NCSX

Structural Design Analysis Report
Station 3 Lift Fixture

NCSX-CALC-18-003-00

May 19, 2008

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PPPL	PRINCETON PLASMA PHYSICS LABORATORY	PROCEDURE	No. ENG-033 Rev 2 Attachment 1
PPPL Calculation Form			**Page 1 of 1**

PPPL Calculation Form

Calculation # NCSX-CALC-18-003-00 Revision # __6___ WP #, if any (ENG-032) ______________

Purpose of Calculation: (Define why the calculation is being performed.)

Refer to Objective section within the attached report.

References (List any source of design information including computer program titles and revision levels.)

Refer to the Methods and References sections of the attached report.

Assumptions (Identify all assumptions made as part of this calculation.)

Refer to the Methods sections of the attached report.

Calculation (Calculation is either documented here or attached.)

Refer to the attached report.

Conclusion (Specify whether or not the purpose of the calculation was accomplished.)

Yes, the purpose was accomplished. Refer to the attached report.

Cognizant Engineer's printed name, signature, and date

____

I have reviewed this calculation and to my professional satisfaction, it is properly performed and correct.

Checker's printed name, signature, and data

Executive Summary

The station 3 lift fixture is designed adequately. The lift fixture was analyzed using finite element software providing stress distribution estimates. Simulation of station 3 field period assembly revealed maximum load conditions occurred at simulation steps 146, 115, and 146 for lift points 1, 2, and 3 respectively, with corresponding load magnitudes of 17.9, 9.7, and 12.5 kips. These load configurations were analyzed using an estimated weight of 24 kips (half period + lift fixture) along with the load fractions and vectors obtained from the assembly simulation. The highest stressed state occurs from the lift point 1 configuration, which has a maximum Von Mises stress of 13.45 ksi. Based on this result and the NCSX structural standards, the resulting lift fixture safety factor is 2.67. This is greater than the ASME guideline of 2.0. Stress levels for the remaining two configurations were insignificant resulting in safety factors of 16.6 and 15.7 for lift point configurations 2 and 3.

Record of Changes

Revision	Date	Description
0	5/19/2008	Initial Issue

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Objective

The objective of this analysis was to validate the design adequacy of the station 3 lift fixture by estimating the stress distribution and determining the design safety factors.

Background

Previous estimated weight for the half period (HP) and the lift fixture was 24 kips [1]. Updated computed aided design (CAD) models revalidated this weight [2]. Furthermore, updated simulation of station 3 field period assembly (FPA) reveals maximum load conditions occurring at simulation steps 146, 115, and 146 for lift points 1, 2, and 3 respectively [3]. The corresponding load magnitudes are 17.9, 9.7, and 12.5 kips for lift points 1, 2, and 3. Also note, proof tests are required for all in house fabricated lifting components which include the station 3 lift fixture. Safety standards require proof testing at 125% of the maximum anticipated in service load. Therefore, the required proof test loads for the lift fixture are 22.4 kips, 12.1 kips and 15.6 kips, for lift points 1, 2, and 3 respectively.

Methods

The material properties used for this analysis are listed in table1. In this analysis it was assumed that the material properties and characteristics are homogenous and uniform throughout the volume of the fixture. CAD models were created using ProEngineer (ProE) software. Finite element models (FEM) were created and linear finite element analyses (FEA) performed using Ansys Workbench (AWB) software. Simulation data, created using Fortran and ProMechanism, was obtained from Excel files [3].

ASME BTH-1-2005 *Design of Below the Hook Lifting Devices* [4] provides guidelines for lift fixture design. The design safety factor recommended is 2.0 [4]. Furthermore, ASME [4] provides the following comments for evaluation of FEA results used in conjunction with BTH-1-2005.

BTH-1-2005 is based on classical strength of material methods. These methods effectively compute average stresses acting on structural / mechanical elements. The effects of stress concentrations are not normally required for static strength of a lifter, but are most important when determining fatigue life.

Peak stresses due to discontinuities do not affect the ultimate strength of a structural element unless the material is brittle. The types of steel on which this Standard is based are all ductile materials. Thus, static strength may reasonably be computed based on average stresses.

Linear FEA will typically show peak stresses that indicate failure. This is particularly true when evaluating static strength. While the use of such methods is not prohibited, modeling of the device and interpretation of the results demands suitable expertise to assure the requirements of this standard are met without creating unnecessarily conservative limits for static strength and fatigue life.

Therefore, the NCSX structural standards [5] were used as a basis for evaluating FEA results. For A36 structural steel with yield strength 36 ksi:

Design Tresca Stress Value (S_m):

S_m equals the lesser of : *(2/3)Yield Strength* *= 24 ksi*

(1/2)Ultimate Strength *= 29 ksi.*

Stress Allowable Primary Stress + Bending Stress Condition: < $1.5S_m$ *= 36 ksi.*

Table 1. Material Properties [6].

Structural Steel	
Structural	Add/Remove Properties
Young's Modulus	2.9008e+007 psi
Poisson's Ratio	0.3
Density	0.28383 lbm/in³
Thermal Expansion	6.6667e-006 1/°F
Alternating Stress	
Strain-Life Parameters	
Tensile Yield Strength	36259 psi
Compressive Yield Strength	36259 psi
Tensile Ultimate Strength	66717 psi
Compressive Ultimate Strength	0. psi

Lift Fixture Structural Analysis

CAD models were created in ProE for the maximum load configurations for lift points 1, 2, and 3. These models were imported into AWB, converted into FEM and used for linear FEA. Refer to table 2 in the appendix for model configuration and load vector data. Figure 1 depicts the load conditions and constraint locations for lift point 1. The bottom surfaces of the hoist blocks (lift fixture-modular coil interface) were fully constrained. NOTE: these constraints were used for all FEA performed. Figure 2 represents the FEA results for the lift point 1 configuration. The maximum Von Mises stress for this configuration is 13.45 ksi. Figures 3 and 4 depict the load conditions and FEA results for the lift point 2 configuration. The resulting maximum Von Mises stress is 2166 psi. Figures 5 and 6 depict the load conditions and FEA results for the lift point 3. The maximum Von Mises stress for this configuration is 2283 psi. Based on the NCSX structural standards, discussed in the *Methods* section, the limit stress is 36 ksi. Consequently, the design safety factor for the lift point 1 configuration is 2.67. Additionally, the safety factors for configurations 2 and 3 are 16.6 and 15.7 respectively.

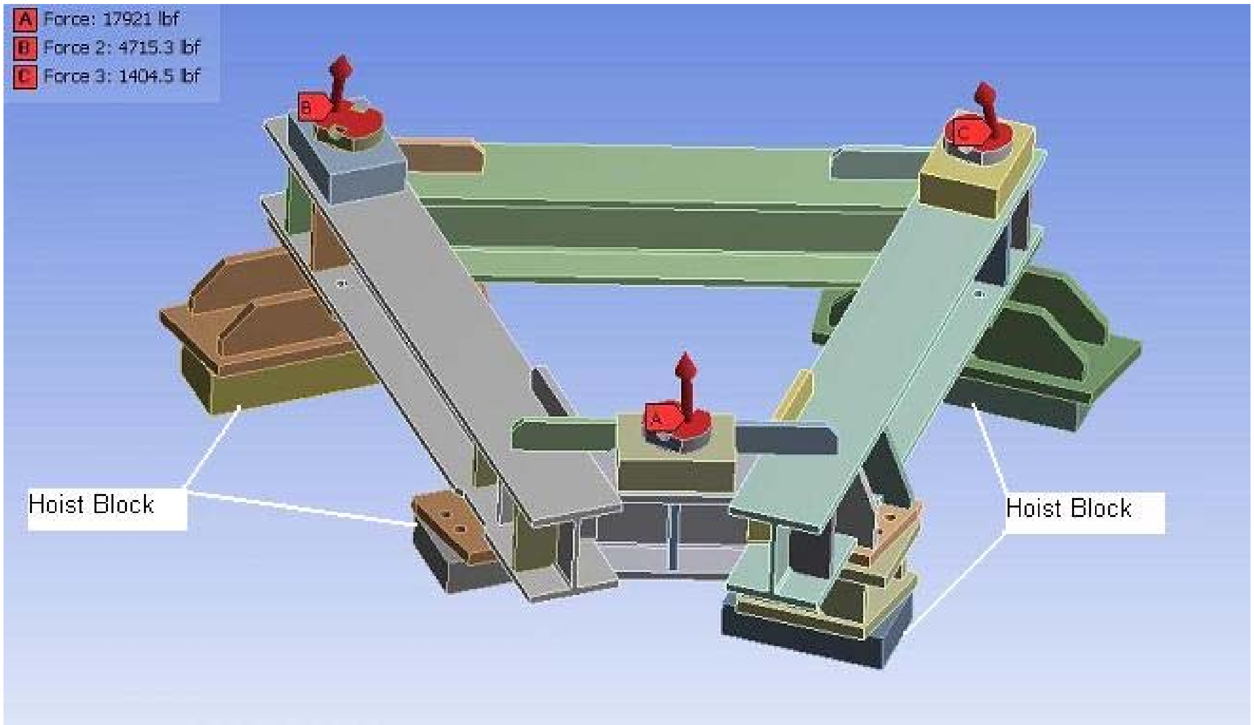

Figure 1. Station 3 Lift Point 1 Configuration: Loading.

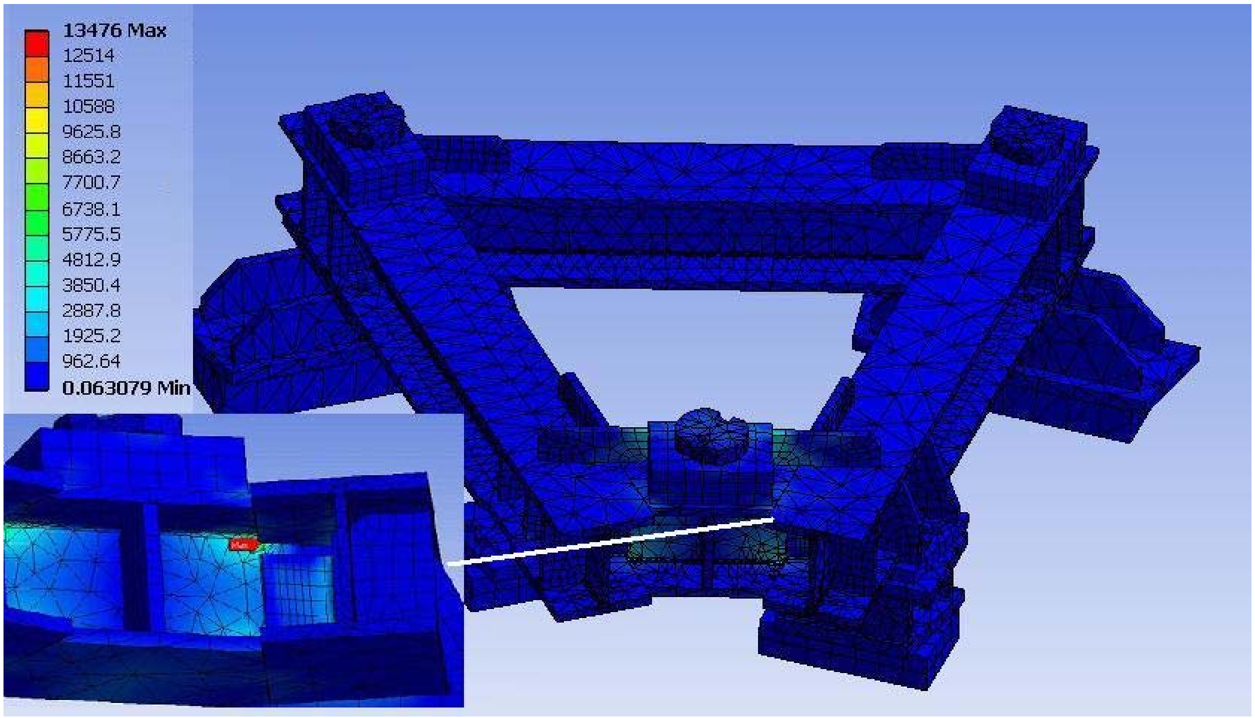

Figure 2. Station 3 Lift Point 1 Configuration: FEA Results.

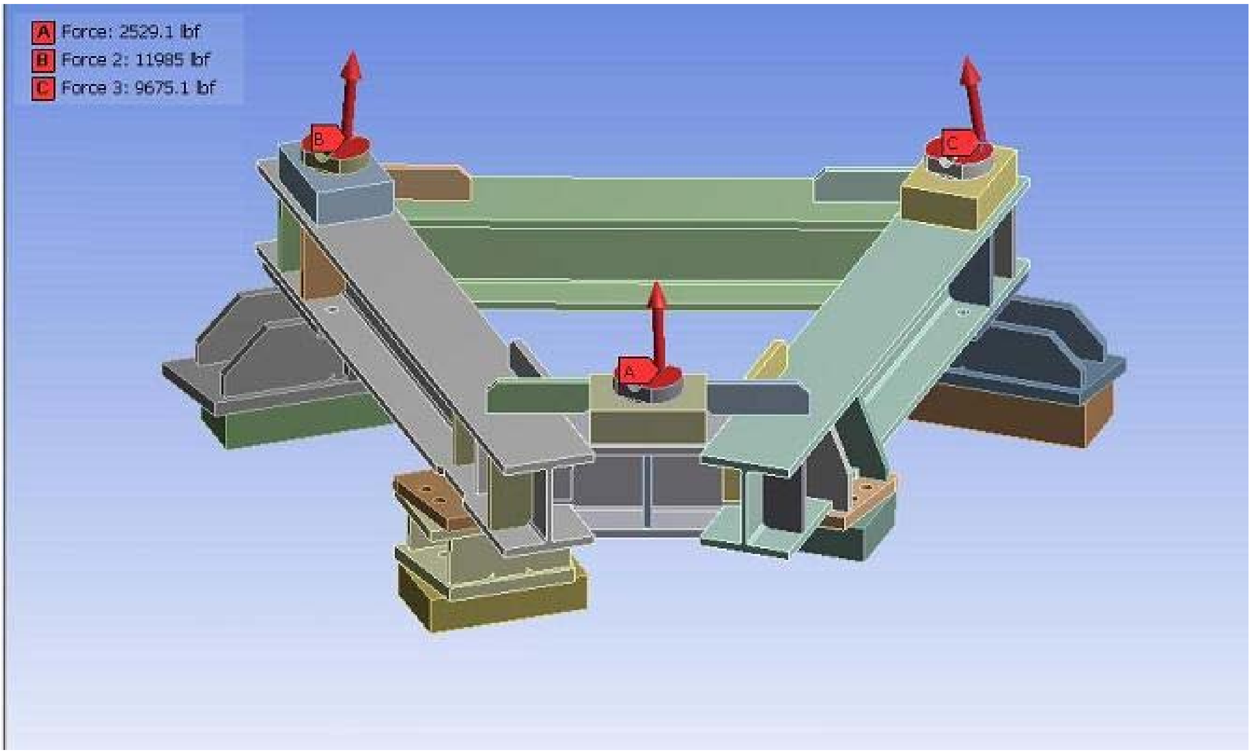

Figure 3. Station 3 Lift Point 2 Configuration: Loading.

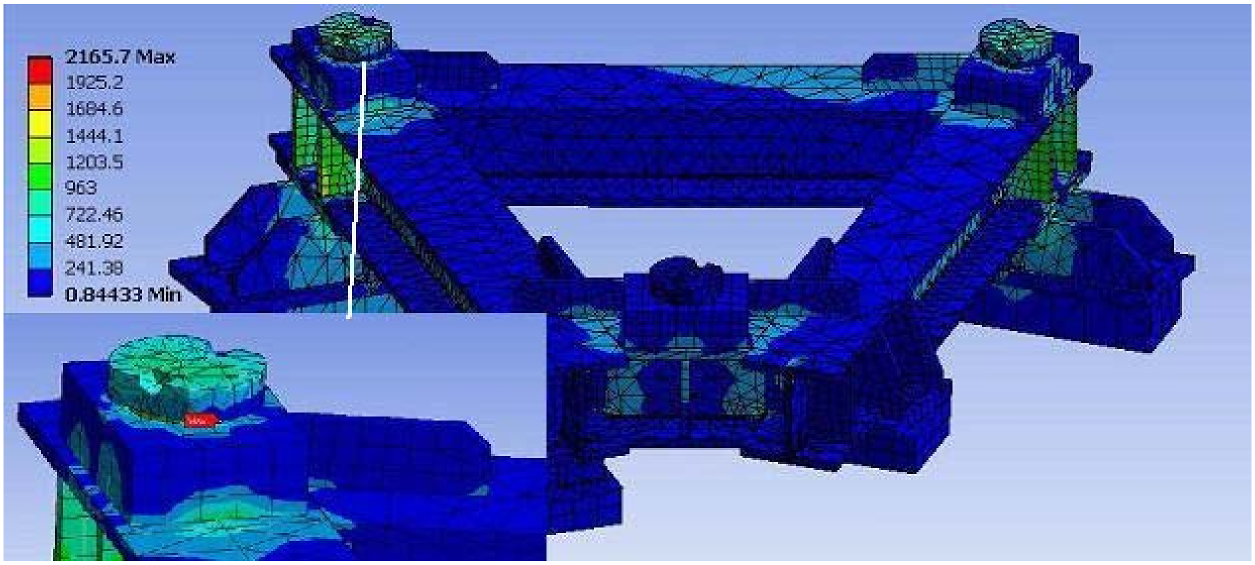

Figure 4. Station 3 Lift Point 2 Configuration: FEA Results.

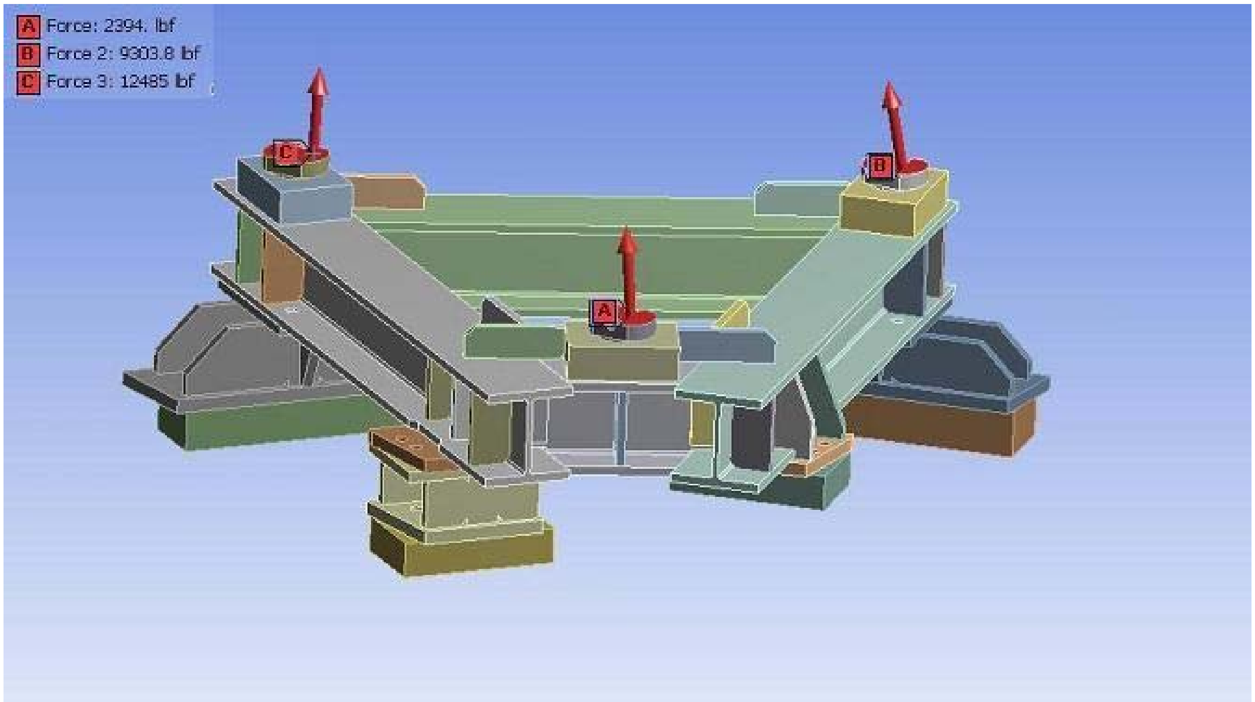

Figure 5. Station 3 Lift Point 3 Configuration: Loading.

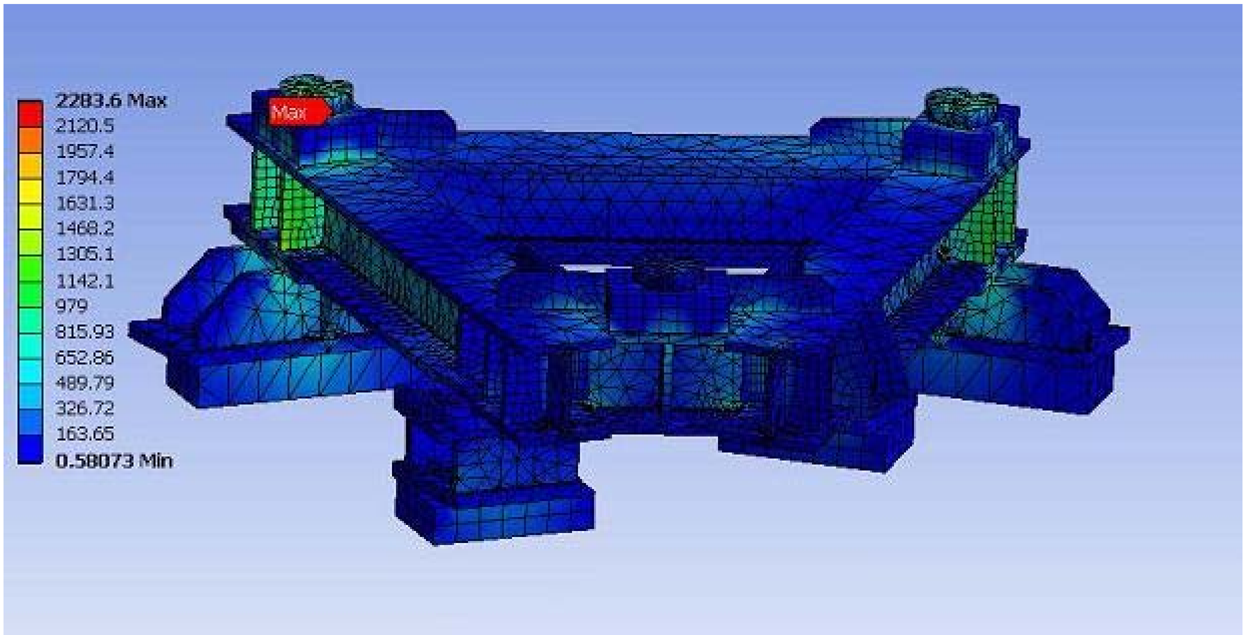

Figure 6. Station 3 Lift Point 3 Configuration: FEA Results.

Summary

Using an estimated weight of 24 kips (half period + lift fixture) along with the load fractions and vectors obtained from assembly simulations, FEA of the maximum load configuration for each lift point validates the design adequacy of the station 3 lift fixture. The highest stressed state occurs in the lift point 1 configuration, which has a maximum Von Mises stress of 13.45 ksi. Based on this result and the NCSX structural standards, the lift fixture safety factor is 2.67, above the recommended ASME safety factor of 2.0 [4]. Stress levels for the remaining two configurations were insignificant resulting in safety factors of 16.6 and 15.7 for lift point configurations 2 and 3.

References

1. Brown, T. Analysis performed on the FPA station 3 lift fixture for its FDR NCSX-CALC-18-002-00. 10 Dec. 2007.
2. Smith, M. ProEngineer filename: ms-se140-003.asm Rep: Hpa_weight.
3. Brooks, A. Excel Files: trace07_path5tom3r14r.xls, trace07_path5tom3r14r.xls.
4. ASME. BTH-1-2205 Design of Below the Hook Lifting Devices. 2006.
5. Zatz, I. J., NCSX Structural Design Criteria NCSX-CRIT-CRYO-00. 2004.
6. Ansys Workbench Material.

Appendix

Table 2. Lift Point Configuration & Load Vectors.

Maximum Loading at Lift Point 1

LEFT Side Simulation at Step 146

	Location						Unit Direction Vectors		
	X	Y	Z	dx	dy	dz	ex	ey	ez
Pt 1	9.9286	-51.603	86.6358	10.7467	-4.8438	220.989	0.04856	-0.0219	0.99858
Pt 2	60.2636	-61.477	79.1693	-39.588	5.0301	228.456	-0.1707	0.02169	0.98508
Pt 3	22.9299	-100.22	76.4361	-2.2546	43.7693	231.189	-0.0096	0.18601	0.9825
Hook	20.6753	-56.447	307.625						

	Load Conditions		Load Vectors		
	Load %	Load	Fx	Fy	Fz
Pt 1	74.7%	17921	870	-392	17896
Pt 2	19.6%	4716	-805	102	4645
Pt 3	5.9%	1405	-13	261	1380

Maximum Loading at Lift Point 2

RIGHT Side Simulation at Step 115

	Location						Unit Direction Vectors		
	X	Y	Z	dx	dy	dz	ex	ey	ez
Pt 1	-0.7347	19.2754	51.5806	21.41	-75.722	256.044	0.07993	-0.2827	0.95588
Pt 2	49.5189	29.3489	59.3241	-28.844	-85.795	248.301	-0.1091	-0.3246	0.93952
Pt 3	12.0923	68.0484	61.2221	8.583	-124.49	246.403	0.03108	-0.4507	0.89211
Hook	25.7494	47.6952	285.625						

	Load Conditions		Load Vectors		
	Load %	Load	Fx	Fy	Fz
Pt 1	10.5%	2529	202	-715	2418
Pt 2	40.3%	9675	-1056	-3141	9090
Pt 3	49.9%	11984	372	-5402	10691

Maximum Loading at Lift Point 3

RIGHT Side Simulation at Step 146

	Location						Unit Direction Vectors		
	X	Y	Z	dx	dy	dz	ex	ey	ez
Pt 1	-5.3884	27.2872	48.7784	26.0637	-83.734	258.847	0.09537	-0.3064	0.94712
Pt 2	44.9466	37.1611	56.2449	-24.271	-93.608	251.38	-0.0901	-0.3475	0.93332
Pt 3	7.6129	75.9003	58.9782	13.0624	-132.35	248.647	0.04632	-0.4694	0.8818
Hook	20.6753	56.4465	285.625						

	Load Conditions		Load Vectors		
	Load %	Load	Fx	Fy	Fz
Pt 1	10.0%	2393	228	-733	2267
Pt 2	38.8%	9304	-838	-3233	8683
Pt 3	52.0%	12485	578	-5860	11009