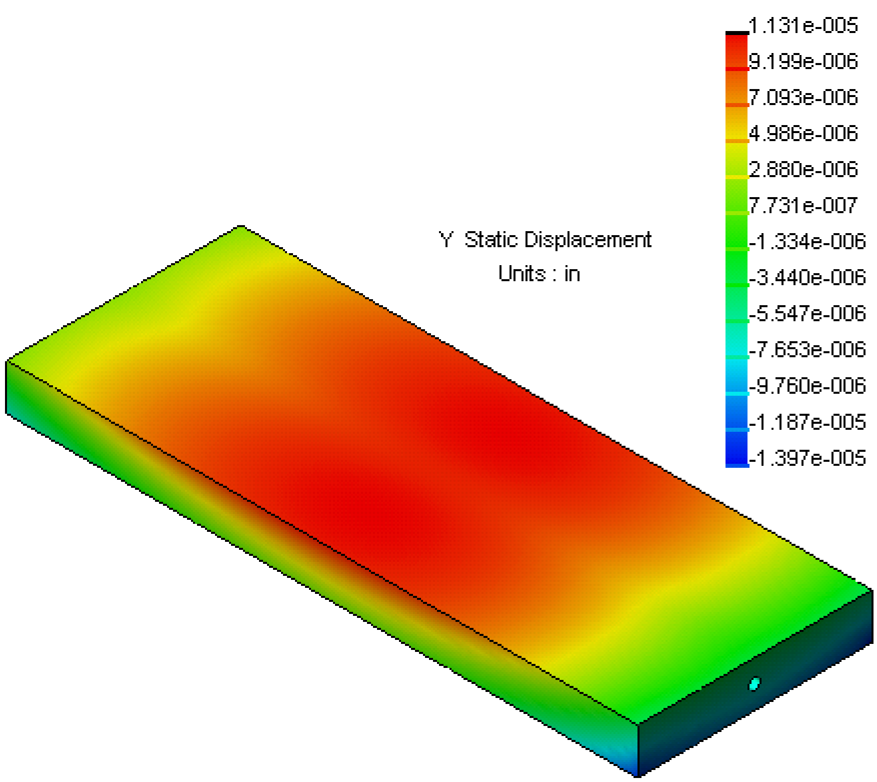

Figure 5; Vertical Displacement Plot, Configuration 'A'

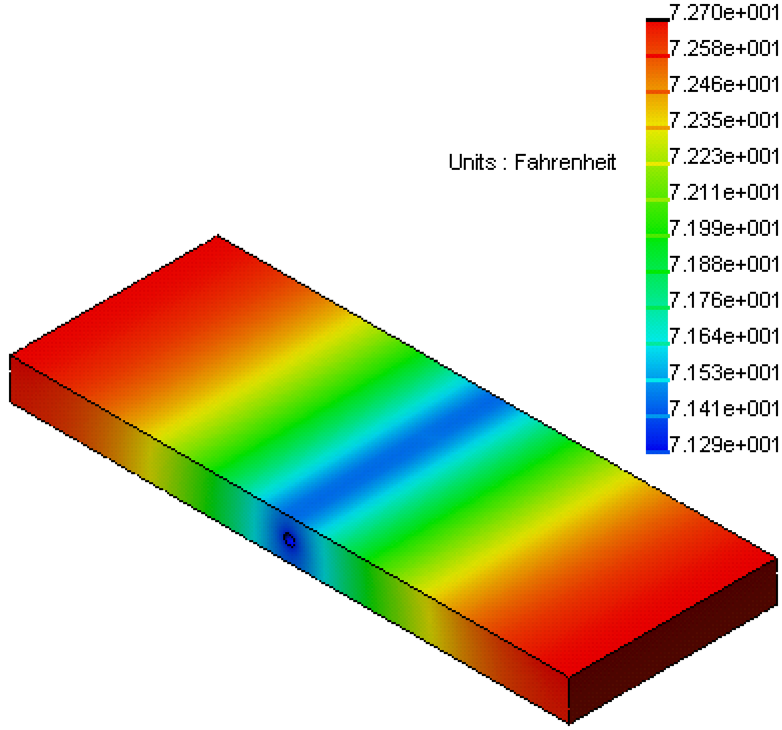

Figure 6; Temperature Plot, Configuration 'B'

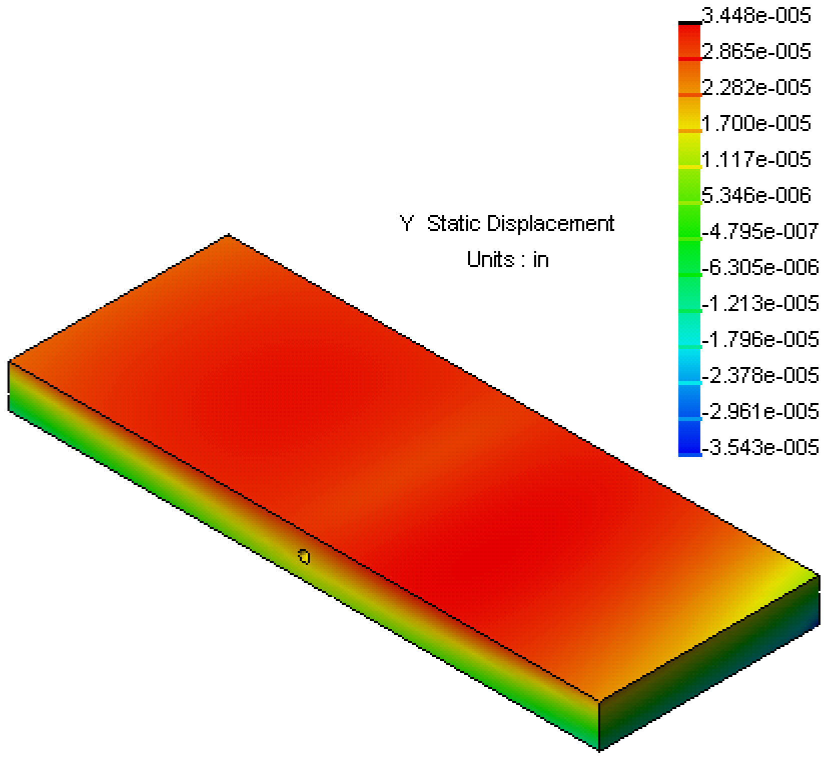

Figure 7; Vertical Displacement Plot, Configuration 'B'

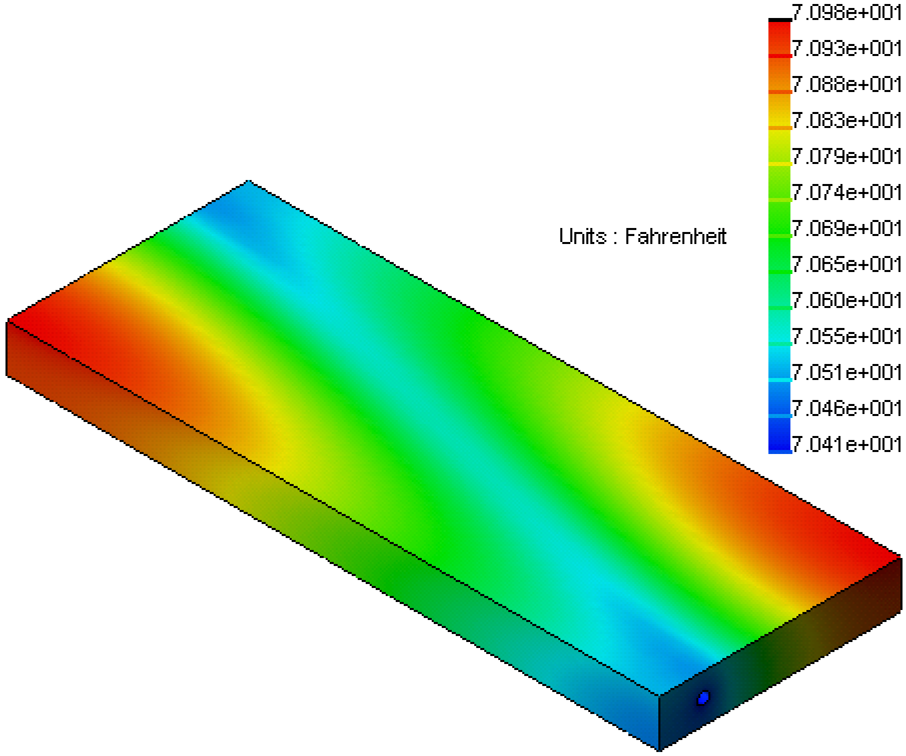

Figure 8; Temperature Plot, Configuration 'C'

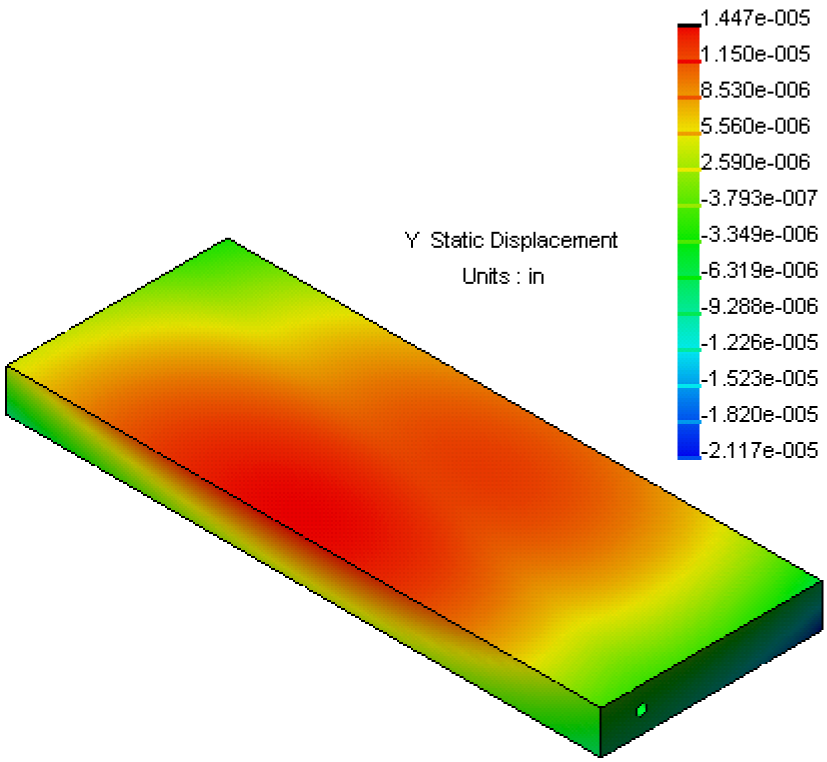

Figure 9; Vertical Displacement Plot, Configuration 'C'

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