Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-283 Date: 26 October 2010

Project Internal Reference:

Project: NOvA FHEP

Title: NOvA FHEP Lifting Fixture ID number 178

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Reviewer(s): Ingrid Fang 11-03-2010

Key Words: NOvA, FHEP, Below-the-hook lifting device

Abstract Summary: Calculations to show conformance with ASME B30.20 for lifting fixtures used to move the upper frame of the NOvA FHEP.

Applicable Codes: ASME B30.20

Givens:

FHEP Detector weight	50,500 pounds
FHEP Table and Pallet weight	26,850 pounds
Number of Lift Points	1
Design Load per lift pt.	77,350 pounds
Test Weight = Load =	~78,000 pounds.

5022TA

BELOW-THE-HOOK LIFTING DEVICE

Engineering Note Cover Page

Lifting Device Numbers:

FNAL Site No/ _____ Div. Specific No. 178 Asset No. _____

If applicable — If applicable — If applicable

ASME B30.20 Group: (check one)

[X] Group I Structural and Mechanical Lifting Devices
[ ] Group II Vacuum Lifting Devices
[ ] Group III Magnets, Close Proximity Operated
[ ] Group IV Magnets, Remote Operated

Device Name or Description NOvA-FHEP LIFTING FIXTURE

Device was (check all applicable)

[ ] Purchased from a Commercial Lifting Device Manufacturer. Mfg Name _____
[ ] Designed and Built at Fermilab
[X] Designed by Fermilab and Built by a Vendor. Assy drawing number 3929.000-MC-466741
[ ] Provided by a User or other Laboratory
[ ] Other: Describe _____

Engineering Note Prepared by Dave Pushka Date 26 October 2010

Engineering Note Reviewed by _____ Date _____

Lifting Device Data:

Capacity 80,000 pounds

Fixture Weight 6800 pounds

Service: [X] normal [ ] heavy [ ] severe
(refer to B30.20 for definitions)

Duty Cycle __n/ a_____ 8, 16 or 24 hour rating (applicable to groups III, and IV)

Inspections Frequency Before each use

Rated Load Test by FNAL (if applicable) Date 03/11/11 Load ~~80,000~~ 94,000 pounds

[ ] Check if Load Test was by Vendor and attach the certificate

Satisfactory Load Test Witnessed by: JOHN VOIRIN John Voirin

Signature (of Load Test Witness) DAVE PUSHKA Dave Pushka

Notes or Special Information:

Discussion:

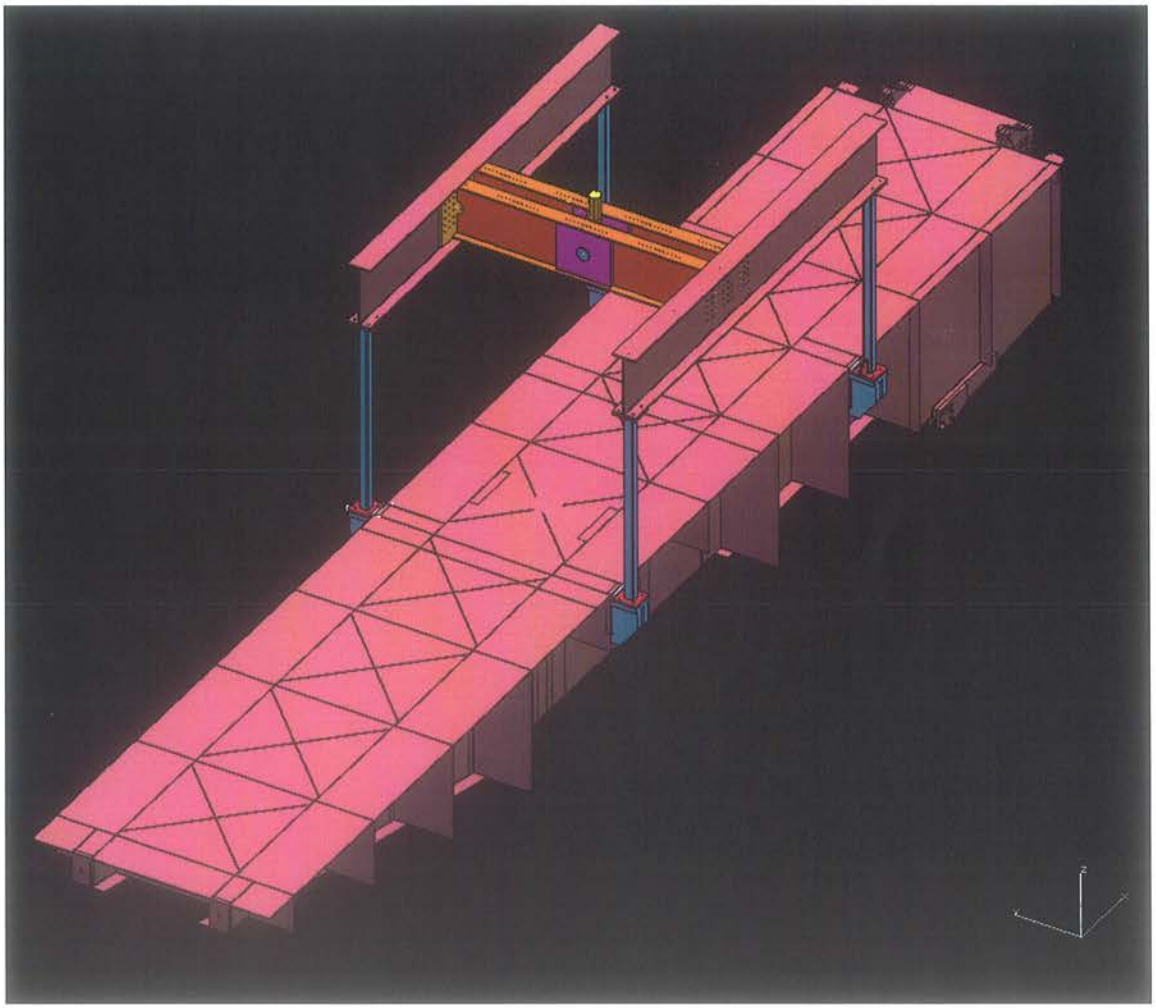

Image 1, Solid Model of the FHEP_LIFT_FIX_ASSY_1

Image 1 shows a solid model of the lifting fixture attached to the FHEP table without the FHEP detector in place.

The CDF crane hook, shown in yellow, is just barely visible in the center of the fixture.

The orange wide flange beams (perpendicular to the long axis of the table) are described in the calculations as cross beams.

The brown wide flange beams (which are parallel to the long axis of the table are described in the calculation as transverse beams.

The yellow plates shown between the orange and brown beams are called end plates in the calculations.

The blue vertical members are described as vertical members in the calculations.

Connections to the table (from the lower end of the vertical members) are made using a weldment called FHEP_LIFT_FIX_SPACER. This member spaces the vertical columns far enough apart that the FHEP detector (which is wider than the table is) fits between the vertical supports.

Because this part is geometrically complicated, FEA using Ideas was performed to calculate the stresses.

The rear vertical members see a larger load due to the location of the center of gravity of the combined table, FHEP and pallet with respect to the table lifting lug locations. The maximum vertical loading is 23,800 pounds and is calculated in the hand calculations below.

In the FEA, the vertical load applied to the top holes. Vertical displacement ("z" direction) restraints are placed at the inner diameter of the 2 inch hole and on the horizontal shelf. The 2 inch bolt restrains motion in the "y" (horizontal) direction and the horizontal ledge preventing vertical translation.

FEA Results of the Table Adapter (FHEP_LIFT_FIX_SPACER) follow on the next page:

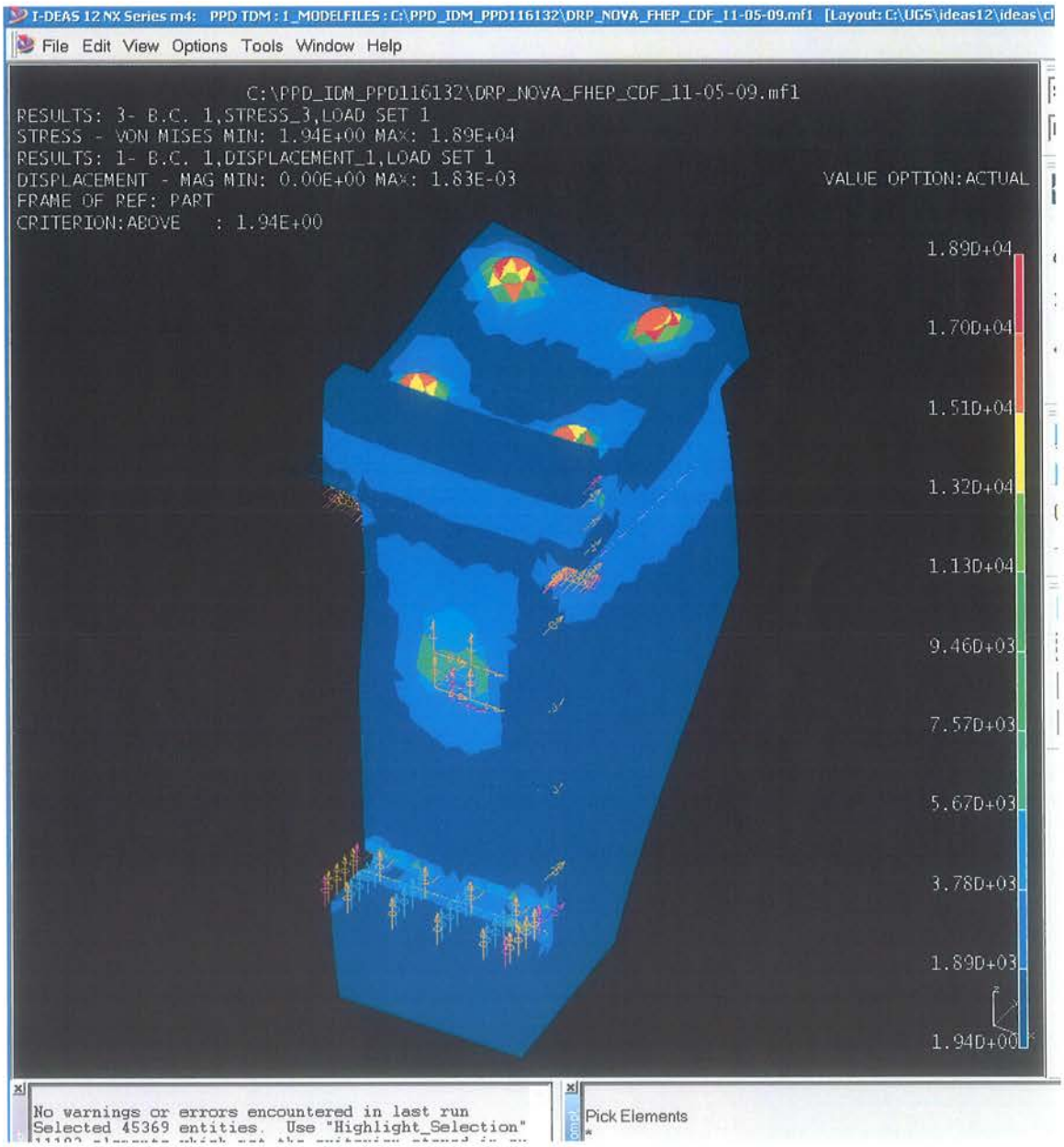

Image 2, Side View of the Table Adapter (Spacer Weldment).

Bulk of the material is stressed at less than 12,000 psi. Therefore, A36 material is acceptable.

Peak stress, which is a local stress is 18,900 psi and occurs in the local vicinity of the bolt holes.

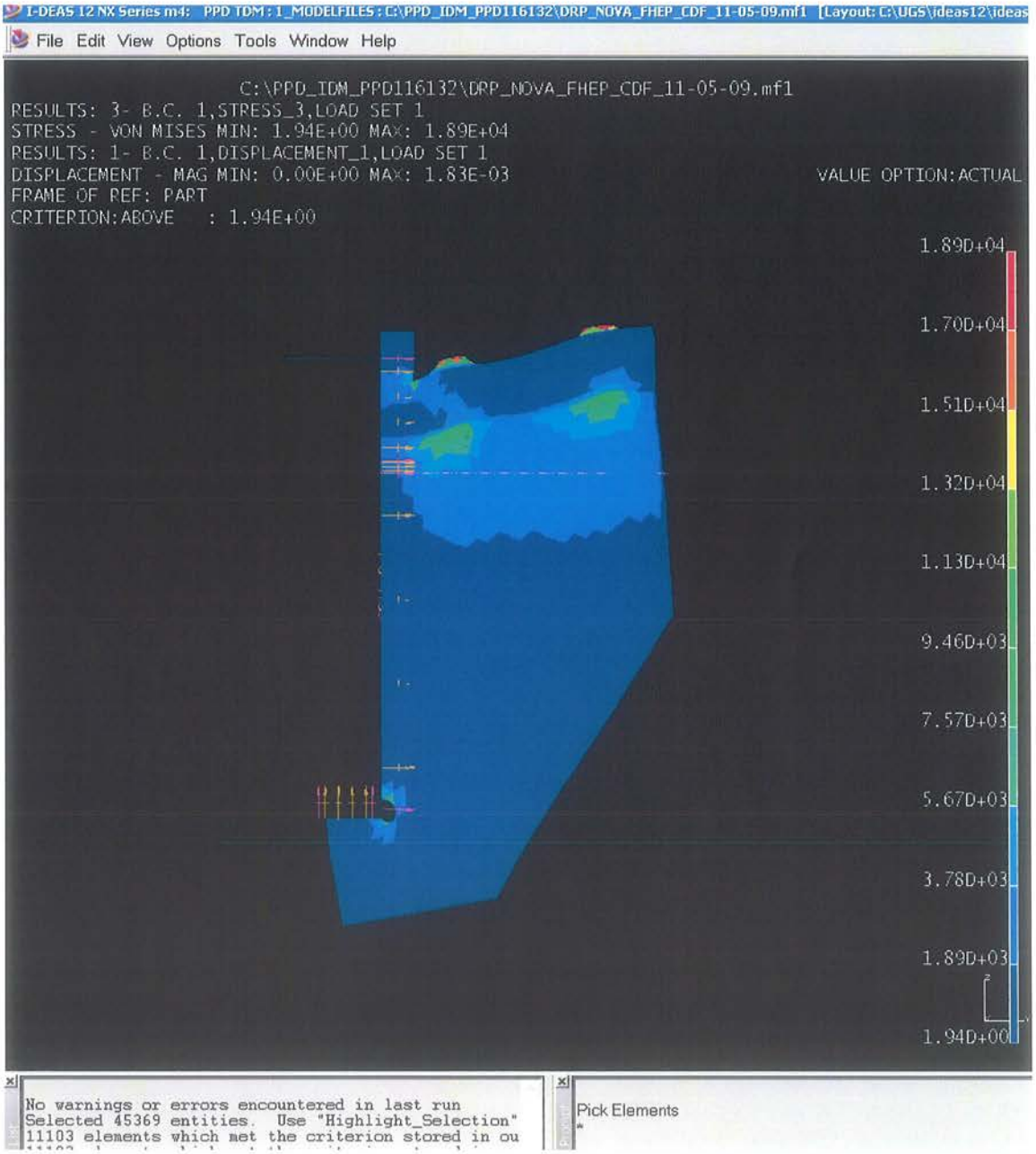

Image 3. Same results as shown in Image 2, but viewed from the side

Hand Calculations for the remaining parts of the lifting fixture follow on the next page:

FHEP Lifting Fixture

Load (See drawing 466566):		
Weight of Table	24,000	pounds
Weight of FHEP Plastic	50,500	pounds
Weight of Pallet	2,850	pounds
Sum of Table and FHEP Plastic	77,350	pounds
Design Capacity	50	tons
Design Capacity	100,000	pounds
Width of FHEP Table	104	inches
Distance between 2" hard point holes in FHEP Table	175.25	inches
Crane Hook Pin Sizing:		
Pin Span	8.57	inches
Pin Diameter	5.5	inches
Shear Area = pi() *(D/2)^4	24	square in
Shear Stress, Tau = P/A	4,209	psi
Moment of Inertia for bending	14	in^4
Modulus, S = pi()*d^3/32	16	in^3
Bending Moment, M = P*L/4	214,250	in-pounds
Bending Stress, Sigma = M/S	13,117	psi
Pin Material:	4,140	
Pin Yield Stress	62,000	psi
ASME B30.20 Allowable stress @ 1/3 Fy	20,667	psi
Allowable stress exceeds actual stress, Therefore, Okay		
Cross Beam (W24 by 62) Sizing:		
Use two sections of A36 material		
Load, P, for each section of beam is:	50,000	pounds
Allowable Bending Stress = 0.33 Fy	11,880	psi
Find Minimum "S" Value for simple beam:		
Maximum Moment = P*L/4		
L = Cross Span	112	inches
PL/4 =	1,400,000	in-pounds
Bending Stress, Sigma = M/S		
Maximum allowable bending stress, Sigma =	11,880	psi
Therefore, Minimum S value = M/ S	118	in^3
Select a W24 by 62		
Available S for a W24 by 62 is	131	in^3
Moment of Inertial for above section	1,550	in^4
Half the depth, y	11.87	in
Bending Stress, for W24 by 62, Sigma = My/I	10,721	psi
Allowable Bending Stress > Actual bending stress, therefore, Okay.		

Weld between W24 by 62 and End Plates:

Connection takes only shear.

Assume single side weld (weld between beam web and plate only the side of the beam that is accessible)

Design weld for a shear of:	25,000	pounds
Length of weld is beam depth less cut out, less 2 * k dimension from AISC		
Beam depth	23.74	inches
Cut out (clearance hole for bolt line)	6	inches
k dimension (from AISC W shape properties)	1.375	inches
Length of weld, L :	15	inches
Allowable shear (Fv) is 1/3 Fy per ASME B30.20		
Allowable shear stress, Fv :	23,333	psi
Assume fillet weld where P = A * Fv		
Area = P/ Fv	1.0714	inches^2
Area = 0.707* w * L		
Leg length, w = A / (0.707 * L)	0.1011	inches

Therefore, the minimum weld size is a 0.11 inch fillet

End Plate is 1" thick material, A-36

Actual specified fillet weld leg width is 5/16 inch to match minimum fillet weld size for this material thickness

Therefore, the minimum weld size exceeds the provided, therefore, Okay.

Bolting from W24 by 62 Beam End Plates to the Side Plate

Design load at each end of the beam:	50,000	pounds
Bolt size:	0.750	Inch
Bolt type (specification)	A-325	
Bolt loading: Single Shear in a standard 1/16 oversized hole		
Assume threads are in the shear plane		
AISC allowable shear for above conditions:	9,300	pounds
Number of bolts required:	5	
Number of bolt holes provided in the design	11	

Number of bolts exceed the required, therefore, okay.

Transverse Beam Sizing:

Use one section of A36 material on each side of fixture		
Load, P, for each section of beam is:	50,000	pounds
Allowable Bending Stress = 0.33 Fy	11,880	psi
Transverse Beam Span, L	174.25	inches
Beam Diagram is Case 8 in AISC 9th, page 2-298		
Dimension "a"	72	inches
Dimension "b"	102	inches
Maximum Moment, M = P*a*b/L	2,112,482	inch-pour
Find Minimum "S" Value for simple beam:		
Bending Stress, Sigma = M/S		
Maximum allowable bending stress, Sigma =	11,880	psi
Therefore, Minimum S value = M/ S	178	in^3
Select a W27 by 84		
Available S for a W27 by 84 is	131	in^3
Moment of Inertial for above section	2,850	in^4
Half the depth, y	13.36	in
Bending Stress, for W24 by 62, Sigma = My/I	9,899	psi

Allowable Bending Stress > Actual bending stress, therefore, Okay.

Vertical Member Sizing:

Use A500 box section, Fy = 46,000 psi		
Allowable stress from ASME B30.20 = 0.33Fy	15,333	psi
Maximum Load on any one vertical member, P =	23,770	pounds
Required Tensile Area based on allowable stress, A	1.550	in^2
Choose a 4 by 4 by 1/2 wall tube, Tensile Area, A =	6.360	in^2
Maximum actual Tensile Stress in Vertical Member, Sigma =	3,737	psi

Allowable Tensile Stress > Maximum Actual tensile stress, therefore, Okay.

Vertical Member Attachment Bolting Sizing:

Use four bolts in tension at top and bottom of member		
Number of bolts in tension	4	
Bolt Size,	0.750	inch
Bolt specification (ASTM Designation)	A325	
AISC Allowable tensile load per bolt for this spec and size:	19,400	pounds
Maximum load on all four bolts:	23,770	pounds
Actual load on each bolt assuming uniformly shared loading	5,942	pounds

Allowable Tensile Stress on bolt > Actual tensile stress on bolt, therefore, Okay.

Vertical Member to End Plate Weld Sizing:

Maximum Load on any one vertical member, P =	23,770	pounds
Use E70XX weld rod, Fy =	70,000	psi
Per ASME, allowable stress = Fy/3, = F allow =	23,333	psi
Assume weld encircles the tube, length, L = 4 * 4in =	16	inches
Assume fillet weld with P = A x F allow		
Fillet weld area, A = 0.707 * w * L (where w = weld leg length)		
Find minimum required weld leg length, w =	0.0901	inches
Use an actual weld leg length of 5/16 inch to match minimum fillet weld size based on the end plate thickness		
Weld capacity for a 5/16 inch fillet, all the way around =	81,823	pounds

Actual Weld Capacity > Maximum Load on Weld, therefore, Okay.

Vertical Member to Table Adapter Sizing:

A "Chair" shaped weldment is used to connect the bottom of the vertical columns to the table.

FEA is used to show the bulk material stresses are less than the allowable

Bolt from Table Adapter to Table Sizing:

Holes on the table a 2"-4.5 tapped holes

Yield strength on 2" dia. A449 bolts in single shear is:	58,000	psi
Number of connections to table:	4	
Load of table, pallet and FHEP	77,471	pounds
Distance from rear connection to c.g.	68	inches
Distance from rear connection front conn.	176	inches
Distance from front connection to c.g.	108	inches
Load on rear connections (both sides)	47,539	pounds
Load on one rear connection bolt	23,770	pounds
Load on one front connection bolt	14,966	pounds
Allowable stress on A449 bolts per ASME B30.20 = 1/3Fy	19,333	psi
Minor Diameter of 2-4.5 bolts	1.727	inches
Allowable Load = Allow stress * area	45,309	pounds

Actual Load on 2 inch bolt is less than the allowable load, Therefore, Okay

Component Weights:		
Table Adapter (FHEP_LIFT_FIX_SPACER) weight per unit	183	pounds
Number of units	4	
Vertical Members (FHEP_LIFTOFIX_COL_WELDMENT_1)	147	pounds
Number of units	4	
Transverse Beams (W27 by 84)	1,260	pounds
Number of units	2	
Cross Beams (W24 by 62)	558	
Number of units	2	pounds
Cross Beam End Plates	204	
Number of units	2	
Pin Reinforcement Plates	327	
Number of units	4	
Pin	121	pounds
Number of units	1	
Total Weights (Sum of the wt/unit*# units)	6,792	pounds

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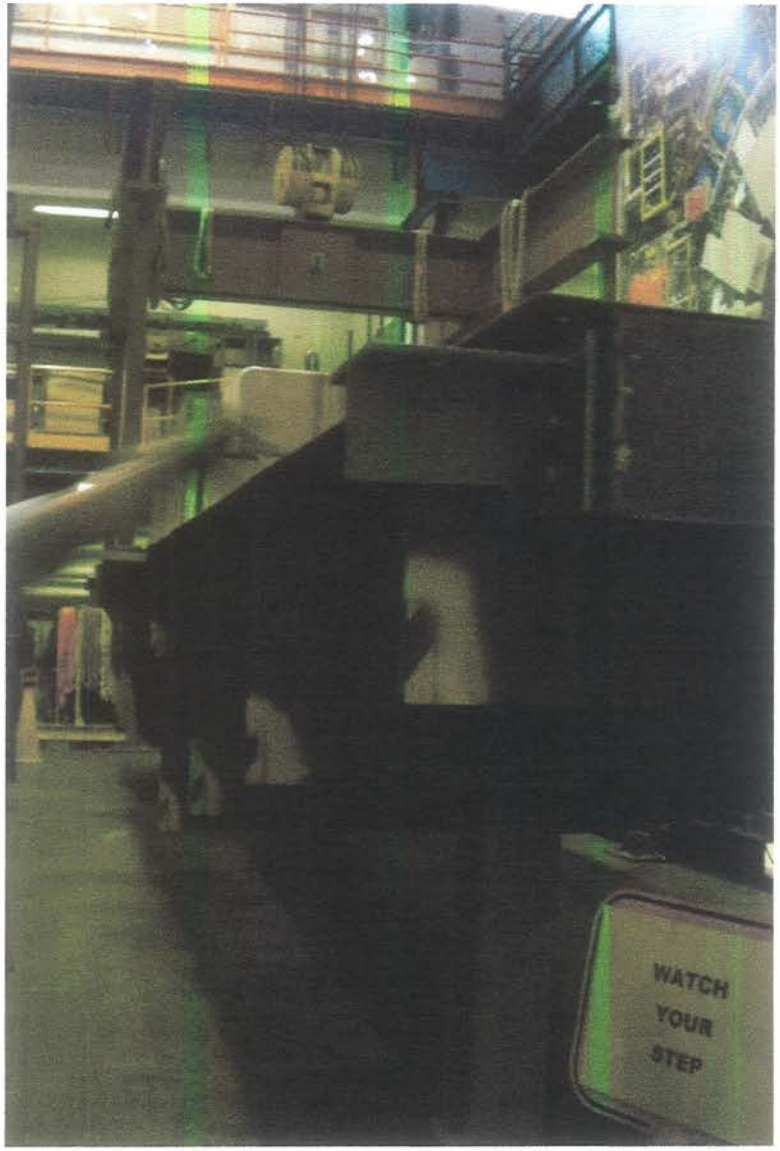
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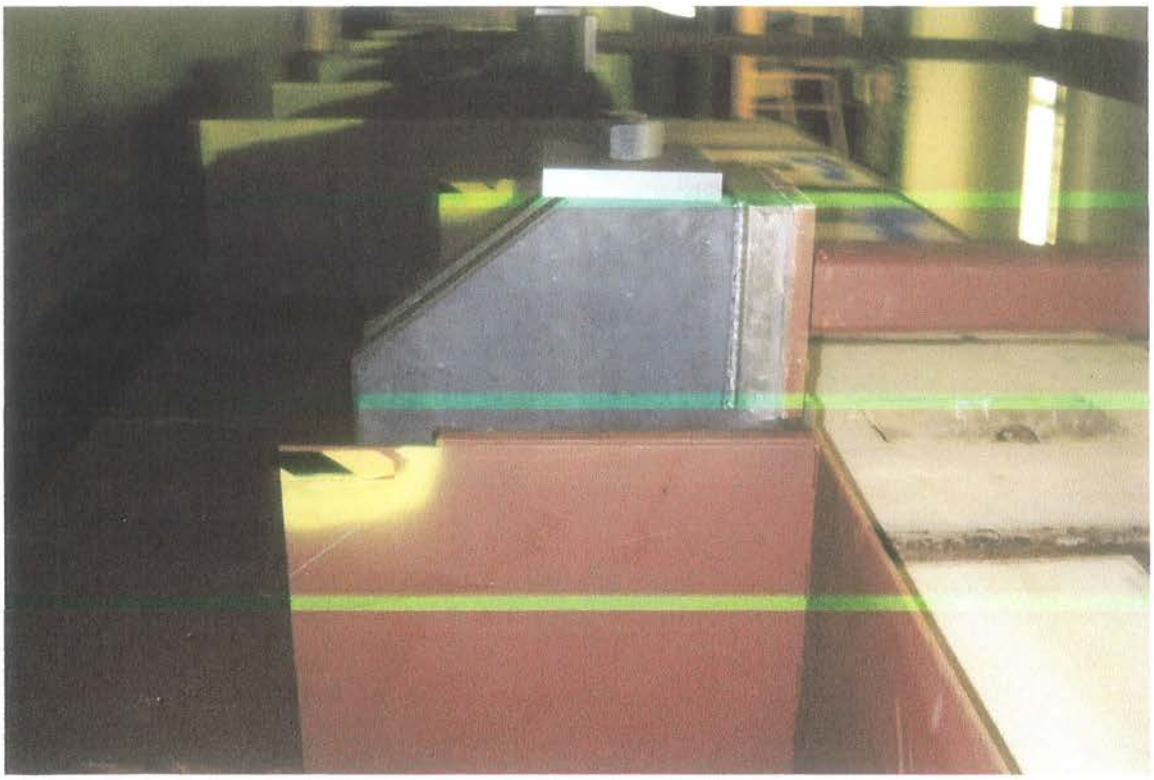

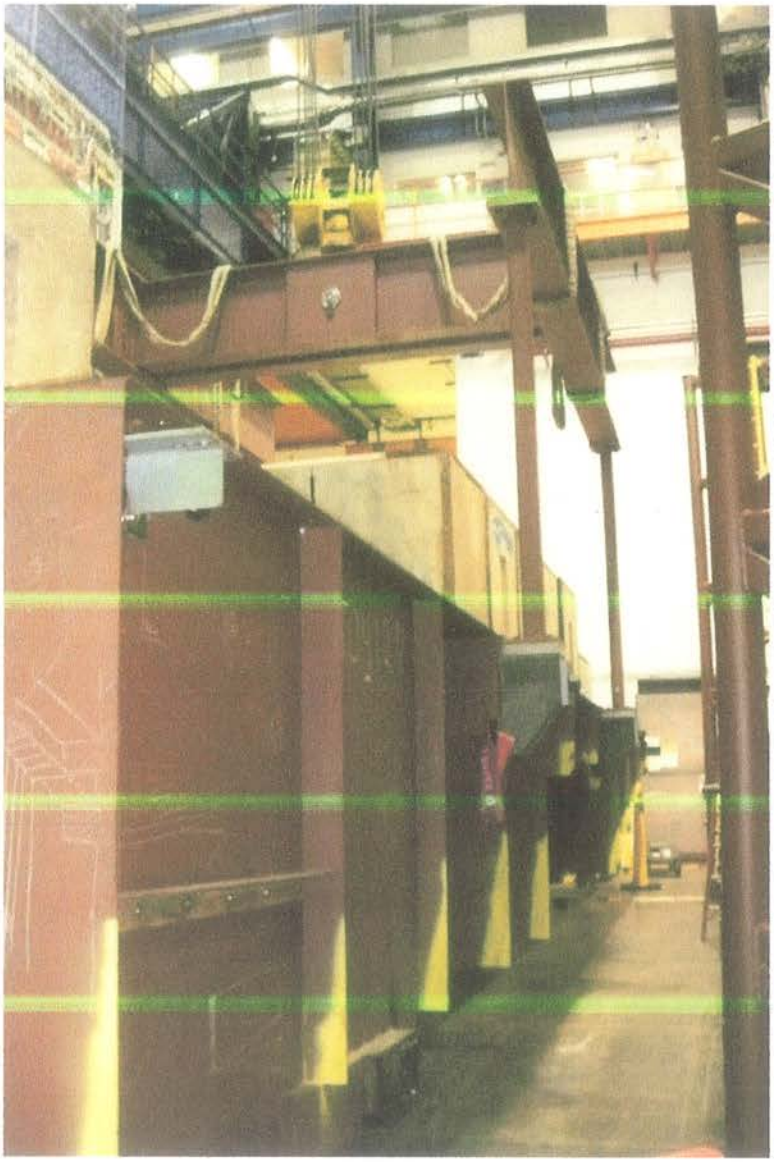

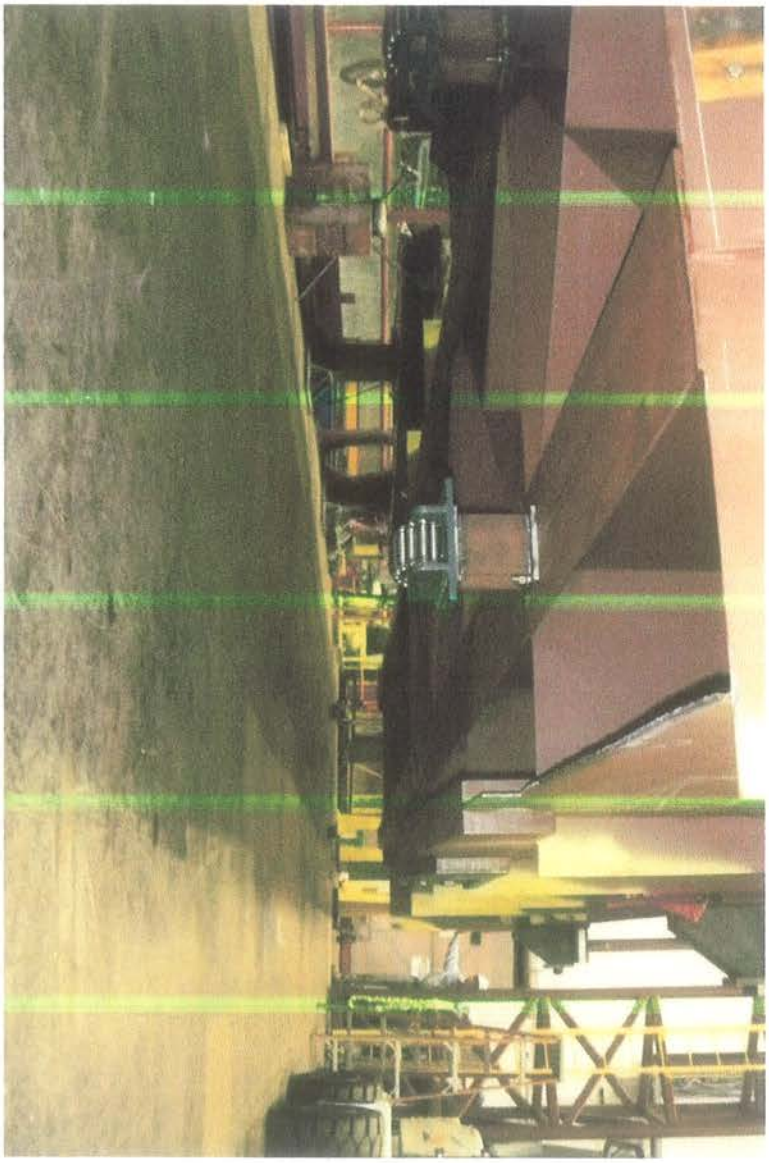
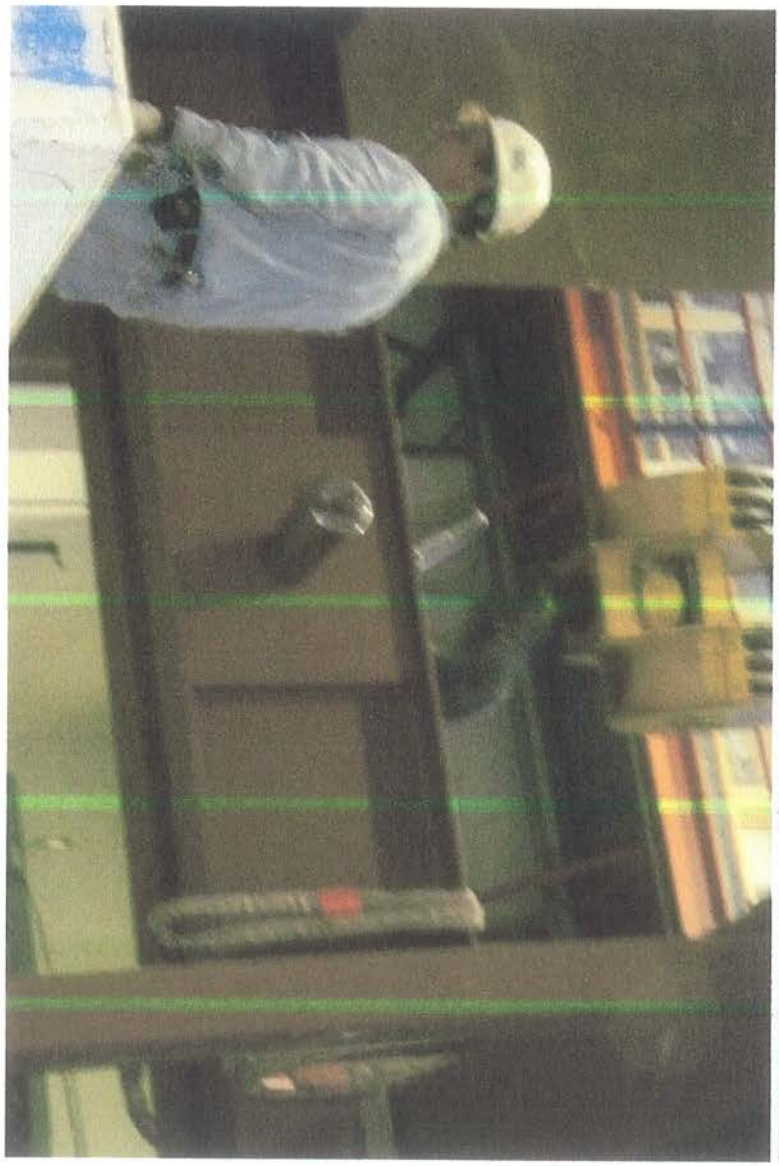
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