Expansion and Strength Analysis of 2-Piece Gutter Bracket

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Simutech Group Project #: 11361-0

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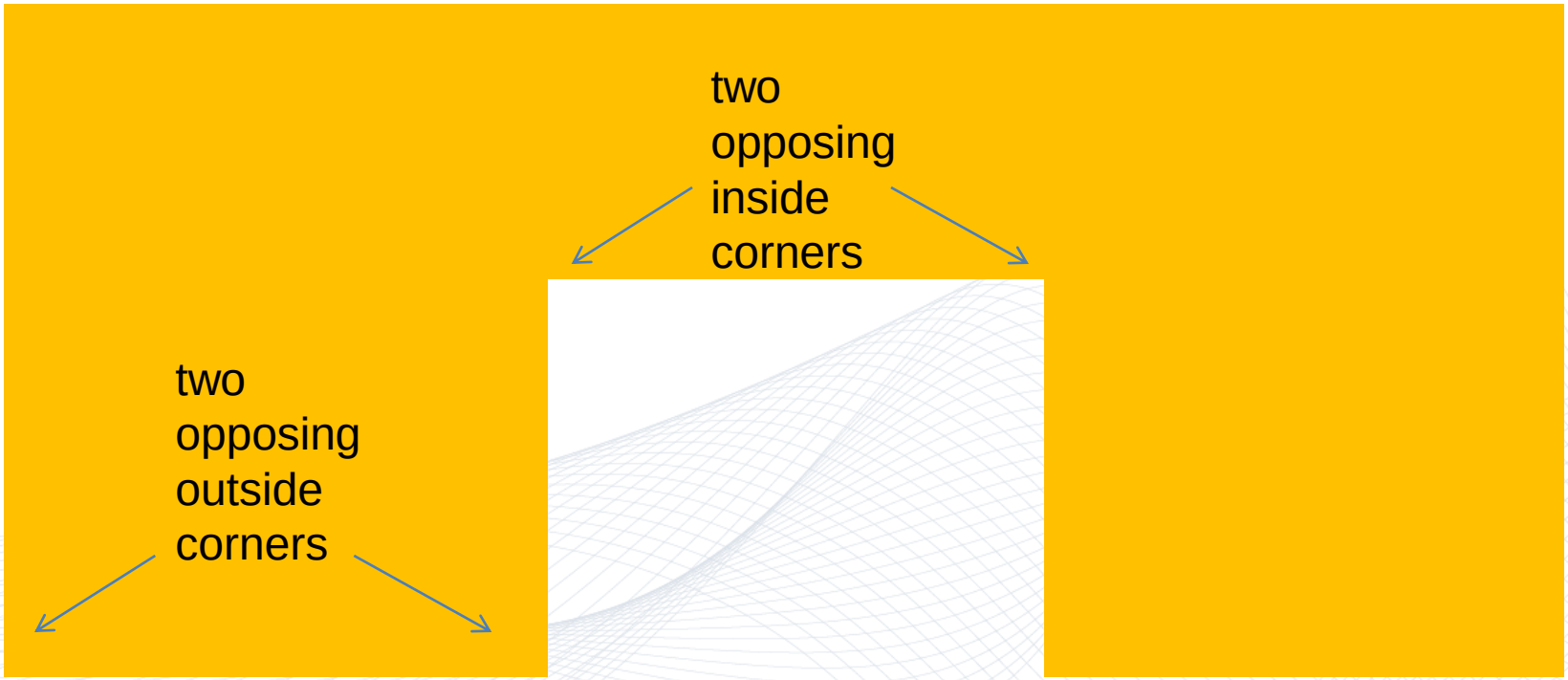
Summary

- The expansion box should be at least 8.5 inches long with a 2 inch gap between end caps when installed. If the gap is increased due to installation tolerances, the expansion box length should be increased the same amount. For a 3 inch gap, the expansion box should be at least 9.5 inches long.
- The maximum span of gutter allowed without an expansion joint is 40 feet.
  - The 2 piece bracket must be at least 24” away from the corner to accommodate growth/contraction of gutter without causing damage to gutter. A ledge type bracket is necessary at corner location to hold up gutter but not restrict thermal expansion toward or away from fascia.
  - A 0.5” spacer is needed between the bracket (0.125” thick) and fascia to give a total gap of 0.625” between the gutter and fascia to accommodate worst case contraction at an outside corner and expansion at an inside corner.
- The proposed 2-piece bracket is acceptable for a load of 160 lbs if the aluminum yield strength is at least 20,000 psi.
  - Consider using 5052-H32 in sheet metal form. This aluminum alloy has good workability and very good corrosion resistance. The minimum yield strength is 28,000 psi.
  - Consider using 6063-T6 in extruded form. This aluminum alloy has very good corrosion resistance. The minimum yield strength is 25,000 psi.
  - These alloys are very common and references to both of these alloys being used in architectural fabrication have been found.
  - #8 and #10 18-8 stainless steel screws are adequate for 160 lb load.

Assumed Conditions

- Assume house layout to include worst case inside and outside corners.
- Installation temperature = 40°F to 90°F
- Maximum temperature = 120°F (Worst case change in temperature of 80°F with installation temperature)
- Minimum temperature = -20°F (Worst case change in temperature of 110°F with installation temperature)
- Coefficient of linear thermal expansion for cellular PVC = 2.6×10^{-5} in/in/°F



Thermal Expansion
80 foot span

- The length changes by 0.025 inches (~1/32”) for each degree Fahrenheit.
- If installed at 40°F, the change in length from 40°F to 120°F is 2.00 inches.
  - Therefore, there must be at least one 2 inch gap between the end caps in an 80 foot run.
- If installed at 90°F, the change in length from 90°F to -20°F is 2.75 inches.
  - Therefore, the expansion joint must have at least 2.75” of overlap between the expansion box and end cap (1.375” on each side).

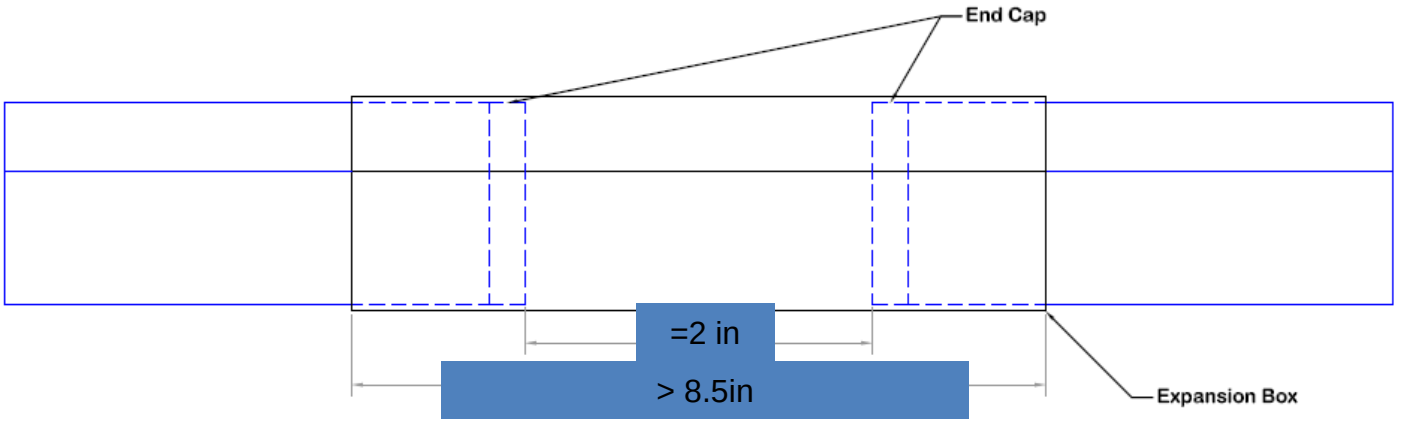
Thermal Expansion
80 foot span

- The expansion box is fastened to the fascia and does not move.

- The expansion box must be able to accommodate a minimum full range of 1.375” (contraction) + 2” (expansion) + 1.375” (contraction) = 4.75” long. This minimum only applies to the scenario where the expansion box is placed exactly in the center of the 80 foot span.
- The amount of overlap (1.375”) on each end for contraction should be doubled to account for the extreme case where the expansion box is placed at the end of the 80 foot span. Therefore, overlap on each side should would be at least 2.75”. Therefore, a minimum total expansion box length of 2.75” + 2” + 2.75” = 7.5” is required.

Thermal Expansion
80 foot span

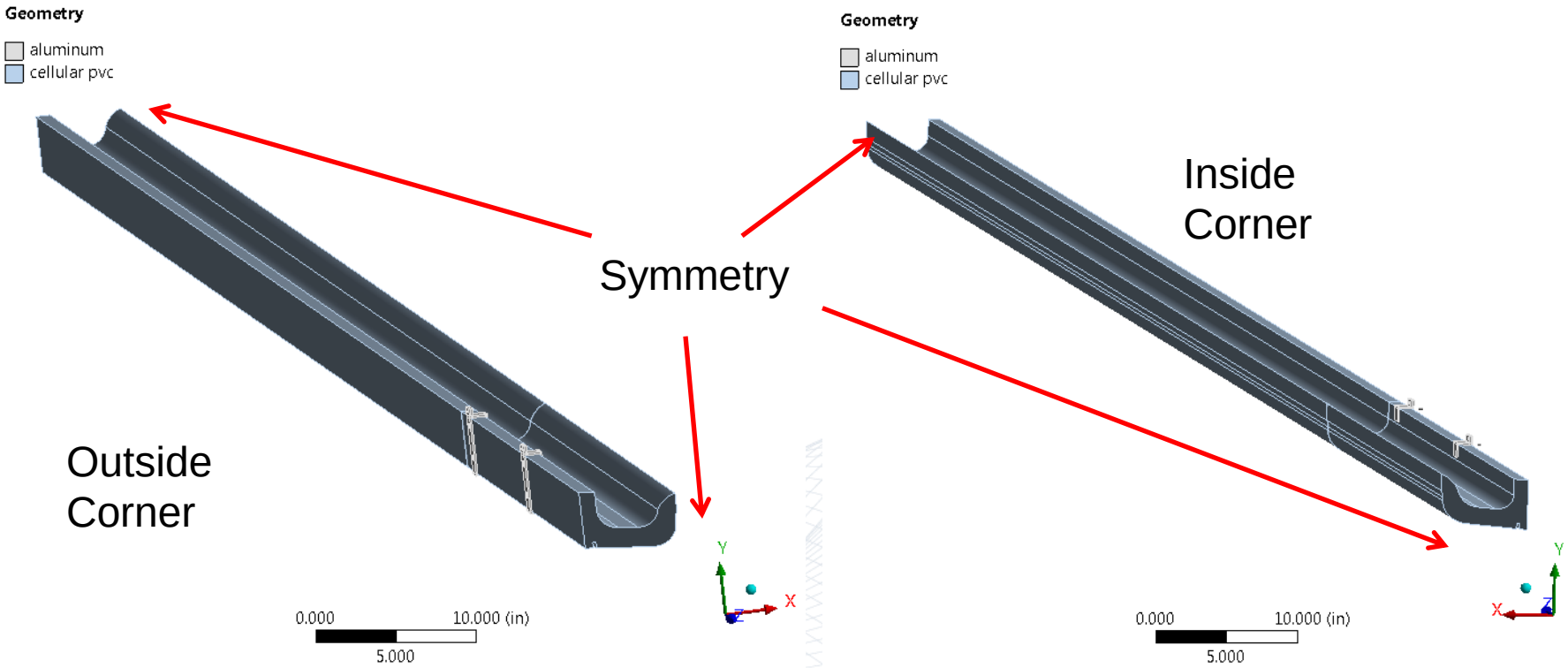
- Additional overlap (>0.5”) will of course be necessary on each side to maintain engagement with gutter under extreme conditons. Otherwise, the gutter may slip out of the expansion box. The minimum, final recommended expansion box length is 0.5” + 7.5” + 0.5” = 8.5” if the end cap gap is 2”.
- If the gap between the end caps is increased from 2” due to installation tolerances, the length of the expansion box should be increased the same amount.



Gutter Stress and Displacement Evaluation

- Assumptions
  - Gutter length of 40 feet
    - Symmetric models include 20 feet with symmetry boundary conditions to mathematically represent 40 feet in actuality.
  - 2 piece bracket 24” away from corner.
  - Worst case condition where there are 2 opposing outside corners or 2 opposing inside corners.
    - Without an opposing corner, the bracket attachment to the gutter can accommodate any thermal expansion/contraction.

Gutter Stress and Displacement Analysis Models

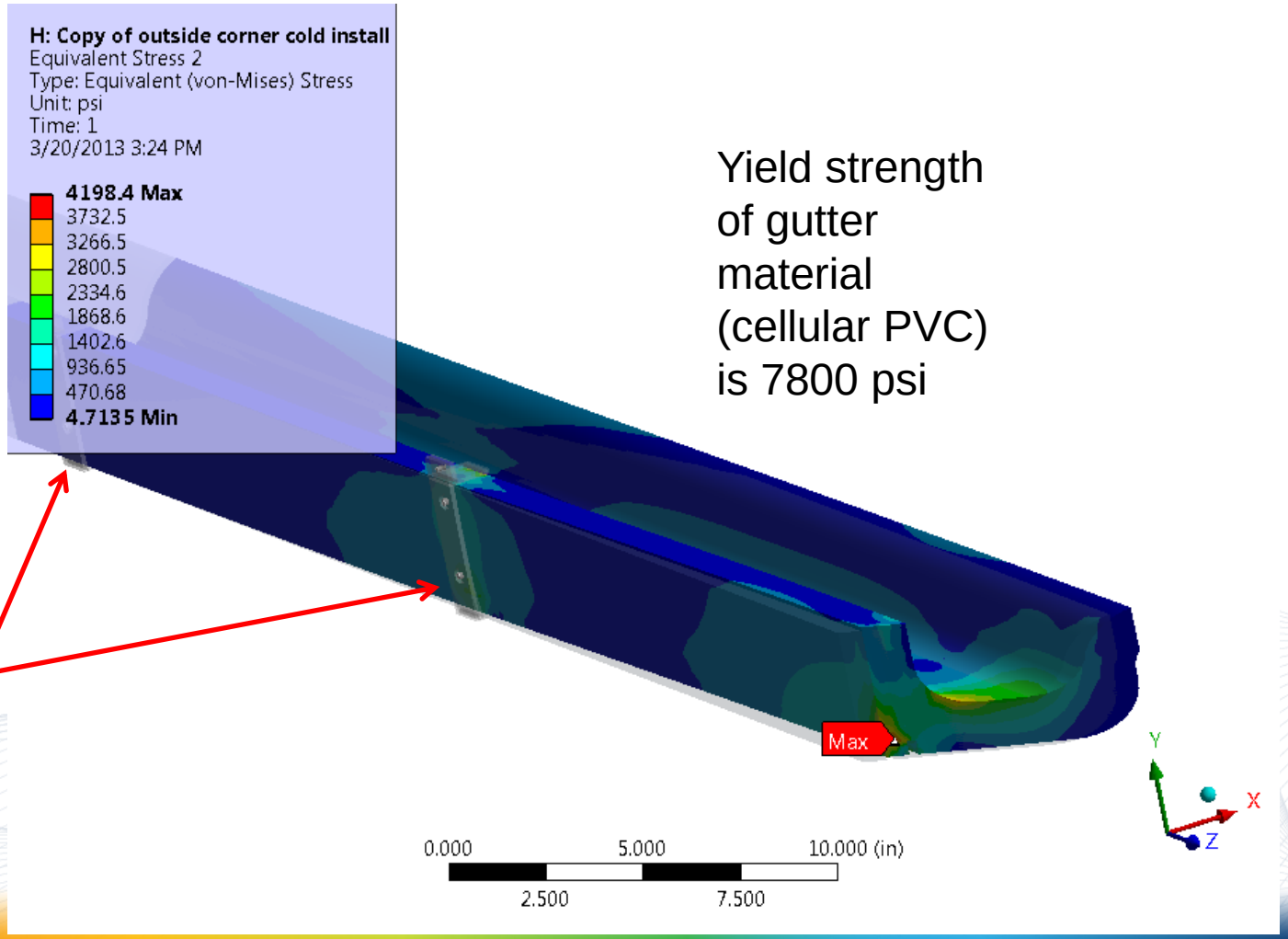


Stress on outside corner
Install temp 40F, hot temp 120F
40 foot span
2 piece bracket 24” back from corner

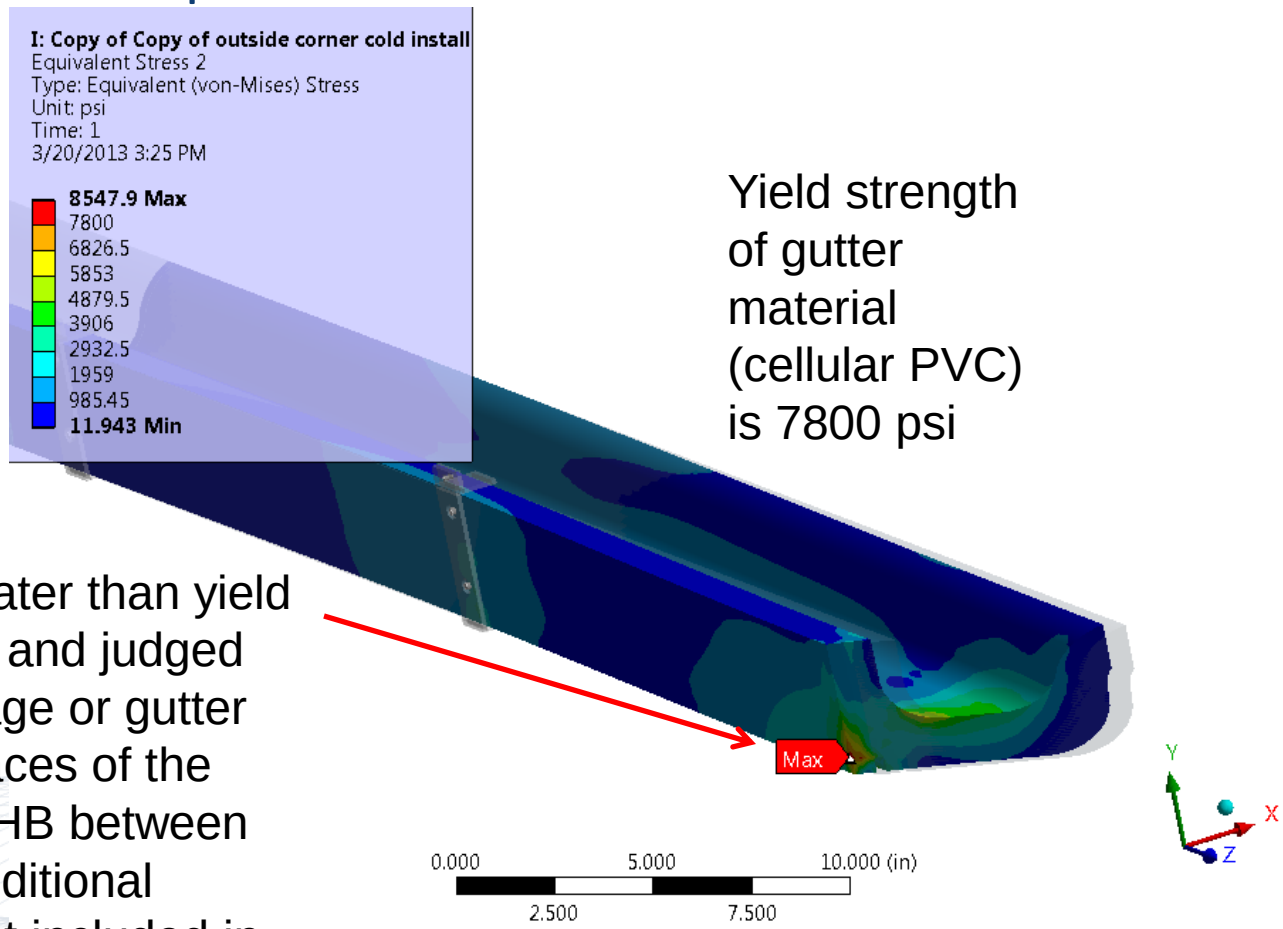
Maximum stress is less than yield strength and therefore the gutter material will not be damaged.

Yield strength of gutter material (cellular PVC) is 7800 psi

Brackets



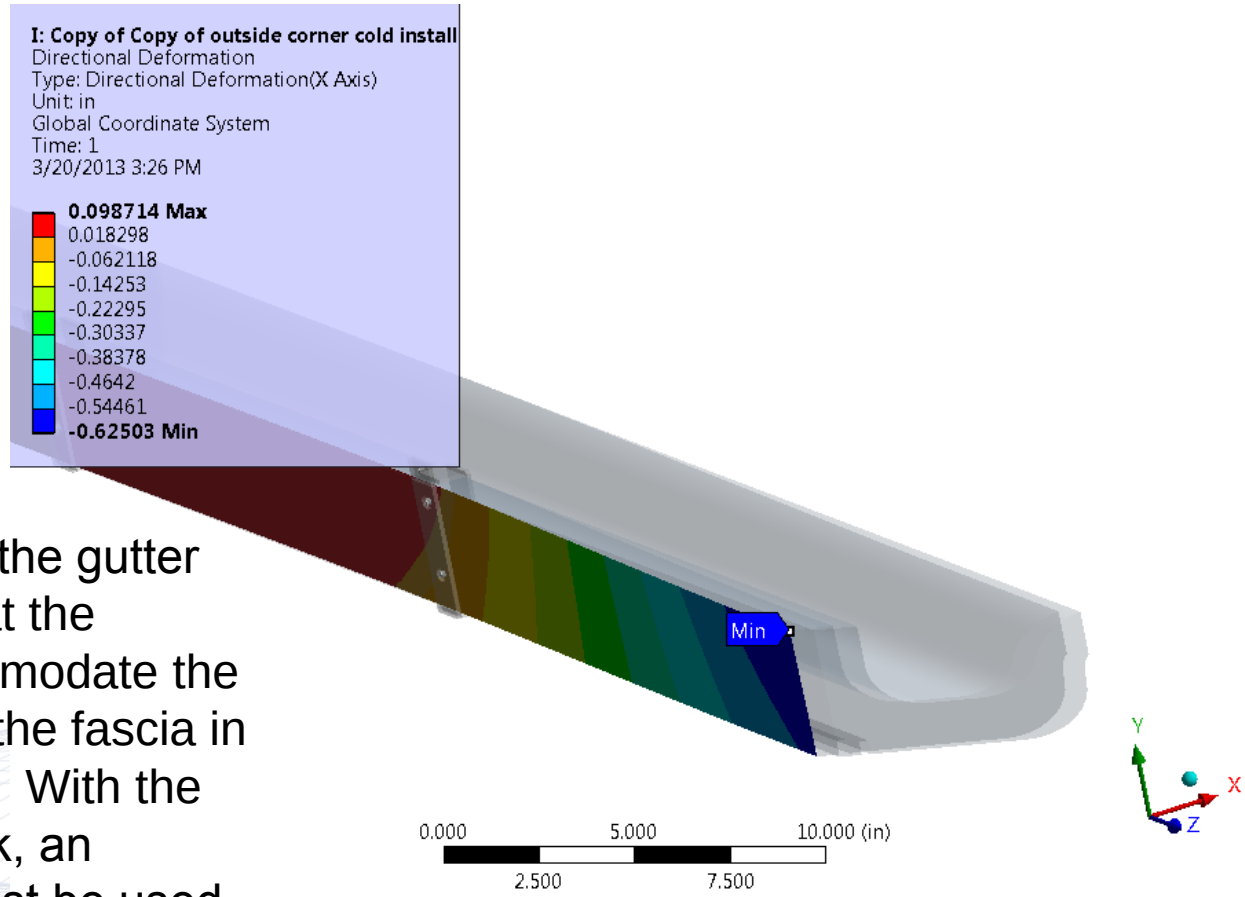
Stress on outside corner
Install temp 90F, cold temp -20F
40 foot span
2 piece bracket 24” back from corner



Yield strength of gutter material (cellular PVC) is 7800 psi

Maximum stress is greater than yield strength at single point and judged not to cause joint leakage or gutter damage. The cut surfaces of the PVC gutter have 3M VHB between them which will give additional compliance which is not included in the analysis model.

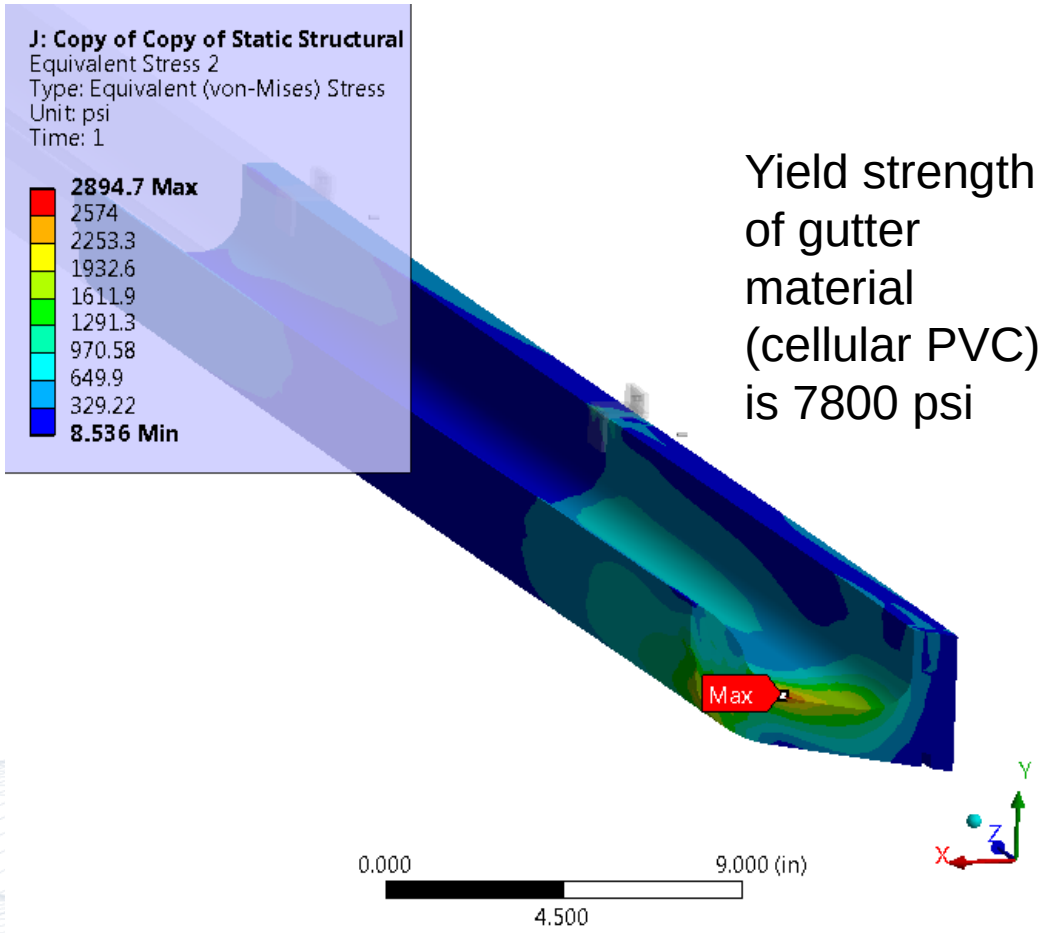
Displacement on outside corner
Install temp 90F, cold temp -20F
40 foot span
2 piece bracket 24” back from corner



A gap of 0.625” between the gutter and fascia is necessary at the outside corners to accommodate the contraction of gutter into the fascia in this worst case condition. With the bracket being 0.125” thick, an additional 0.5” spacer must be used between the bracket and fascia.

Stress on inside corner
Install temp 40F, hot temp 120F
40 foot span
2 piece bracket 24” back from corner

Maximum stress is less than yield strength and therefore the gutter material will not be damaged.



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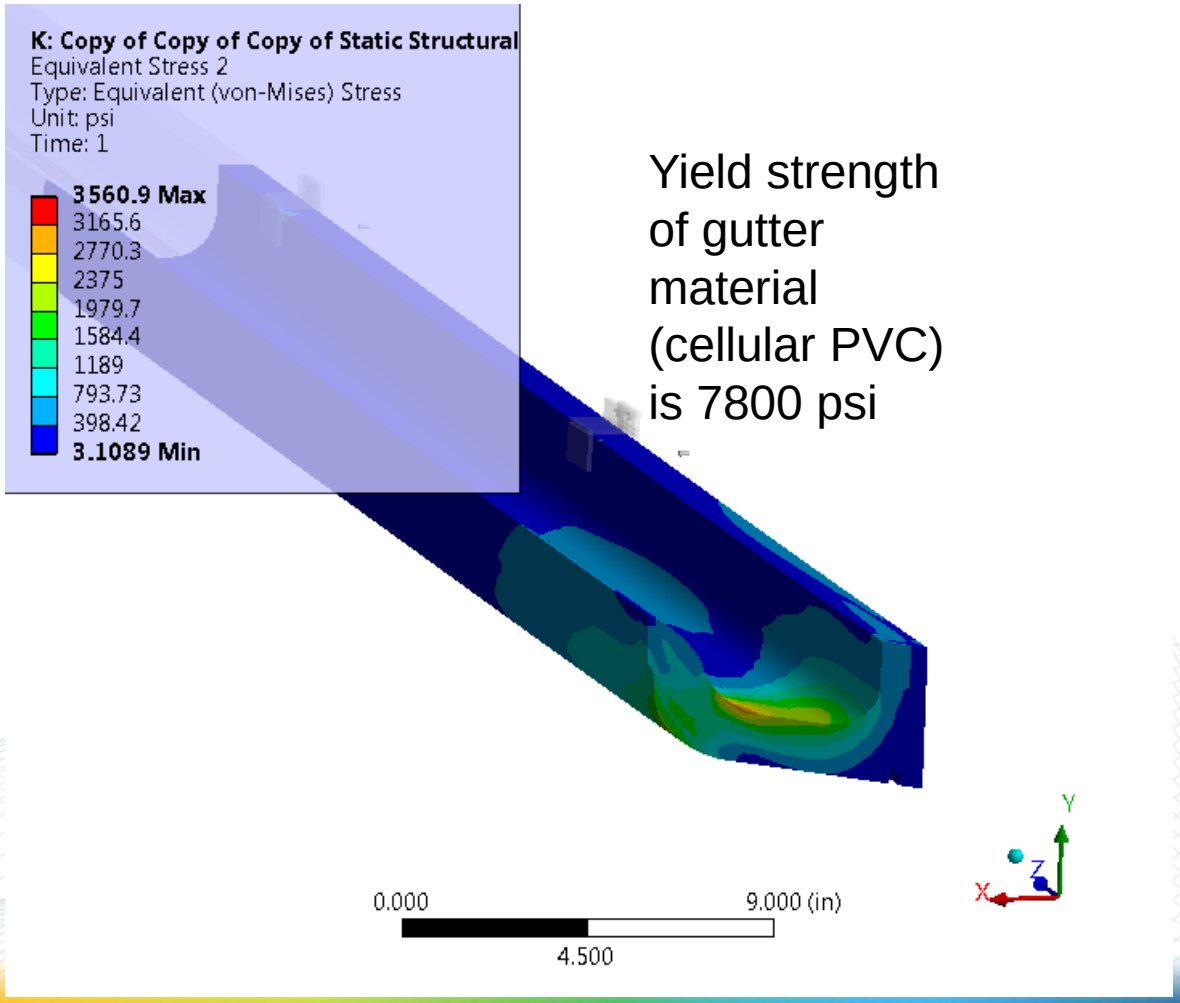
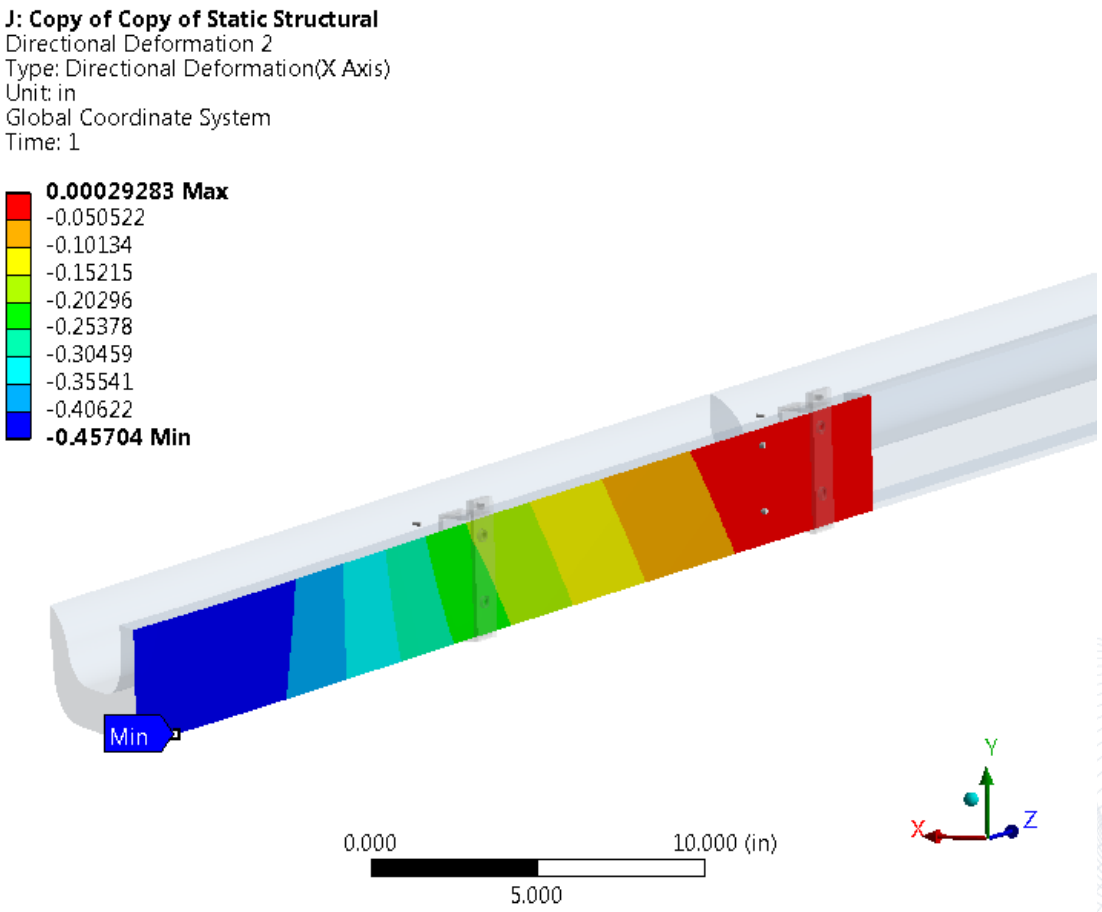


Yield strength of gutter material (cellular PVC) is 7800 psi

Displacement on inside corner
Install temp 40F, hot temp 120F
40 foot span
2 piece bracket 24” back from corner

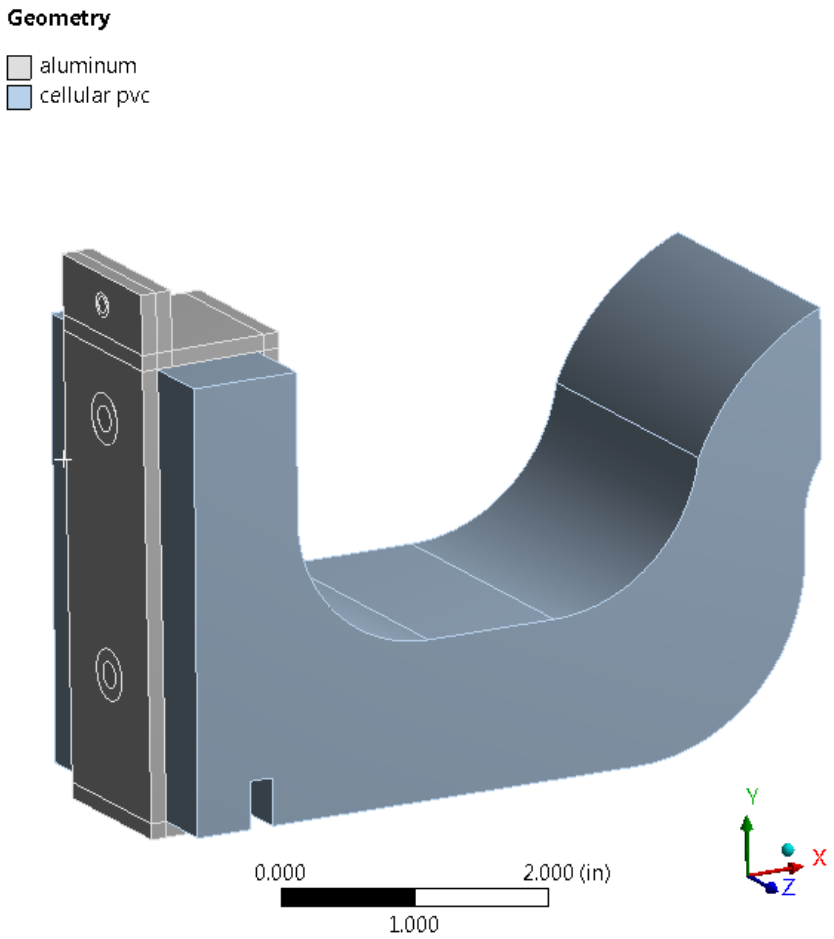
A gap of 0.46” between the gutter and fascia is necessary at the inside corner to accommodate the expansion of gutter into the fascia in this worst case condition. With the bracket being 0.125” thick, an additional 0.34” spacer must be used between the bracket and fascia.

The outside corner condition requires a 0.625” gap and therefore governs the size of spacer used.



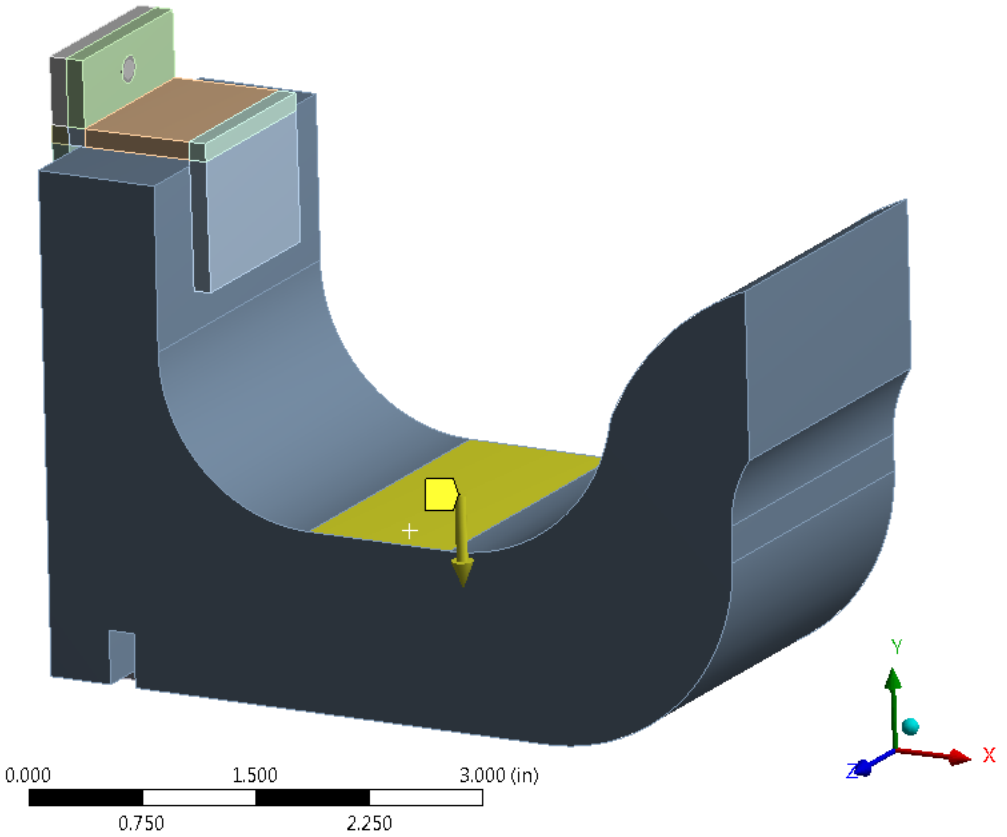
Bracket Evaluation

- Two piece bracket modeled in detail
- A segment of the gutter is used to best represent how the load is transferred to bracket



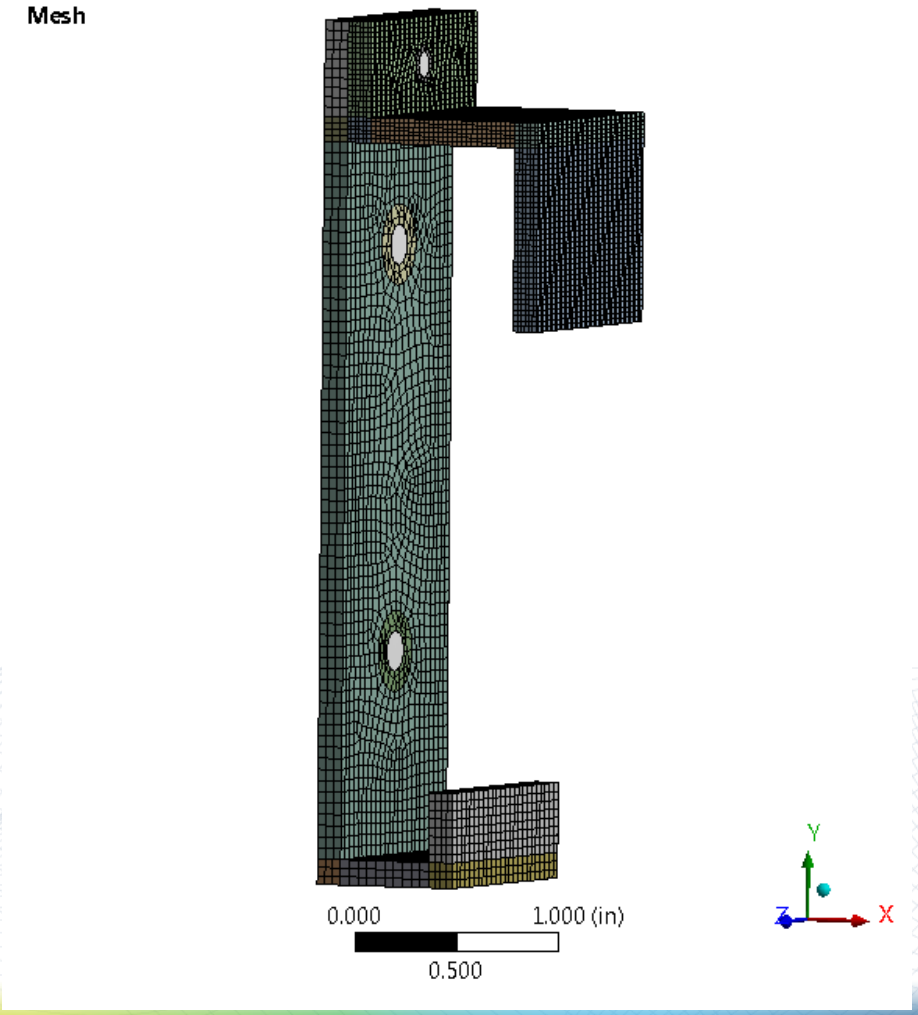
Bracket Evaluation

- 160 lbf load applied in center of gutter



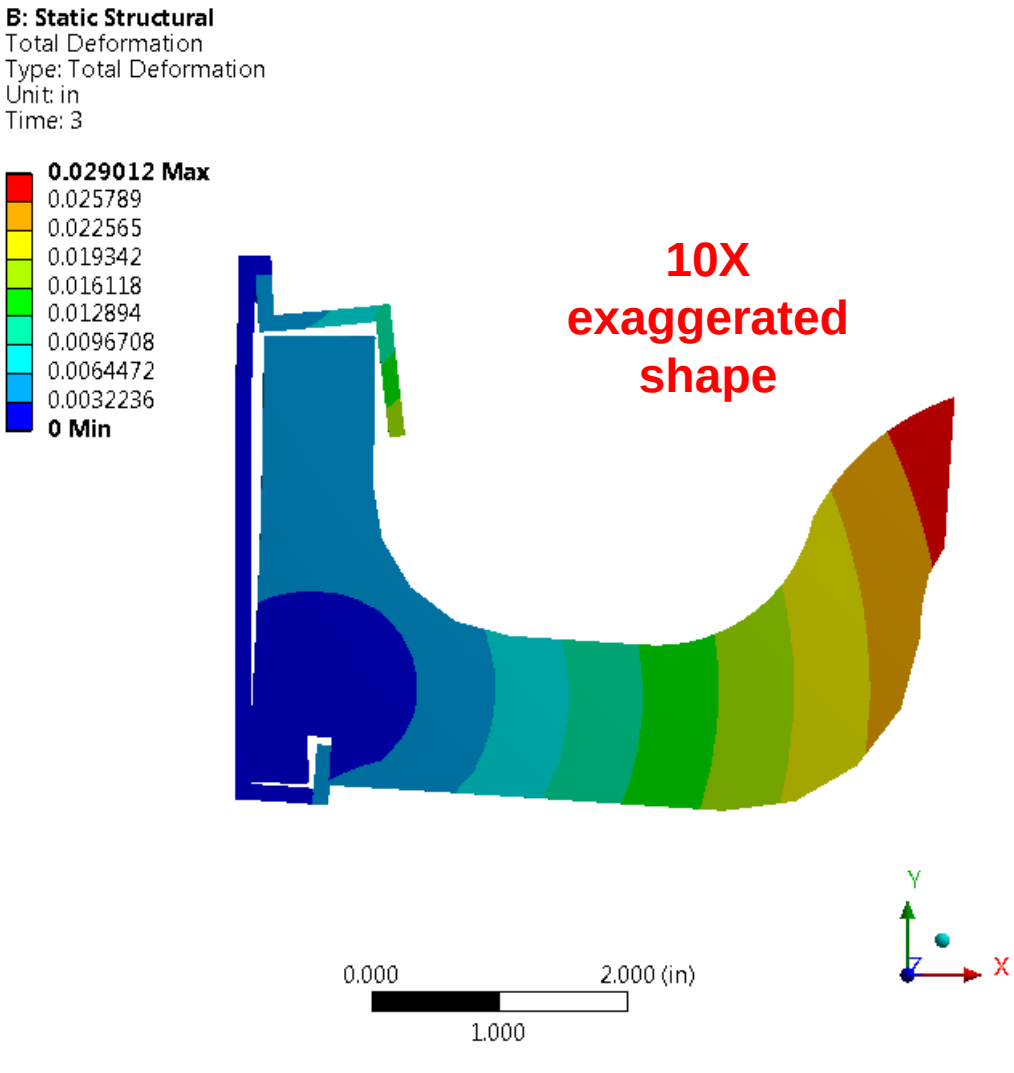
Bracket Evaluation

- Mesh
  - At least 3 elements through the thickness of all regions.



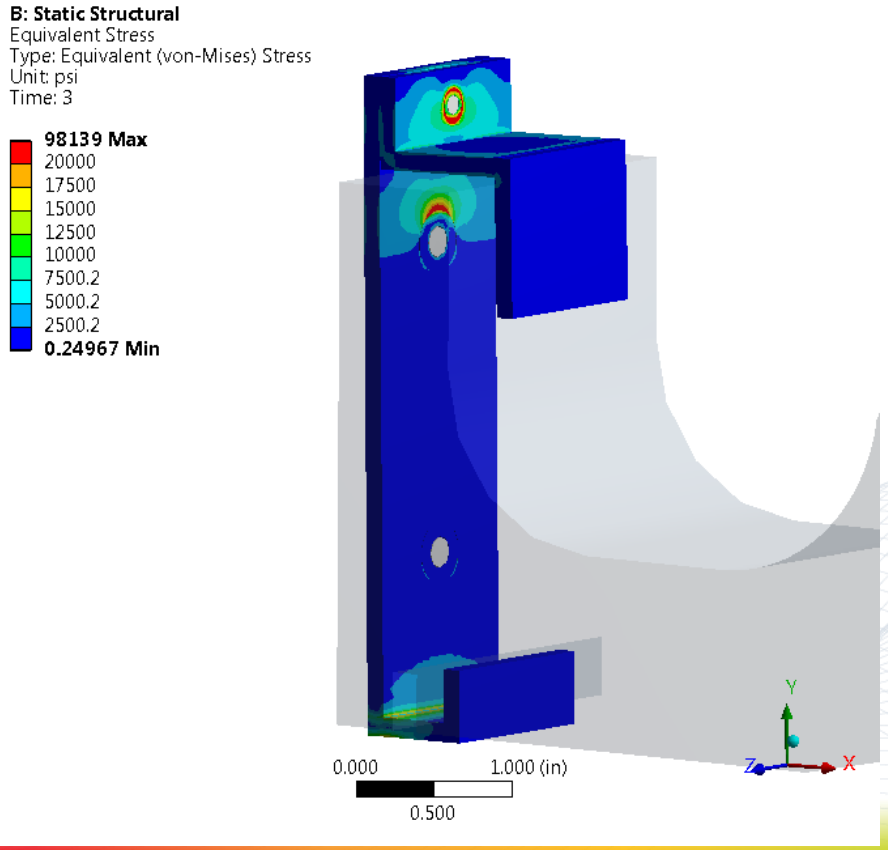
Bracket Evaluation

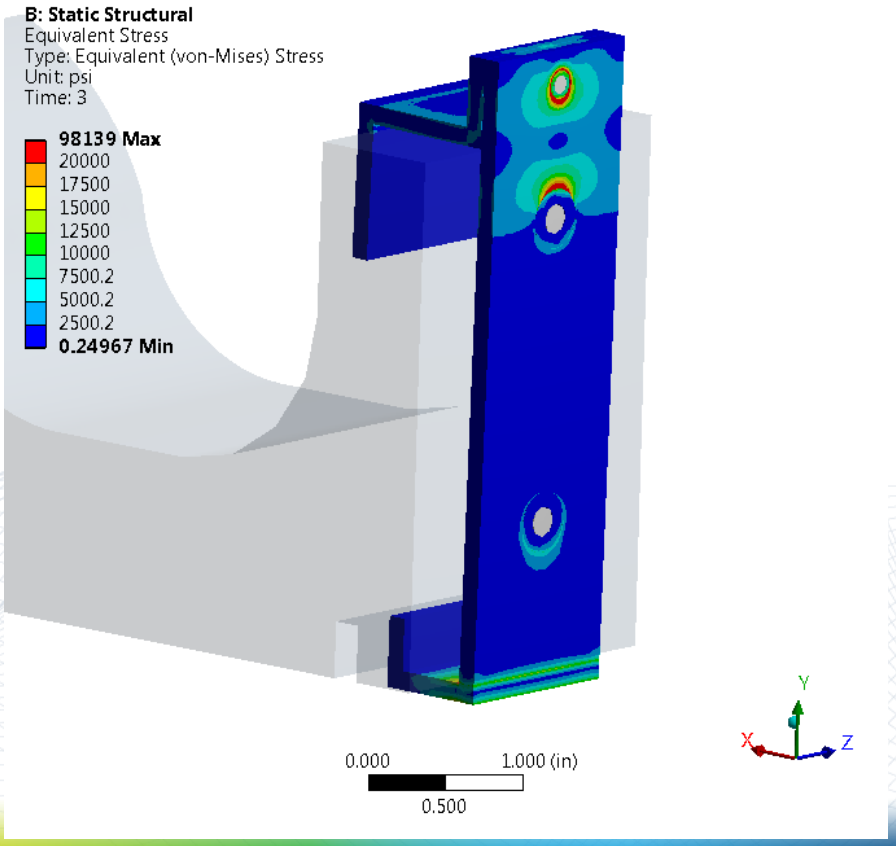
- Displacement



Bracket Evaluation

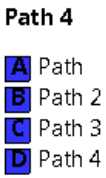
- Stress distribution in bracket under 160 lbf load. Regions in red are above 20,000 psi. Very localized to fastener locations which are simplified in the model.
  - Peak stress is not a good measure of the load carrying capacity. Stress concentrations at screws do not influence load carrying capacity.

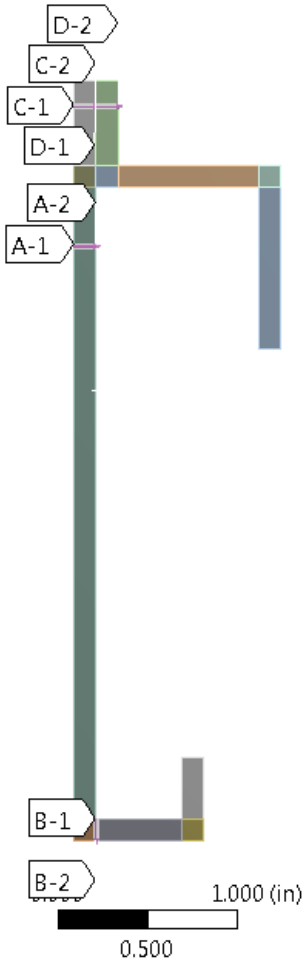




Bracket Evaluation

- Linearized stress will be used to determine true strength of bracket.
  - Methodology used to determine if measurable yielding is occurring through the thickness. Removes the stress concentrations of the screws.
  - 4 paths are used which are located at local peak stress locations.
  - The maximum linearized stress is 18,400 psi and therefore material yield strength of 20,000 psi is adequate for structural integrity of bracket with a 160 lbf load.





Location	Stress, psi
Path (at top screw into fascia)	17,520
Path 2 (bottom of bracket)	16,055
Path 3 (connecting screw between pieces, through clip)	18,434
Path 4 (connecting screw between pieces, through hanger)	17,444

Screw Evaluation

- 18-8 stainless steel screws are used for the assembly.
  - Minimum yield strength = 40,000 psi
- Two #10 screws attach bracket to fascia.
  - Loads extracted from analysis model

Fastener	Axial (lb)	Shear (lb)	Stress (psi)
Top #10	22	84	11,800
Bottom #10	1	19	2,700

- One #8 screw attaches 2 pieces of bracket together.

Fastener	Axial (lb)	Shear (lb)	Stress (psi)
#8	263	4.3	24,900

- All stresses below yield strength, therefore screws are capable of holding load without failure.