

NCSX

Analysis performed on the
FPA Station 3 lift fixture for its FDR

NCSX-CALC-18-002-00

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Executive Summary:

This report summarizes the analysis performed on the Station 3 lift fixture. Hand calculations and FEA analysis of the lift fixture was performed to verify the adequacy of the design in supporting the weight of the module coil half period (MCHP) as it is maneuvered over the vacuum. A peak stress of 16.2 ksi was found at a web corner in the area where the maximum support load is introduced. Four SAE J429 Grade 8 bolts are used to attach the lift fixture to the MCHP at each of four lift fixture / MCHP interfacing surfaces. To maintain a no slip condition at the lifting fixture a bolt preload of 20,000 lbs is needed.

References:

PPPL CAD Drawing No.: NCSX-SE185-314 shts. 1 and 2

PPPL CAD Drawing No.: NCSX-SE185-315 shts. 1 thru 6

PPPL CAD Drawing No.: NCSX-SE185-316 shts. 1 thru 5

ProE/Mechanica file: stb-station3_rigging_step247.prt

Station3 stress analysis.xls

Lift Weight and load fraction Calculation

The MCHP is manipulated over the VV from the left and right side with a slight different degree of motion and different loading induced in the lift fixture. Figure 1 below shows the fraction of load carried by each sling to the lift fixture attachment points as the MCHP is moved over the VV. The worst condition occurs on the left side at the installation position designated as Step 247.

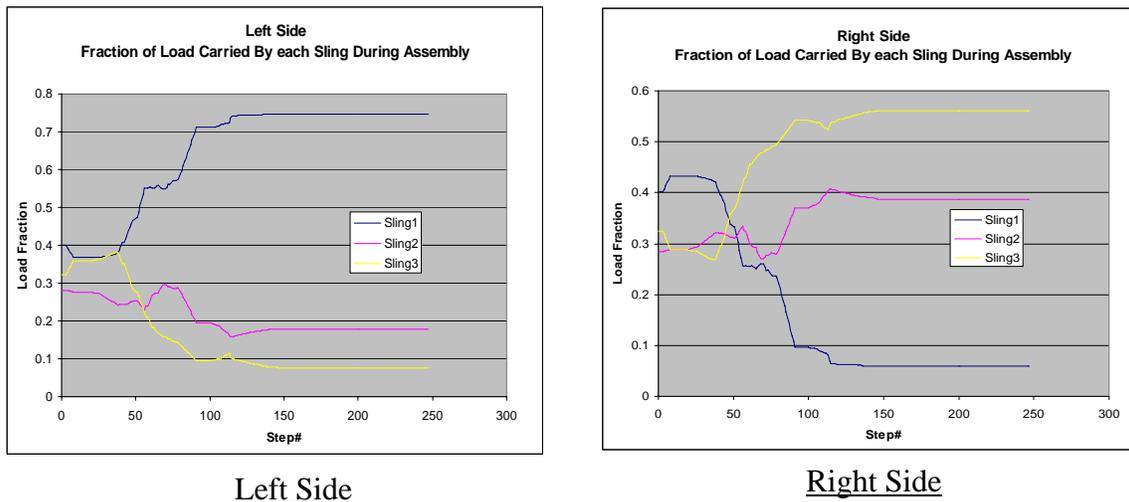


Fig 1 Fraction of load carried by each sling

The weight of the MCHP and lift fixture was based on ProE calculations of the models of each component and then adjusted upwards based on as-built weight measurements of the

Type-B modular coil. A 10% additional factor was added to account for overcasting and miscellaneous items. The tabulation shown in Figure 2 summarizes the weigh distribution among the components as well as a tabulation of the maximum lift load at each support point based on the left side installation position designated as Step 247.

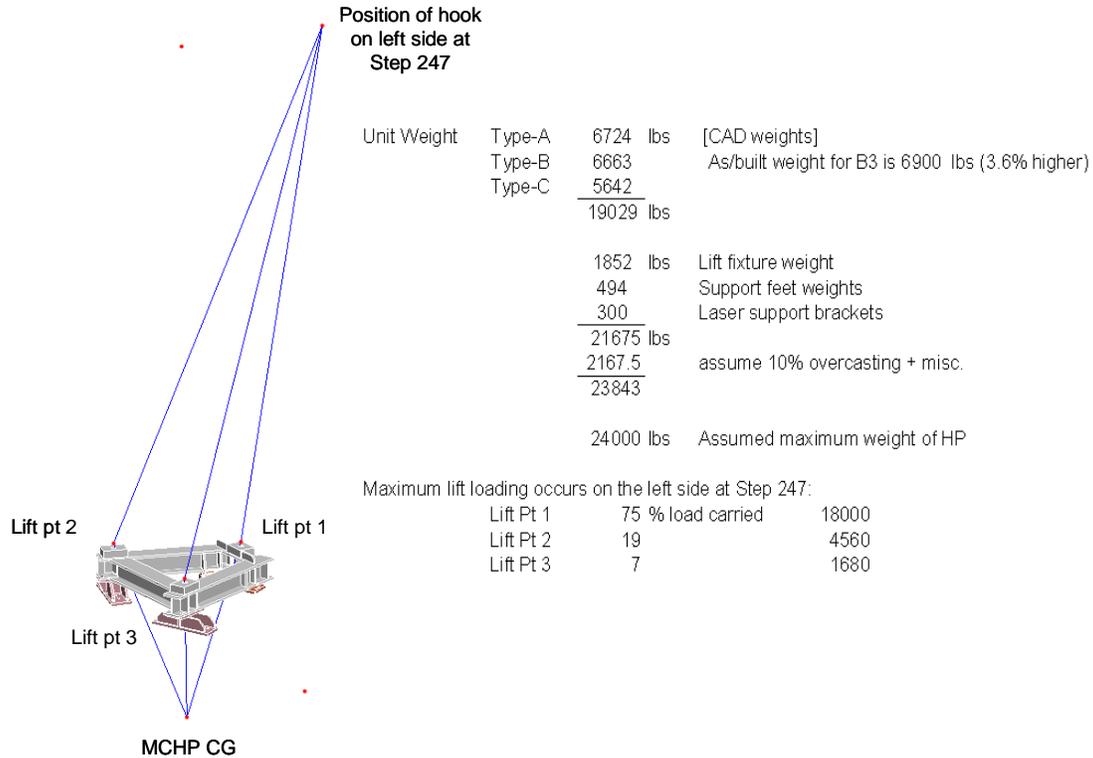


Fig 2 Weight and lift load calculations

FEA analysis of lift fitting

A linear FEA analysis was performed using ProE/Mechanica. The lift support frame was fully constrained at the bottom pads and the load was applied in the direction of the rigging support (shown in Figure 2). Step 247 loads were applied at the three lift points. The support frame is made from ASTM A36 material. ASTM minimum values for A36 structural shapes are 36 ksi yield and 58-80 ksi tensile. The allowable stress (S_m) was initially taken to be the lesser of $1/3$ ultimate or $2/3$ yield, which would be 19.3 ksi ($1/3$ ult based on 58 ksi). Mike Viola did some research and found that design factors for Design Category A lifting devices shall be not less than 2.00 for limit states of yielding or buckling and 2.40 for limit states of fracture and for connection design. This set the limit stress at 18 ksi ($1/2 F_y$); the value used in evaluating the FEA results.

Figure 3 shows the FEA analysis summary with a peak stress of 16.8 ksi in the web corner. Local stiffener plates have been added above the I-beams near the support points

to bring the stress level down below allowables. Figure 4 shows the location of the high peak stresses.

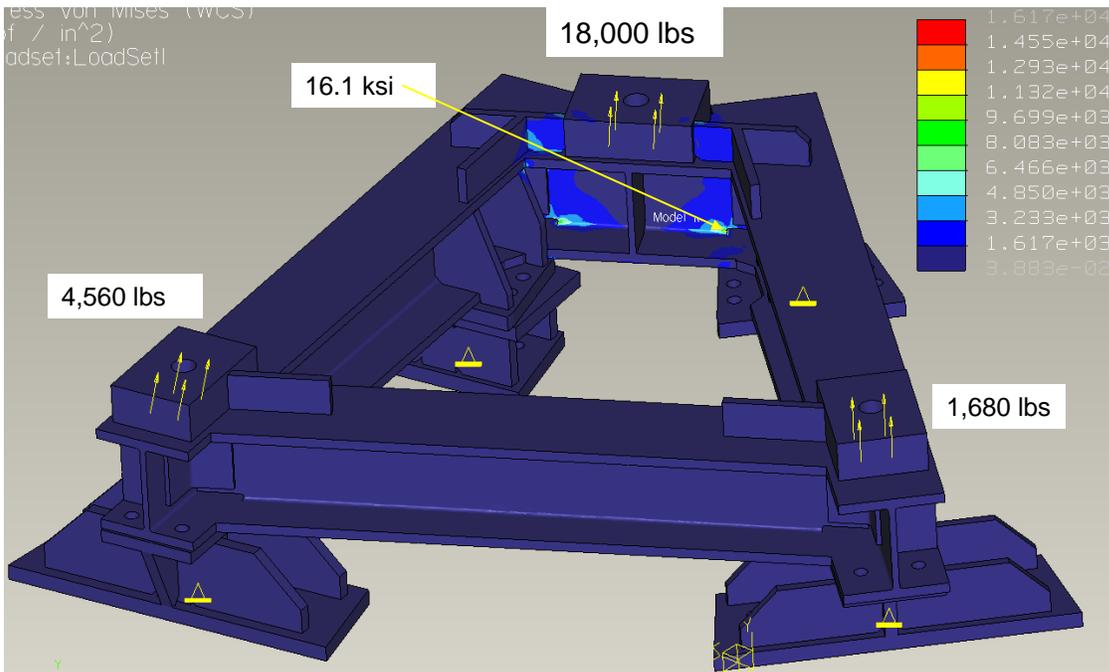


Fig 3 Support frame with the maximum condition, Step 247

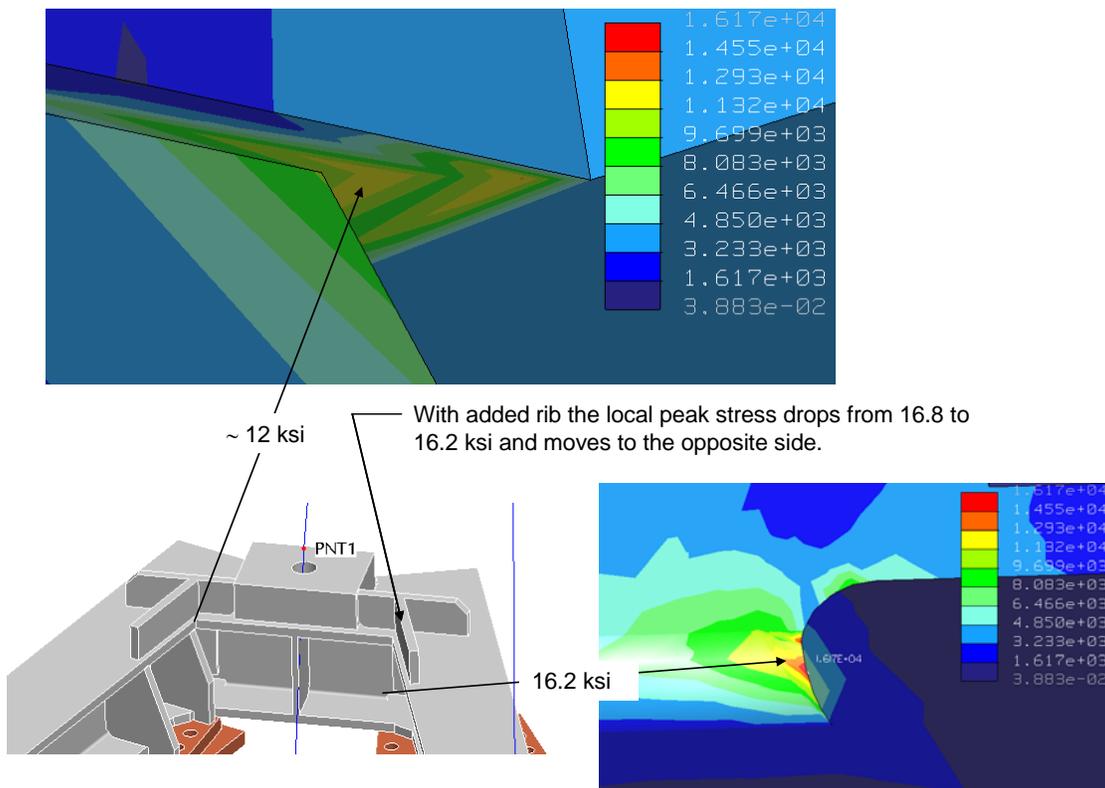


Fig 4 Details of local area peak stresses

The spreadsheet below shows the reaction loads at the support fixture four support pads that attach to the Modular Coil HP. The total loading condition is 24,000 lbs at Step 247 for the left side MCHP assembly over the VV. To limit the required coefficient of friction needed to maintain a no slip condition at the lifting fixture pad interface, a bolt preload of 20,000 lbs is needed.

Fixture Reaction Loads

1-8 bolt, SAE J429 Grade B8 Bolt $F_{tu} = 150 \text{ ksi}$
 $F_y = 130 \text{ ksi}$

Tension allowable (based on 1/3 ult) = 27,551 lbs

Support	Fx	Fy	Fz	Fxz	Fxz/Fy				
1	4209.60	-9180.40	2035.60	4675.94	-0.509				
2	641.61	-4271.40	32.14	642.41	-0.150				
3	33.27	-1365.00	356.28	357.83	-0.262				
4	317.10	-8723.40	-2950.40	2967.39	-0.340				
sum	5201.60	-23540.00	-526.41						
sum check	5201.58	-23540.20	-526.38						
Bolt	Fx	Fy (tension)	Fz	Fxz	Fxz/Fy	Bolt Load (Preload+ Applied)	Joint Load (Preload+ Applied)	Required Friction Coefficient	
1a	676.01	-3555.08	1050.47	1249.20	-0.351	20391	-16836	0.07	
1b	1545.88	-4040.62	963.11	1824.53	-0.452	20444	-16404	0.11	
1c	1025.68	-870.26	-387.63	1096.48	-1.260	20096	-19225	0.06	
1d	962.01	-714.44	403.62	1043.25	-1.460	20079	-19364	0.05	
2a	39.96	-340.48	267.93	270.89	-0.796	20037	-19697	0.01	
2b	463.13	-2399.80	436.60	636.48	-0.265	20264	-17864	0.04	
2c	160.14	-1426.98	-565.82	588.05	-0.412	20157	-18730	0.03	
2d	-21.61	-104.11	-106.57	108.74	-1.044	20011	-19907	0.01	
3a	49.86	-74.98	43.53	66.19	-0.883	20008	-19933	0.00	
3b	111.39	-891.33	322.64	341.33	-0.383	20098	-19207	0.02	
3c	-129.84	-411.31	-11.63	130.36	-0.317	20045	-19634	0.01	
3d	1.86	12.63	1.74	2.55	0.202	19999	-20011	0.00	
4a	1188.81	-4449.10	-567.72	1317.41	-0.296	20489	-16040	0.08	
4b	47.52	72.88	25.51	53.93	0.740	19992	-20065	0.00	
4c	-80.41	-274.59	-165.82	184.29	-0.671	20030	-19756	0.01	
4d	-838.81	-4072.61	-2242.38	2394.13	-0.588	20448	-16375	0.15	0.13 0.30
sum check	4209.58	-9180.41	2035.58						
	641.61	-4271.37	32.14						
	33.27	-1364.99	356.28						
	317.10	-8723.42	-2950.41						
Assumptions									
Joint Stiffness Ratio (kk): $K_b/(K_b+K_m)$						0.11	0.25	0.25	
Bolt Preload (lb): F_b						20000	22000	11000	

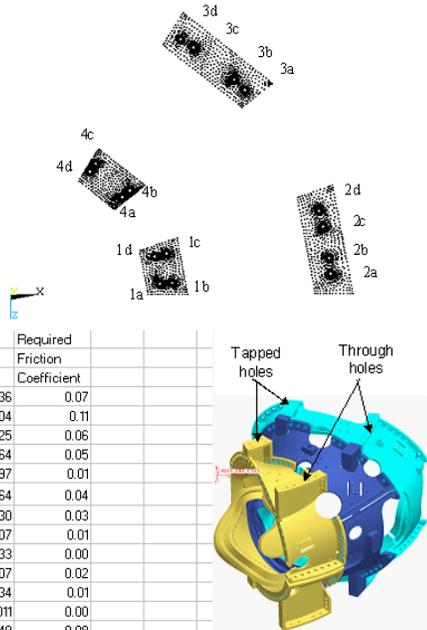


Fig 5 Reaction loads on the fixture support pads for Step 247

SAE J429 Grade 8 Bolts have been called out for the lift fixture / MCHP interface joints. SAE values for this grade bolt are 130 ksi yield and 150ksi ultimate stress. Following the design factors for Design Category A lifting devices (a design factor of 2 against yield) the maximum bolt allowable tension load would be 35,816 lbs (using a .8376" minor diameter for a 1" bolt) which is substantially above the 20,000 lb preload. Using 1/3 F_{tu} as the limit a tension allowable would be 27,551 lbs. For the condition where the bolts are inserted into 1-3/8" tapped holes in the Stellite casting, the pullout load is 45,897 lbs given the thread engagement, 34 ksi Stellite minimum .2 % yield stress and .9375 mean bolt diameter.