Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-288 Date: 20 November 2010

Project Internal Reference:

Project: NOvA

Title: FHEP Pivoter Stability Analysis

Author(s): Dave Pushka

Reviewer(s): Zhijing Tang 11/22/2010

Key Words: NOvA, FHEP, CDF, Stability

Applicable Codes: n/a

Abstract Summary:

This engineering note calculates the transverse horizontal loads applied to the FHEP pivoter in CDF due to seismic loading. Member sizing to restrain the individual components from tipping due to these loads are also included.

The lower frames can be tied together as they move together. The upper frames need to be able to move vertically independently to allow the table to be aligned w.r.t. the lower frame portions which extend under the pallet. The upper frames are tied to the lower frames with a pin at the back and are supported by kneeling jacks at the front. This pin transfers moment between the upper and lower frames.

Figure 1 Above Image shows the pivot pin between the upper and lower weldments.

Figure 2 Above Image shows the four kneeling jacks (gray) between the lower weldment (brown) and the upper weldment (light gray).

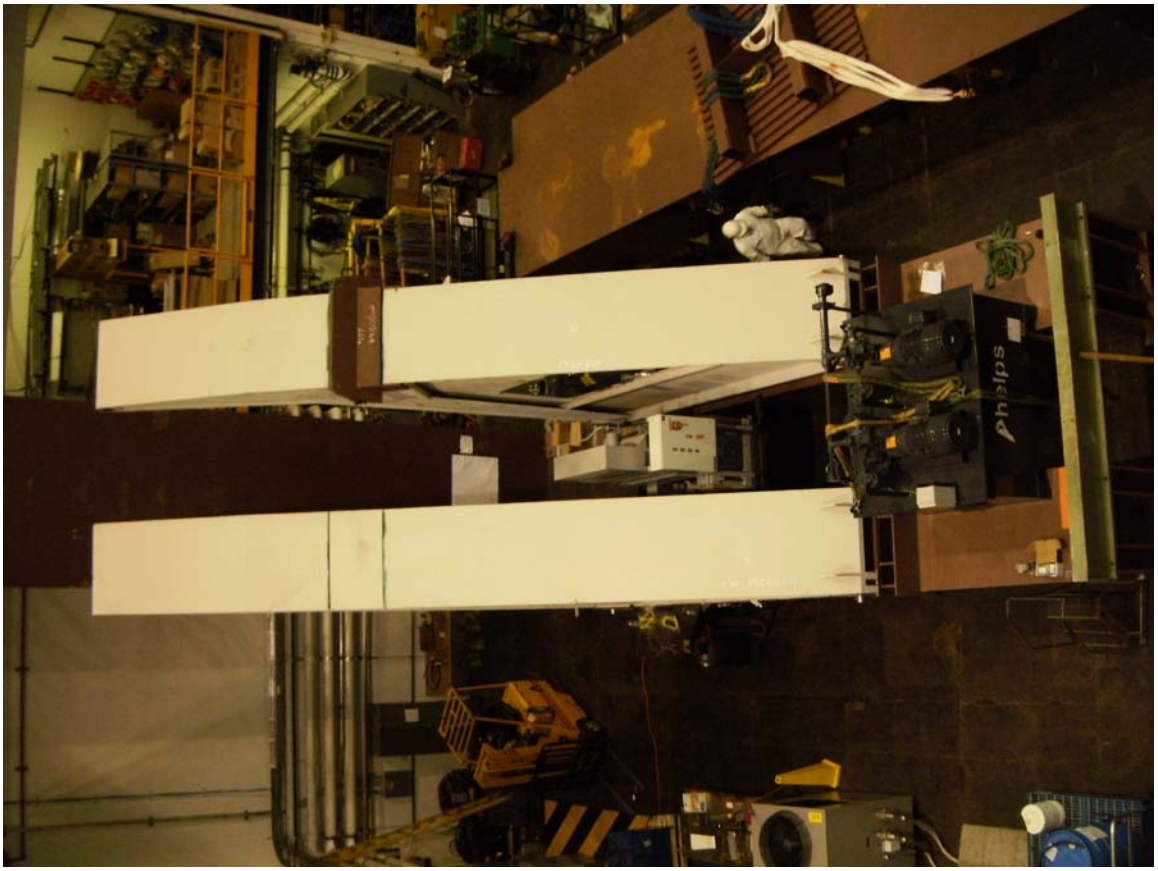


Figure 3 Above Images shows the W18by46 beam (green) between the lower weldments.

Calculations Start on the Next page:

Transverse loading of the CDF FHEP Pivoter

Weights:

Lower Weldments per drawing 466518	31,100	pounds
Upper Weldments per drawing 466549	35,275	pounds
FHEP Detector Block per drawing 486364	50,392	pounds
FHEP Pallet per drawing 486364	2,850	pounds
FHEP Table per drawing 486364	24,296	pounds

Vertical Distances from C.G.s to Top of Rail:

From Ideas Model File Measurements:

Upper Weldment Distance of C.G. above bottom flange	106.68	inches
Lower Weldment Distance of C.G. above bottom flange	21.53	inches
Distance from Upper Weldment bottom flange to top of rail	65.95	inches
Distance from Lower Weldment bottom flange to top of rail	0.5	inches
Distance from Main Pivot centerline to top of rail	310.67	inches

From Drawing 486364:

Distance from FHEP Detector Block to Main Pivot Centerline	48.77	inches
Pallet C.G. to Main Pivot Centerline	48.77	inches
Table C.G. to Main Pivot Centerline	-15.02	inches

Vertical Distance from C.G.s to top of rail calculated from above values:

Lower Frame	22.03	inches
Upper Frame	172.63	inches
EP detector Block	359.44	inches
FHEP pallet	359.44	inches
FHEP Table	295.65	inches

Number of Items in complete Assembly:		
Lower Frame	2	
Upper Frame	2	
FHEP detector Block	1	
FHEP pallet	1	
FHEP Table	1	
Assumed Horizontal (Transverse) Acceleration due to Seismic, a	**0.06**	**g**
Determine the C.G. Height of the combined assembly:		
Total Weight of block, pallet, table, 2 * upper weldment, 2* lower weldment:	210,288	pounds
Sum of the Moments from above but using a = 1g:	39,869,729	inch-pounds
Elevation of the combined C.G. = sum of moments / total weight	189.6	inches

Consider Tipping of Lower Weldment on Rail:

Moments on Lower Weldments due to ("a ")*(weight)*(vertical distance)*(number of items in assembly) with values taken from the above cells:		
Lower Frame	82,216	inch-pounds
Upper Frame	730,743	inch-pounds
FHEP detector Block	1,086,774	inch-pounds
FHEP pallet	61,464	inch-pounds
FHEP Table	430,987	inch-pounds
Sum of Moments due to transverse seismic accelerations (This is the sum of the five above values):	2,392,184	inch-pounds
Distance Between rail Centerlines	94.25	inches
Load on Rails to counteract uplift due to seismic loads:	25,381	pounds
Available Load to counteract uplift due to seismic loads from half the block, pallet, and table weight + 1 upper weldment + 1 lower Weldment:	105,144	pounds

<u>Summary: If the two lower weldments are sufficiently tied together, the seismic induced transverse loading will not tip the assembly and lift one side off the rail.</u>

Examine if the two lower weldments are sufficiently well tied together to prevent tipping about the rail:

Moment capacity of W18by46 which ties the lower frames together:

Section Modulus of beam, S (in^3)	78.8	in^3
Allowable Bending Stress = 0.6 Fy	21,600	psi
Sum of Moments due to transverse seismic accelerations from above:	2,392,184	inch-pounds
Actual Bending Stress, Sigma = Moments / Section Modulus (S)	30,358	psi

<u>Summary: This beam is not sufficient by itself. Consider additional bracing near the front of the lower weldment ties.</u>

Existing W18 by 46 is attached with four 3/4 -10 A325 bolts in the bottom flange spaced 36 inches apart

Allowable bolt tension is	19.4	kips
Distance between bolt in tension and compression	30	inches
Number of bolts in tension	2	
Allowable Moment in W18 by 46 based on bolting:	1,164,000	inch-pounds
Bending Stress, Sigma = Moments / Section Modulus (S) based on connection capacity	14,772	psi

Add another W18 by 46 between the two lower frames attached to the vertical sides of the lower frames:

Use a plate welded to the end of the section as a moment connection.

Use two rows of 3/4 inch A325 bolts at 21 inches center to center spacing.

Determine the number needed to fully develop moment capability

Distance of bolt line center to center, inches	21	inches
Design for a moment capability of:	1,200,000	inch-pounds
Bolt tension for couple based on above moment and spacing:	57,142.86	pounds
Allowable Tension of above bolts per AISC 9th edition Table I-A	19,400	pounds
Number of bolts needed:	2.9455	
Number of bolts used:	3	

Examine Tipping of Upper Frame on Kneeling Jacks:

Weight on each side of Upper Frame Kneeling Jack pair = 1/2 block weight + 1/2 table weight = 1/2 pallet weight + upper frame weight:	74,044	pounds
Centerline to centerline kneeling Jack Spacing:	30	inches
Sum of Moments due to transverse seismic accelerations from above for the upper frames, table, block and pallet (not the lower frames):	2,309,968	inch-pounds
Assume each side shares the moment equally, M per side = M/2	1,154,984	inches
Load on one kneeling jack to counteract uplift due to seismic loads = above moment divided by the c -c spacing (30") of the kneeling jacks:	38,499	pounds

Actual load on the kneeling jacks (74 kips) exceeds the required load (38 kips).

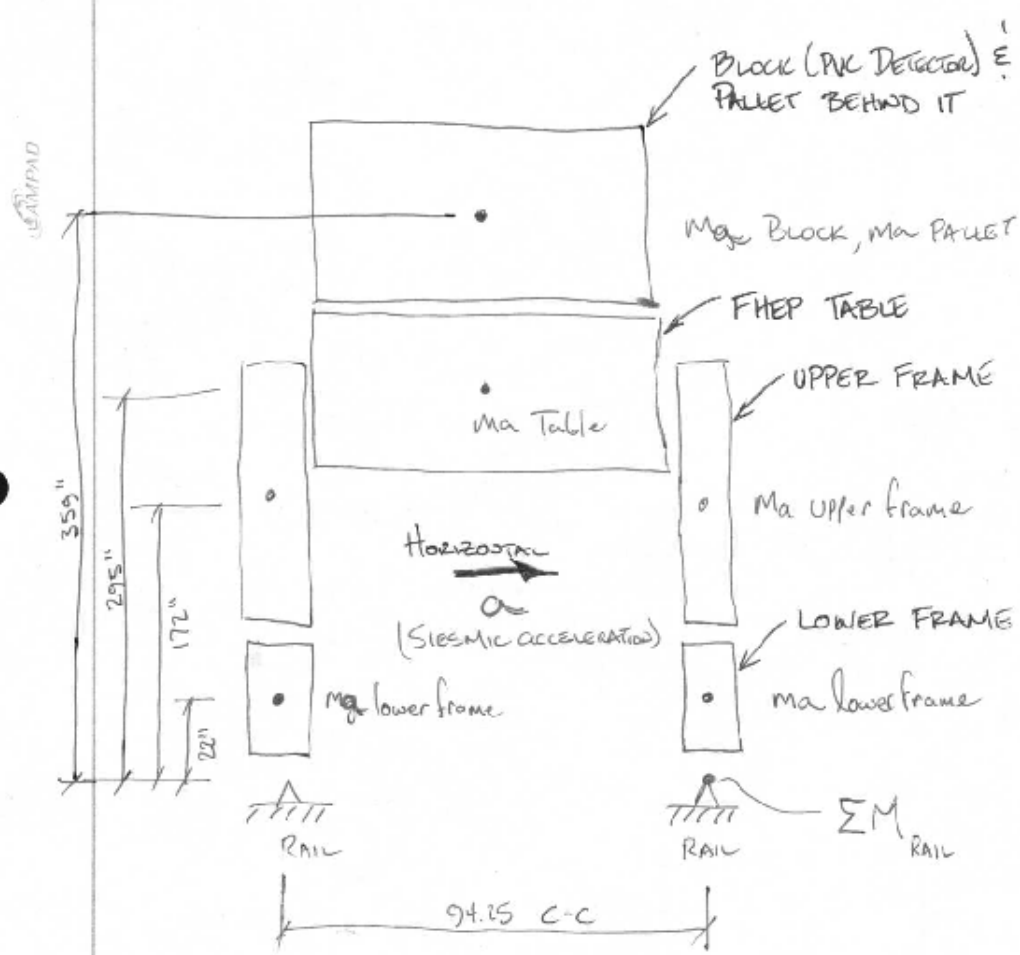
<u>Summary: the load on the stiff upper weldments is sufficient to prevent the seismic induced transverse loading from lifting one side off of one kneeling jack.</u>

Sketches follow on the next page:

LATERAL STABILITY
FHEP @ CDF FOR NOvA 11/16/2010

D. POSHKA

END VIEW:



$$M = \Sigma(m \cdot a \cdot d)$$

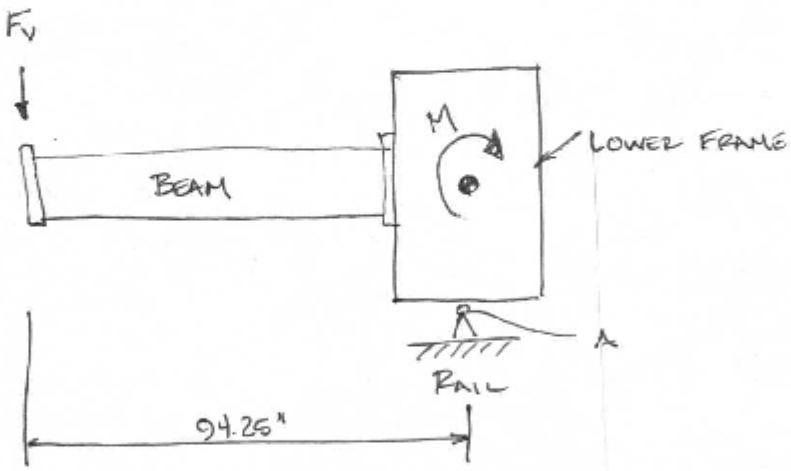
$$M = 2{,}392{,}184 \text{ in-pounds}$$

11/16/2010 | D. PUSHKA

$$\text{MOMENT}_A = \sum (m \cdot a \cdot d_{\text{vertical}})$$

$$= 2{,}392{,}184 \text{ in-LBS}$$

$$F_V = \frac{M}{94.25''} = 25{,}381 \text{ POUNDS.}$$



FOR SIMPLICITY, IGNORE BEAM SPAN TAKEN UP BY THE LOWER FRAMES ∴ BENDING MOMENT IN BEAM = 2,392,184 in-LBS.