1.6 RESULTS

Results for the analyses previously described are summarized in this section.

1.6.1 Modal Analysis

A pre-stressed modal analysis was performed to calculate the natural frequencies of the GS-50873-GA filter cartridge assembly. Because of the large mass matrix involved in the analysis, an iterative Block Lanczos solver was selected to calculate the eigenvalues and eigenvectors, which correspond to the natural frequencies and mode shapes, respectively.

Figure 1.6-1 through 1.6-4 show the significant mode shapes with appreciable mass participation factors for the GS-50873-GA filter cartridge assembly. Figure 1.6-5 shows a directional deformation mode shape for significant mass participation factor in the horizontal (Global-Z) direction. Figures 1.6-6 and 1.6-7 show a directional deformation mode shape for significant mass participation factors in the vertical (Global-Y) direction.

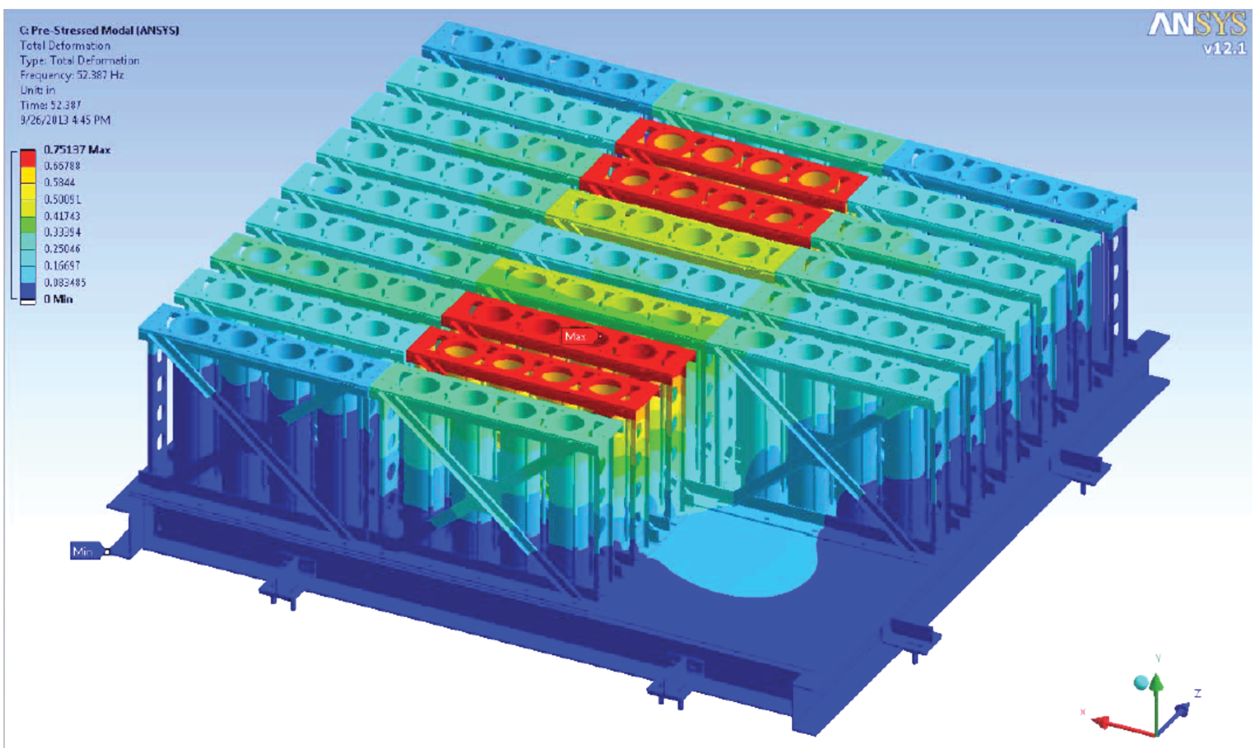


Figure 1.6-1 Significant Mode Shape, M1, Transverse Bending, Frequency = 52.387 Hz, GS-50873-GA Filter Cartridge Assembly

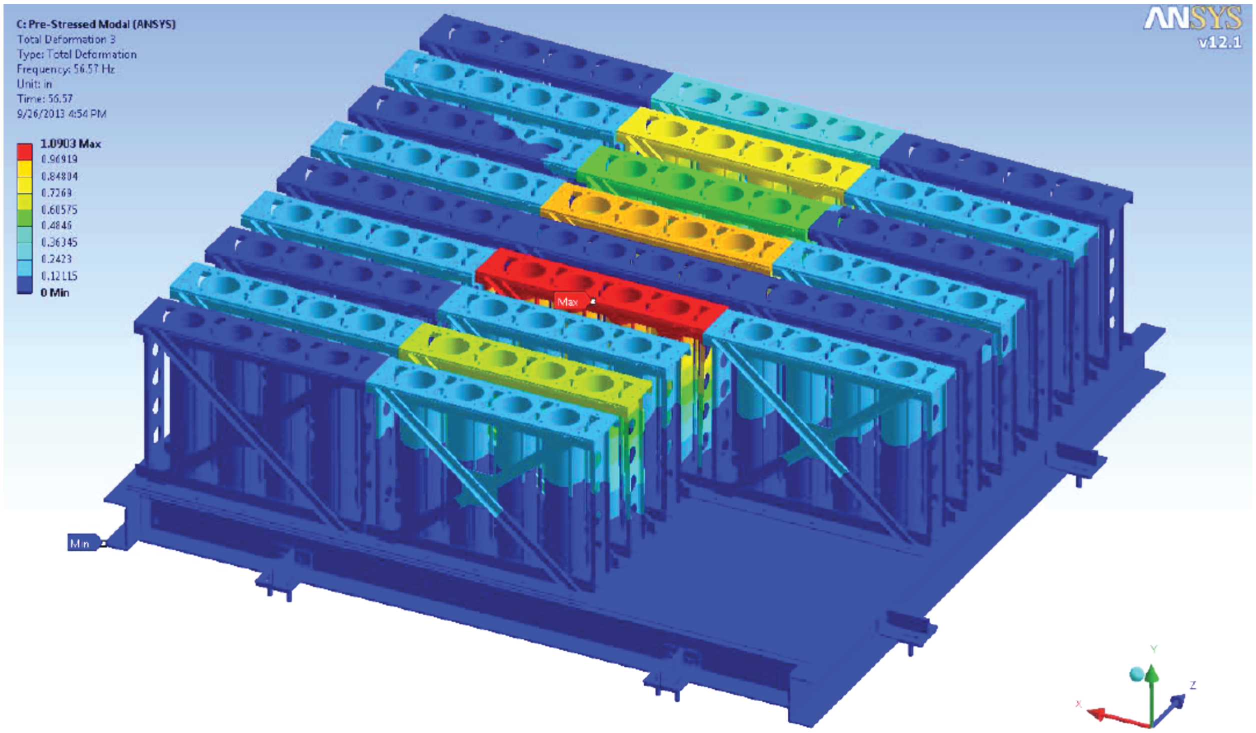


Figure 1.6-2 Significant Mode Shape, M3, Transverse Bending, Frequency = 56.57 Hz,
GS-50873-GA Filter Cartridge Assembly

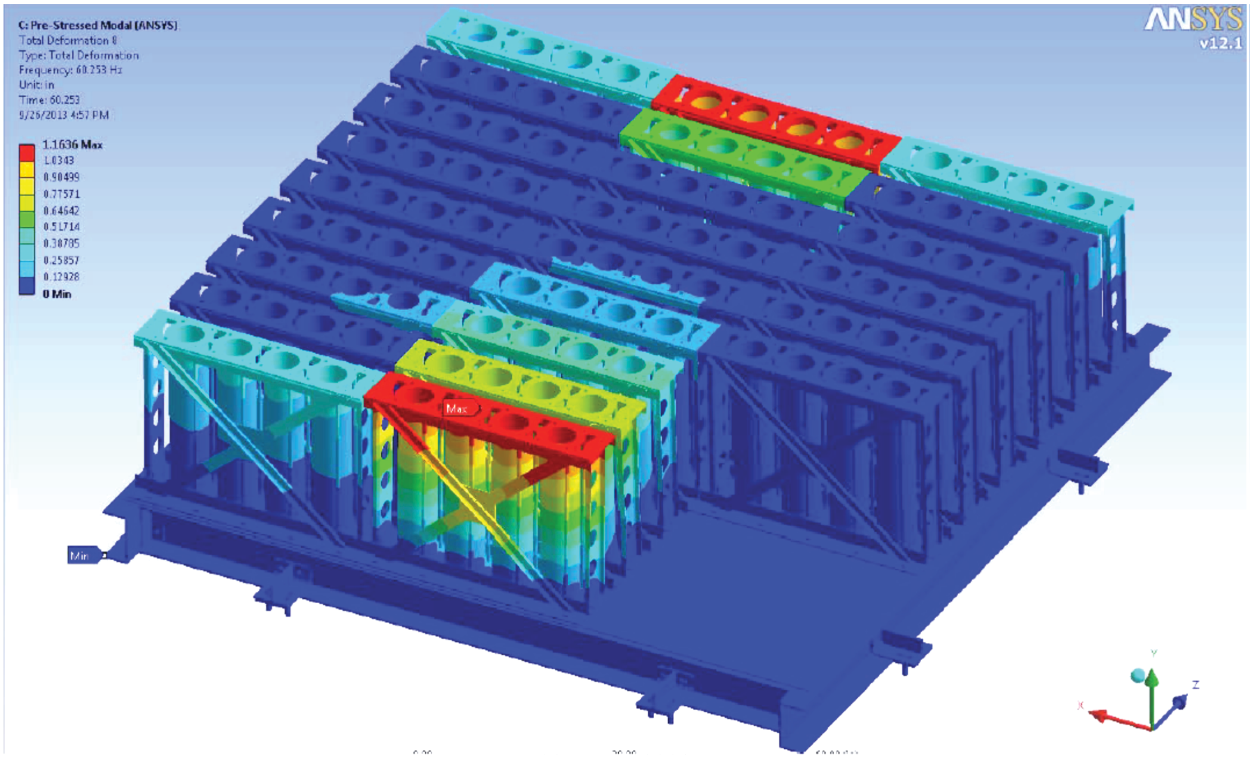


Figure 1.6-3 Significant Mode Shape, M8, Transverse Bending, Frequency = 60.253 Hz, GS-50873-GA Filter Cartridge Assembly

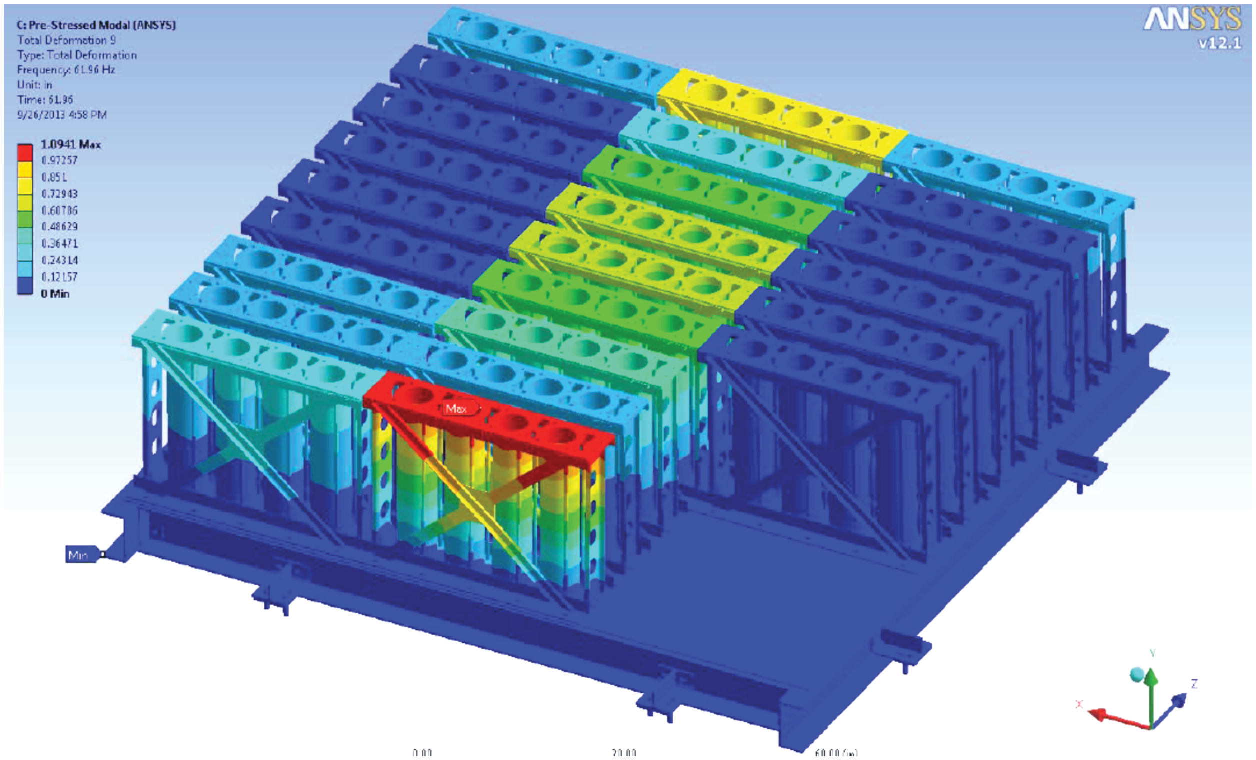


Figure 1.6-4 Significant Mode Shape, M9, Transverse Bending, Frequency = 61.96 Hz, GS-50873-GA Filter Cartridge Assembly

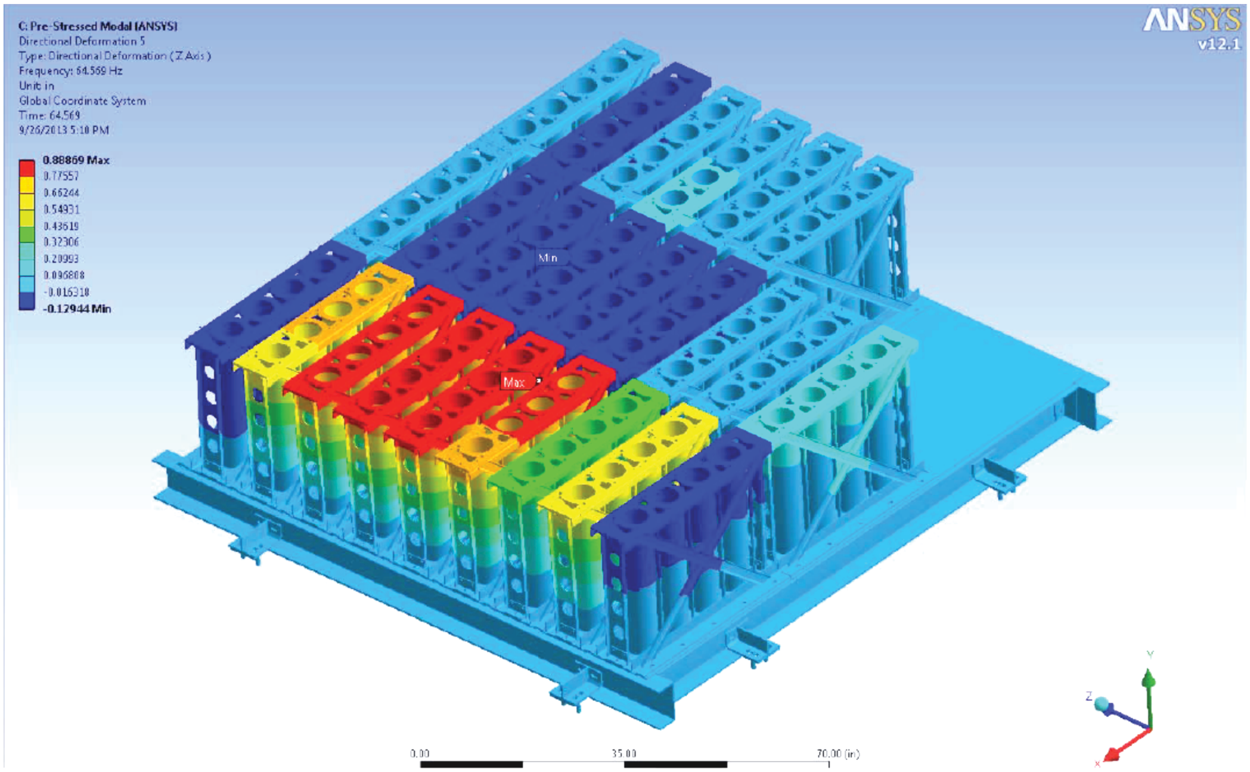


Figure 1.6-5 Significant Mode Shape, M21, Transverse Bending, Frequency = 64.569 Hz, GS-50873-GA Filter Cartridge Assembly

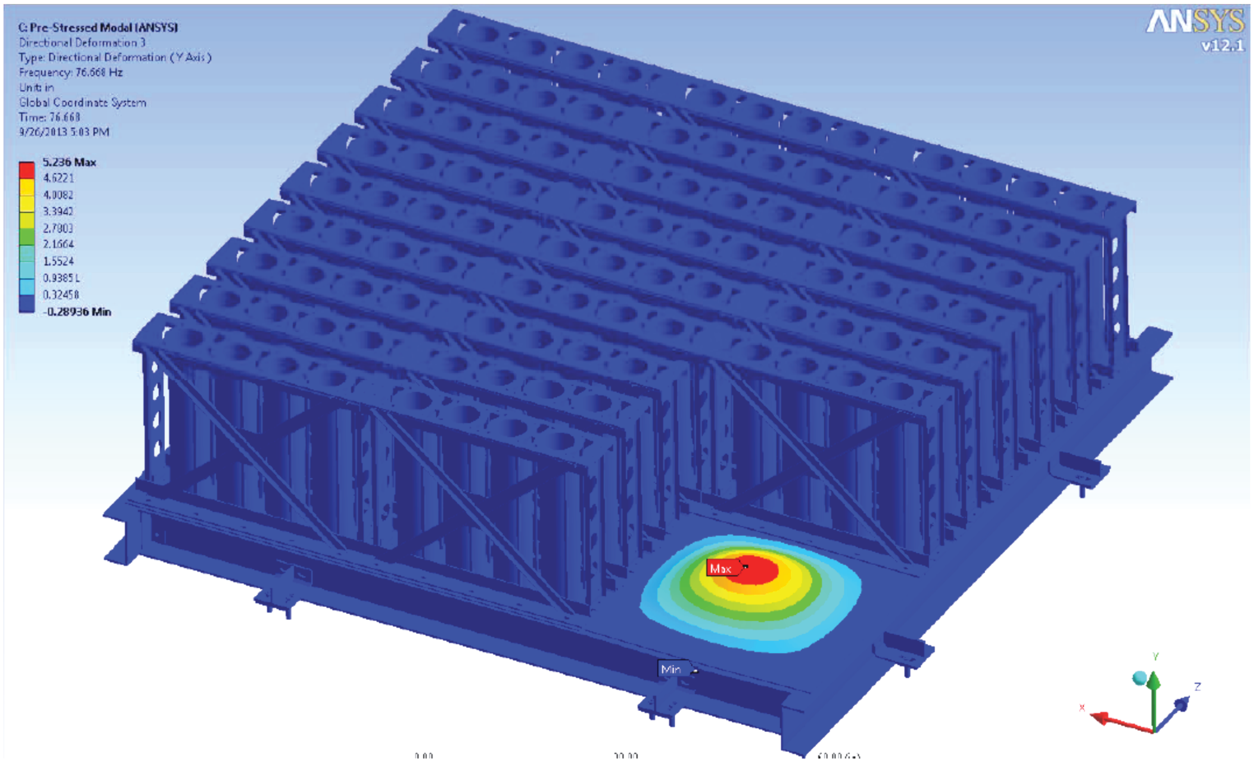


Figure 1.6-6 Significant Mode Shape, M25, Vertical Displacement of Access Panel, Frequency=76.668 Hz, GS-50873-GA Filter Cartridge Assembly

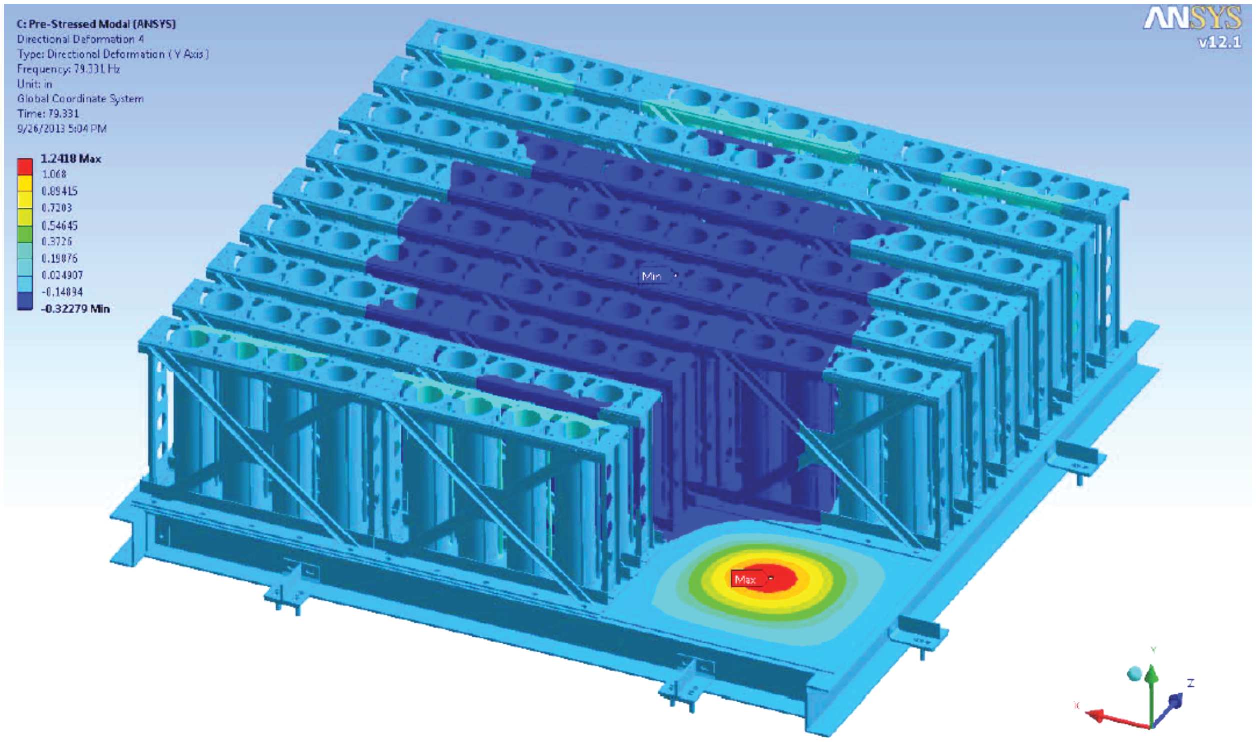


Figure 1.6-7 Significant Mode Shape, Vertical Displacement of Access Panel, Frequency =79.331 Hz, GS-50873-GA Filter Cartridge Assembly

1.6.2 Response Spectral Analysis

A single point spectrum analyses for both SSE and OBE events were performed to calculate the maximum response of the structures to the seismic loading. In a single response spectrum, the structure is excited by a spectrum of known direction, amplitude and frequency, acting uniformly on all support points.

Displacements from the response spectrum analysis are shown in Figures 1.6-8 through 1.6-11. Please note that in the response spectrum analyses, displacements are positive magnitudes and do not represent relative displacement with respect to the global coordinate system. Figures 1.6-8 and 1.6-10 show the directional deformation in the direction of application of the input spectrum for the Vertical direction SSE in global Y-direction and bounding Horizontal SSE in global Z-direction. Figures 1.6-9 and 1.6-11 show the directional deformation in the direction of application of the input spectrum for the Vertical direction OBE in global Y-direction and bounding Horizontal OBE in global Z-direction.

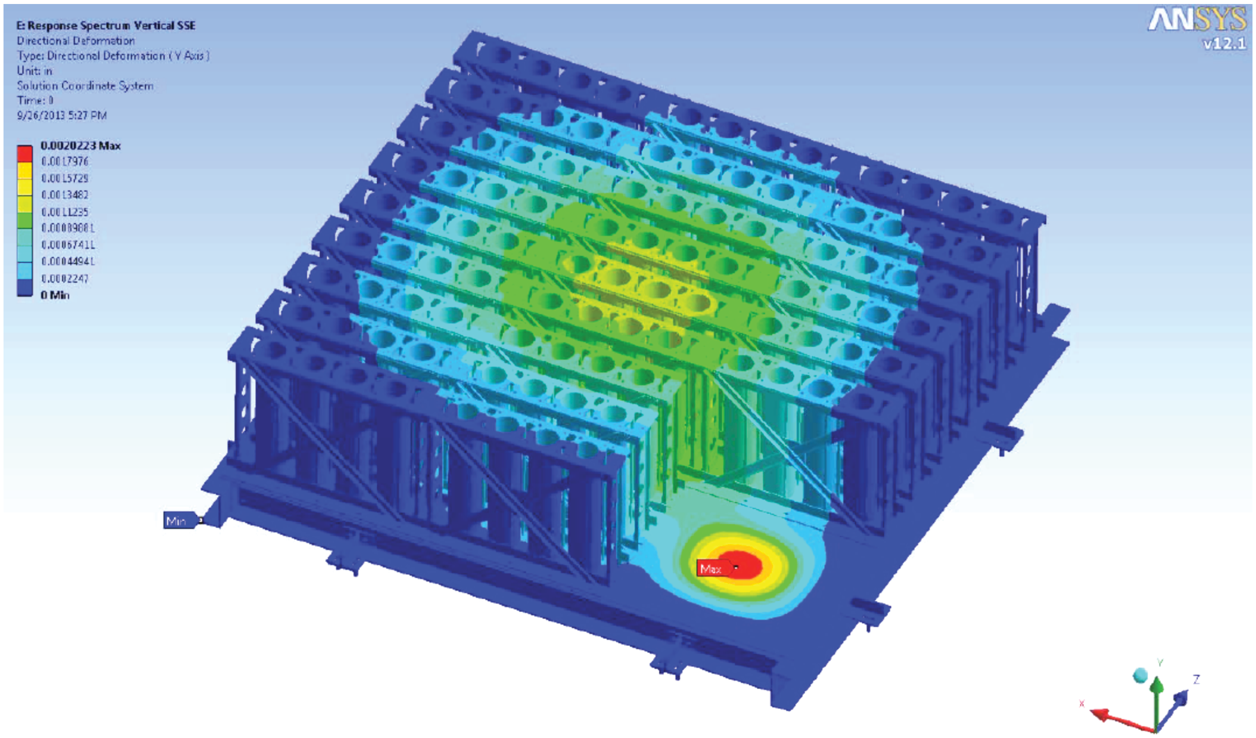


Figure 1.6-8 Displacement Contour Plot, Global Y for Vertical Direction SSE Response Spectrum for GS-50873-GA Filter Cartridge Assembly

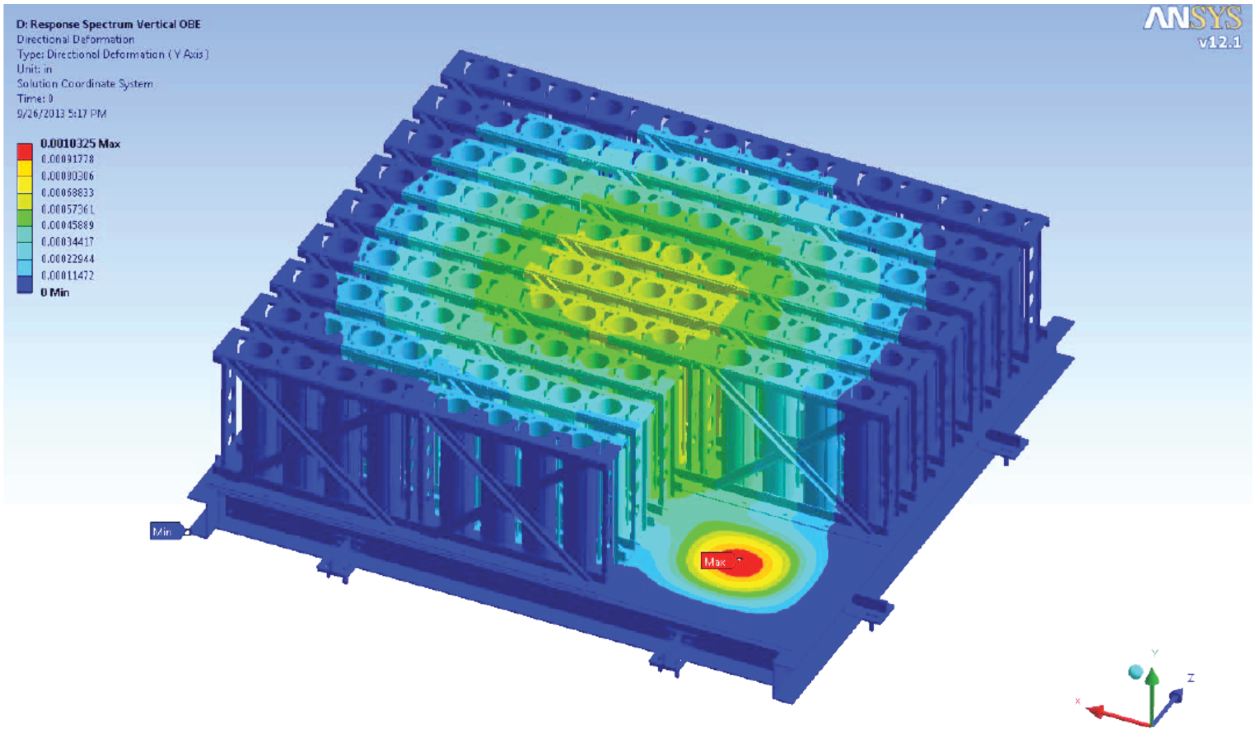


Figure 1.6-9 Displacement Contour Plot, Global Y for Vertical Direction OBE Response Spectrum for GS-50873-GA Filter Cartridge Assembly

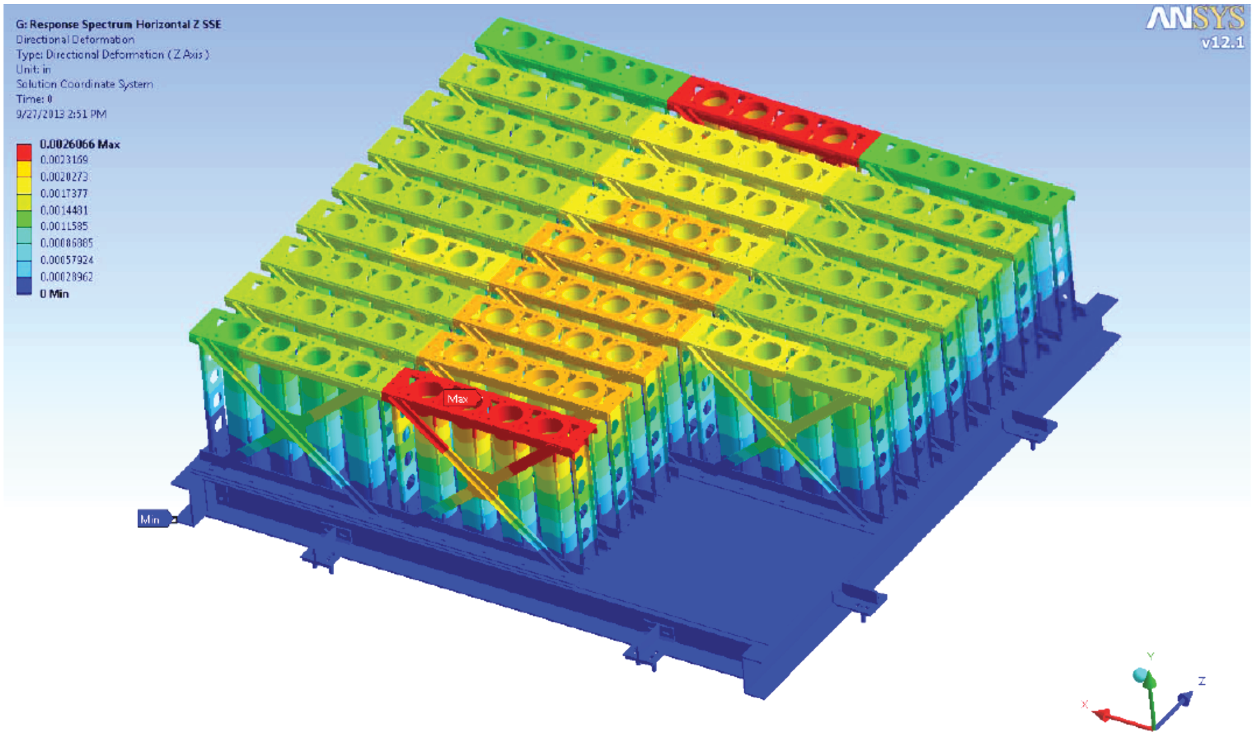


Figure 1.6-10 Displacement Contour Plot, Global Z for Horizontal Direction SSE Response Spectrum for GS-50873-GA Filter Cartridge Assembly

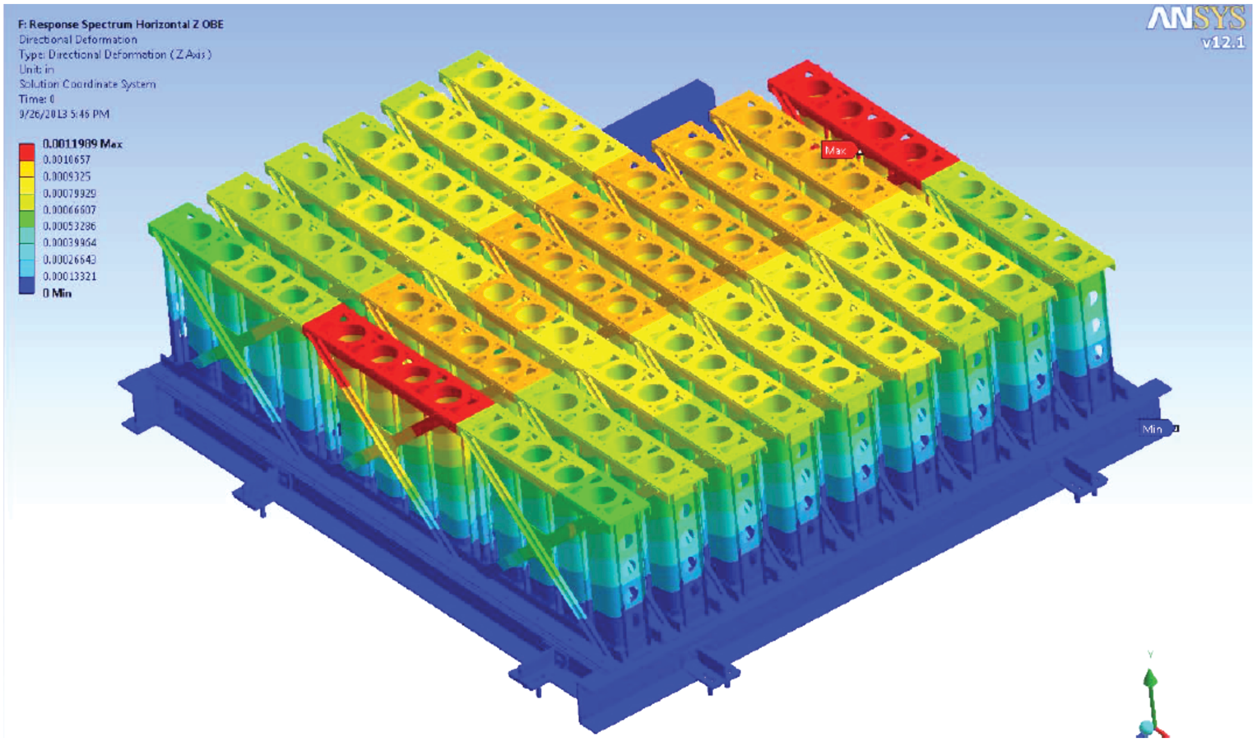


Figure 1.6-11 Displacement Contour Plot, Global Z for Horizontal Direction OBE Response Spectrum for GS-50873-GA Filter Cartridge Assembly

1.6.3 Stresses Comparison with ASME Code Allowable Stresses

The maximum FEA normal stress at any node is below the minimum membrane only allowable stress from the ASME Code. Since the stresses are low and below that minimum allowable criterion, linearization was not performed to satisfy the assessment. This is conservative since the FEA stresses include both membrane and bending components, and are compared to a membrane only allowable. Figure 6-12 shows an example normal stress contour plot for the vertical direction (Y-Axis) SSE response spectrum loading for the GS-50873-GA Filter Cartridge Assembly. Figure 6-13 shows an example shear stress contour plot for the vertical direction (Y-Axis) SSE response spectrum loading for the GS-50873-GA Filter Cartridge Assembly. Figure 1.6-14 shows an example normal stress contour plot for the vertical direction (Y-Axis) OBE response spectrum loading for the GS-50873-GA Filter Cartridge Assembly. Figure 1.6-15 shows an example shear stress contour plot for the vertical direction (Y-Axis) SSE response spectrum loading for the GS-50873-GA Filter Cartridge Assembly. The tabulated data of normal stresses versus allowable stresses are shown for Service Levels A through D in Tables 1.6-1, 1.6-2, 1.6-3 and 1.6-4 for the GS-50873-GA Filter Cartridge assembly.

Figure 1.6-16 shows example normal stress contour plot for the hydrodynamic drag force when applied in one of the horizontal directions (Z-Axis) for the GS-50873-GA Filter Cartridge Assembly. Figure 1.6-17 shows example shear stress contour plot for the hydrodynamic drag force when applied in one of the horizontal directions (Z-Axis) for the GS-50873-GA Filter Cartridge Assembly. It is noted here that the normal stress state in the limiting hydrodynamic drag load direction is then combined by taking the SRSS to generate one resultant stress state for Service Level D load combination. The resulting stresses are used as input for the total stress evaluation shown in Table 1.6-4.

In the stress qualification of the Hilti Anchor bolts, the most limiting tensile/compressive reaction force and shear reaction force are considered in the bolt stress calculation. Reference 7, Section 3.3.3, provides an allowable tensile load of 2,530 lbf and an allowable shear load of 4,890 lbf for Hilti HSLG-R M 12/25 Anchor Bolt. These tensile and shear reaction loads are applicable for Hilti anchor bolts installed in normal-weight concrete with an allowable compressive strength of 3,000 psi. The cumulative bolt reaction force for the limiting Service Level D load combination is 836.13 lbf in the tension direction and 4381.56 lbf in the shear direction. It is noted here that all sixteen Hilti anchor bolts (two Hilti anchor bolts for each attachment location) are modeled and resisting the applied load. In the scenario of any of the Hilti anchor bolts not being installed due to presence of concrete rebar in the containment floor, it is logical that the remaining Hilti anchor bolts will see an increase in both tensile/compressive and shear reaction loads. In such a case, a separate analysis for the limiting Service Level D load combination will need to be performed taking into account the missing Hilti anchor bolts. Additionally, the existing Hilti anchor bolts can be overdesigned to a Stainless Steel HSLG-R M16 Hilti anchor diameter. The M16 Hilti anchor bolt provides an allowable tensile load of 4,705 lbf [Reference 7] and an allowable shear load of 8,965 lbf [Reference 7].

Table 1.6-1 ASME Code, Section III, Division 1 Stress Qualification for the GS-50873-GA Filter Cartridge Assembly, Service Level A

Strainer Stress						
Stress type	**Service Level A**	**Service Level B**	**Service Level C/D**	**Allowable Stress_Service Level A (psi)**	**FEA_Peak Stress_Service Level A Load Combination (psi)**	**Stress Check (Y/N)**
Primary Membrane Stress, σm[1]	1.0×S	1.10×S	1.50×S	13,850.0000	1,905.8500	Y
Primary Membrane + Bending Stress, σm + σb[2]	1.5×S	1.65×S	1.80×S	20,775.0000	1,905.8500	Y
Support Stress						
Stress type	**Service Level A**	**Service Level B**	**Service Level C/D**	**Allowable Stress_Service Level A (psi)**	**FEA_Peak Stress_Service Level A Load Combination (psi)**	**Stress Check (Y/N)**
Plate and Shell Type Components						
Primary Membrane Stress, Sm[3]	1.0×S	1.33×S	1.50×S	13,850.0000	1,905.8500	Y
Primary Membrane + Bending Stress, Sm + Sb[4]	1.5×S	2.00×S	2.25×S	20,775.0000	1,905.8500	Y
Linear Type Components						
Tension Stress[5]	0.60×Sy	1.33×Level A	1.5×Level A	15,000.0000	1,137.4000	Y
Shear Stress[6]	0.40×Sy	1.33×Level A	1.5×Level A	10,000.0000	1,835.4500	Y
Compression Stress[7]	0.47×Sy	1.33×Level A	1.5×Level A	11,750.0000	1,905.8500	Y
Bending Stress[8]	0.66×Sy	1.33×Level A	1.5×Level A	16,500.0000	1,155.4700	Y
Bolting						
Tension Stress[10]				14,489.3458	3,113.1557	Y
Shear Stress[11]				27,894.8428	148.2591	Y

For Axial Compression +Bending Stress Criteria[9]	
Computed Bending Stress (Z Axis)	398.3750
Computed Bending Stress (X Axis)	418.4200
Computed Axial Stress (Y Axis)	1,905.8500
Equation 21 Load combination Criteria (≤1.0)	0.1766
Hoop Stress (Membrane + Bending) – Head Loss Loading Acriss filter Tubes, 2 feet of water	500.6500

Notes:

S: Allowable Stress
Sy: Yield strength
Su: Tensile strength

1. Table NC-3321-1. S defined in Section II, Part D, Subpart 1, Table 1A
2. Table NC-3321-1. S defined in Section II, Part D, Subpart 1, Table 1A
3. Subsection NF-3251.1 Eq. 1. S defined in Section II, Part D, Subpart 1 Table 1A
4. Subsection NF-3251.1 Eq. 2. S defined in Section II, Part D, Subpart 1 Table 1A
5. Subsection NF-3322.1 Eq. 1
6. Subsection NF-3322.1 Eq. 3a
7. Subsection NF-3322.1 Eq. 6a
8. Subsection NF-3322.1 Eq. 15b
9. As per NF 3322.1, Equation 21
10. Reference 7, Section 3.3.3, Allowable Tensile Load of 2540 lbf for Hilti HSLG-R M 12/25 Anchor Bolt, FEA cumulative bolt reaction force is 545.74 lbf, Ultimate Tensile Strength for Hilti HSLG-R M 12/25 Anchor Bolt used is 102 ksi [Reference 7]
11. Reference 7, Section 3.3.3, Allowable Shear Load of 4890 lbf for Hilti HSLG-R M 12/25 Anchor Bolt, FEA cumulative bolt reaction force is 25.99 lbf, Ultimate Tensile Strength for Hilti HSLG-R M 12/25 Anchor Bolt used is 102 ksi [Reference 7]

Table 1.6-2 ASME Code, Section III, Division 1 Stress Qualification for the GS-50873-GA Filter Cartridge Assembly, Service Level B

Strainer Stress						
Stress type	**Service Level A**	**Service Level B**	**Service Level C/D**	**Allowable Stress_Service Level B (psi)**	**FEA_Peak Stress_Service Level B Load Combination (psi)**	**Stress Check (Y/N)**
Primary Membrane Stress, σm[1]	1.0×S	1.10×S	1.50×S	15,235.0000	2,600.4300	Y
Primary Membrane + Bending Stress, σm + σb[2]	1.5×S	1.65×S	1.80×S	22,852.5000	2,600.4300	Y
Support Stress						
Stress type	**Service Level A**	**Service Level B**	**Service Level C/D**	**Allowable Stress_Service Level B (psi)**	**FEA_Peak Stress_Service Level B Load Combination (psi)**	**Stress Check (Y/N)**
Plate and Shell Type Components						
Primary Membrane Stress, Sm[3]	1.0×S	1.33×S	1.50×S	18,420.0000	2,600.4300	Y
Primary Membrane + Bending Stress, Sm + Sb[4]	1.5×S	2.00×S	2.25×S	27,700.0000	2,600.4300	Y
Linear Type Components						
Tension Stress[5]	0.60×Sy	1.33×Level A	1.5×Level A	19,950.0000	1,831.9800	Y
Shear Stress[6]	0.40×Sy	1.33×Level A	1.5×Level A	13,300.0000	2,280.3991	Y
Compression Stress[7]	0.47×Sy	1.33×Level A	1.5×Level A	15,627.5000	1,905.8500	Y
Bending Stress[8]	0.66×Sy	1.33×Level A	1.5×Level A	21,945.0000	1,749.3306	Y
Bolting						
Tension Stress[10]				14,489.3458	3,915.1010	Y
Shear Stress[11]				27,894.8428	4,402.5934	Y

For Axial Compression +Bending Stress Criteria[9]	
Computed Bending Stress (Z Axis)	694.5800
Computed Bending Stress (X Axis)	694.5800
Computed Axial Stress (Y Axis)	2,376.8900
Equation 21 Load combination Criteria (≤1.0)	0.1824
Hoop Stress (Membrane + Bending) – Head Loss Loading Acriss filter Tubes, 2 feet of water	500.6500

Notes:

S: Allowable Stress
Sy: Yield strength
Su: Tensile strength

1. Table NC-3321-1. S defined in Section II, Part D, Subpart 1, Table 1A
2. Table NC-3321-1. S defined in Section II, Part D, Subpart 1, Table 1A
3. Subsection NF-3251.1 Eq. 1. S defined in Section II, Part D, Subpart 1 Table 1A
4. Subsection NF-3251.1 Eq. 2. S defined in Section II, Part D, Subpart 1 Table 1A
5. Subsection NF-3322.1 Eq. 1
6. Subsection NF-3322.1 Eq. 3a
7. Subsection NF-3322.1 Eq. 6a
8. Subsection NF-3322.1 Eq. 15b
9. As per NF 3322.1, Equation 21
10. Reference 7, Section 3.3.3, Allowable Tensile Load of 2540 lbf for Hilti HSLG-R M 12/25 Anchor Bolt, FEA cumulative bolt reaction force is 686.32 lbf, Ultimate Tensile Strength for Hilti HSLG-R M 12/25 Anchor Bolt used is 102 ksi [Reference 7]
11. Reference 7, Section 3.3.3, Allowable Shear Load of 4890 lbf for Hilti HSLG-R M 12/25 Anchor Bolt, FEA cumulative bolt reaction force is 205.26 lbf, Ultimate Tensile Strength for Hilti HSLG-R M 12/25 Anchor Bolt used is 102 ksi [Reference 7]

Table 1.6-3 ASME Code, Section III, Division 1 Stress Qualification for the GS-50873-GA Filter Cartridge Assembly, Service Level C

Strainer Stress						
Stress type	**Service Level A**	**Service Level B**	**Service Level C/D**	**Allowable Stress_Service Level C (psi)**	**FEA_Peak Stress_Service Level C Load Combination (psi)**	**Stress Check (Y/N)**
Primary Membrane Stress, σm[1]	1.0×S	1.10×S	1.50×S	20775.0000	3206.1213	Y
Primary Membrane + Bending Stress, σm + σb[2]	1.5×S	1.65×S	1.80×S	24930.0000	3206.1213	Y
Support Stress						
Stress type	**Service Level A**	**Service Level B**	**Service Level C/D**	**Allowable Stress_Service Level C (psi)**	**FEA_Peak Stress_Service Level C Load Combination (psi)**	**Stress Check (Y/N)**
Plate and Shell Type Components						
Primary Membrane Stress, Sm[3]	1.0×S	1.33×S	1.50×S	20,775.0000	3,206.1213	Y
Primary Membrane + Bending Stress, Sm + Sb[4]	1.5×S	2.00×S	2.25×S	31,162.5000	3,206.1213	Y
Linear Type Components						
Tension Stress[5]	0.60×Sy	1.33×Level A	1.5×Level A	22,500.0000	2,437.6713	Y
Shear Stress[6]	0.40×Sy	1.33×Level A	1.5×Level A	15,000.0000	2,737.6563	Y
Compression Stress[7]	0.47×Sy	1.33×Level A	1.5×Level A	17,625.0000	1,905.8500	Y
Bending Stress[8]	0.66×Sy	1.33×Level A	1.5×Level A	24,750.0000	1,844.9873	Y
Bolting						
Tension Stress[10]				14,489.3458	4,769.6582	Y
Shear Stress[11]				27,894.8428	4,402.5934	Y

For Axial Compression +Bending Stress Criteria[9]	
Computed Bending Stress (Z Axis)	1,300.2713
Computed Bending Stress (X Axis)	1,300.2713
Computed Axial Stress (Y Axis)	2,710.6300
Equation 21 Load combination Criteria (≤1.0)	0.2255
Hoop Stress (Membrane + Bending) – Head Loss Loading Acriss filter Tubes, 2 feet of water	500.6500

Notes:

S: Allowable Stress
Sy: Yield strength
Su: Tensile strength

1. Table NC-3321-1. S defined in Section II, Part D, Subpart 1, Table 1A
2. Table NC-3321-1. S defined in Section II, Part D, Subpart 1, Table 1A
3. Subsection NF-3251.1 Eq. 1. S defined in Section II, Part D, Subpart 1 Table 1A
4. Subsection NF-3251.1 Eq. 2. S defined in Section II, Part D, Subpart 1 Table 1A
5. Subsection NF-3322.1 Eq. 1
6. Subsection NF-3322.1 Eq. 3a
7. Subsection NF-3322.1 Eq. 6a
8. Subsection NF-3322.1 Eq. 15b
9. As per NF 3322.1, Equation 21
10. Reference 7, Section 3.3.3, Allowable Tensile Load of 2540 lbf for Hilti HSLG-R M 12/25 Anchor Bolt, FEA cumulative bolt reaction force is 836.13 lbf, Ultimate Tensile Strength for Hilti HSLG-R M 12/25 Anchor Bolt used is 102 ksi [Reference 7]
11. Reference 7, Section 3.3.3, Allowable Shear Load of 4890 lbf for Hilti HSLG-R M 12/25 Anchor Bolt, FEA cumulative bolt reaction force is 410.67 lbf, Ultimate Tensile Strength for Hilti HSLG-R M 12/25 Anchor Bolt used is 102 ksi [Reference 7]

Table 1.6-4 ASME Code, Section III, Division 1 Stress Qualification for the GS-50873-GA Filter Cartridge Assembly, Service Level D

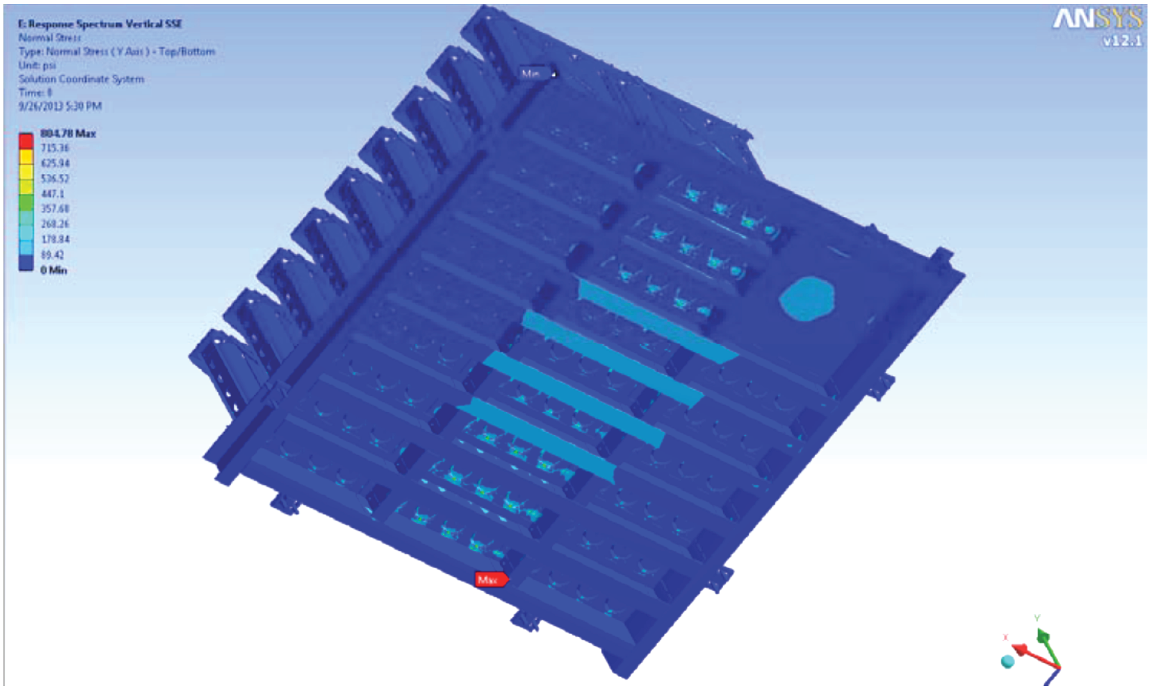
Strainer Stress						
Stress type	**Service Level A**	**Service Level B**	**Service Level C/D**	**Allowable Stress_Service Level D (psi)**	**FEA_Peak Stress_Service Level D Load Combination (psi)**	**Stress Check (Y/N)**
Primary Membrane Stress, σm[1]	1.0×S	1.10×S	1.5×S	20,775.0000	16,095.3386	Y
Primary Membrane + Bending Stress, σm + σb[2]	1.5×S	1.65×S	1.80×S	24,930.0000	16,095.3386	Y
Support Stress						
Stress type	**Service Level A**	**Service Level B**	**Service Level C/D**	**Allowable Stress_Service Level D (psi)**	**FEA_Peak Stress_Service Level D Load Combination (psi)**	**Stress Check (Y/N)**
Plate and Shell Type Components						
Primary Membrane Stress, Sm[3]	1.0×S	1.33×S	1.5×S	20,775.0000	16,095.3386	Y
Primary Membrane + Bending Stress, Sm + Sb[4]	1.5×S	2.00×S	2.25×S	31,162.5000	16,095.3386	Y
Linear Type Components						
Tension Stress[5]	0.60×Sy	1.33×Level A	1.5×Level A	22,500.0000	15,326.8886	Y
Shear Stress[6]	0.40×Sy	1.33×Level A	1.5×Level A	15,000.0000	11,589.2231	Y
Compression Stress[7]	0.47×Sy	1.33×Level A	1.5×Level A	17,625.0000	14,795.0673	Y
Bending Stress[8]	0.66×Sy	1.33×Level A	1.5×Level A	24,750.0000	13,290.5170	Y
Bolting						
Tension Stress[10]				14,489.3458	4,769.6582	Y
Shear Stress[11]				27,894.8428	24,994.4637	Y

For Axial Compression +Bending Stress Criteria[9]	
Computed Bending Stress (Z Axis)	12,111.8400
Computed Bending Stress (X Axis)	8,366.4000
Computed Axial Stress (Y Axis)	2,710.6300
Equation 21 Load combination Criteria (≤1.0)	0.9479
Hoop Stress (Membrane + Bending) – Head Loss Loading Acriss filter Tubes, 2 feet of water	500.6500

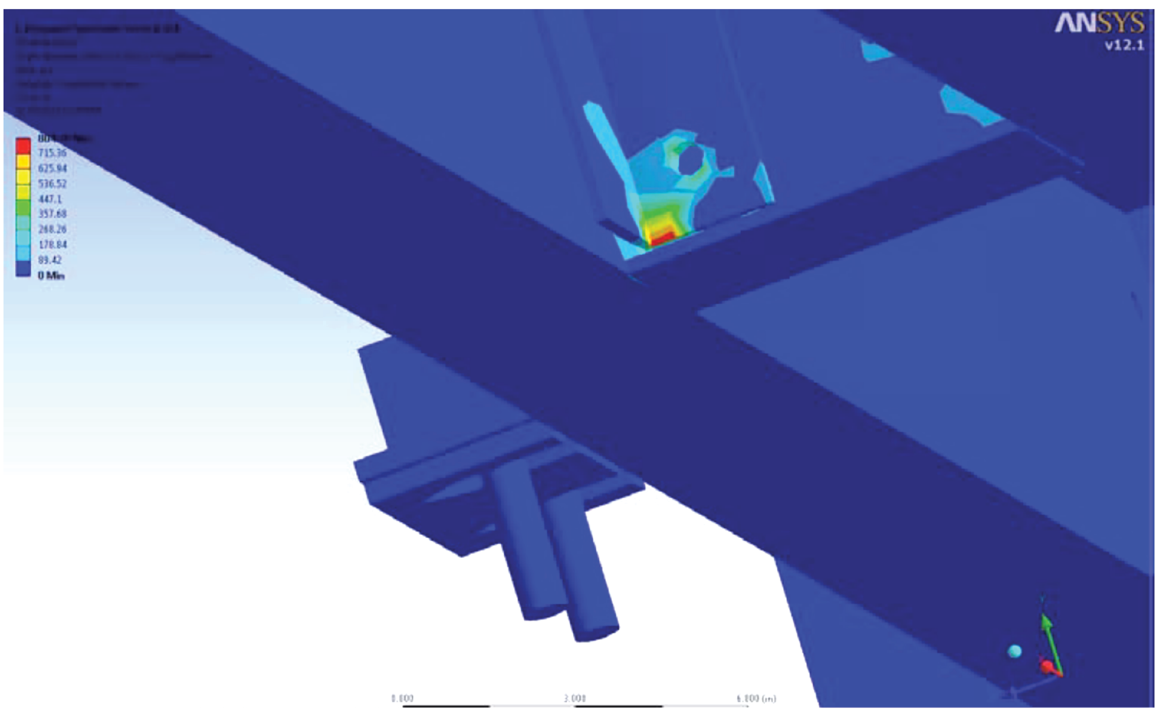
Notes:

S: Allowable Stress
Sy: Yield strength
Su: Tensile strength

1. Table NC-3321-1. S defined in Section II, Part D, Subpart 1, Table 1A
2. Table NC-3321-1. S defined in Section II, Part D, Subpart 1, Table 1A
3. Subsection NF-3251.1 Eq. 1. S defined in Section II, Part D, Subpart 1 Table 1A
4. Subsection NF-3251.1 Eq. 2. S defined in Section II, Part D, Subpart 1 Table 1A
5. Subsection NF-3322.1 Eq. 1
6. Subsection NF-3322.1 Eq. 3a
7. Subsection NF-3322.1 Eq. 6a
8. Subsection NF-3322.1 Eq. 15b
9. As per NF 3322.1, Equation 21
10. Reference 7, Section 3.3.3, Allowable Tensile Load of 2540 lbf for Hilti HSLG-R M 12/25 Anchor Bolt, FEA cumulative bolt reaction force is 836.13 lbf, Ultimate Tensile Strength for Hilti HSLG-R M 12/25 Anchor Bolt used is 102 ksi [Reference 7]
11. Reference 7, Section 3.3.3, Allowable Shear Load of 4890 lbf for Hilti HSLG-R M 12/25 Anchor Bolt, FEA cumulative bolt reaction force is 4,381.56 lbf, Ultimate Tensile Strength for Hilti HSLG-R M 12/25 Anchor Bolt used is 102 ksi [Reference 7]

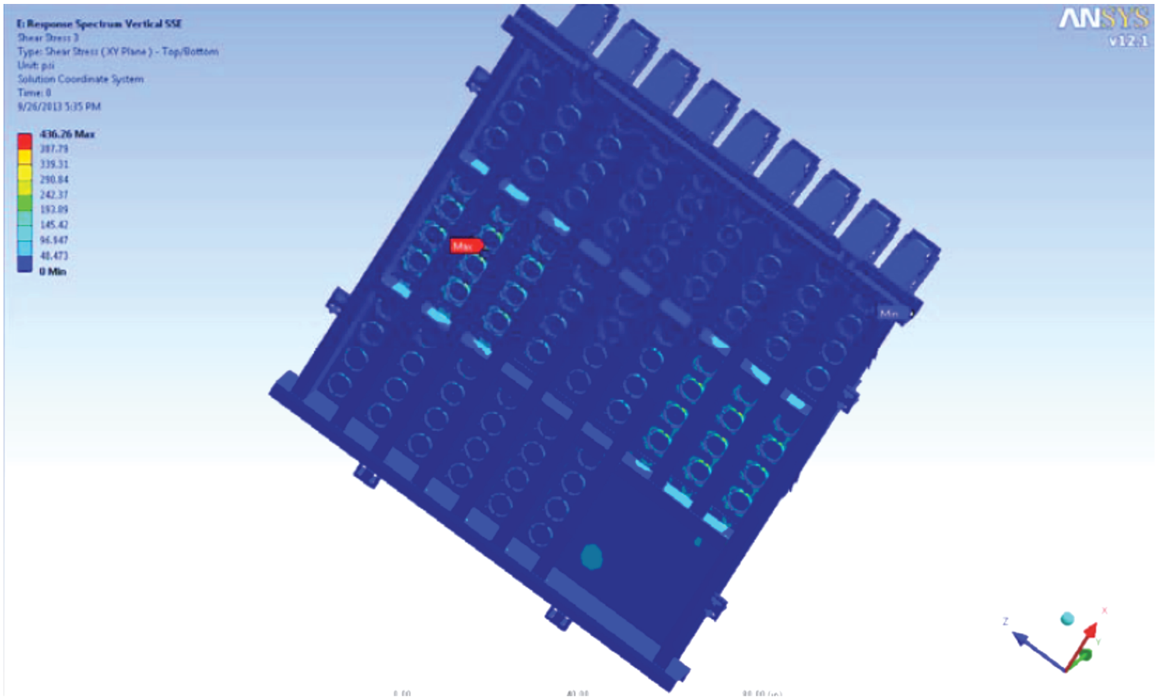


(a) Isometric View

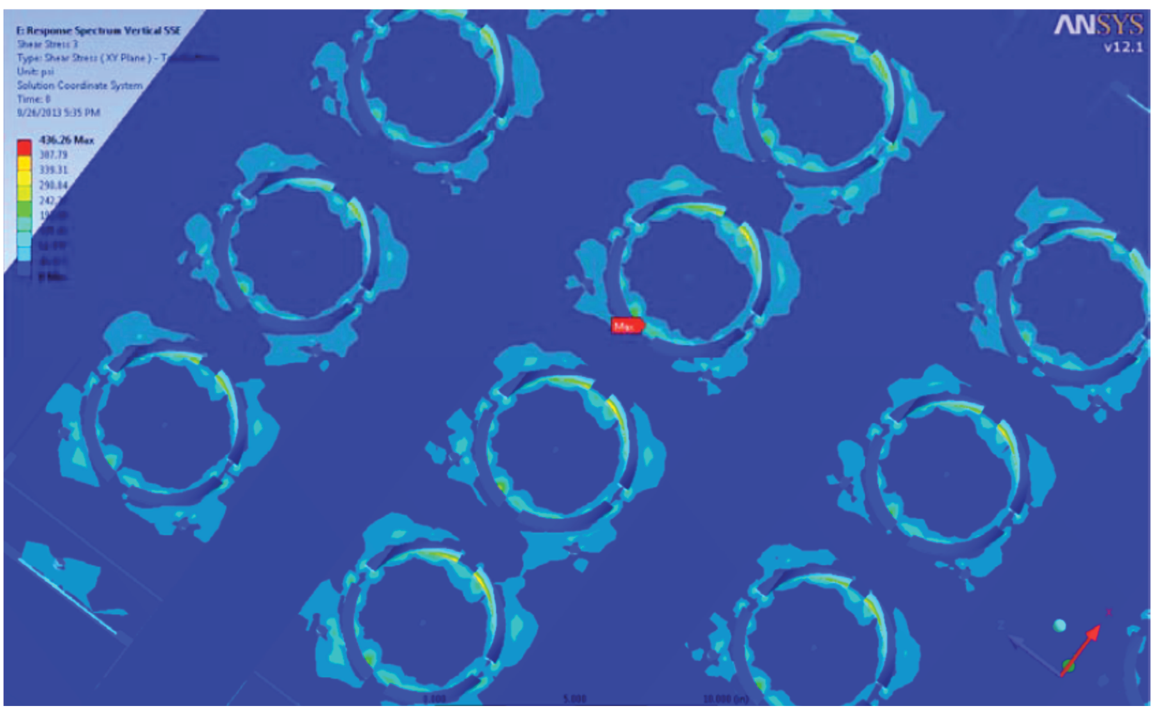


(b) Close-Up View of Peak Normal Stress at Angle between C-channel and transverse I-beam

Figure 1.6-12 Normal Stress Contour Plot for Vertical Direction (Y-Axis) SSE Response Spectrum Loading for GS-50873-GA Filter Cartridge Assembly

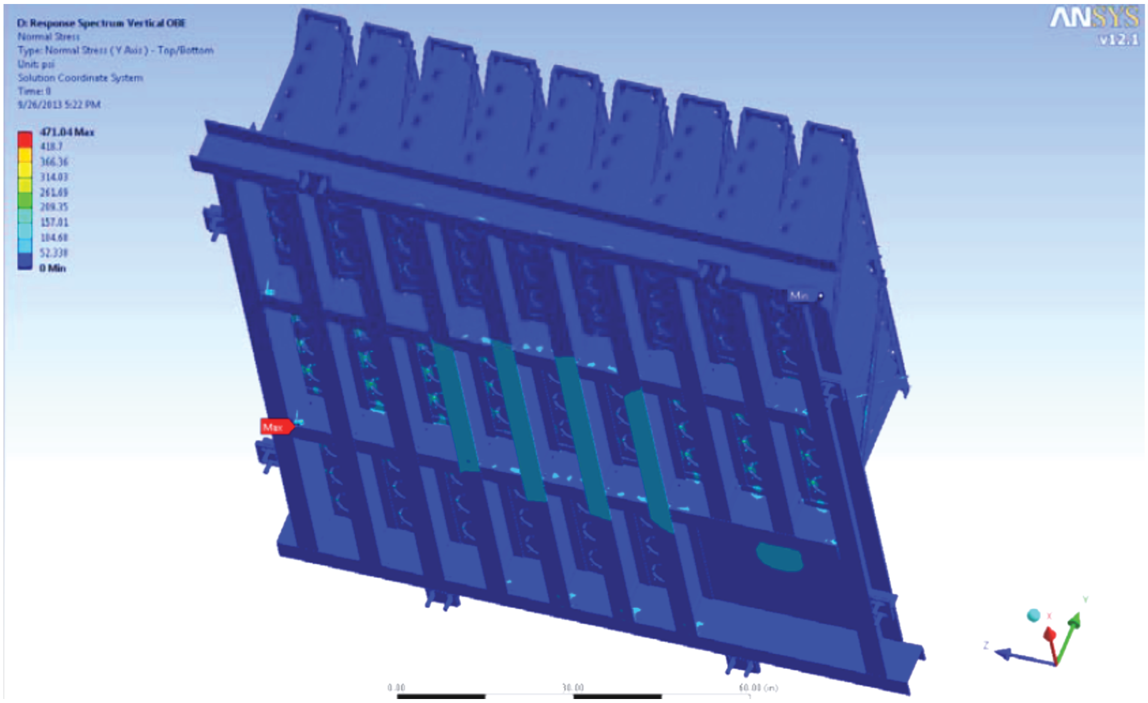


(a) Isometric View

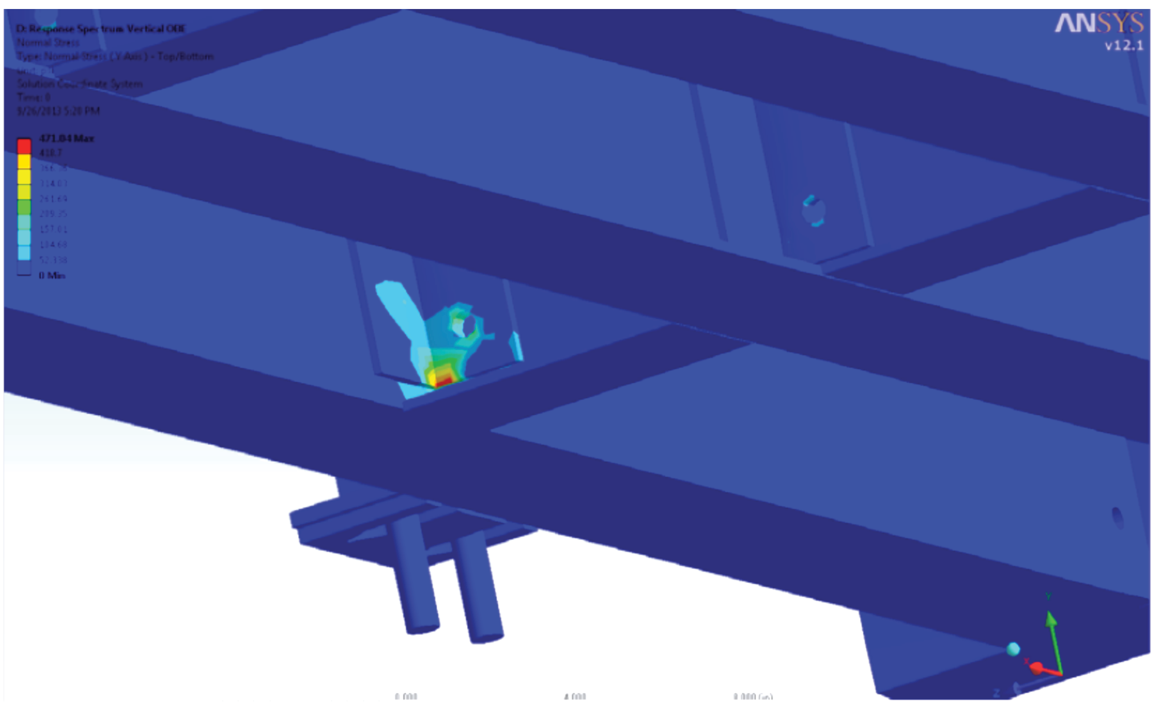


(b) Close-Up View of Peak Shear Stress at Bottom plate weld stud location

Figure 1.6-13 Shear Stress Contour Plot for Vertical Direction (Y-Axis) SSE Response Spectrum Loading for GS-50873-GA Filter Cartridge Assembly

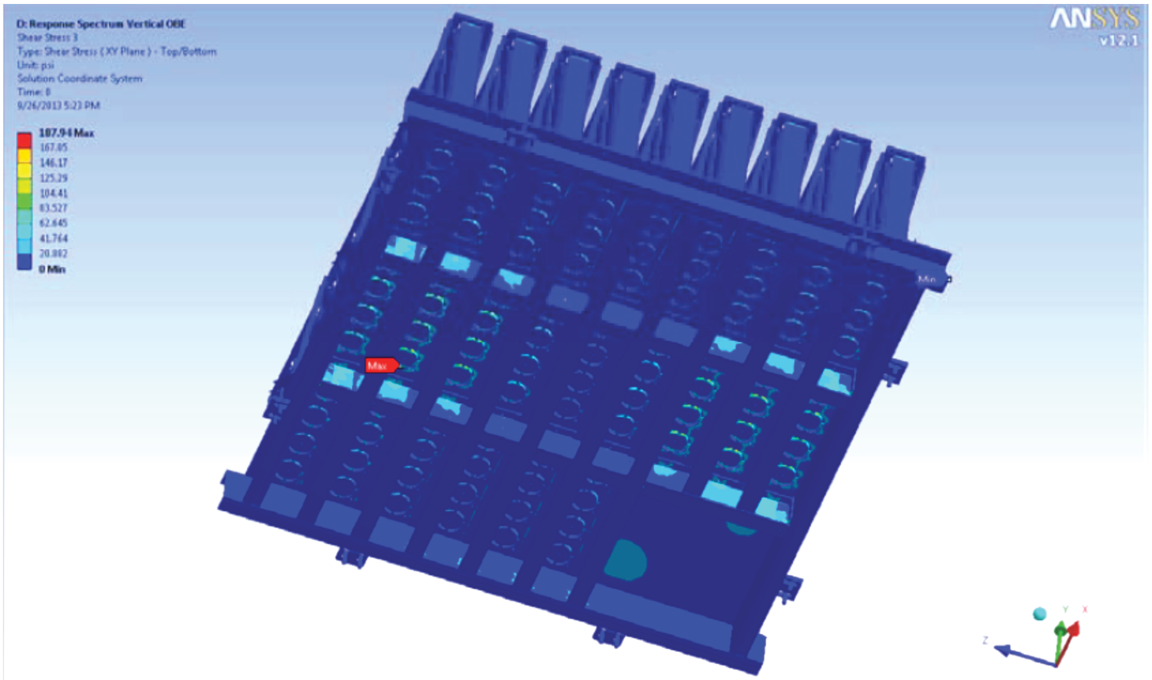


(a) Isometric View

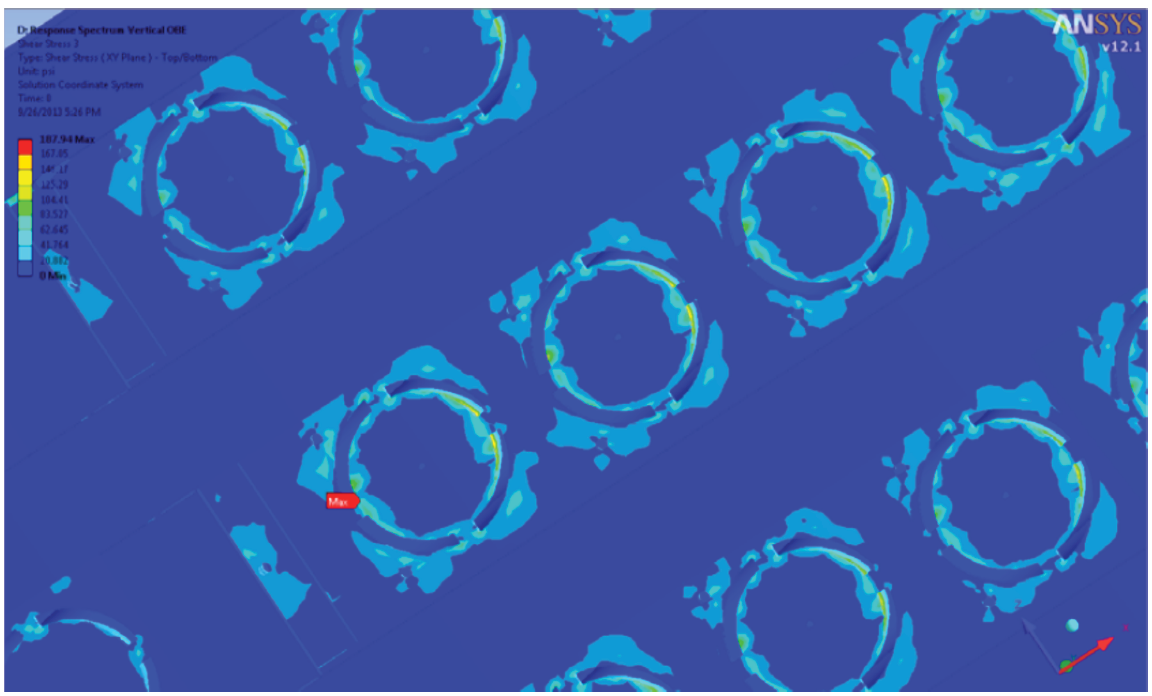


(b) Close-Up View of Peak Normal Stress at Angle between C-channel and transverse I-beam

Figure 1.6-14 Normal Stress Contour Plot for Vertical Direction (Y-Axis) OBE Response Spectrum Loading for GS-50873-GA Filter Cartridge Assembly

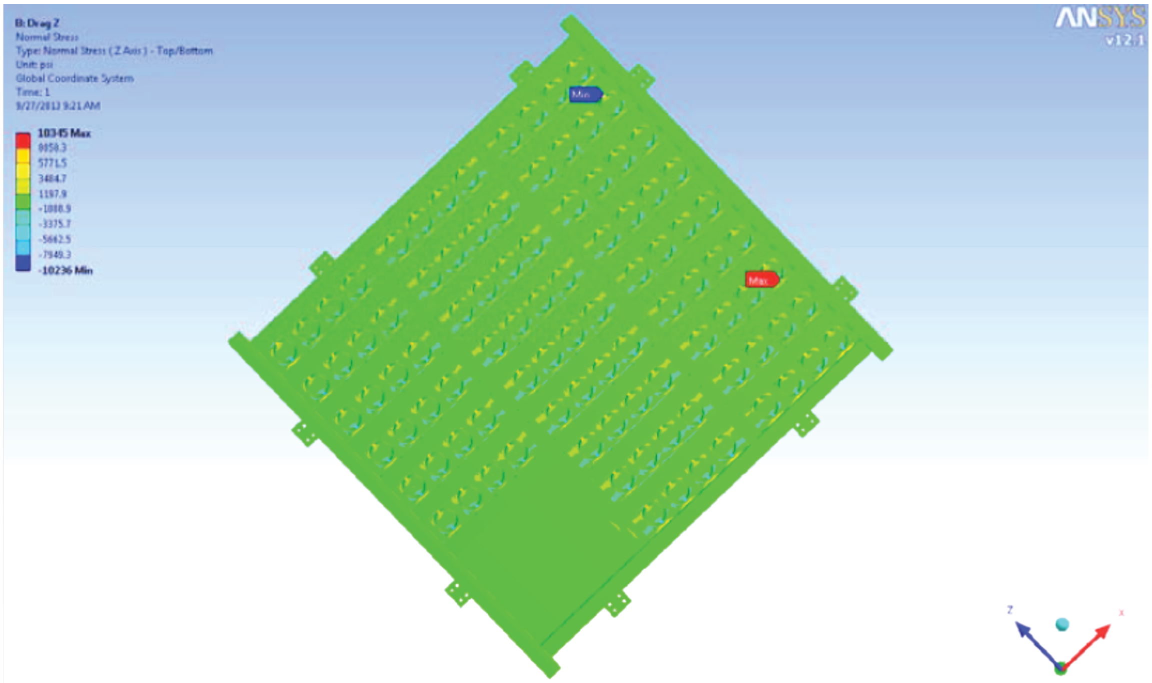


(a) Isometric View



(b) Close-Up View of Peak Shear Stress at Bottom plate weld stud location

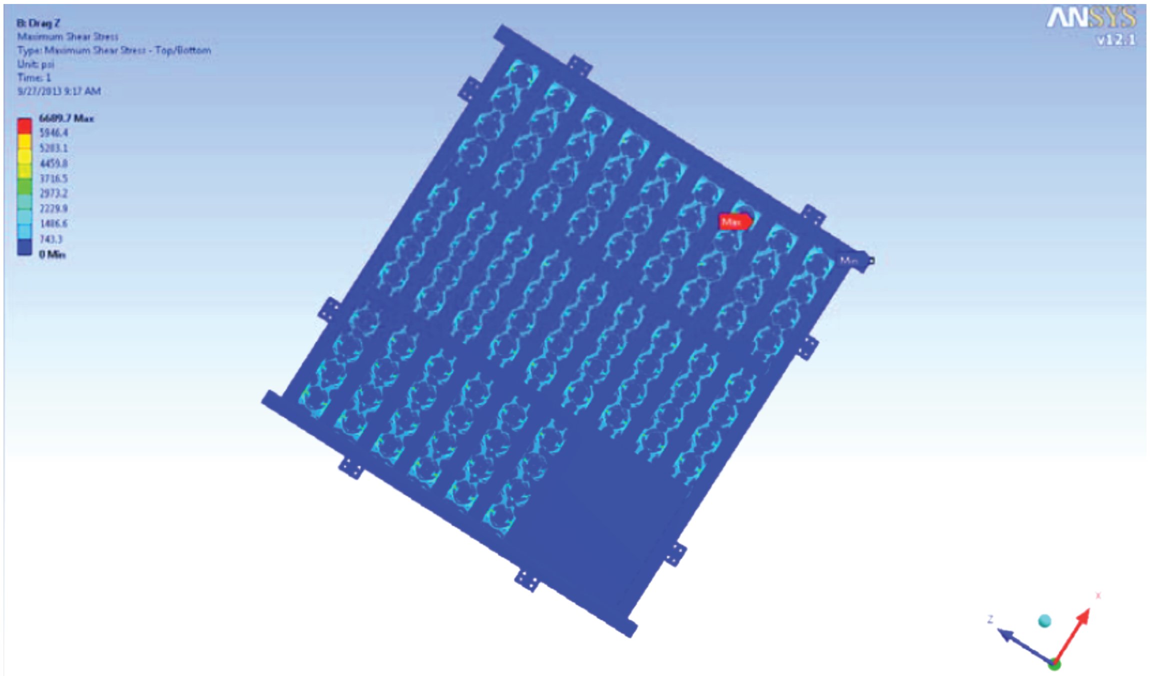
Figure 1.6-15 Shear Stress Contour Plot for Vertical Direction (Y-Axis) OBE Response Spectrum Loading for GS-50873-GA Filter Cartridge Assembly



(a) Isometric View

(b) Close-Up View of Peak Normal Stress at Bottom plate weld stud location

Figure 1.6-16 Normal Stress Contour Plot for Horizontal Direction (Z-Axis) Hydrodynamic Drag Force Loading for GS-50873-GA Filter Cartridge Assembly



(a) Isometric View

(b) Close-Up View of Peak Shear Stress at Bottom plate weld stud location

Figure 1.6-17 Shear Stress Contour Plot for Horizontal Direction (Z-Axis) Hydrodynamic Drag Force Loading for GS-50873-GA Filter Cartridge Assembly

1.7 CONCLUSIONS

Stress results from response spectrum and static structural finite element analyses for the GS-50873-GA filter cartridge assembly shows that all the components structurally meet the requirements for stress qualification per ASME Code, Section III, Division 1, Subsections NC and NF, as appropriate.

2. TRASH RACK STRUCTURAL ANALYSIS

2.1 DESCRIPTION OF TRASH RACK

The In-containment Refueling Water Storage Tank (IRWST) spillways allow accumulated water in the adjacent Holdup Volume Tank (HVT) to spill into the IRWST thereby replenishing the IRWST water volume. The spillways are adequately sized to allow the maximum flow into the HVT to be returned to the IRWST after filling. The vertical screens, which is trash rack, is provided at the entrance of the HVT to prevent debris from entering the HVT and thus the IRWST.

Following an accident, water introduced into containment drains to the HVT. Debris that may exist in containment may be transported to the HVT with this fluid. Debris greater than 101.6 mm (4 in) diameter is prevented from entering the HVT by a vertical trash rack, which is located at the entrance to the HVT (Refer to Figure 2.1-1). A trench exists at the base of this trash rack to prevent high density debris that may be swept along the floor by fluid flow toward the HVT from reaching the trash rack. The vertical orientation of the trash rack will help impede the deposition of debris buildup on the strainer surface. Particles that are smaller than the trash rack mesh will enter the HVT. The figure 2.1-1 shows the location of trash rack and the figure 2.1-2 shows the 3D view of trash rack.

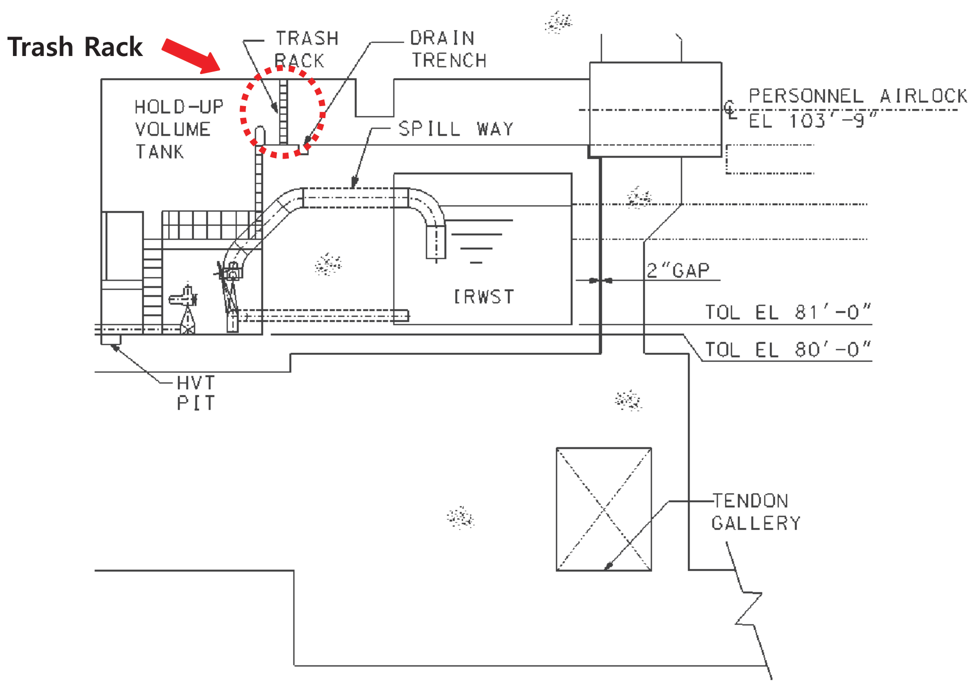


Figure 2.1-1 Trash Rack Location

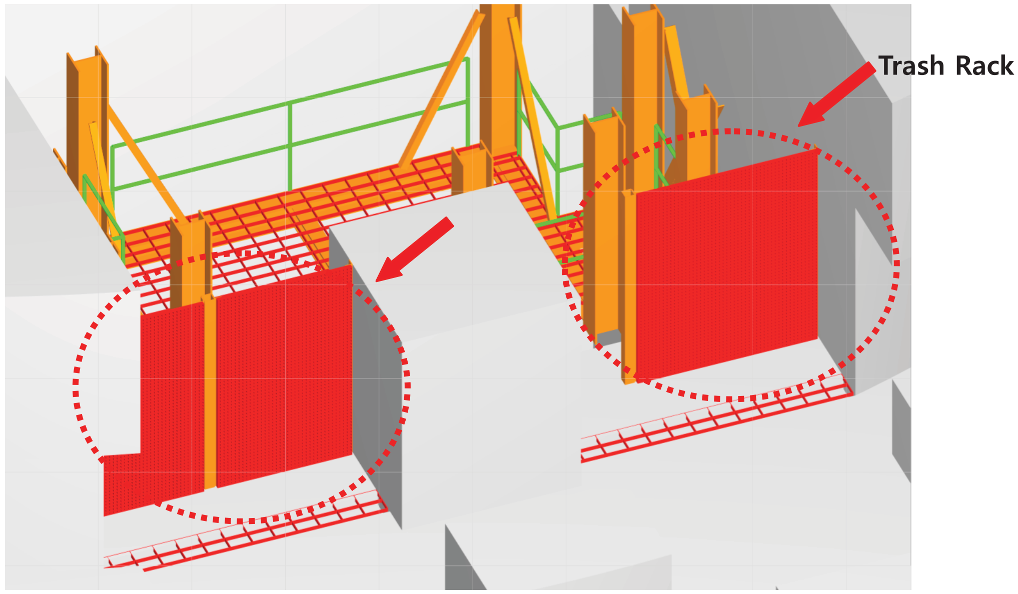


Figure 2.1-2 3D view of Trash Rack

2.2 TRASH RACK ANALYSIS

The trash rack is designed with grating mesh. The both sides of grating mesh are supported by steel and concrete structures as shown on Figure 2.1-2.

As the trash rack is designed to prevent debris larger than 101.6 mm (4 in.), water flow blockage will not happen even though the grating mesh is blocked by debris. Therefore the hydraulic-pressure load due to blockage will be negligible. But the trash rack is designed to resist the hydraulic pressure load of 2.3 m (90.5 in) water depth assuming hydraulic water pressure buildup due to grating mesh blockage. In addition, the trash rack is designed considering seismic load due to self weight excitation of grating mesh. But the seismic load is negligible since the self-weight of grating mesh is very small compared to the assumed hydraulic pressure load.

3. REFERENCES

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Appendix A

Hydrodynamic Mass Calculations

The objective of this appendix is to provide an estimate of the hydrodynamic mass of a strainer cartridge for use in the response spectrum analyses. Because the strainers must resist specific seismic accelerations, the mass of the assembly for use in the dynamic analysis must include not only the intrinsic mass of the material, but also the hydrodynamic “added mass” due to the disturbances generated in the fluid (both inside and surrounding the tubes) when the tubes are in motion in the fluid. The hydrodynamic mass is significant, and in this subject case where you have an accelerating motion, it exceeds the mass of the materials of the strainer cartridges themselves.

An unperforated circular cylinder immersed in and filled with fluid has a hydrodynamic mass equivalent to that of a volume of fluid equal to twice the volume of the cylinder. This accounts for the mass of the fluid inside the cylinder and for the “virtual inertia” of the surrounding fluid which is forced to accelerate because of the motion of the cylinder. Strictly, this value occurs in two-dimensional (2-D) flow, for example where the length of the cylinder is considerably greater than the diameter so that end effects can be considered small, or where the flow around the ends is effectively constrained by end plates.

For a perforated cylinder, however, the nature of the flow is different than for an unperforated surface. Of primary importance is the fact that fluid can flow “through” the surface of the cylinder. The fluid encounters resistance to this passage into and out of the cylinder, so the pressures acting on the body are substantially different from those generated when fluid cannot pass through the boundary at all, and consequently must stagnate at some points on the body.

It is noted here that when the displacement of the strainers is of large amplitude with respect to the surrounding fluid, the hydrodynamic mass of the perforated strainer tubes also becomes large, in fact considerably greater than the intrinsic mass of the cartridge components. By contrast, when the displacement is of small amplitude the hydrodynamic mass of the strainer tubes rapidly decreases, and in fact approaches zero. For this analysis the hydrodynamic mass calculations consider the filter tubes to be unperforated, which provide a conservative estimate for the “added” hydrodynamic mass for all components of the individual filter cartridge assembly.

The filter cartridge assembly is made up of a row of vertical concentric pairs of tubes, fabricated of perforated stainless steel sheet. Depending on the installations required to suit the geometry of various plants, cartridges of different heights are designed.

The hydrodynamic mass calculation is described below for the filter cartridge assembly GS-50873-GA. In the case of the GS-50873-GA filter cartridge assembly, it consists of four concentric tube pairs arranged in a row. The nominal diameters of outer and inner strainer tubes are 6.0 inches and 5.0 inches, respectively. The tubes are thin walled, with a sheet thickness of 0.0625 inches.

Assumptions:

1) The FEA includes the hydrodynamic “added mass” of the cartridge tubes and frame structure due to the disturbances generated in the fluid in motion, and the debris “added mass” accumulated in the cartridge.

2) The mass moment of inertia due to the fluid inside the concentric tube pairs of the filter cartridge and dead weight of the inner tubes are accounted for as an effective density increase across the inner tubes.

3) The mass moment of inertia due to the added mass and dead weight of the outer tubes are accounted for as an effective density increase across the outer tubes.

4) The added mass due to the debris is applied as an effective density increase across the 5 inch inner tube and 6 inch outer tube of each of the filter cartridge assemblies since it causes the most conservative bending moment for a lateral spectral acceleration.

5) The 'filter module' consists of cross-braces, cross-brace gussets, bottom support, bottom support outer channel, exposed cross brace arm, tie rods and sleeves.

6) The 'filter tubes' consists of the inner and outer filter tubes within the filter cartridge assembly.

7) The 'structural components' consist of the C-Channel in contact with the floor, I-beams that run longitudinally across the filter cartridge assembly and end support brackets.

Input:

Outer Diameter of Outer Filter Tube, Do [6]	6"
Outer Diameter of Inner Filter Tube [6]	5"
Shell Thickness of Outer Filter Tube [6]	0.0625"
Height of the Outer/Inner Filter Tube [6]	26.628"
Density of water at Service Level B Condition Temperature [14]	0.03429398 lb/in^3
Total Debris Mass (including coatings, latent fiber and latent particulate) [Reference 5]	533.192 lb (114.5 Kg)
Cumulative CAD Volume for all tubes within the 4 filter module	645.84 in^3
Cumulative CAD Volume for all twenty-four top plates in GS-50873-GA filter cartridge assembly	574.128 in^3

Calculations:

Inner Diameter of Inner Filter Tube (D_i)	$= (5 - 2 \times (0.0625)) = 4.875''$
Fluid Mass Inertia inside the inner tube	$= \frac{\pi}{4} \times {D_i}^2 \times H \times \rho$ $= \frac{\pi}{4} \times (4.875)^2 \times (26.628) \times (0.03429398)$ $= 17.04494 \text{lb}$
Fluid Mass Inertia inside the inner tube for one filter module	$= 17.04494 \times 4 = 68.17978 \text{ lb}$
Fluid Mass Inertia inside the annulus	$= \frac{3.1416}{4} \times (5.875^2 - 5^2) \times 26.145 \times 0.03429398$ $= 6.77908 \text{ lb}$
Fluid Mass Inertia inside the annulus for one filter module	$= 6.77908 \times 4 = 27.11632 \text{ lb}$
"Added" Hydrodynamic Mass per unit length for a cylindrical cross section [14]	$= \pi \times \rho \times {D_0}^2 \times H$ $= 3.1416 \times 0.03429398 \times (\frac{6}{2})^2 \times 26.628$ $= 25.81956 \text{ lb}$
Total Fluid Mass	$= (4 \times 25.81956) + 27.11632 + 68.17978$ $= 198.5743 \text{ lb}$
Effective Adjusted Material Density of Filter Tubes	$= 0.29 \times 0.8817 + \left(\frac{198.5743}{645.84 \times 0.29}\right) \times 0.03429398$ $+ \left(\frac{25.81956 + \left(\frac{533.192}{96}\right)}{25.81956}\right) \times (0.29 \times 0.8817)$ $+ \left(\frac{25.81956 + \left(\frac{533.192}{96}\right)}{25.81956}\right) \times 0.034294$ $= 0.6444 \text{ lbf/in}^3$
Effective Adjusted Material Density of Filter Module	$= (\rho_{steel} \times \text{Buoyancy Factor}) + \rho_{water_{ServiceLevel}D}$ $= (0.29 \times 0.8817) + 0.03429398$ $= 0.2899 \text{ lbf/in}^3$

The weight density used for 18Cr-8Ni stainless steel is 0.29 lbf/in^3. The effective material density of 0.6444 lbf/in^3 is conservatively applied to both the inner and outer filter tubes.

Table A-1: Effective Material Densities for Various Components of the GS-50873-GA Filter Cartridge Assembly

Component Designation	Effective Material Weight Density (lbf/in^3)
Filter Module	0.29
Filter Tubes	0.6444
Structural Components	0.29