# Universal Safety Inspection Cage – Engineering Testing Results 2018

## 1.0 Test Reports

**1.1 Test Setup** – A curved section of steel simulating the kiln shell of a 4.0M kiln was set up and lined with 220mm refractory brick for the cage to sit on. A 250 lb. piece of concrete was raised to 125 inches above the top of the cage centered on various areas of the cage. A rope suspended the impactor and an operator would cut it initiating free fall above the desired impact location.

**1.2 Results**

**1.2.1 Center Impact** – The impactor struck the top of the cage dead center. See video *(Universal Safety Cage test)* There cage compressed 8 inches and rebounded slightly higher as the legs lifted off the lining an inch or two. The impactor stayed in contact with the top of the cage so it rebound was about the same as the cage.

There was no detectable deformation in the cage during inspection other that dents and nicks form the impact. Some minor damage to the netting was noted.

**1.2.2 Leg Impact** – The impactor struck the top section of the leg, mid span of the webbed section. See video (name here). The impactor was deflected to the right side. The cage had a corresponding deflection to the left but stayed within an inch or two of its original location. The impactor then struck the side of the shell and deflected in toward the base of the cage where it was caught by the netting.

There was a significant impact dent on the leg section with some minor buckling of the webbed section. There was also some minor bending of the leg shape.

**1.2.3 Offset Impact** – This impact was targeted at one of the ribs, between the legs, to test the rib and net strength. The impact struck the rib at about mid length and was caught somewhat by the net. This caused a considerable torque on the cage but it maintained its position and did not tip over. The impactor fell over the side onto the shell and then into the base of the cage.

The rib had partially buckled and the net had some minor damage.

## 1.3 Analysis

**1.3.1** The cage faired better in the drop test results than anticipate. This is likely due to the effects of damping during the compression and rebound of the members. Also, the spring rate of the leg is likely less than calculated due to the looseness of parts and the flexing of the leg hub which was modeled as rigid. The calculated model anticipated bucking and yielding during this test but there was little to no yielding with the center impact.

**1.3.2** The leg impact showed buckling directly at the impact site and slightly below it which is desirable and anticipated by design. This impact also caused some bending in the lower leg weldment; the 2.0” x 1/8” wall tube. The leg may have buckled under this impact but we believe the shape and size of the spring inside the tube acts as a mandrel, preventing it from buckling.

**1.3.3** The rib impact faired better than expected. The rib buckled significantly and deflected down. The combination of the rib and the net stop the impactor but didn’t capture it; this was desired. This impact is arrested more than the others and cage stability and flipping was a concern. However, this model uses spikes nested inside the rubber feet which bite into the brick and prevent the cage from flipping.

## 1.4 Conclusion

**1.4.1** The cage performed overall as expected, absorbing the impact energy without failure. This performance held true through multiple strikes upon different sections of the cage.

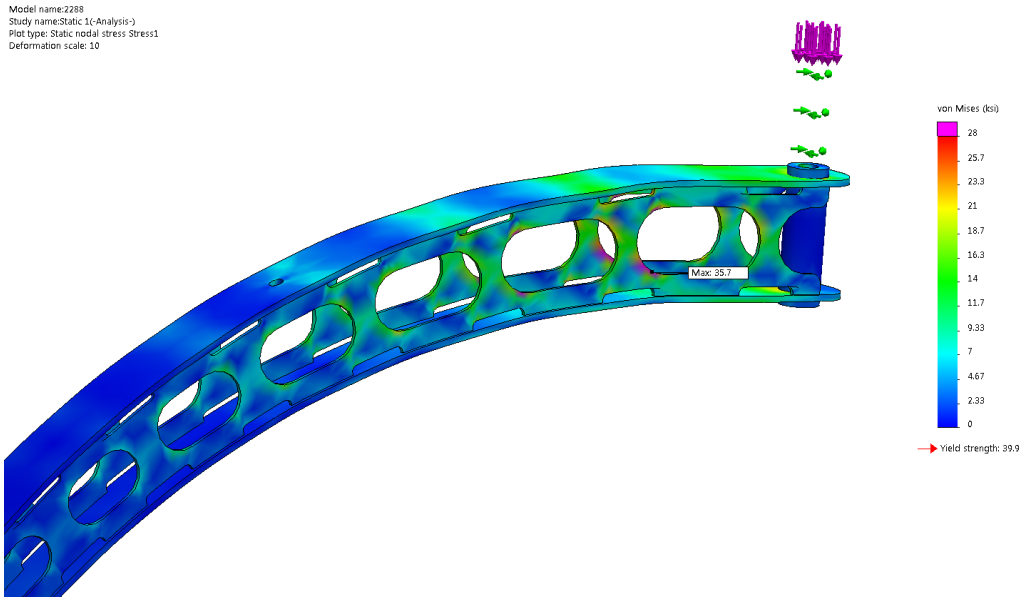
2.0 Finite Element Analysis - Finite Element Analysis was conducted on one leg to determine the stress concentration spring coefficient.

2.1.1 Load Case – Vertical impact along the z-axis. One of four legs was analyzed.

2.1.2 Forces – Load was 2500 lbs. static directly above the pin sleeve.

2.1.3 Constraints – Pin sleeve was constrained from translation in the X and Y directions. Rotation was constrained in all directions. The foot was constrained from translation in all directions. Rotation was free in all directions.

2.1.4 Results I. – Stresses concentrated on the webbing with higher values near the pin sleeve. This is desirable as the yield failure will produce a cascading buckling from the top web working down the leg; absorbing the greatest amount of energy.



2.1.5 Results II. – Deflection was an “S” shape with a vertical change in height of 17.8mm.