Scissor Mechanisms

Scissor mechanisms are very common for lifting and stabilizing platforms. A variety of man-lifts, service platforms and cargo lifts utilize this visually simple but structurally complex mechanism.

Figure 1
Torero Cabin Service Truck

Scissor Mechanism was chassis mounted
and lifted the cabin to service aircraft

My introduction to scissor mechanisms came in 1979, with my employment at the then Cochran-Western Corporation. A pair of scissor lift mechanisms was used on the aircraft cargo loaders. The aft scissor stabilized the 15,000 Lb cargo from a low height of 20" to the maximum height of 144". The forward scissor lifted and stabilized the forward platform with the operator and the 15,000 Lb load; the lift range was 70" to 218".

The typical scissor is comprised of an inner and outer section. The inner scissor is comprised of a pair of longitudinal arms and one or more lateral beams. One end of the longitudinal arms is pinned to either the chassis or platform, while the other end of the arms pushes against the platform or chassis with a roller or slider mechanism. The mid-point of the longitudinal arms is the location of the pivot between the inner and outer sections. The outer section is comprised of a pair of longitudinal arms, which are similar to the inner section, but the outer arms are typically not structurally connected. The outer arms pin to either the platform or chassis, which the inner's are not pinned and push against the opposite frame.

If the scissors just stabilize the platform, then the platform is lifted by an external mechanism. When the scissors lift and stabilize the platform, then a means within the scissor mechanism causes the scissors to rotate and, thus, lift/lower the platform.

The scissor mechanism does not analyze readily with hand calculations because it often has multiple load paths; further, certain loads are dependent upon deflection and constraints. The following cursory analysis is directed towards the inner scissor section.

In Figure 2, a typical inner scissor is shown. For purposes of this study, the scissor arms are 160" long and the width is 50". The cross section of the arms and the cross tube is a 6" x 6" x 0.25" wall square tube.

Position 1 along the scissor arm is the "pinned' connection. For this analysis, the connection supports forces in the three orthogonal directions but moment loads are not supported.

Position 9 of the scissor is the mid-point of the arm and, thus, considered the center pivot location.

Position 17 of the scissor arm is the "roller" end of the arm. For this analysis, only a vertical (Z axis) reaction force is supported by one of the longitudinal arms. The "roller" end of the second arm is free to move; this second arm "roller" is where deflection (Z= -1.00") or force (Fz = -317.846 Lb) loads are applied.

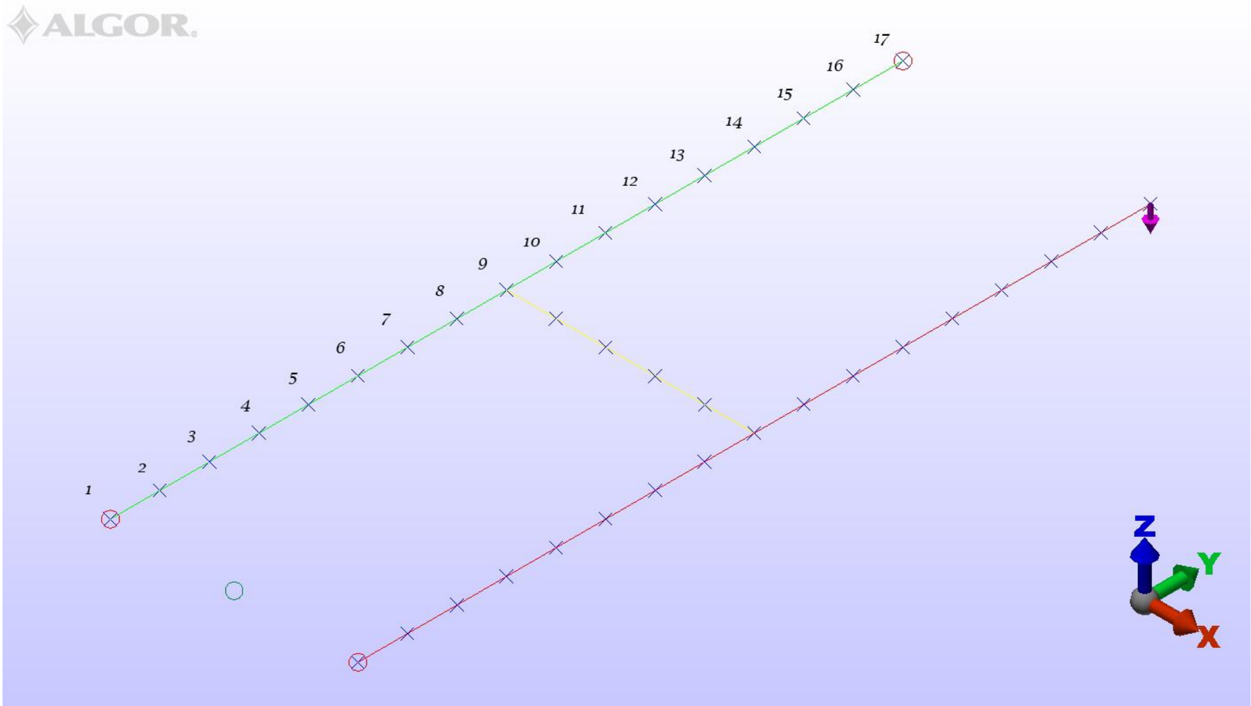

Figure 2
Basic Inner Scissor Section
Lateral Beam in Location 9 (Center Pivot)

The global X-Y-Z axis orientation is shown in Figure 2.

The X axis is lateral to the scissor arm. For the first analyses, the scissors are rotated about the "pinned" end (location 1) and the X axis through an angle of 60 degrees. For geometry considerations, scissors don't often attain even 60 degree of rotation.

For modeling purposes, the Z axis is "up".

Rotation of the Inner Scissor Arm
With the Lateral Beam Located at the Center Pivot

The first sequence of analyses is of the basic inner scissor arm with the lateral beam located at the center pivot. As the inner scissor arm is rotated up in 5 degree increments, a deflection of Z = -1.0” is applied to the free end of the scissor arm.

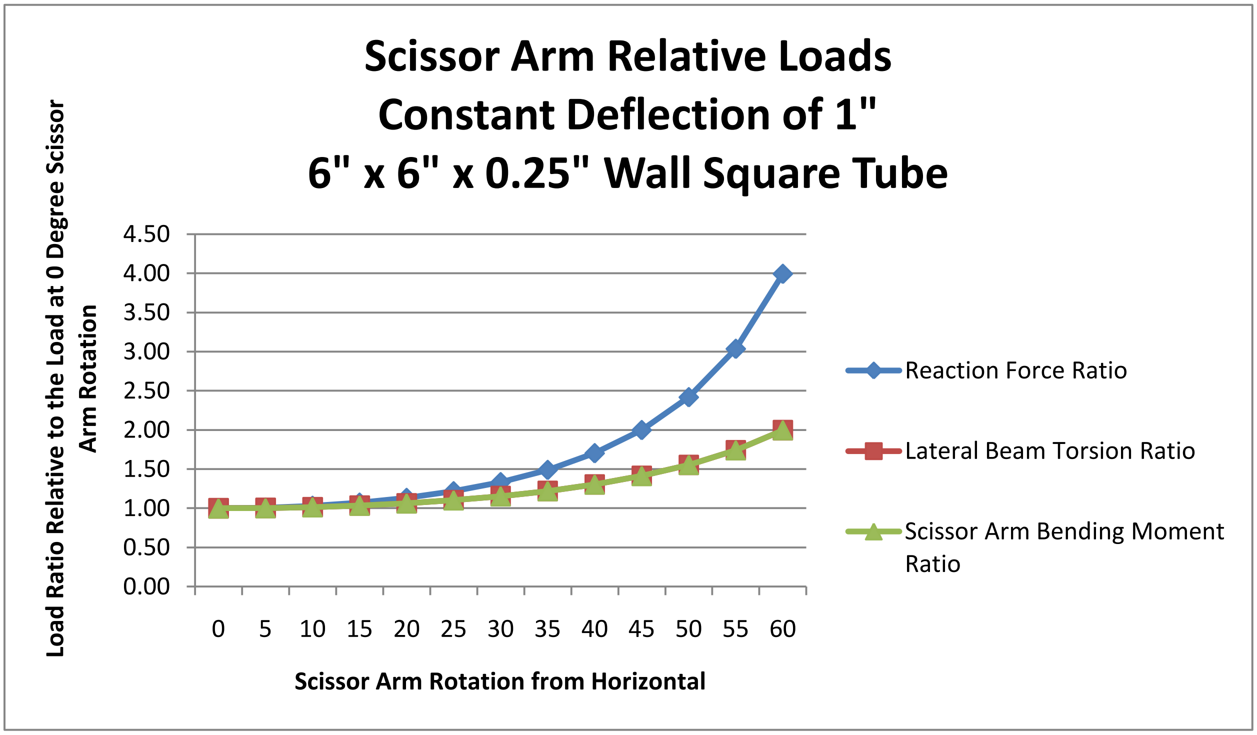

Figure 3
Rotation of Basic Inner Scissor Arm
Z = -1.0” Constant Deflection

Figure 3 shows the results of the analyses.

1. The Reaction Force is the force required to provide the vertical deflection of 1.00”
2. The Reaction Force is 317.846 Lb, when the scissors are at the 0 degree rotation position.
3. The Ratio (Reaction Force, Lateral Beam Torsion and Scissor Arm Bending Moment) is determined relative to the value when the scissor is in the down (0 degree) position.

As anticipated, the scissors become increasingly stiff, as the arm is rotated. This is because the load is increasingly directed along the axis of the scissor arm.

Figure 4 shows the results of the analyses but for constant load, instead of constant deflection.

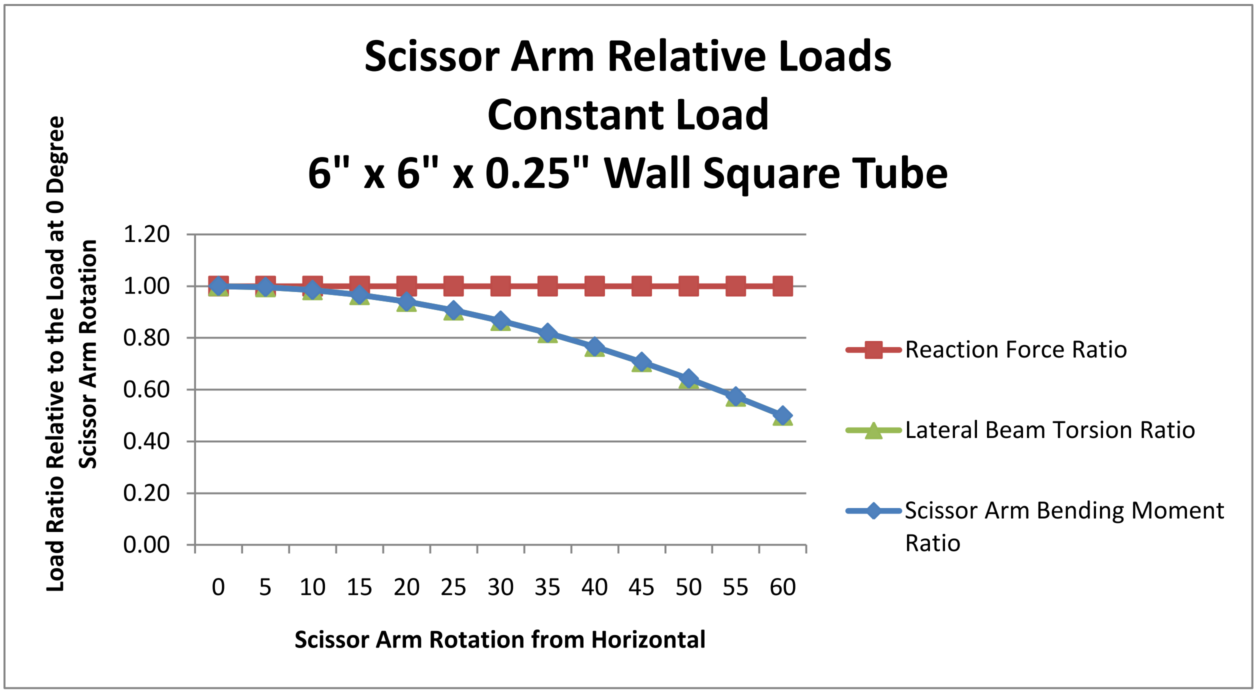

Figure 4
Rotation of Basic Inner Scissor Arm
F_Z = -317.846 Lb Constant Load

Basic Inner Scissor Arm
With a Single Lateral Beam at Various Positions

The next series of analyses is for a basic inner scissor arm but the single lateral beam was located at various positions along the length of the scissor arm.

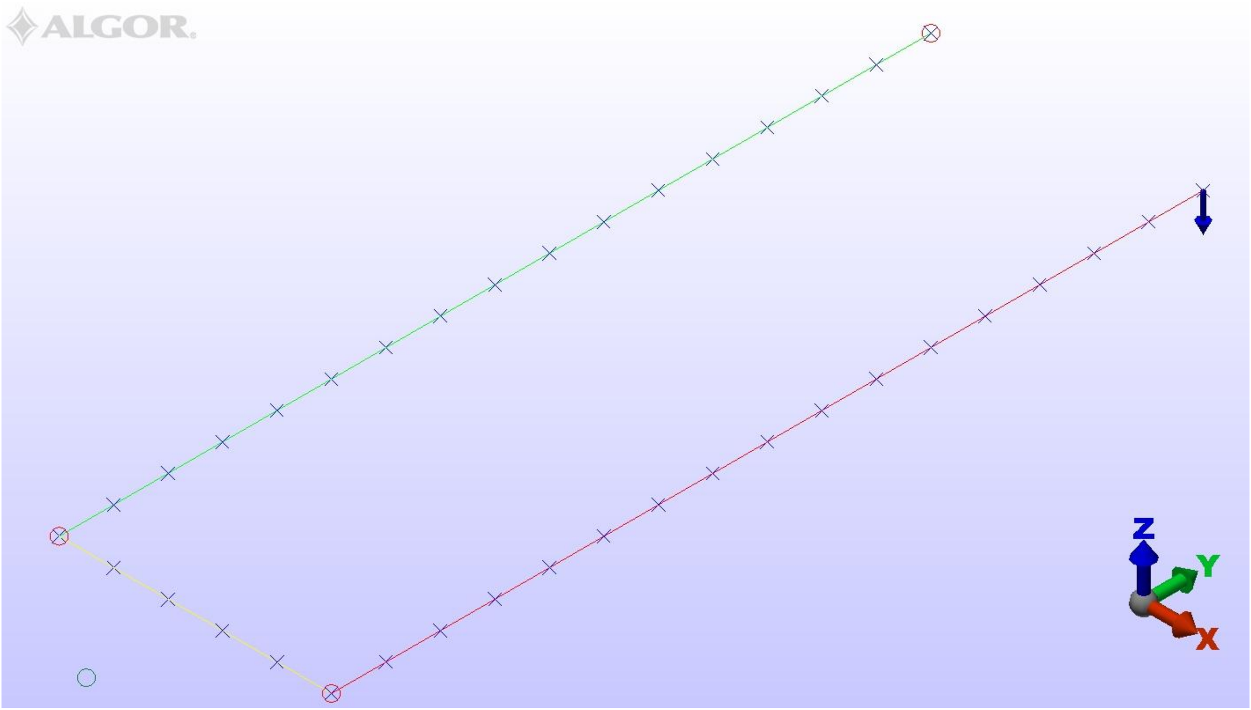

Figure 5
Basic Inner Scissor Arm
Lateral Beam in Location 1

Figure 6 shows the analyses results for the scissor arm in the 0 degree (down) position. For a single lateral beam at various positions,

1. As the lateral beam was shifted away from Position 9 (center pivot) with constant load, the deflection increased.
2. With the lateral beam shifted to Positions 1 or 17 (ends of the scissor arms), the deflection increased by 71% relative to the Position 9 deflection.
3. As the lateral beam was shifted away from the Position 9 (center pivot), the scissor arm bending moment increased.
4. With the lateral beam shifted to Positions 1 or 17 (ends of the scissor arms), the scissor arm bending moment increased by 100% relative to the Position 9 bending moment.
5. With constant deflection, the scissor arm bending moment maximum is located between Positions 4 and 5 and Positions 13 and 14.

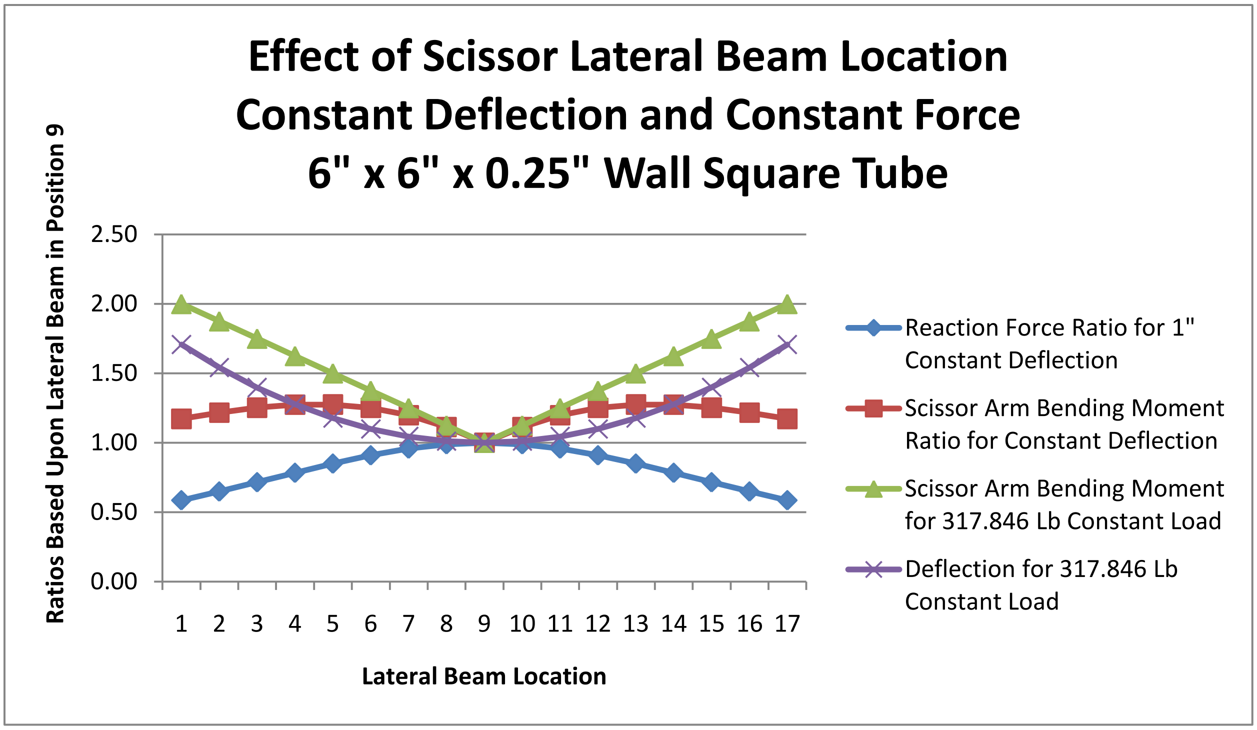

Figure 6
Basic Inner Scissor Arm
Lateral Beam in Locations 1-17
Constant Deflection and Constant Force

Inner Scissor Arm with Two Lateral Beams
Lateral Beams at Position 9 and Other Locations

The next analyses set is for an inner scissor with lateral cross tubes located at Position 9 (center pivot) and a second lateral beam located at various other locations. The scissor was loaded with a vertical force.

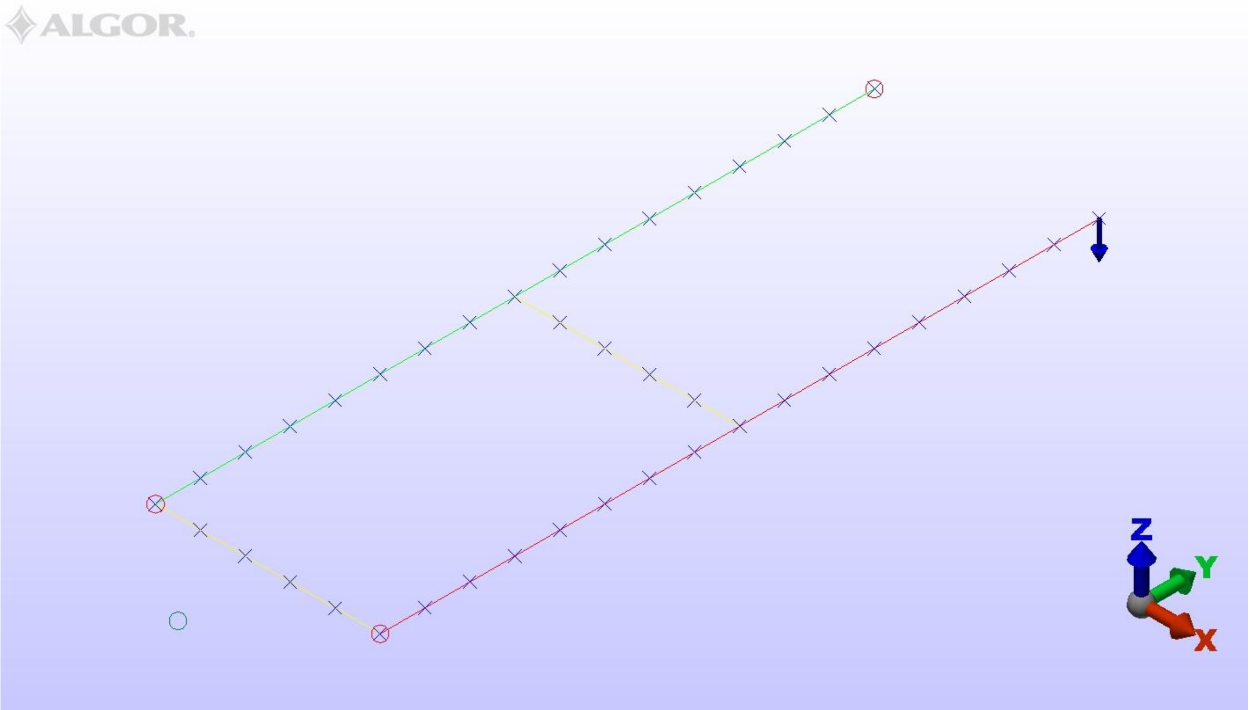

Figure 7
Inner Scissor Shown with Lateral Tubes at Positions 1 and 9

Figure 8 shows the analyses results for the scissor arm in the 0 degree (down) position. To provide a reference to previous analyses, I included the analysis for a single lateral beam, which was located at Position 9; further, the data from this analysis was used as the basis for the Ratio calculations. For this set of scissors with a lateral beam at Position 9 and a second lateral beam at various positions,

1. The maximum bending moment of the scissor arm is not affected by the location of the lateral beams.
2. The deflection Ratio is significantly less than for a single lateral beam.
3. As the second lateral beam is moved from Position 1 to Position 8 (Position 17 to Position 10), the deflection Ratio increased from 0.32 to 0.54.
4. The torsion of the lateral beam, at Position 9, is less than half that of the single lateral beam.
5. As the second lateral beam is moved from Position 1 to Position 8 (Position 17 to Position 10), the torsion of the second beam approaches the torsion of the lateral beam, which was at Position 9.

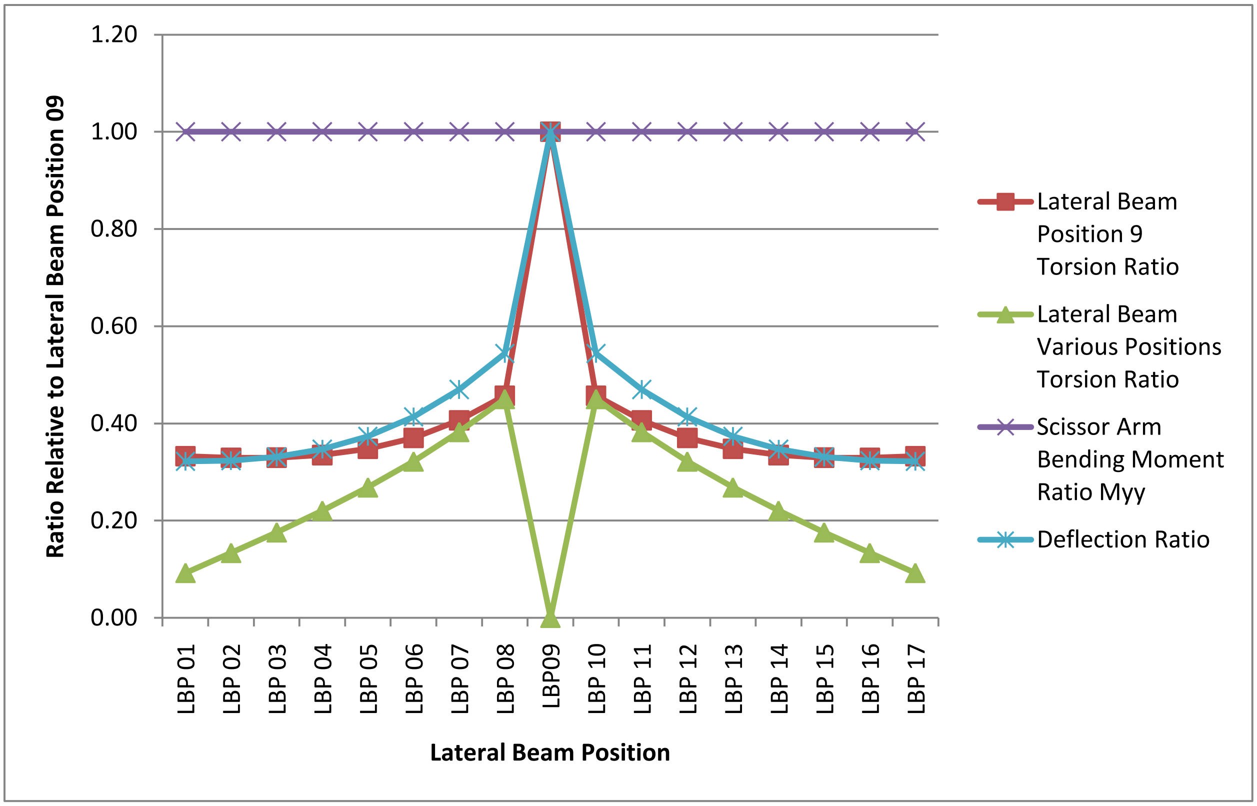

Figure 8
Inner Scissor with Lateral Tubes at Positions 9 and Various Other Positions
Constant Force

Inner Scissor Arm with Two Lateral Beams
Lateral Beams Symmetrically Located

The final analyses set is for an inner scissor with a pair of lateral cross tubes located symmetrically relatively to Position 9 (center pivot). The scissor was loaded with a vertical force.

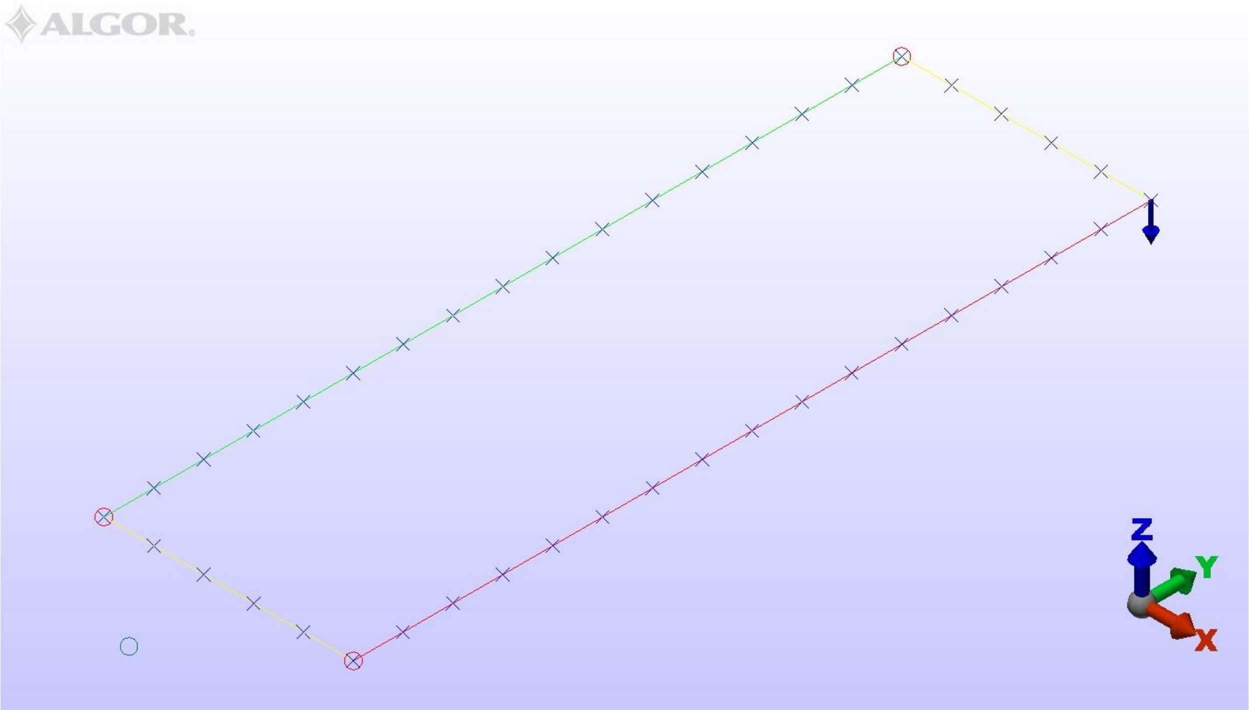

Figure 9
Inner Scissor Shown with Lateral Tubes at Positions 1 and 17

As in the previous analyses, I included the configuration with a single lateral beam, which was located at Position 9; this provides the reference for the Ratio calculation and relationship to the previous analyses. A vertical force of F_Z = -317.846 Lb was applied to the scissor for a constant load. Figure 10 shows an overview of the results of the analyses. As the lateral beams are moved towards the center pivot, then,

1. The deflection ratio increases from 0.11 to 0.46.
2. The scissor arm bending moment initially decreases from 0.17 to 0.11, then increases to 1.00.
3. The torsion ratio of the lateral beams increases from 0.09 to 0.39.
4. The scissor arm torsion ratio increases from 0.13 to 0.26.

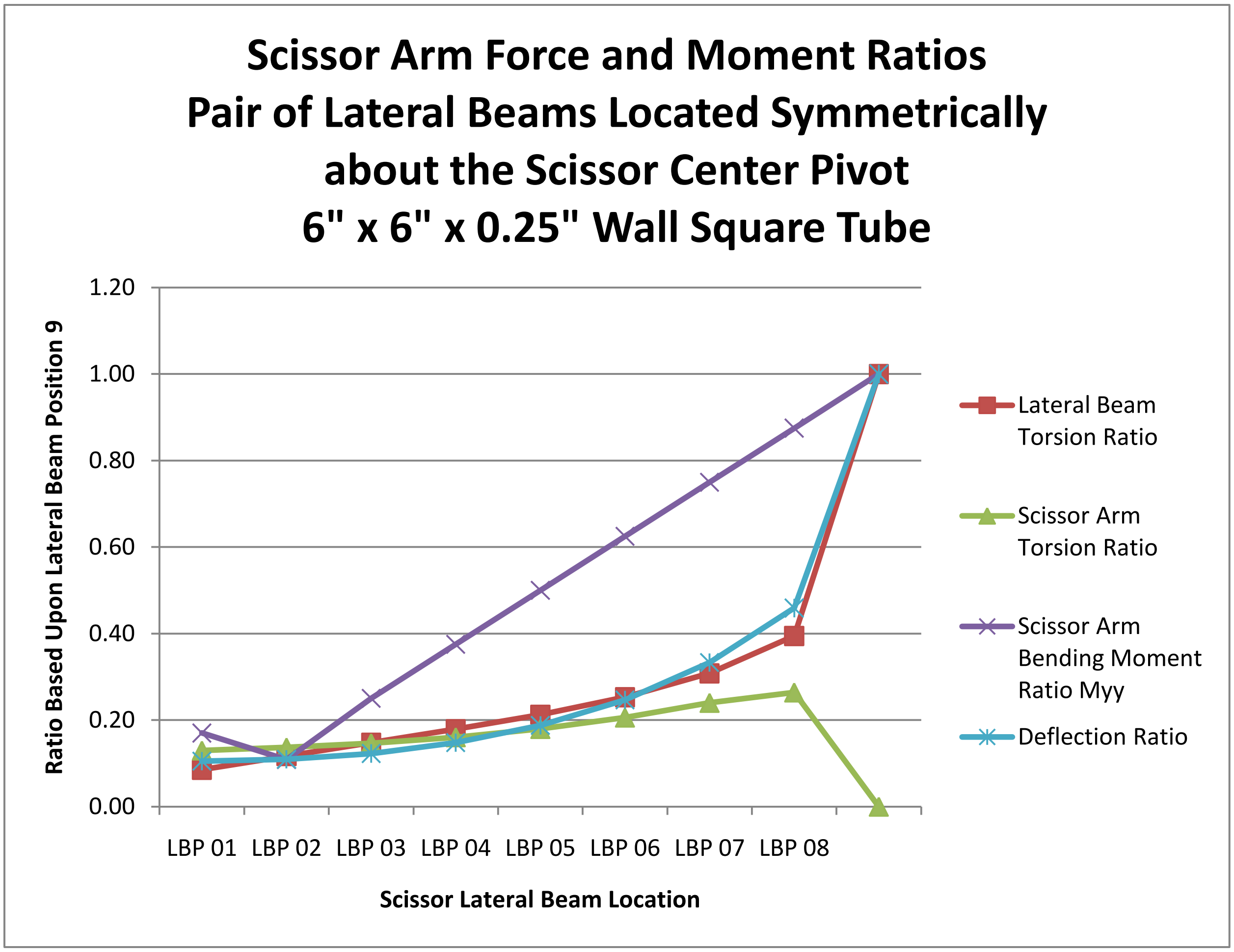

Figure 10
Inner Scissor with Symmetrically Located Lateral Tubes
Constant Force

Conclusion

The location and the quantity of the lateral beam(s) are very important to the function of a scissor mechanism. As shown in Figures 11, 12 and 13, these two factors have significant impact upon the structural deflection and stress.

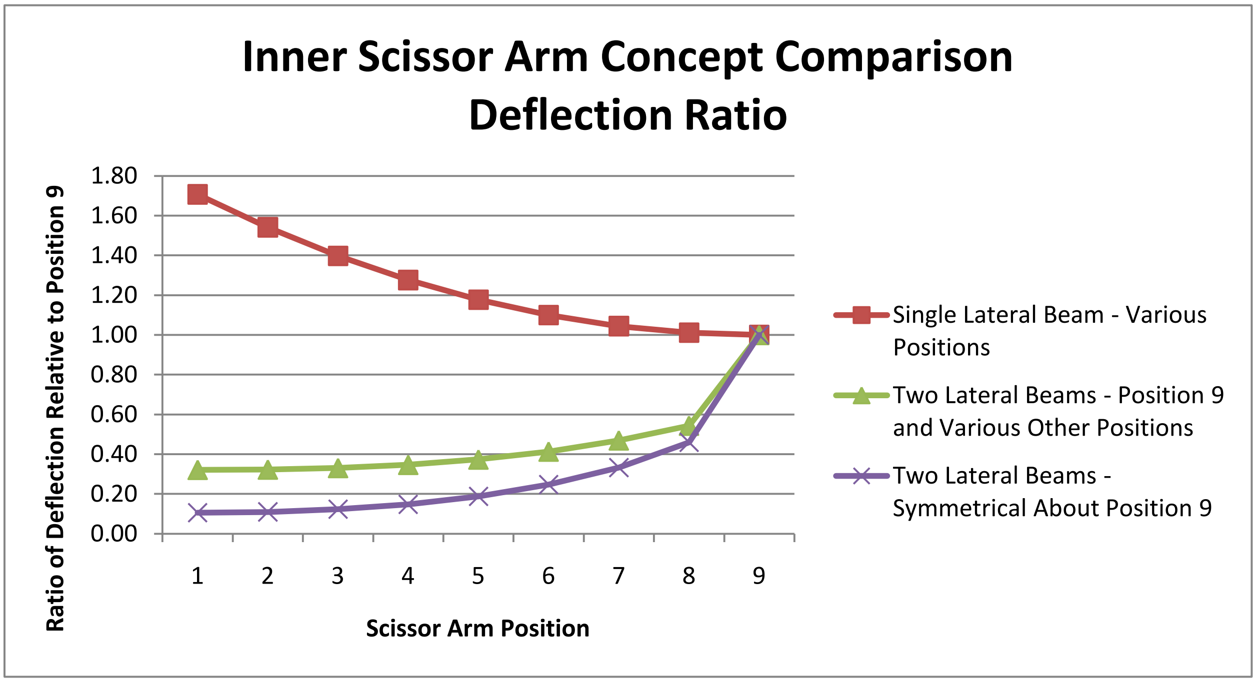

Figure 11
Inner Scissor Arm Concept
Deflection Comparison

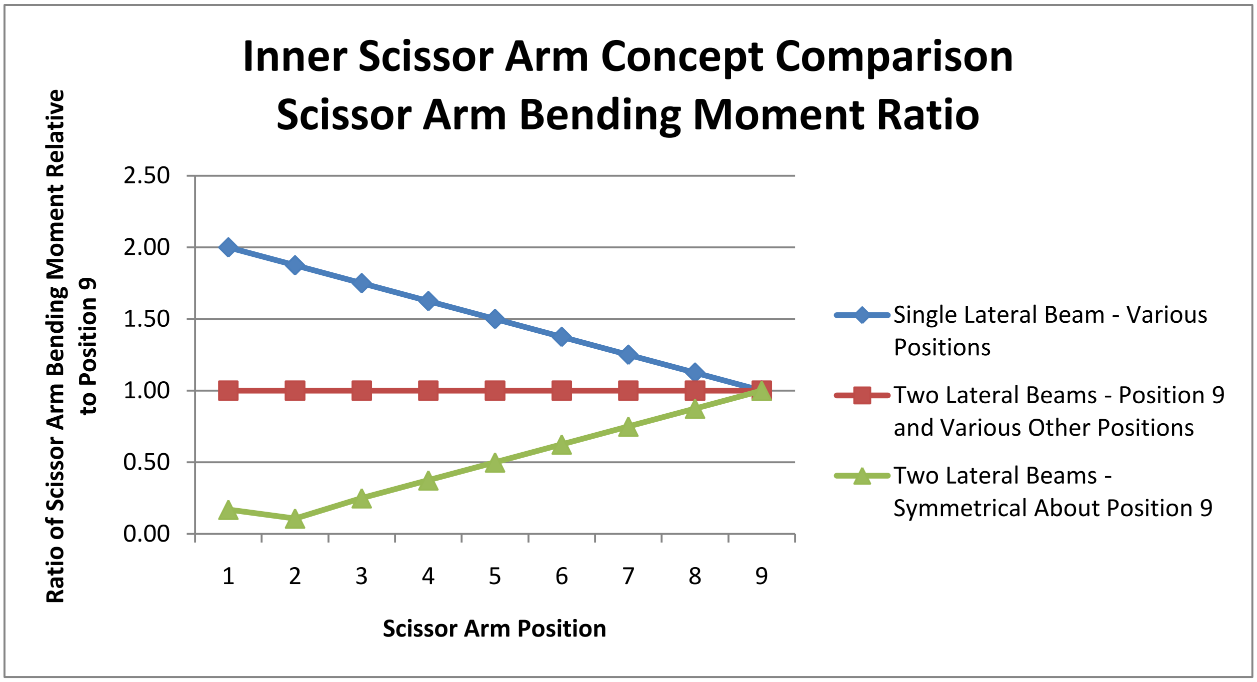

Figure 12
Inner Scissor Arm Concept
Scissor Arm Bending Moment Comparison

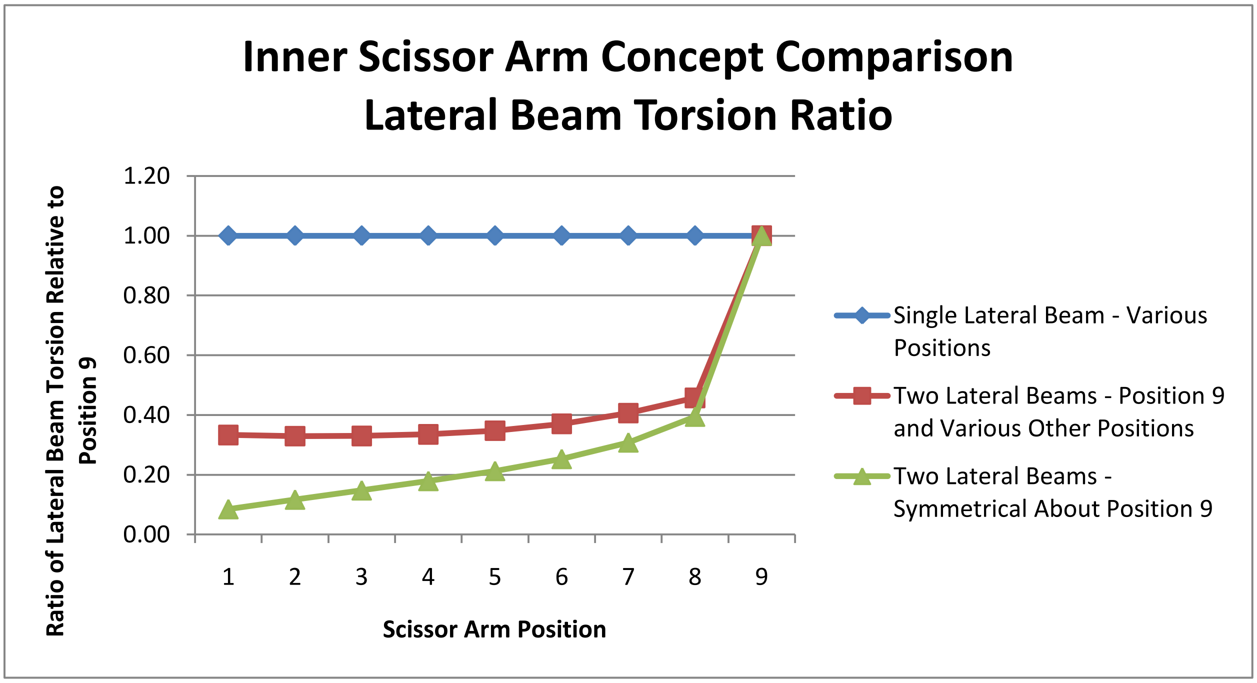

Figure 13
Inner Scissor Arm Concept
Lateral Beam Torsion Comparison