High efficiency 56” cyclone explosion simulation report

Goal: To calculate pressure resulted from explosion of a 100 Kst dust cloud inside 56” high efficiency cyclone and achieve structural integrity.

Approach: Utilizing the latest available technology in dust hazard analysis a dust cloud model was used to replicate the explosion behaviour of a dust sample measured in Siwek explosion chamber with the following characteristics:

- Particle concentration with an ideal distribution
- Fine wood flour particles size (3-80 micron)
- Kst 100 (Bar-m/sec)
- Pmax of 8.7 (bar)

The results were then used to analyze and reinforce the cyclone structure to withstand a 100 Kst dust explosion.

A multi-phase CFD software package capable of handling lagrangian particles, chemistry, phase change and combustion was used for these calculations. The model is capable of predicting shock waves through the use of a variable density solver.
To read more about this approach and a brief description about the model go to:
https://baumpneumatics.ca/explosion-venting/
Figure 1 shows the High Efficiency Cyclone, the vortex breaker, and the square transition

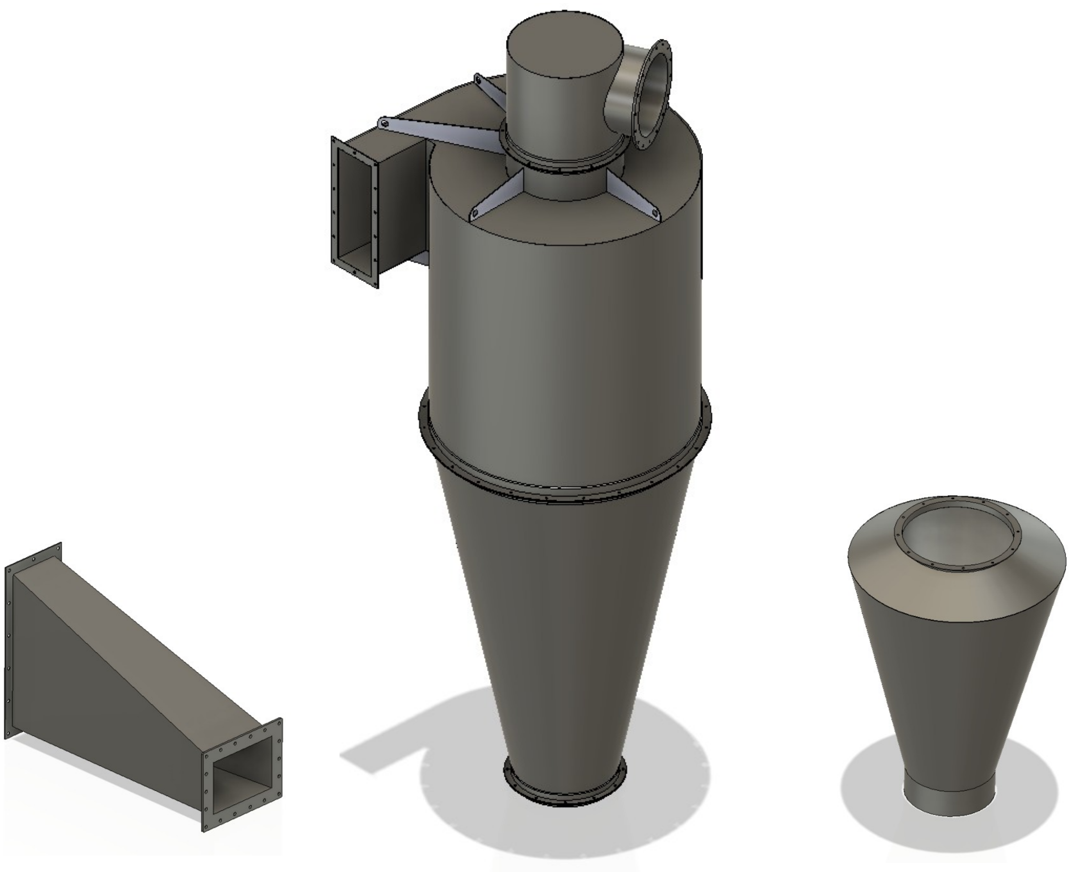


Figure1. the High Efficiency 56” Cyclone and the vortex breaker

Figure 2 shows Dust cloud and ignition source locations. Cyclone was assumed to be open at the outlet and inlet and closed at the bottom. Distribution of wood particles (sieve analysis) was not included in the calculation inputs. Additionally effect of swirl on particle position was not included instead two dust cloud spheres where placed inside the cyclone to account for a worst case scenario where a second explosion is caused with the help of flame propagation into new volumes where oxygen is still available. Please note that simulation results only covers boundarys of the cyclone shown in these figures.

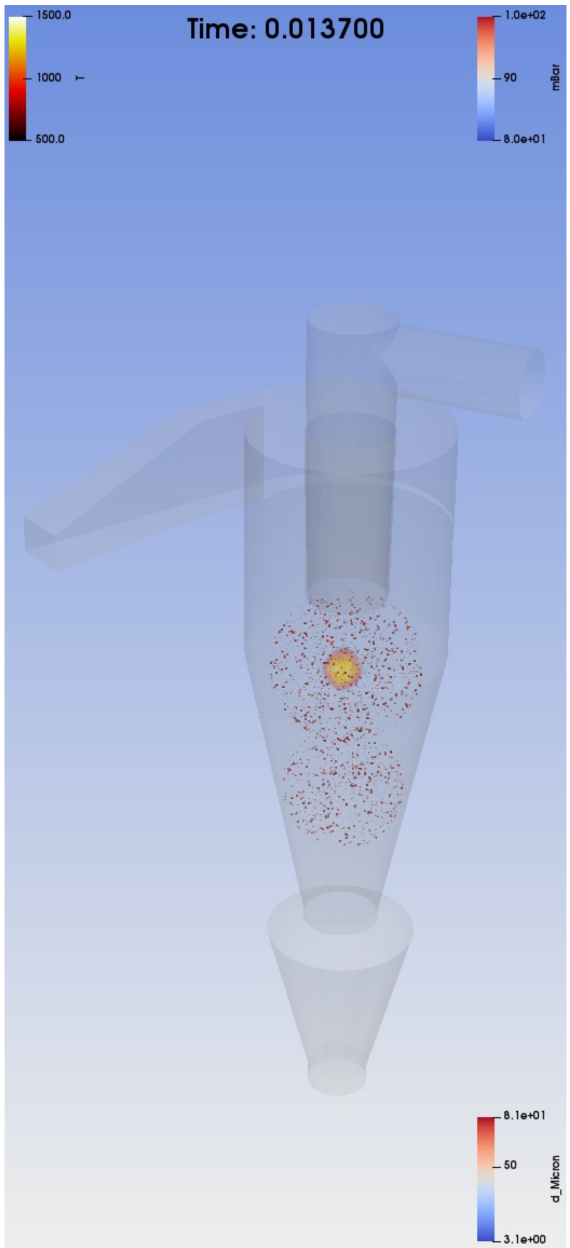
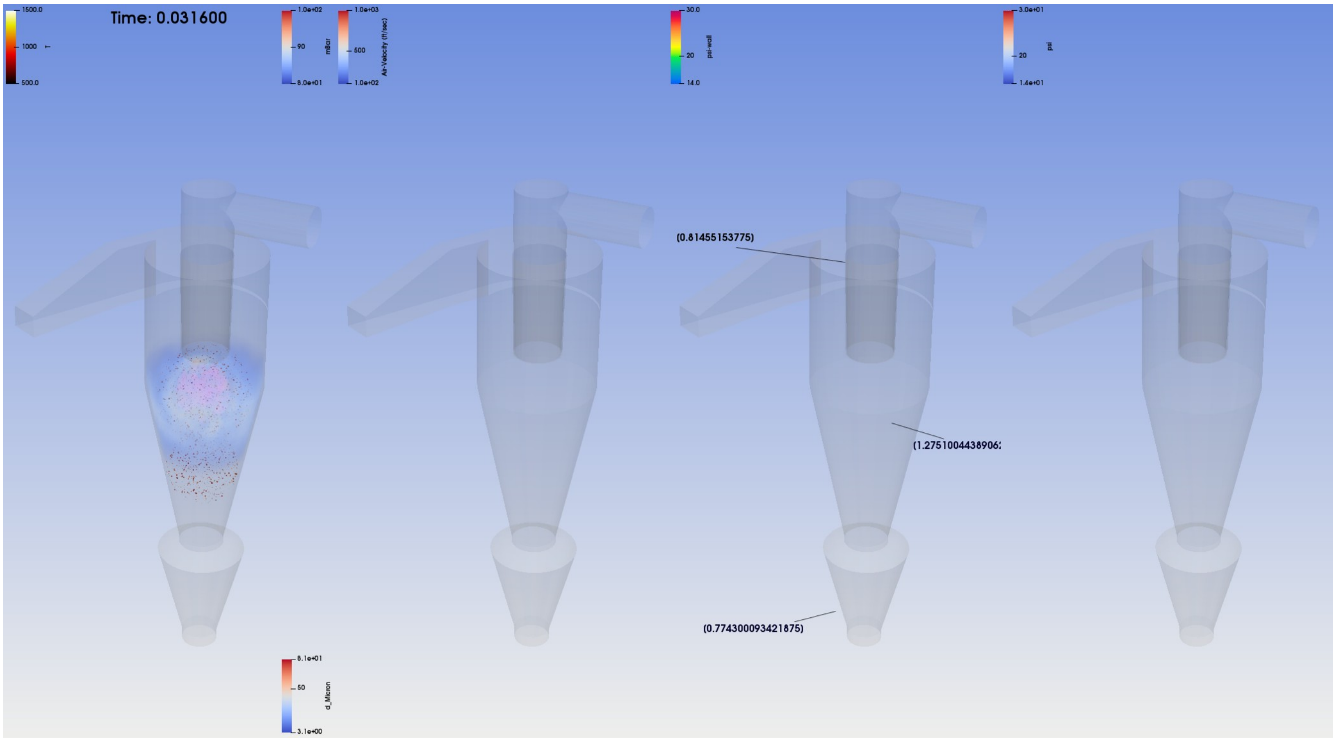


Figure 2. Dust cloud and ignition source locations

Figure 3 shows the 100 mBar pressure wave (limit for the explosion vents activation)



Gas Temperature (K), particles (Micron) and 100 mBar pressure front	Gas velocity (ft/s)	Pressure exerted on walls (psig)	Gas pressure (psig)

Figure 3. 100 mBar pressure wave

Figure 4 shows the 100 mBar pressure wave after 4.9 milliseconds (ms) and expanded flame front.

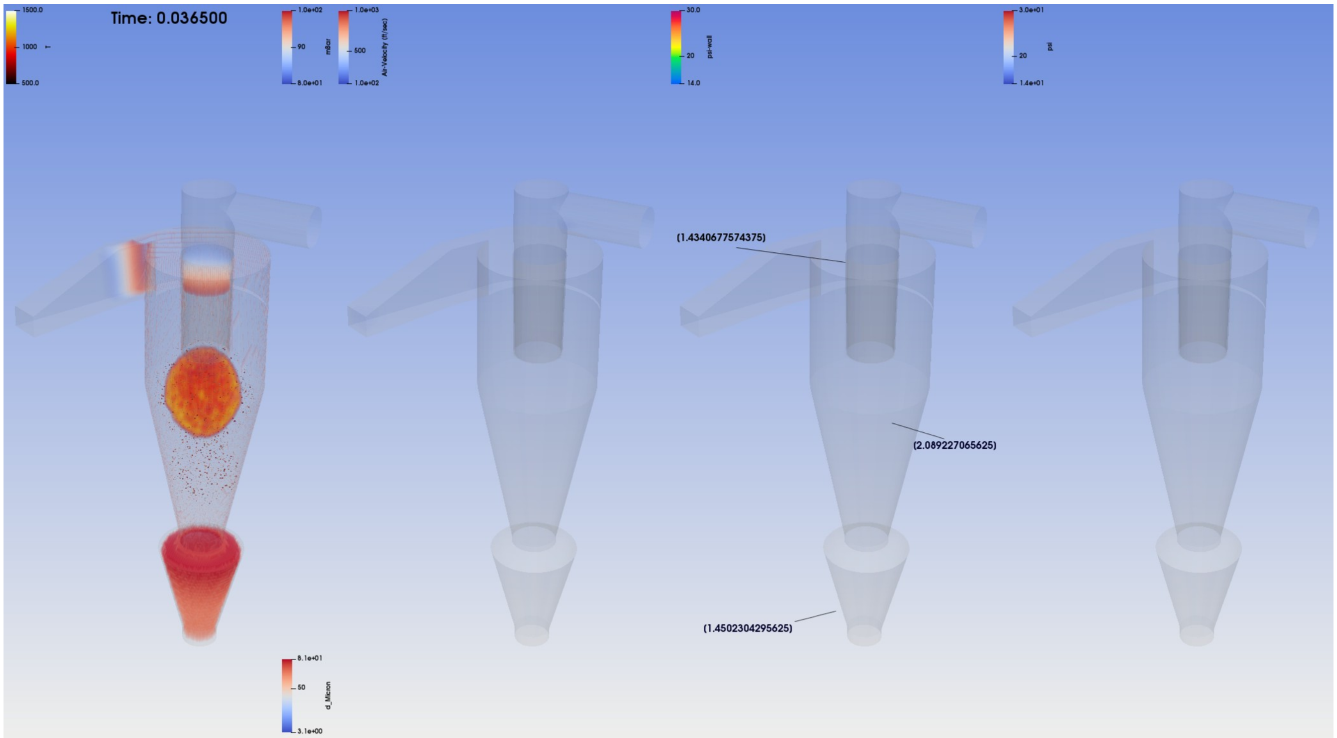


Figure 4. flame front and 100 mBar pressure front at 36.5 ms

Figure 5 shows flame front reaching the cyclone outlet and pressure buildup has been started on the cyclone body and the vortex breaker. Note the second dust ball is entering the vortex breaker.

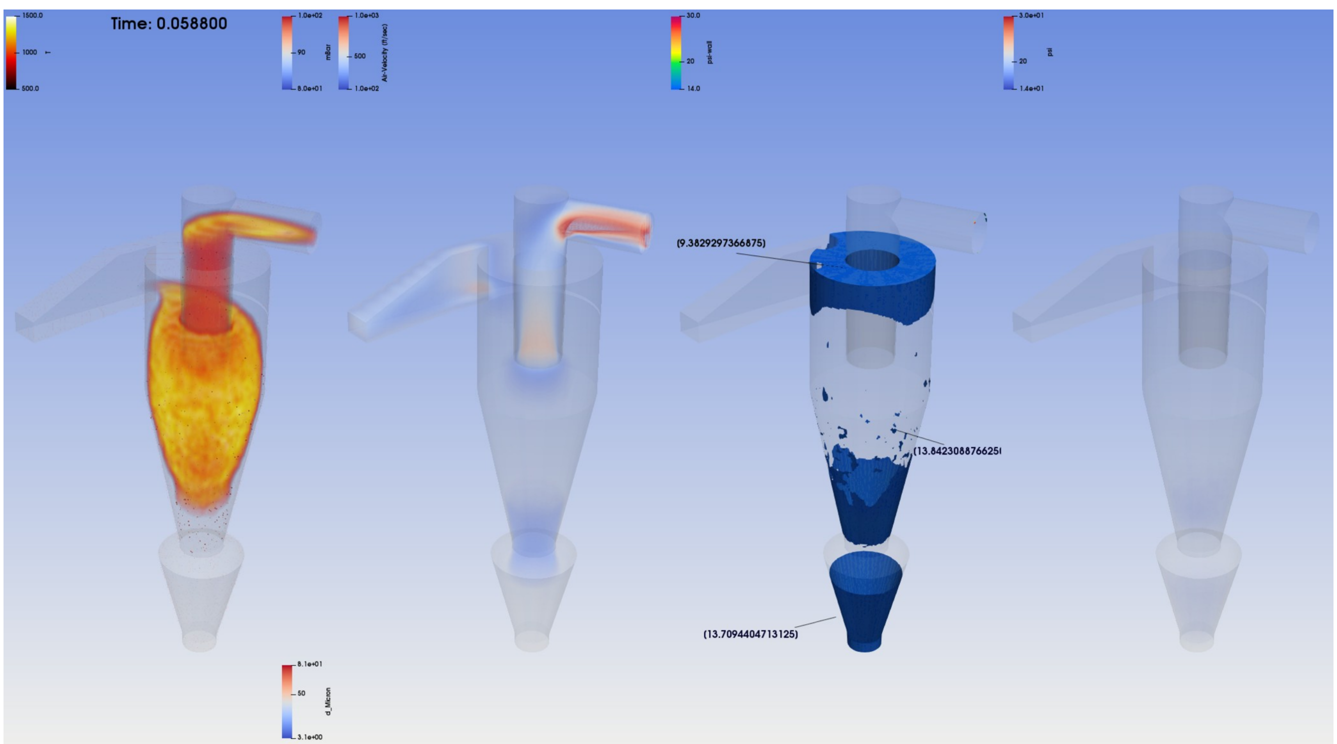


Figure 5. flame front, gas velocity and wall pressure and at 58.8 ms

Figure 6 shows the second explosion at vortex breaker and the relative pressure in the cyclone

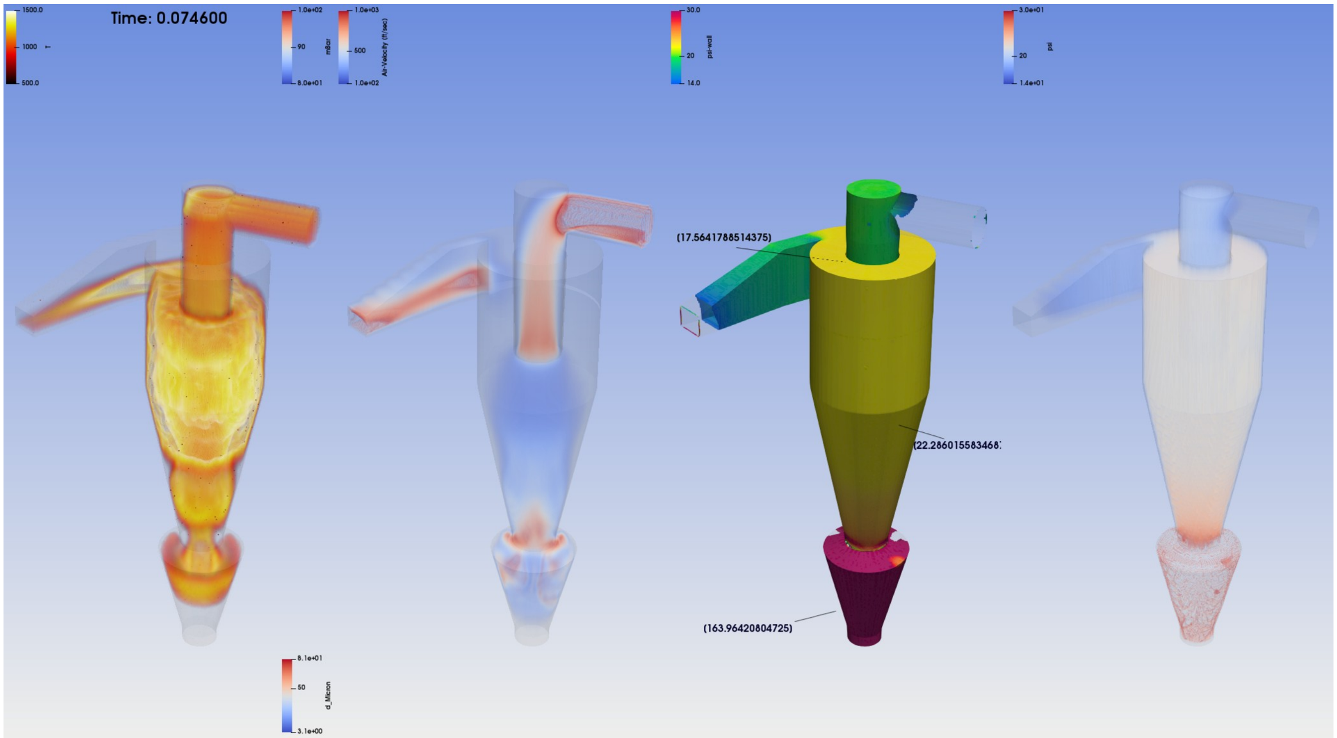


Figure 6. flame front gas velocity and wall pressure and at 74.6 ms

CFD analysis showed the following max pressures was exerted to the cyclone body, the vortex breaker, and the transition

	Pressure (psi)
Cyclone Body	43
Vortex Breaker	164
Square Transition	30

Stress analysis

Pressure values calculated from the CFD analysis was used to asses the cyclone structure using FEM. Figure 7 shows the original design under 43 psi of pressure.

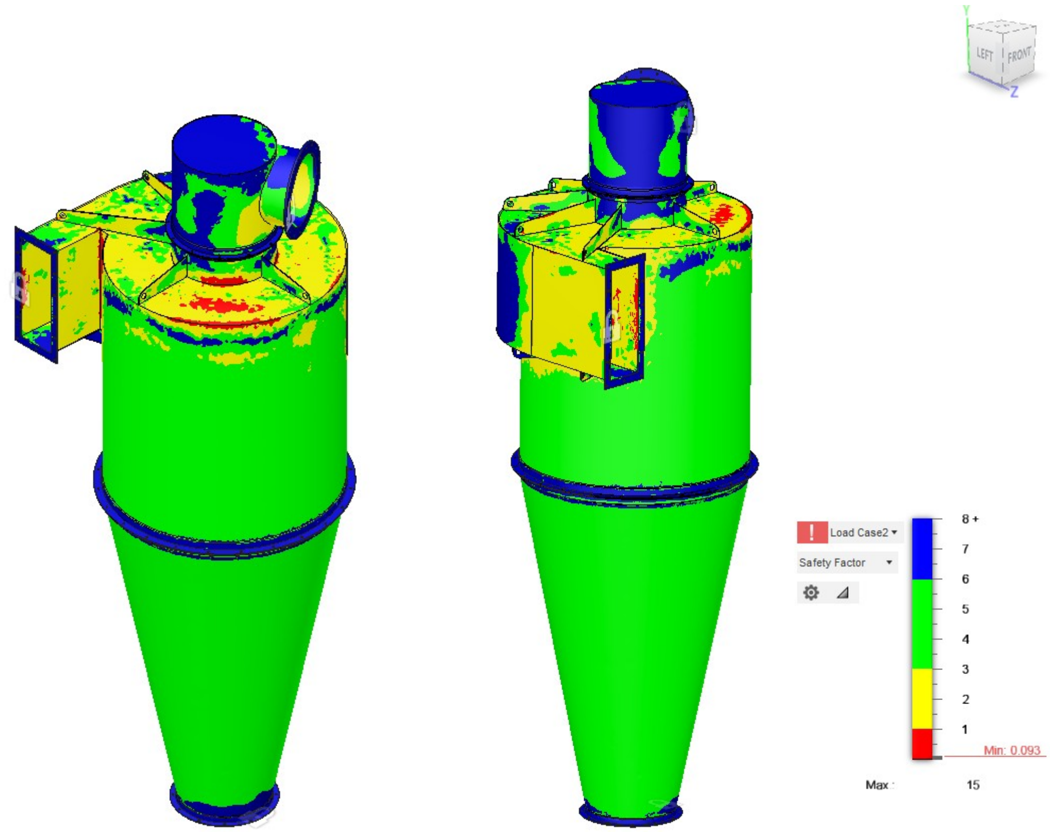


Figure 7. Safety factor contour for original cyclone design under 43 psi of pressures

Cyclone body and cone show high safety factor values however the top section requires reinforcements.
Figure 7 shows reinforced cyclone structure based on original design stress analysis.

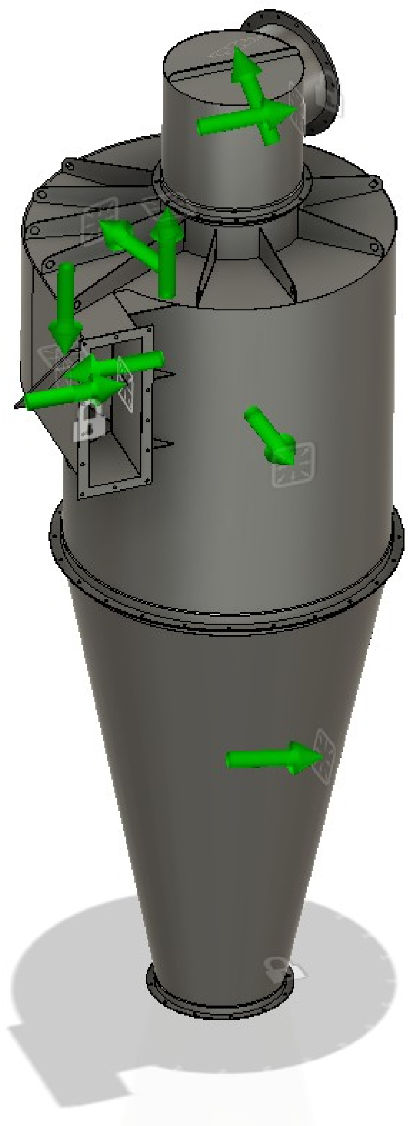


Figure 7. reinforced cyclone

Figure 8 shows the improvements in Safety Factor on the reinforced structure under 43 psi of pressure

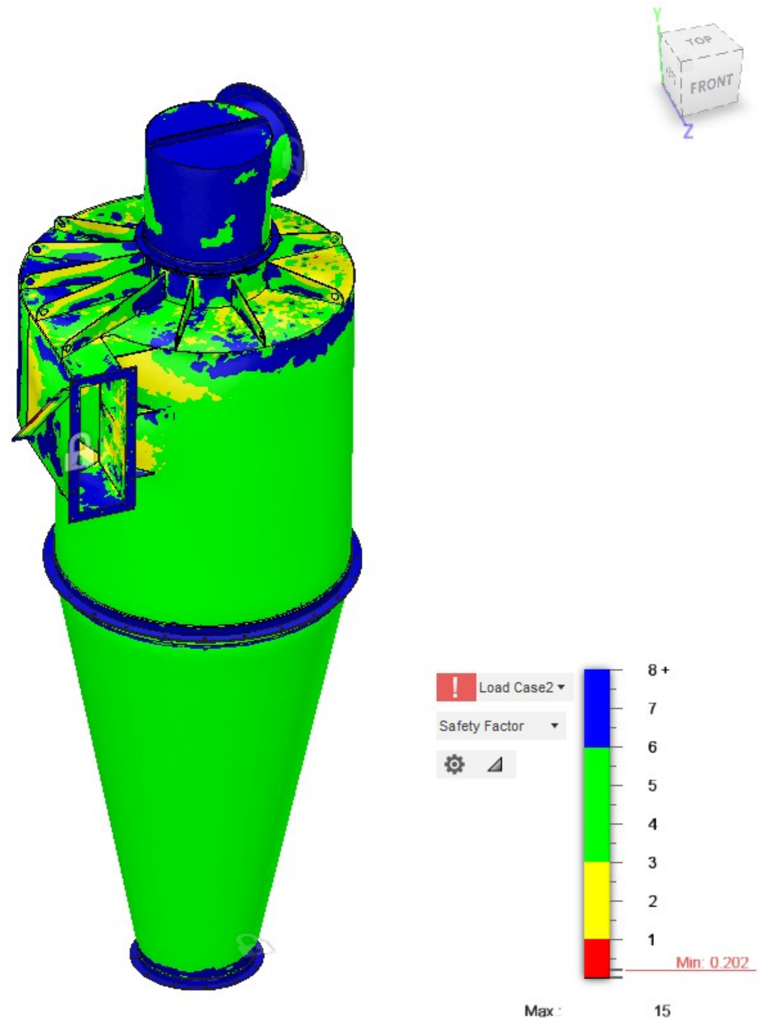


Figure 8. Safety factor contour for reinforced cyclone under 43 psi of pressure

The vortex breaker and square transition were analyzed separately under 164 and 30 psi of pressure respectively. Note that the higher pressure value in vortex breaker is partly due to the lower volume where the second explosion happens (see CFD result video) and partly due to the boundary condition at the bottom (closed condition) meaning the structure downstream of the vortex breaker will experience the high pressure. Figure 9 and 10 show vortex breaker and square transition with and without reinforcements.

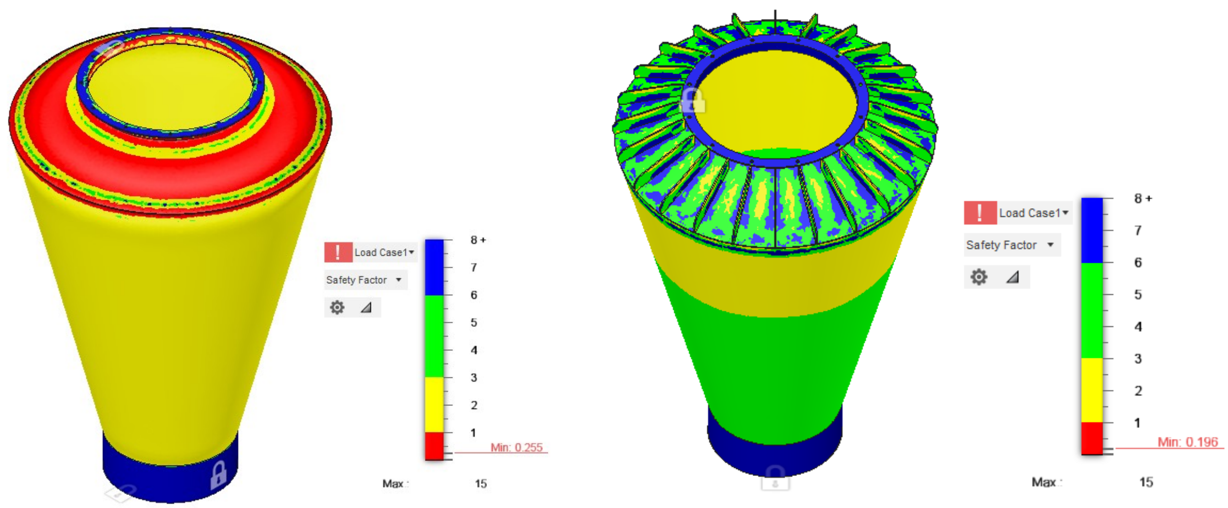


Figure 9. Vortex breaker with and without flatbars as reinforcement

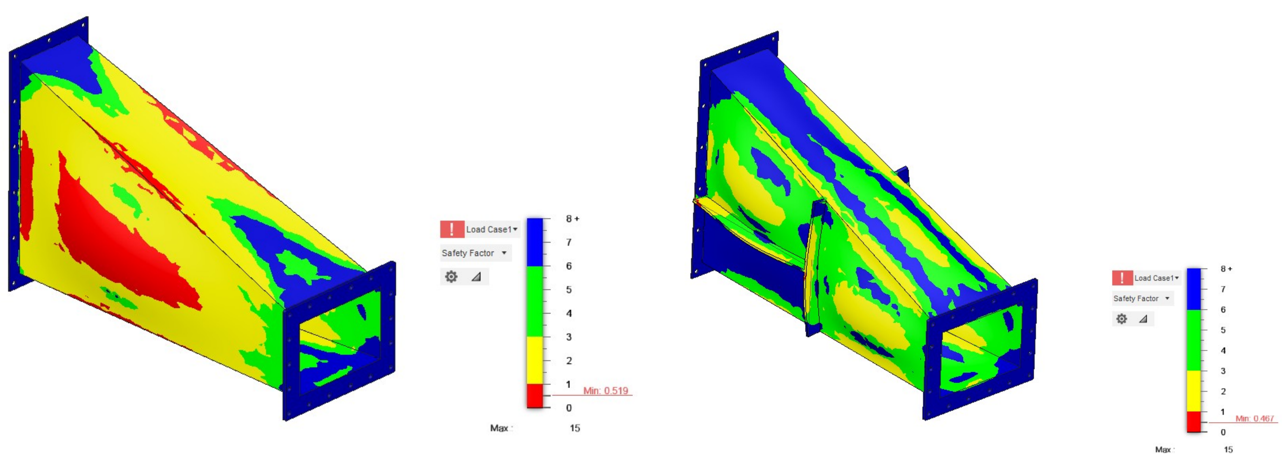


Figure 10. Square transition with and without flatbars as reinforcement

Summary of the design changes

Based on CFD and stress analysis the following changes was applied to the 56” cyclone design to ensure integrity of the design under 100 Kst dust explosion.

- A curved section was added to the top section to redirect high velocity gases in case of an explosion
- A flatbar reinforcing the top section of the cyclone was added
- Multiple gussets were added to the top of the cyclone and the inlet transition to increase rigidity of the design
- Multiple flatbars were added to the vortex breaker to increase rigidity of the design under higher pressure resulted from a secondary explosion
- Four flatbars reinforcing the square transition was added to the side panels