Seismic Analysis:

Contents:

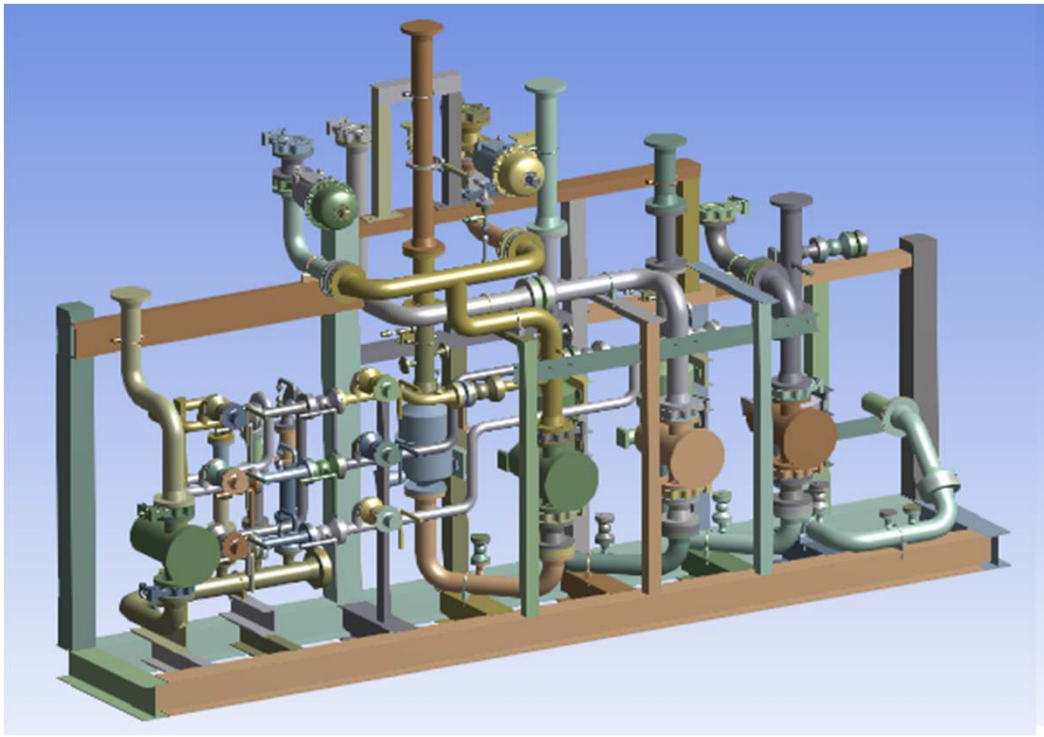
- Material Properties
- Geometry Overall
- Geometry Connections
- Seismic Analysis (Modal and Response Spectrum Analysis)
- Boundary Conditions
- Modal Analysis
- Response Spectrum Analysis
- Results
- Conclusion

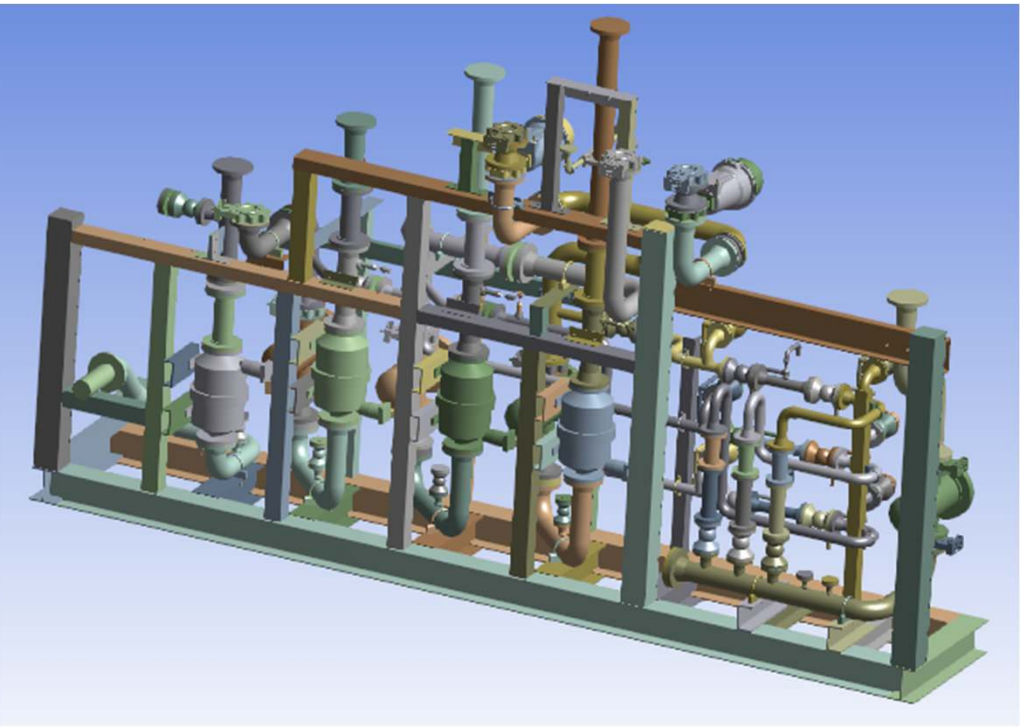
Material Properties:

- Table below shows the list of Standard Material Properties and the corresponding parts to which they are applied.
- Some parts (i.e. - Strainer) may consist of sub-components of various materials. In these cases, one material is assumed for the entire part in this analysis.

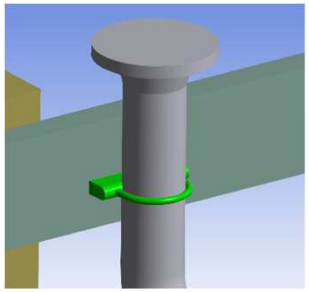
Part	Material name
4in-BUTTERFLY_VALVE	ASTM A351 Gr. CF-8M
4IN-STRAINER	CAST STEEL ASME 106 - B
GASKET	Flexitallic 150# CGI Gaskets - Stainless Steel Grade 304
BALL VALVE	ASTM A351 CF8M
FLOW METER VALVE	ASTM A 516 GR 70
CONTROL VALVE	ASTM A216 Grade WCB Cast Steel
CAM LOC COUPLING	Aluminum alloy
PIPES	ASTM A-106 GR B BBE
CHECK VALVE	ASTM 126, Cast Iron Alloy
INJECTOR PACK BLEED RING	ASTM A516 GR 70
VACUUM DRAIN	ASTM A351 CF8M
BRODIE BIROTOR PLUS METER	ASTM A516 GR 70
THERMAL RELIEF	ASTM 60-40-18 (ISO 400-18, EN-JS 1025) Ductile Cast Iron
CAPS	STAINLESS STEEL
STEEL FRAME / Hooks	STEEL A36
Actuator Body / Disc	ASTM A351 Gr. CF-8M
Actuator O – Rings	Silicone Rubber
Actuator washer	Flexitallic 150# CGI Gaskets - Stainless Steel Grade 304

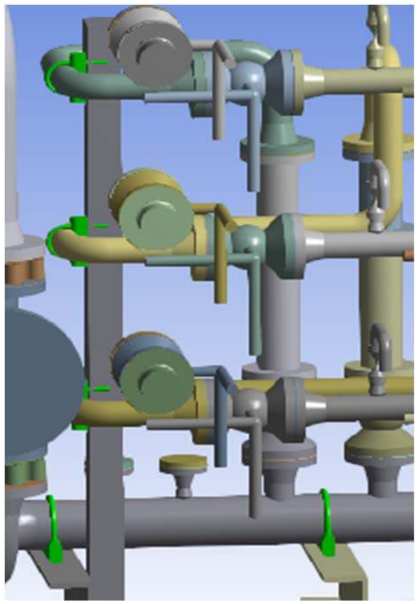
Geometry Overall:

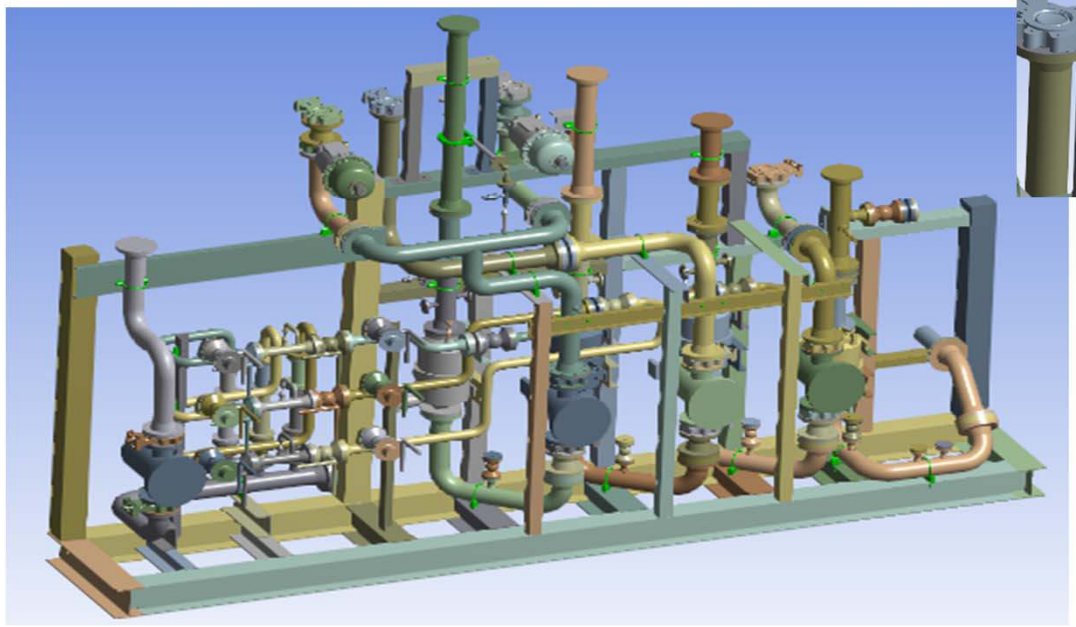


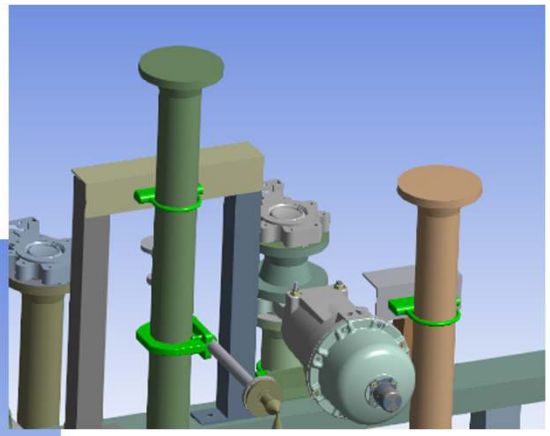


Geometry Connections:









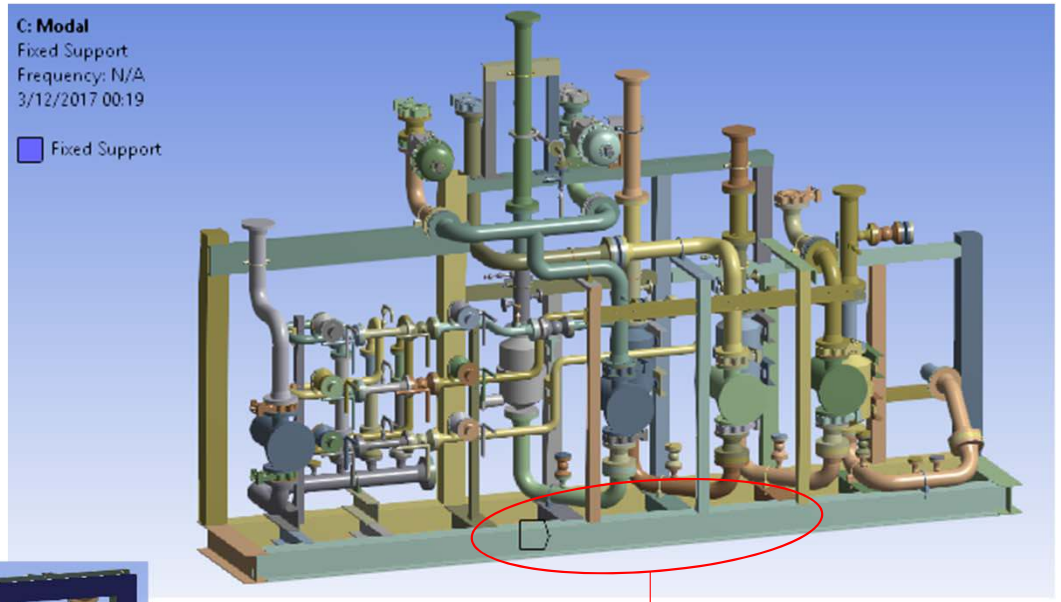
- Piping structure is constrained to the frame by I-Rods shown in green in pictures above.
- All other direct component & part contacts are defined as welded connections.

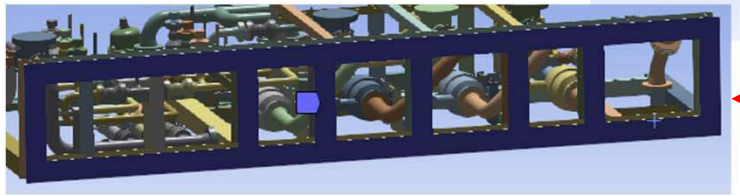
Seismic Analysis:

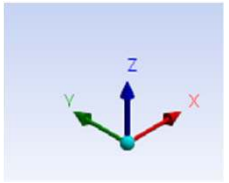
- Two (2) types of analyses are carried out under seismic analysis of this Skid structure:
  - **Modal Analysis**: This sub-analysis is performed to calculate the natural frequencies of the structure.
  - **Response Spectrum Analysis**: This sub-analysis is performed to calculate the response of horizontal earthquake excitations (design spectrum acceleration with time or frequency).

Modal Analysis:

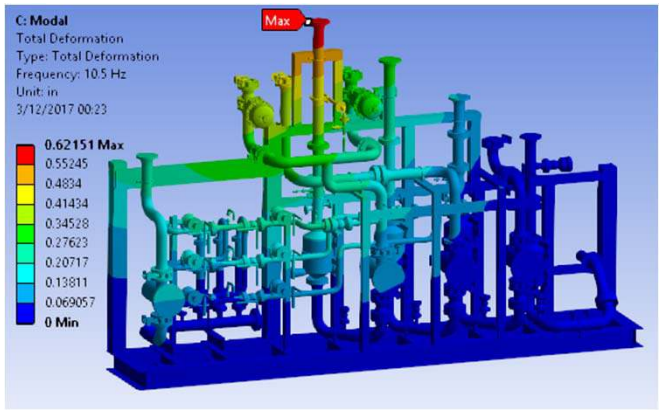
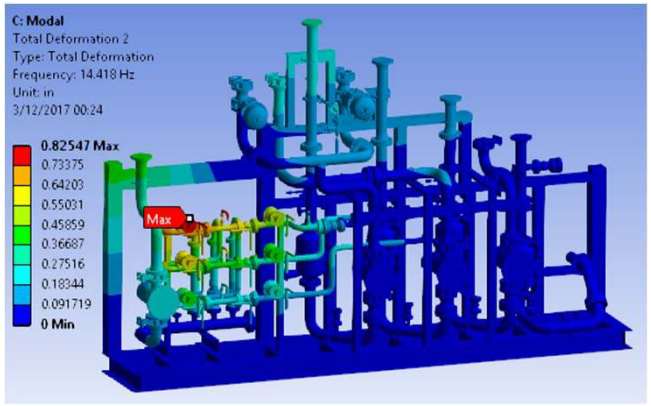
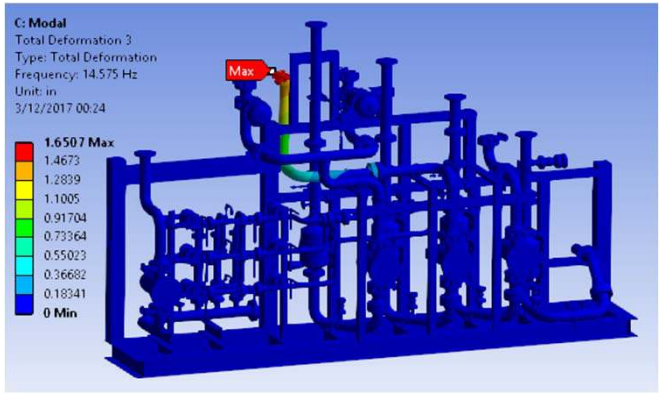
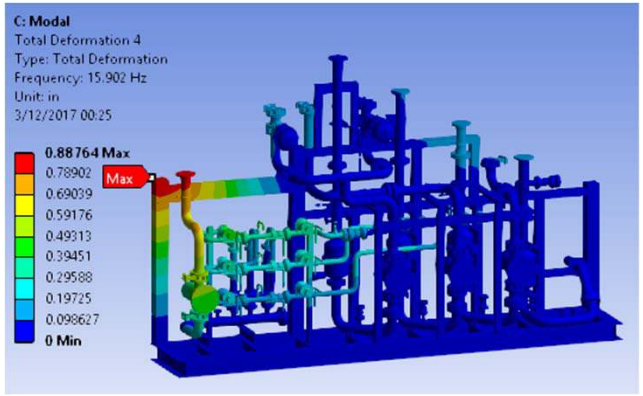
- Boundary Conditions



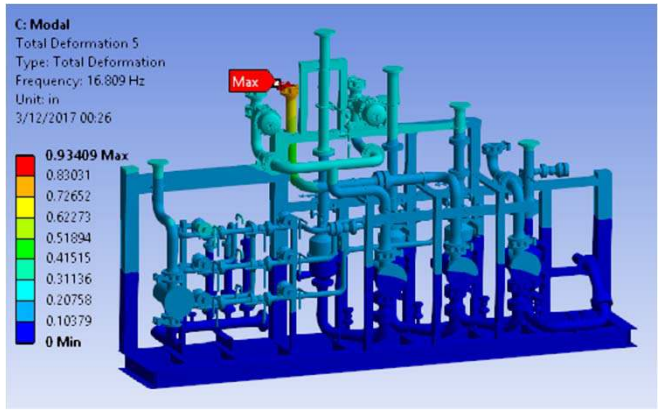
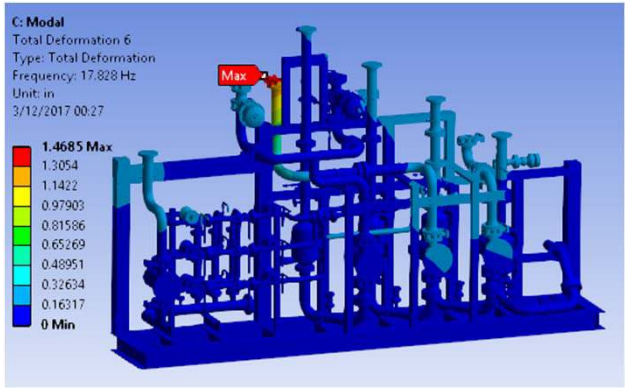
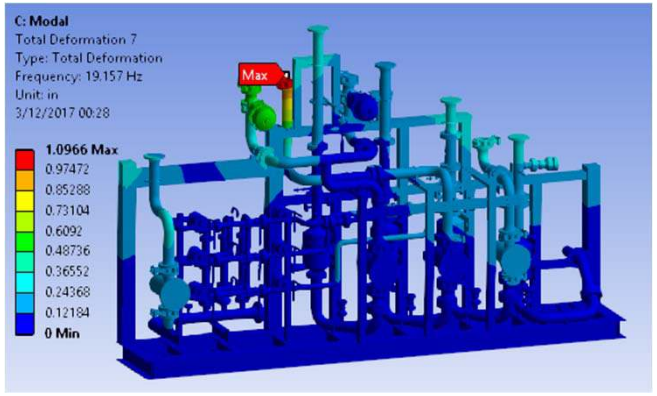
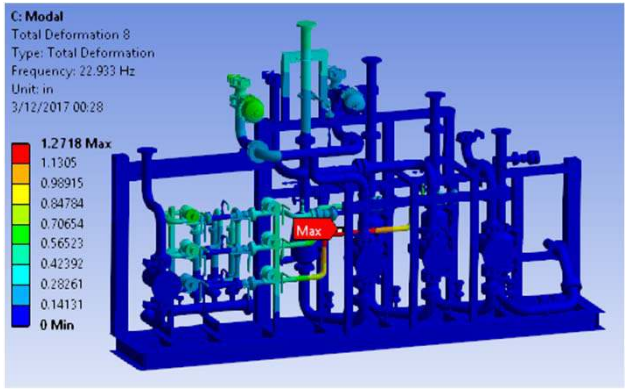




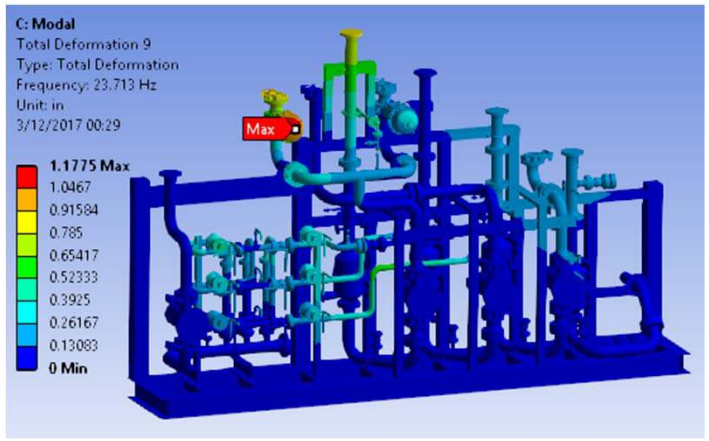
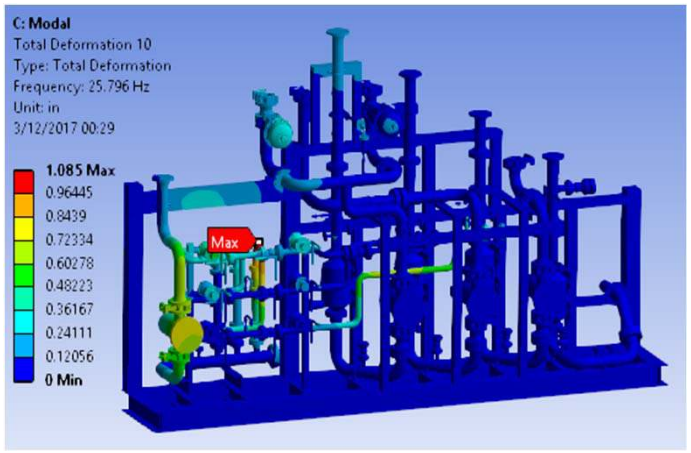
Modal Analysis:

Mode -1 	Mode -2 
Mode -3 	Mode -4 

Modal Analysis:

Mode -5		Mode -6	
Mode -7		Mode -8	

Modal Analysis:

Mode -9 	Mode -10 

Modal Analysis:

Mode	Frequency (Hz)	Displacement (in)
1	10.5	0.62151
2	14.418	0.82547
3	14.575	1.6507
4	15.902	0.88764
5	16.809	0.93409

Mode	Frequency (Hz)	Displacement (in)
6	17.828	1.4685
7	19.157	1.0966
8	22.933	1.2718
9	23.713	1.1775
10	25.796	1.085

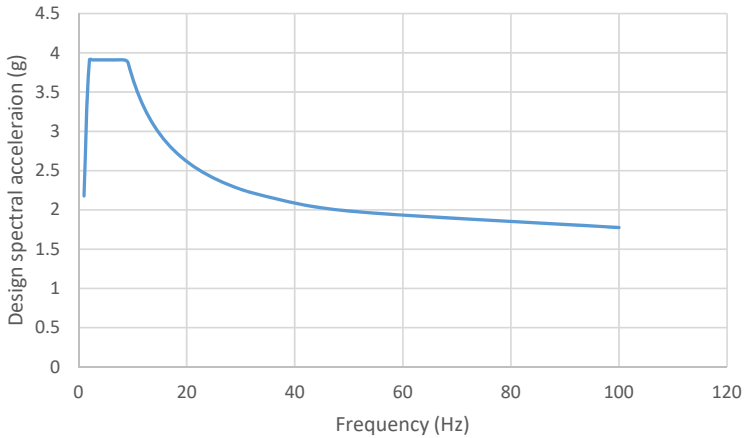
Response Spectrum (RS) Analysis:

- There are two (2) methods to carry out Response Spectrum Analysis – It can be performed either by Response Displacement & Response Velocity (also referred to as or Response Acceleration).

- For this Analysis, design response acceleration (g) is calculated based on Skid site location, and we assume Ss (0.149g) and Sl (0.082g), which should be conservative estimates.

- A MATLAB script is written to calculate the acceleration (g) at different time periods (T = 1/freq.) as shown in the next slide.

Response Spectrum (RS) Analysis:



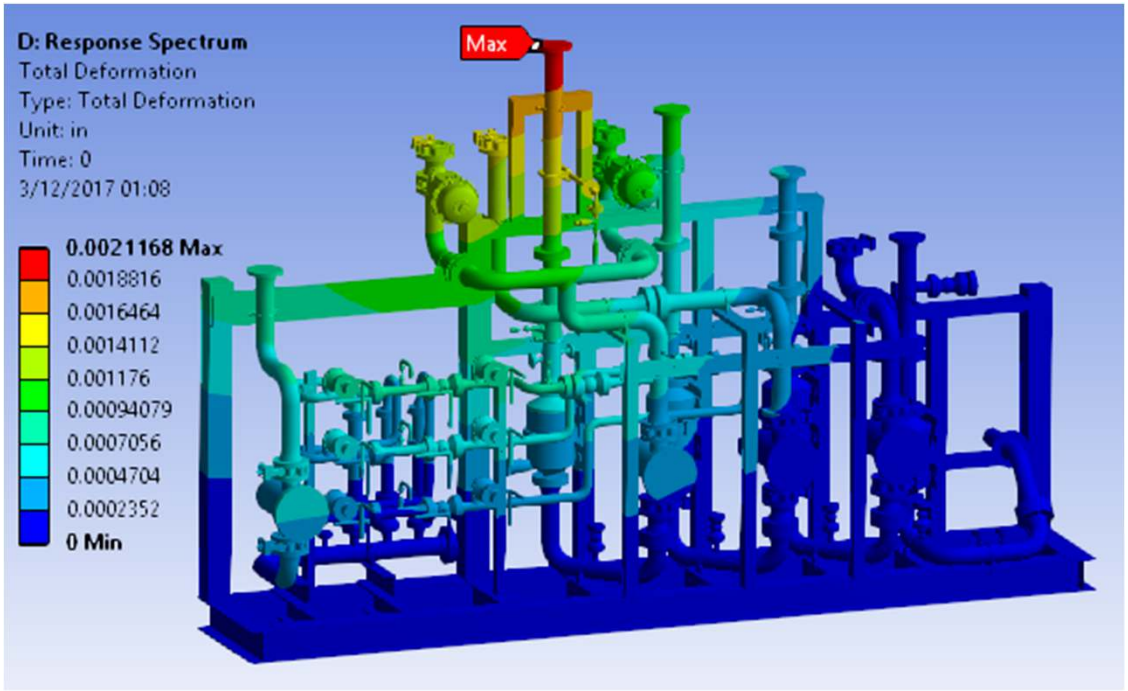
Acceleration (g) at different time period (T = 1/freq.)

- The above data is imported into Simulation Software as Response Spectrum Acceleration (RS).
- RS Analysis is done for the first 5 Modes for Modal Analysis.
- Y direction is considered for horizontal earthquake excitation (design spectral acceleration).

Freq. (Hz)	Acc. (g)
1	2.1785
1.5152	3.3007
2	3.9108
2.5	3.9108
3.5714	3.9108
4	3.9108
4.5455	3.9108
5	3.9108
5.5556	3.9108
6.25	3.9108
6.6667	3.9108
7.6923	3.9108
8.3333	3.9108
9.0909	3.8811
10	3.6705
11.111	3.4598
12.5	3.2492
14.286	3.0386
16.667	2.828
20	2.6174
25	2.4068
33.333	2.1962
50	1.9855
100	1.7749

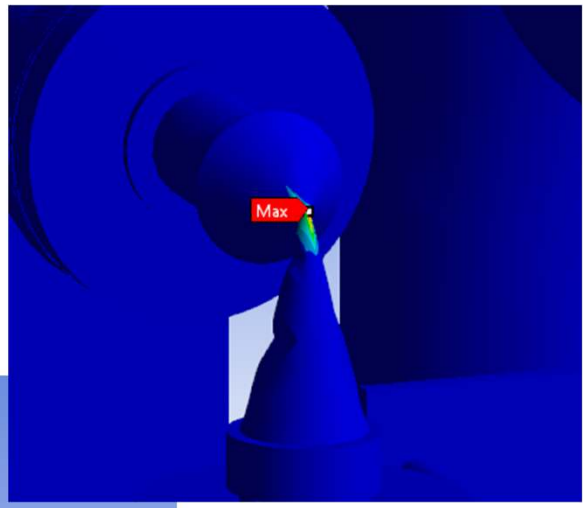
Response Spectrum Analysis:

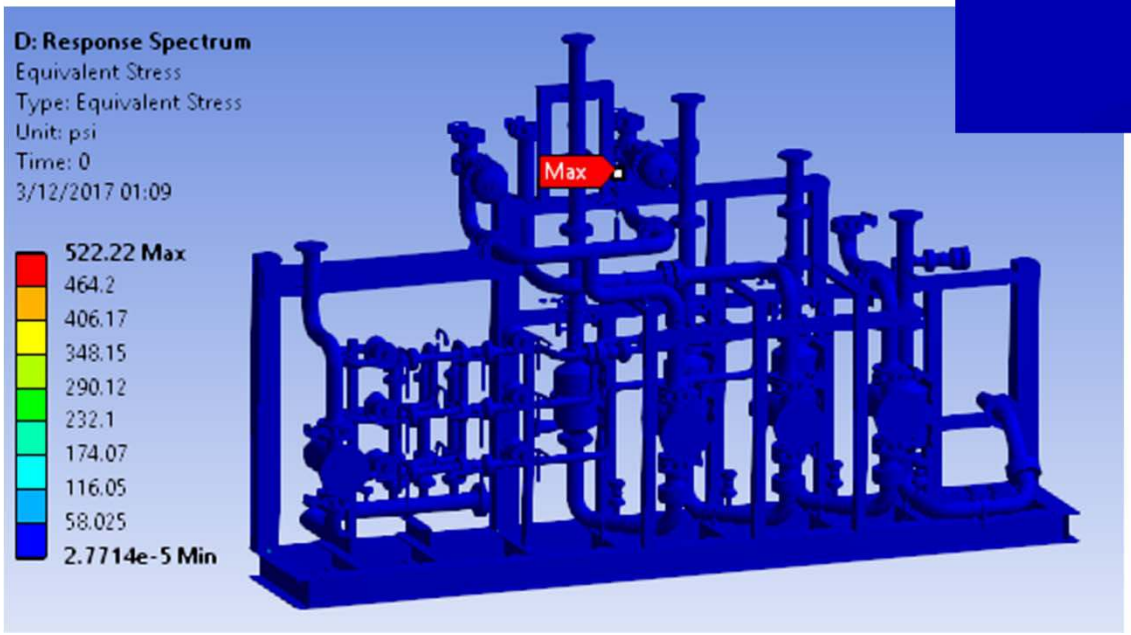
- Total Deformation



Response Spectrum Analysis:

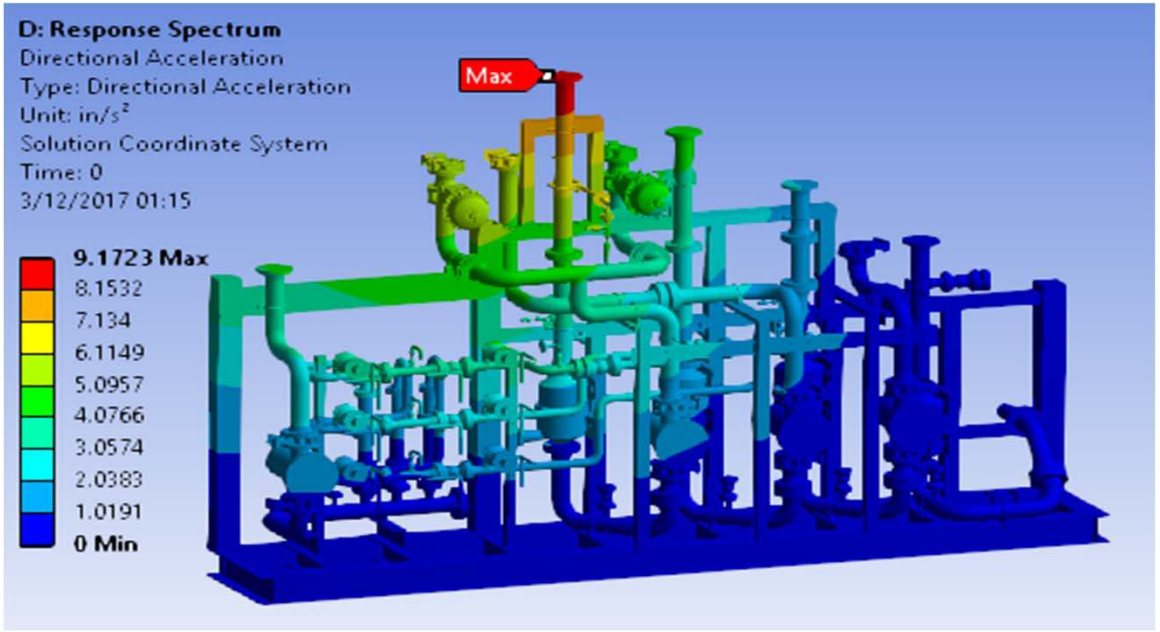
- Max Von-Mises Stress





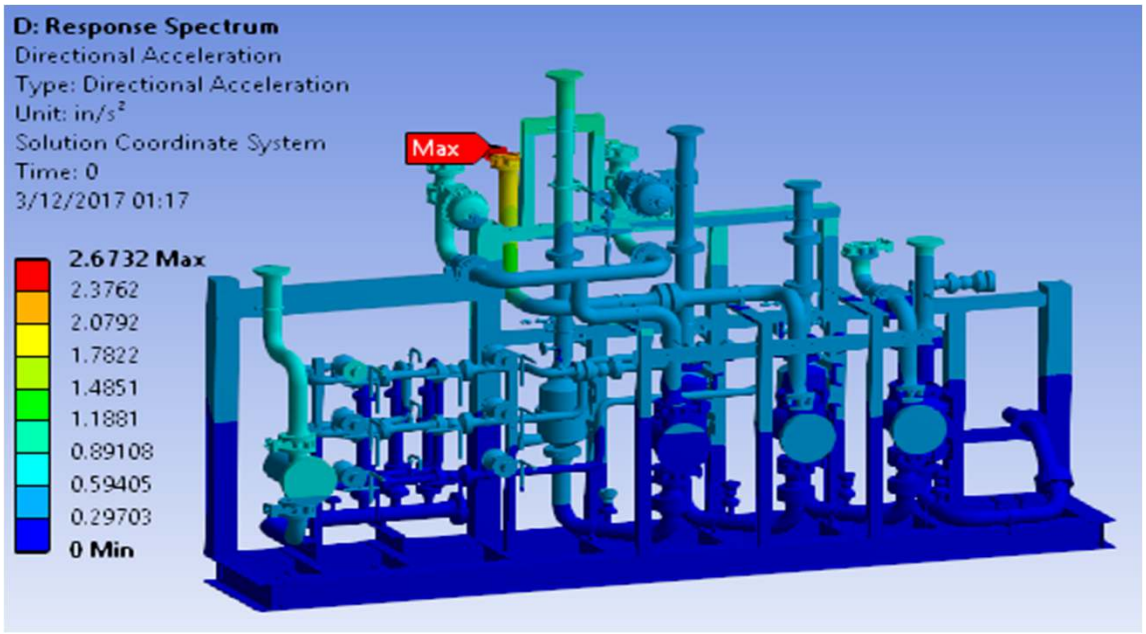
Response Spectrum Analysis:

- Direction Acceleration (Y direction)



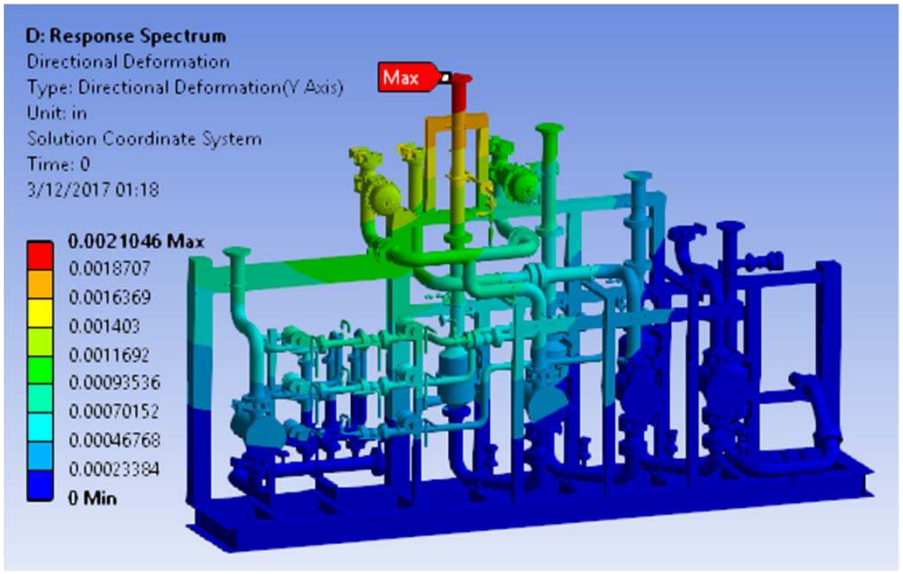
Response Spectrum Analysis:

- Direction Acceleration (X direction)

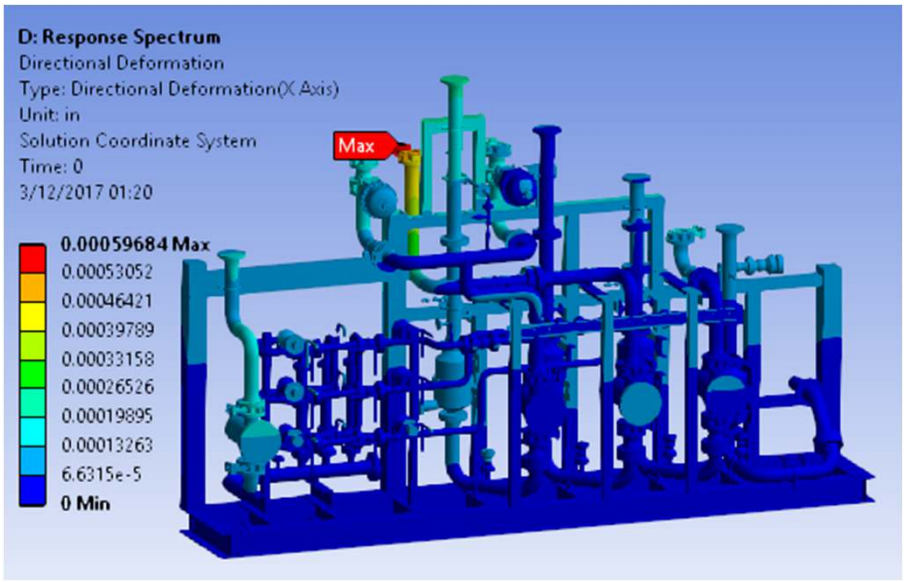


Response Spectrum Analysis:

Directional Displacement (Y)



Directional Displacement (X)



Conclusion:

- All deformations and stresses are relatively small compared to the Ultimate Tensile Strength of the applied materials of the Skid Structure.

- Therefore, after performing this analysis, we can conclude that the overall Skid Assembly passes all structural integrity tests performed under the Seismic Analysis (Modal and Response Spectrum Analysis)

- Therefore, Skid Assembly is safe according to this Analysis.

Linear FE Wind Loading Analysis:

Wind Loading Analysis in +XY Direction

Contents:

- Material Properties
- Geometry
- Geometry connections
- Load and Boundary Conditions
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Material Properties:

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PIPES	ASTM A-106 GR B BBE
CHECK VALVE	ASTM 126, Cast Iron Alloy
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VACUUM DRAIN	ASTM A351 CF8M
BRODIE BIROTOR PLUS METER	ASTM A516 GR 70
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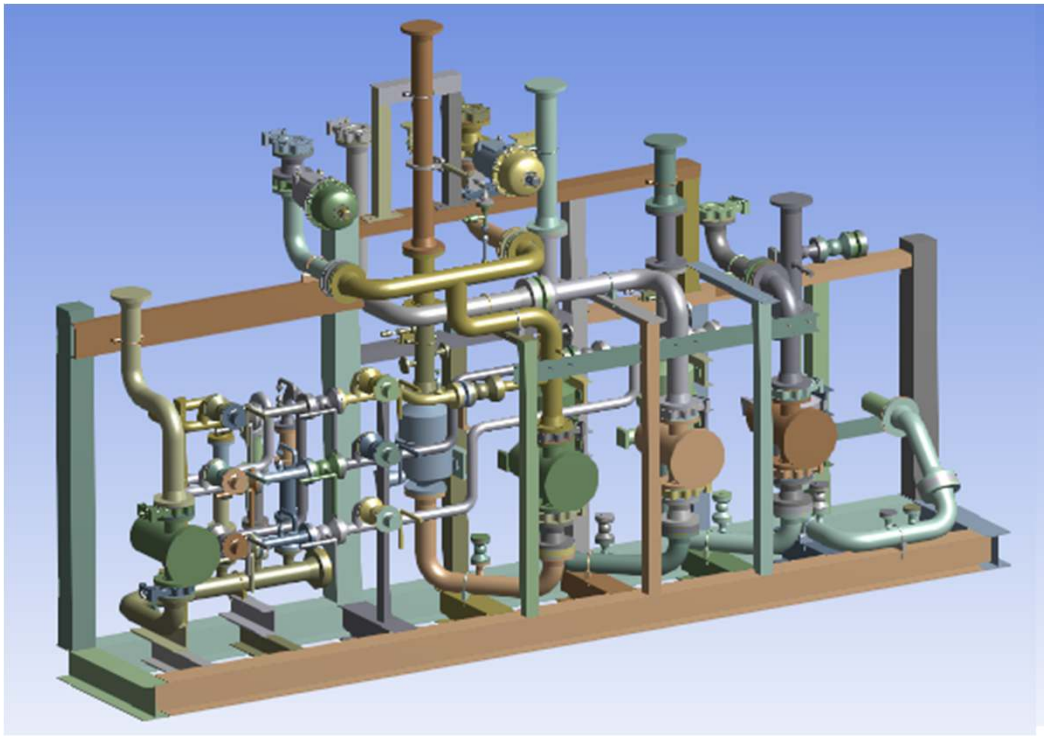
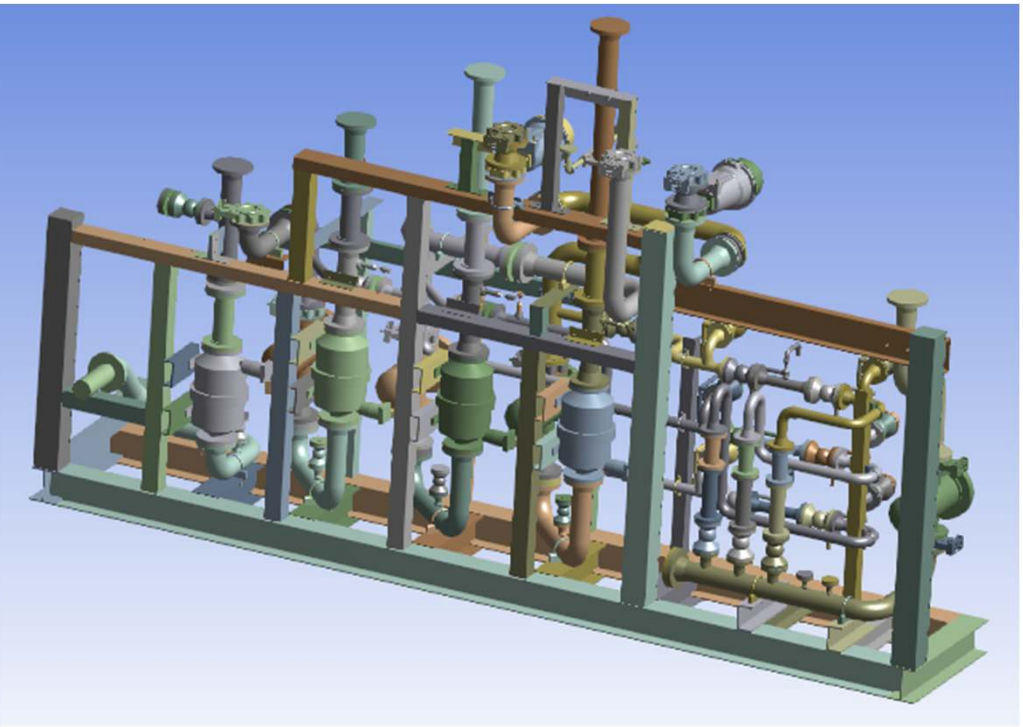
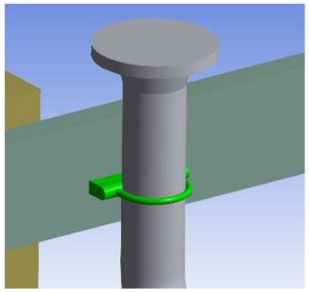
Actuator O – Rings	Silicone Rubber
Actuator washer	Flexitallic 150# CGI Gaskets - Stainless Steel Grade 304

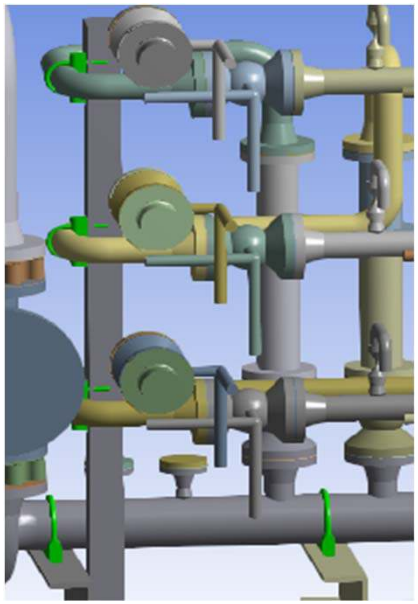
Geometry Overall:

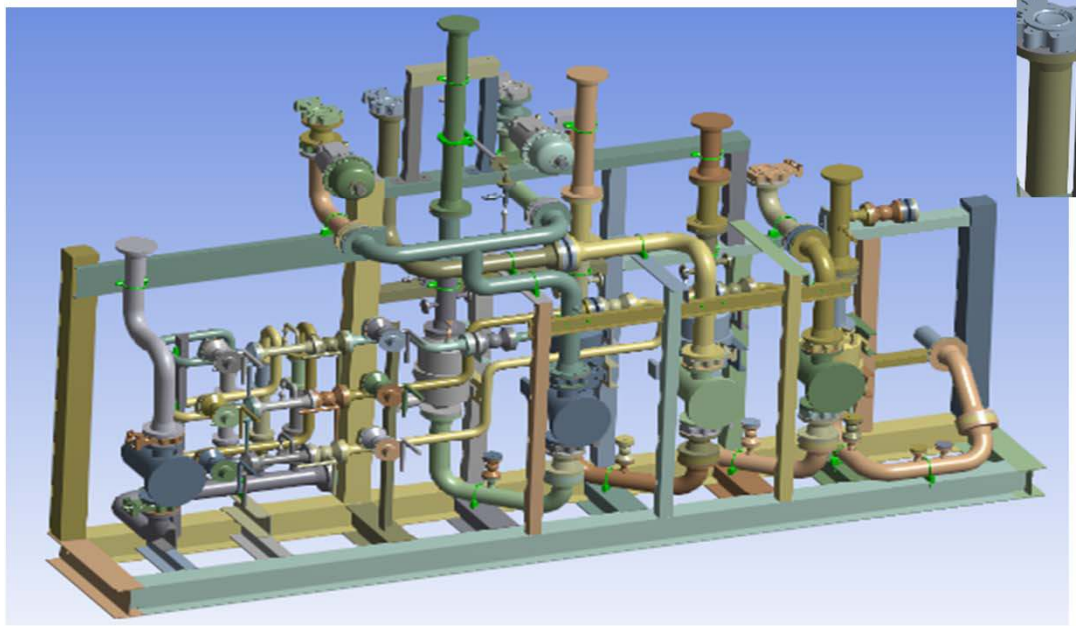


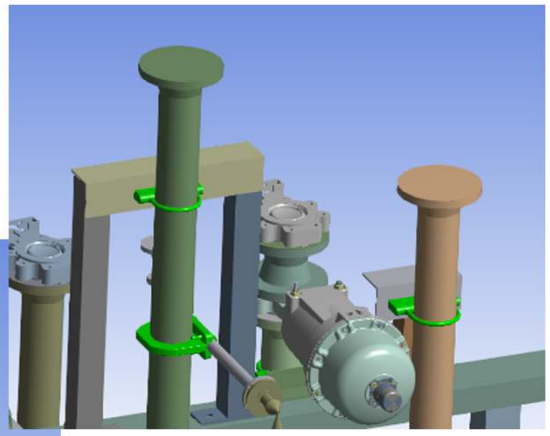


Geometry Connections:









- Piping structure is constrained to the frame by I-Rods shown in green in pictures above.
- All other direct component & part contacts are defined as welded connections.

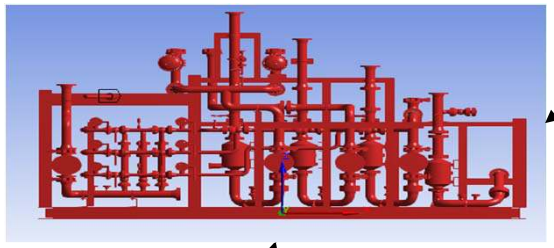
Loads and Boundary Conditions:

- Wind is considered as flowing in +XY direction.
- Gravity loading is also included in this wind loading analysis.
- Wind Pressure calculated at 90mph is **0.1152 psi**
- X and Y component calculation of resultant wind loading:

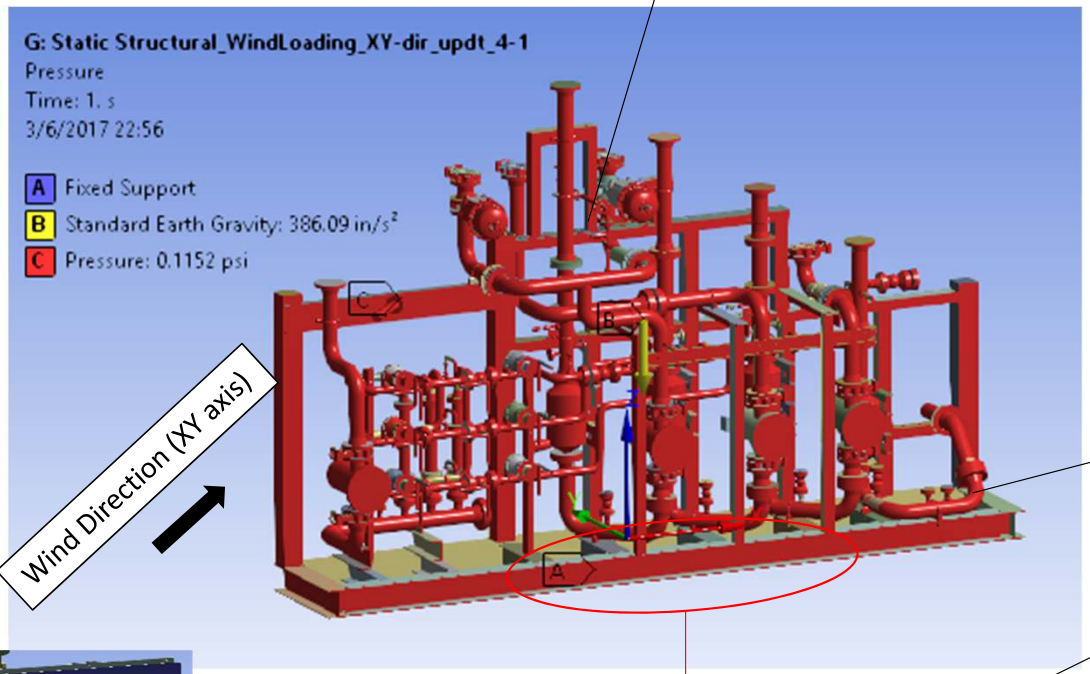
  Resultant Wind load:
  U = 0.1152psi

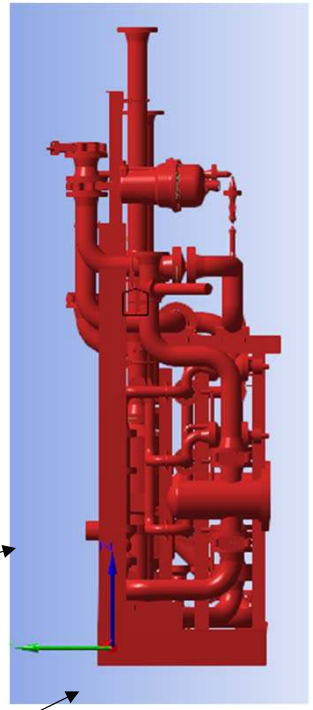
  X-component = U*cos(45°) = 8.146E-02psi

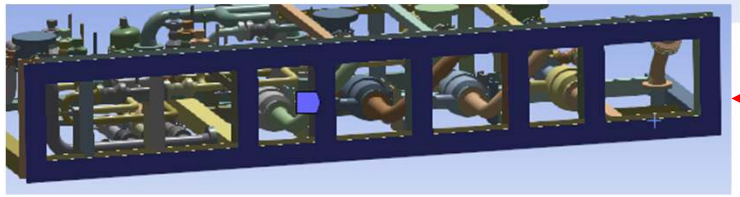
  Y-component = U*sin(45°) = 8.146E-02psi



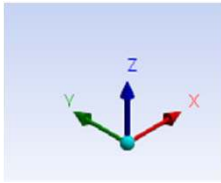
Applied wind pressure on Skid structure surfaces normal to wind +Y direction





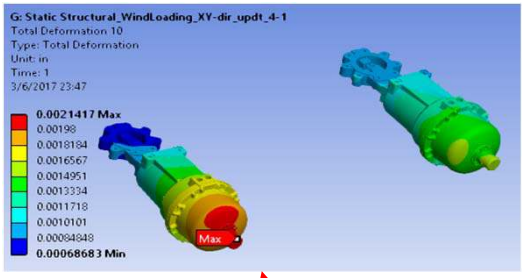


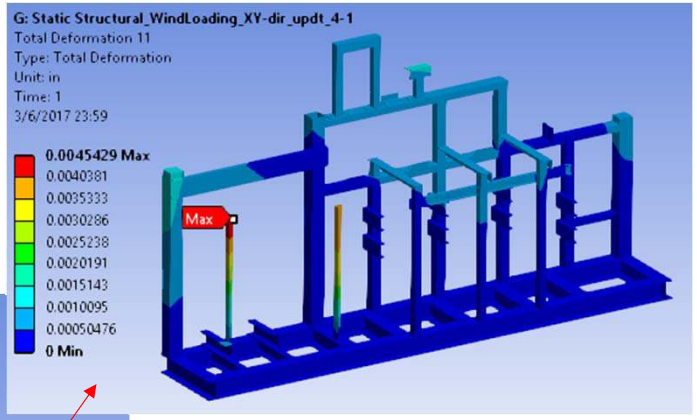
Applied wind pressure on Skid structure surfaces normal to wind +X direction

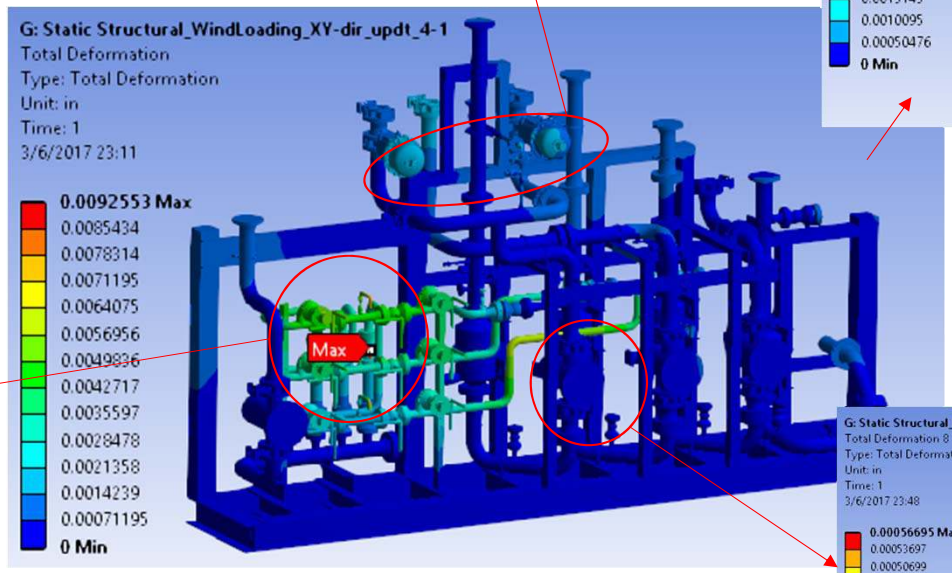


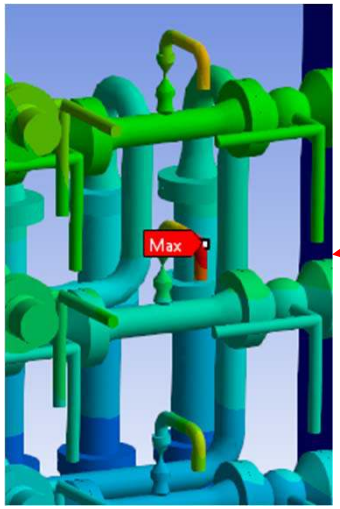
Results:

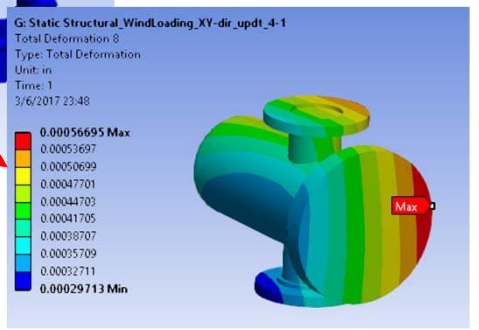
- **Total Deformation (X, Y & Z axes)**

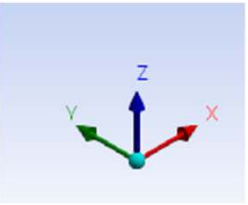








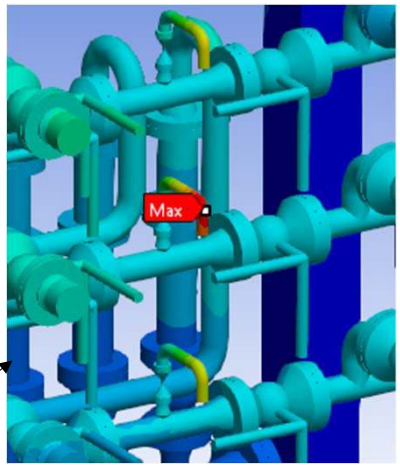


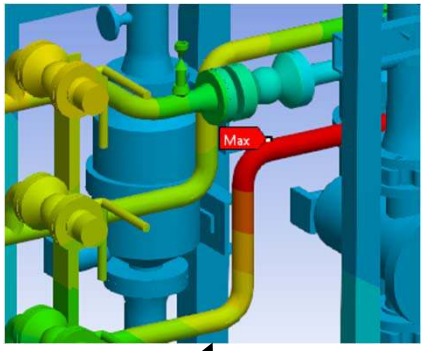


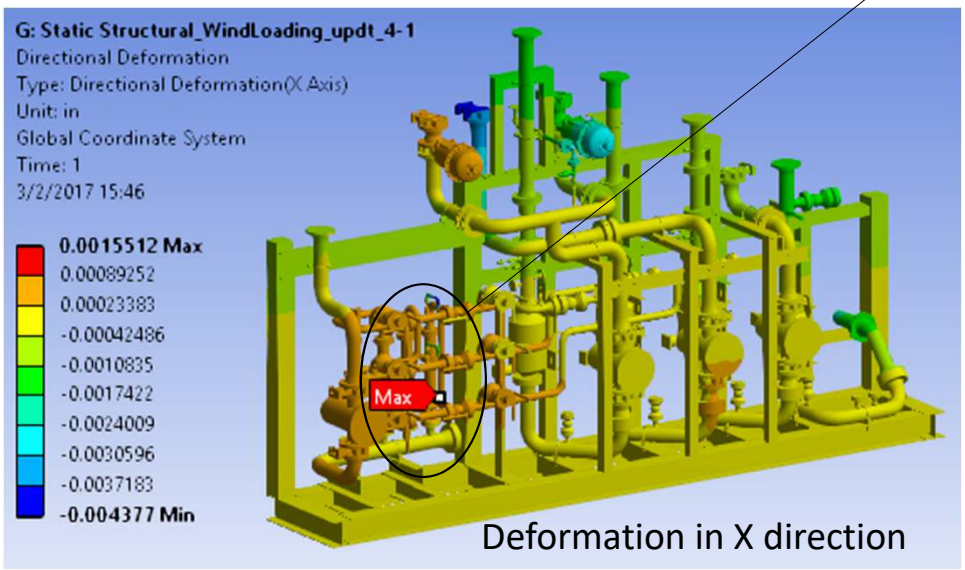
Deformations shown are at true scale (1.0)

Results:

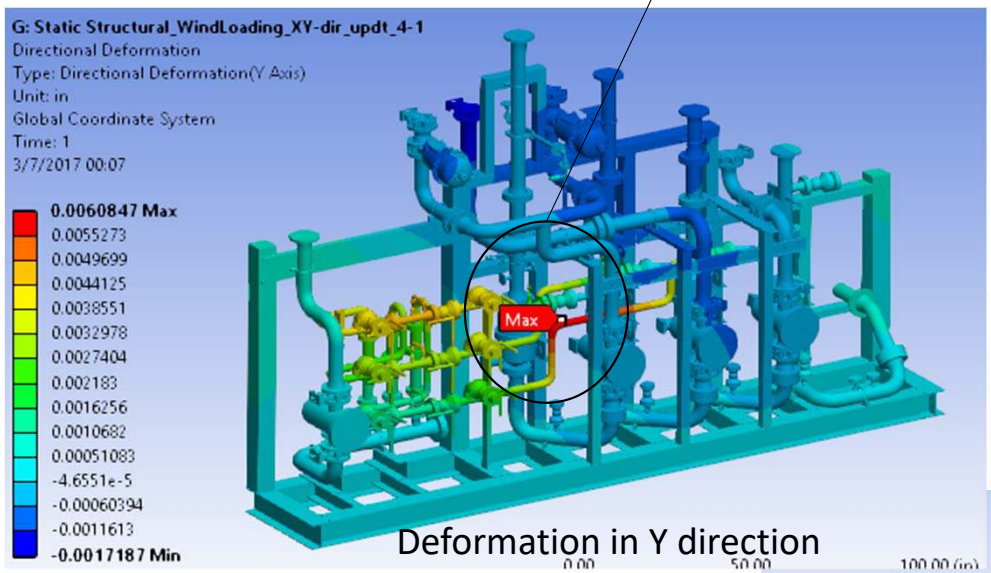
- **Directional Deformation (XY Axis)**







Deformation in X direction

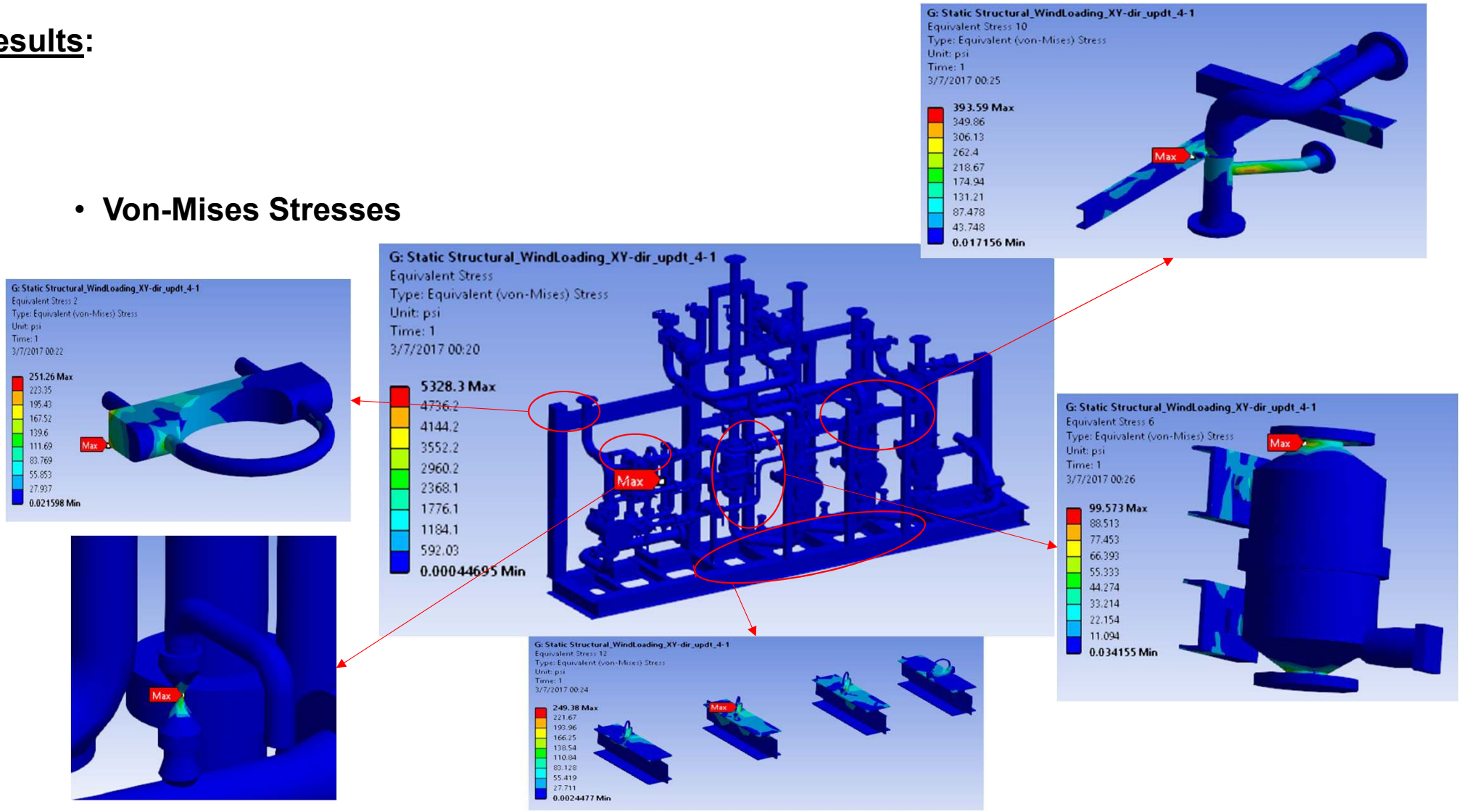


Deformation in Y direction

Deformations shown are at true scale (1.0)

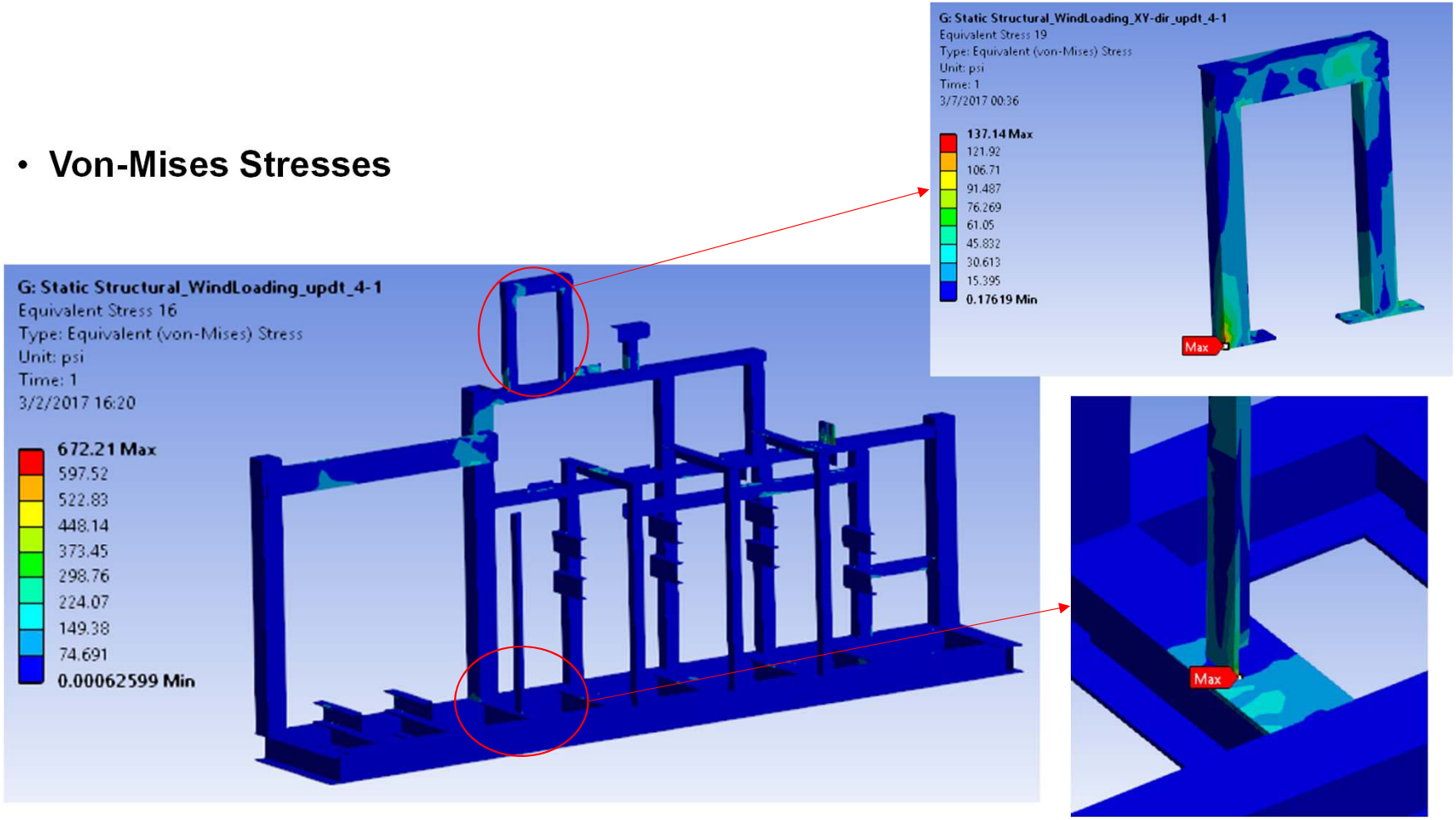
Results:

- **Von-Mises Stresses**



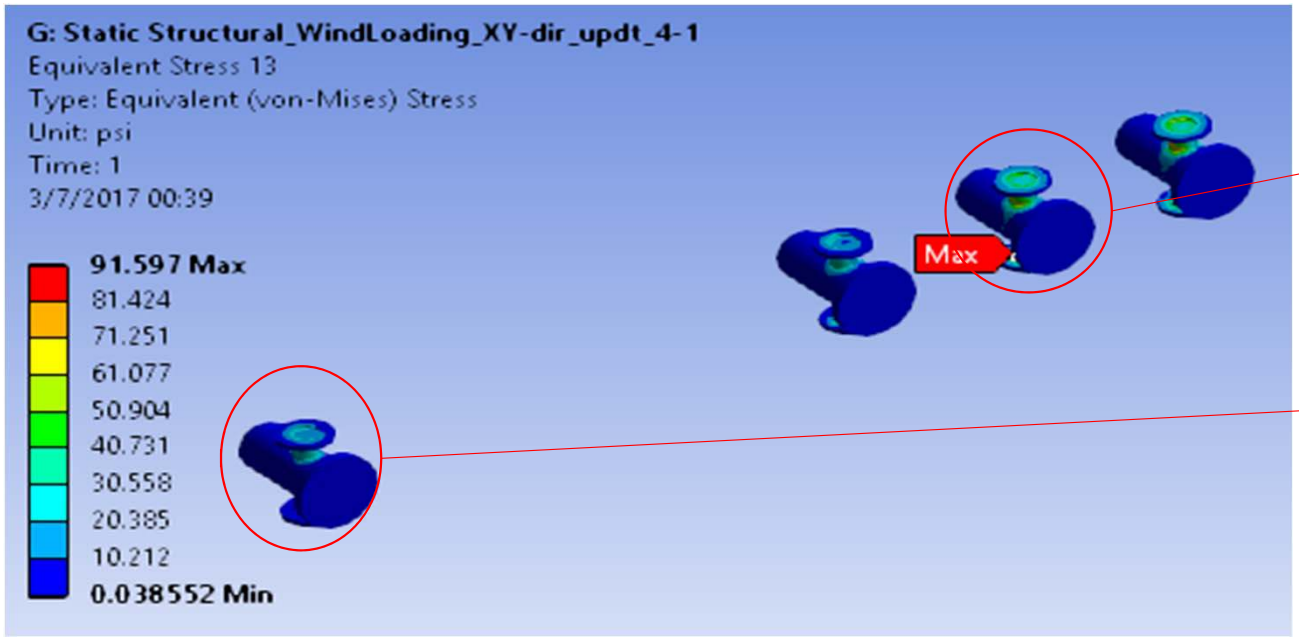
Results:

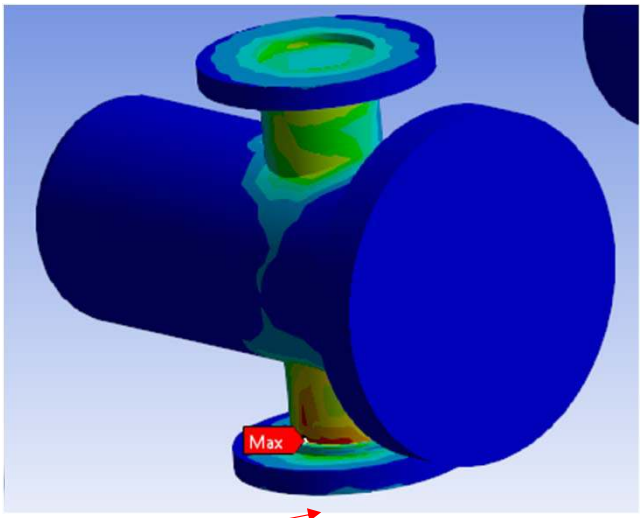
- Von-Mises Stresses

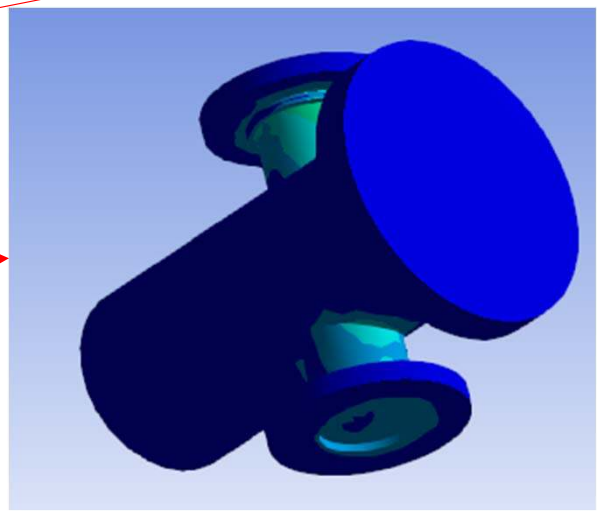


Results:

- **Von-Mises Stresses**



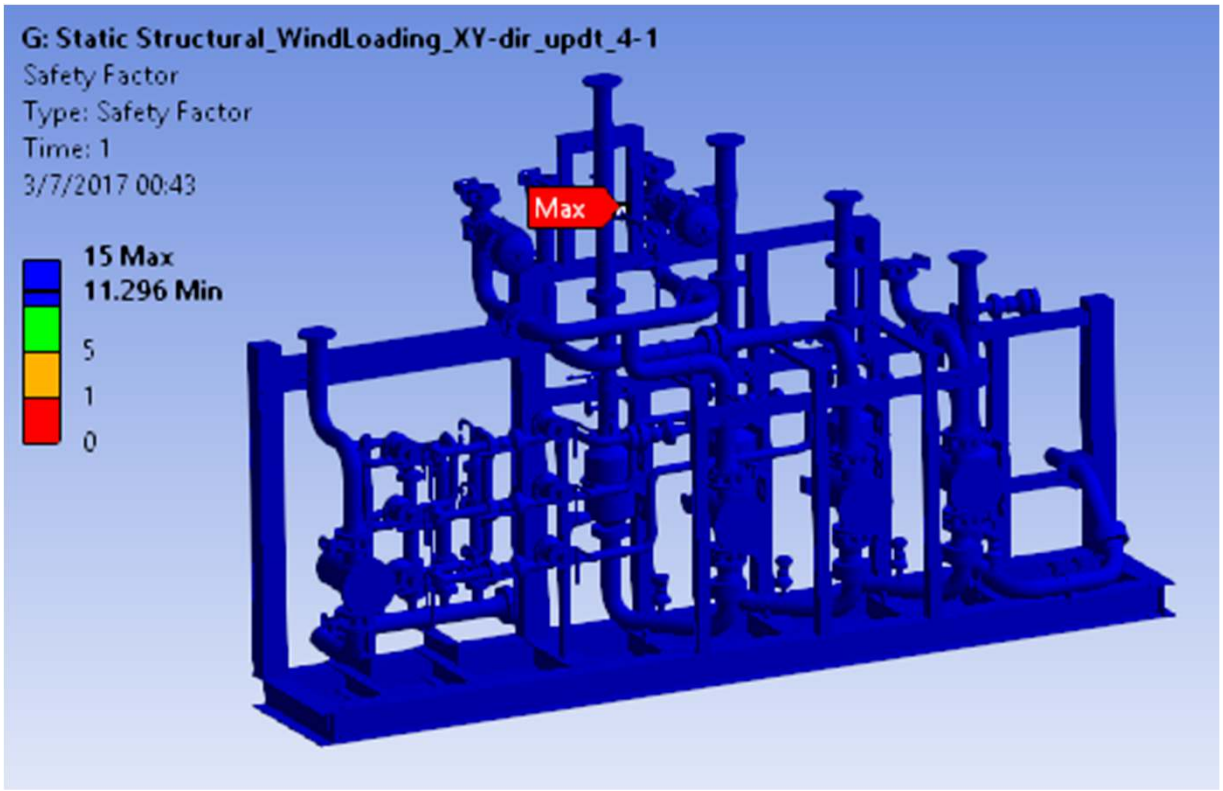




Results:

- **Safety Factor (SF)**

Maximum Safety Factor for the entire Structure is 15 (Very High).



Conclusion:

- The deformations and stresses are all relatively small compared to the Ultimate Tensile Strength of the applied materials of the Skid Structure.

- Therefore, after performing this analysis, we can conclude that the overall Skid Assembly passes all structural integrity tests performed under the force of the 90 mile-per-hour wind loading in the +XY wind direction.

- Therefore, Skid Assembly is safe under this wind loading.