



Fermilab

**Particle Physics Division
Mechanical Department Engineering Note**

Number: MD-ENG- 331

Date: April 16, 2011

Project Internal Reference:

Project: LBNE

Title: The LBNE 35 ton Prototype Top Structure Conceptual Design

Author(s): Edward Chi

Reviewer(s):

Key Words: LBNE, Concrete, Steel Plate, Insulation, Grout, Live load,
Dead load, Gratings, Floor, Handrails, Stairs, Lifting Fixture.

Abstract Summary:

The top structures of the LBNE 35 ton prototype detector consisted of the top insulation, top membrane, liquid Argon pumps, manhole, feed through, working platform and others. The material selection and the conceptual configuration design have included the design criteria with the applicable industrial codes. A brief calculated engineering data, conceptual design layouts, vendor's cost quotation, and other information are presented for the discussion.

Applicable Codes:

“Allowable Stress Design”, AISC, 9th edition

“Structural Welding Code-Steel”, ANSI/AWS D1.1, 1990

“Minimum Design Loads for Building & Other Structures”, ANSI A58.1-1982

“Roark's Formulas for Stress & Strain”, Warren C. Young, 6th edition

The main data of the LBNE 35 ton prototype detector:

- Concrete wall thickness: $t_c = 300$ mm
- Insulation thickness: $t_i = 400$ mm
- Insulation material density: $\rho_i = 125 \text{ kg/m}^3 = 0.004506 \text{ lbs/in}^3$
- The overall dimensions of the enclosure without the top structures:
5,480 mm (L) x 4,460 mm (W) x 2,940 mm (H)
- The main data of the LBNE 35 ton prototype top structures:
(See figure 3 of page 5)
Total weight: $W_t = 10,021$ lbs

Where : $w_{stl} = 3,624$ lbs, main steel plate with 0.375" thickness

$w_{ins} = 2,062$ lbs, top insulation total.

$w_{lifting} = 251$ lbs, lifting device

$w_{beam} = 1,501$ lbs, four of w8 x 24 beams

$w_b = 1,673$ lbs, plate B system which includes: plate B, neck, Argon pumps, LAPD feed through, manhole (with cover?) and others.

$w_{mice} = 0.10 \times (w_{stl} + w_{ins} + w_{lifting} + w_{beam} + w_b) = 911$ lbs

Miscellaneous weight which includes but not is limited:

Metal studs, wood panels, weld metals, assembly hard wares, and others.

Some additional design data for the LBNE 35 ton prototype detector top structure:

- Dead loads:
 1. Main top plate (3/8" thick A36 steel): $L_{d1} = 15.336 \text{ lbs/ft}^2$, plate A area.
 2. Stainless steel membrane (1.2 mm thick): $L_{d2} = 1.932 \text{ lbs/ft}^2$
 3. Insulation material (400 mm thick): $L_{d3} = 10.22 \text{ lbs/ft}^2$
 4. W8 x24 I beam and the lifting fixture: $L_{d4} = 6.30 \text{ lbs/ft}^2$
(Assuming 4 beams, 351 lbs/beam, 251 lbs of the lifting fixture applying dead load to the 263 ft² area uniformly, see figure 5 on page 6).
 5. Plate B area: $L_{d5} = 18.33 \text{ lbs/ft}^2$
(Assuming 1,673 lbs over the area of 74.875" x 175.50")
 6. Floor grating (Duradek T500): $L_{d6} = 3.0 \text{ lbs/ft}^2$
 7. Total Dead load in plate A area:
 $L_{dA} = L_{d1} + L_{d2} + L_{d3} + L_{d4} + L_{d6} = 36.79 \text{ lbs/ft}^2$
 8. Total Dead load in plate B area:
 $L_{dB} = L_{d2} + L_{d3} + L_{d4} + L_{d5} + L_{d6} = 39.78 \text{ lbs/ft}^2$
- Live Load:
 $L_1 = 100 \text{ lbs/ft}^2$
- Excluding the pressure load, the total applying load to the top structure is defined as:

$$L_{\text{totA}} = L_l + L_{dA} = 137 \text{ lbs/ft}^2$$

(Total applying load in plate A area)

$$L_{\text{totB}} = L_l + L_{dB} = 140 \text{ lbs/ft}^2$$

(Total applying load in plate B area)

- Some calculated data from the boundary condition as we defined:
 1. Assuming the detector installed as showing from figure 5, where the live load (100 lbs/ft²) will apply to the top structure through four w8x24 beam, conservatively assume that $L_{\text{totB}} = 140 \text{ lbs/ft}^2$ will apply the whole top floor area, then:

The max. deflection at the beam: $\Delta_{\text{max}} \approx 0.1426''$
The max. bending stress: $f_b \approx 4.586 \text{ ksi}$

(The calculation has not included the geometrical factor of the grating, which will also help to reduce the deflection and the local working stresses.)
 2. The maximum deflection and the working stress @ plate A area:
(See figure 1 and figure 5)

$\Delta_{\text{max}} \approx 0.09516''$
 $f_b \approx 4.352 \text{ ksi}$

Brief introduction of the layout pictures from figure 1 to figure 5:

- Figure 1 is the outside overall view of the detector without the platform.
- Figure 2 with three layouts shows the process of lower part of enclosure.
- Figure 3 showing the main configurations of the top structures.
- There will be a problem for the final installation because of the restriction of the maximum crane height in PC 4 (See figure 6), the lifting device showing from figure 3 and figure 4 has addressed such issue directly.
- Figure 5 showing the overall dimensions of the detector and the configuration of the platform with the accessories.

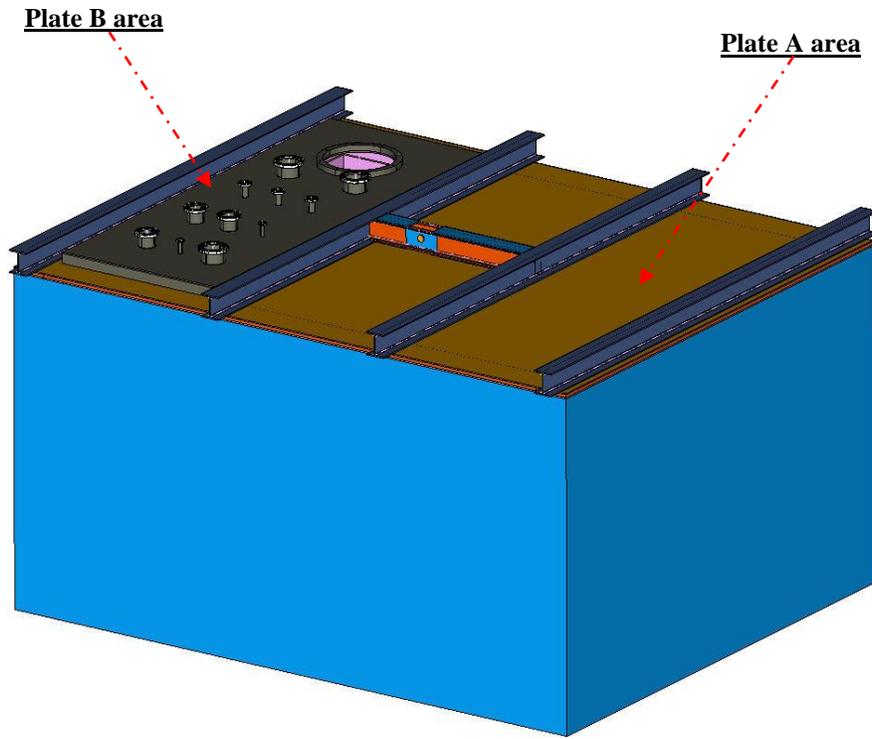


Figure 1, The overall view of the LBNE 35 ton Prototype Detector

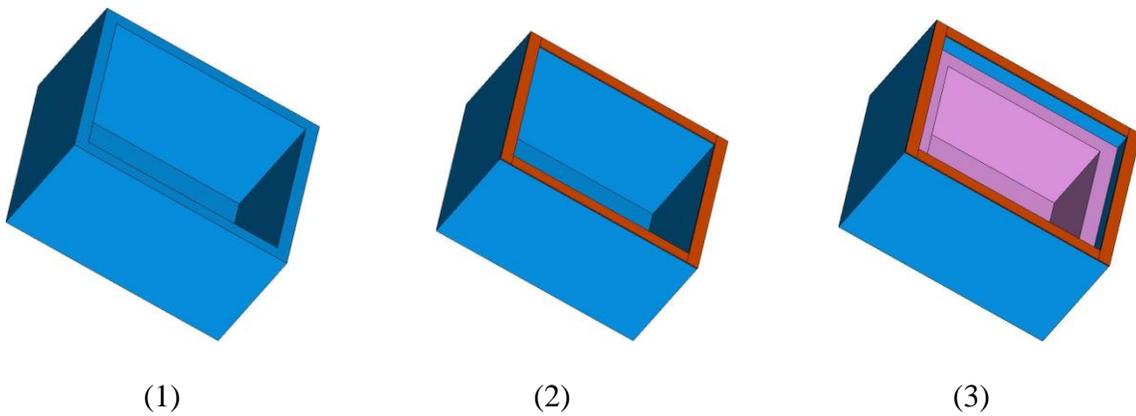


Figure 2, The views of the main detector enclosure

- (1) The Concrete enclosure
- (2) The concrete enclosure with grout and steel connect plates at the top.
- (3) Enclosure with insulation and stainless steel membrane.

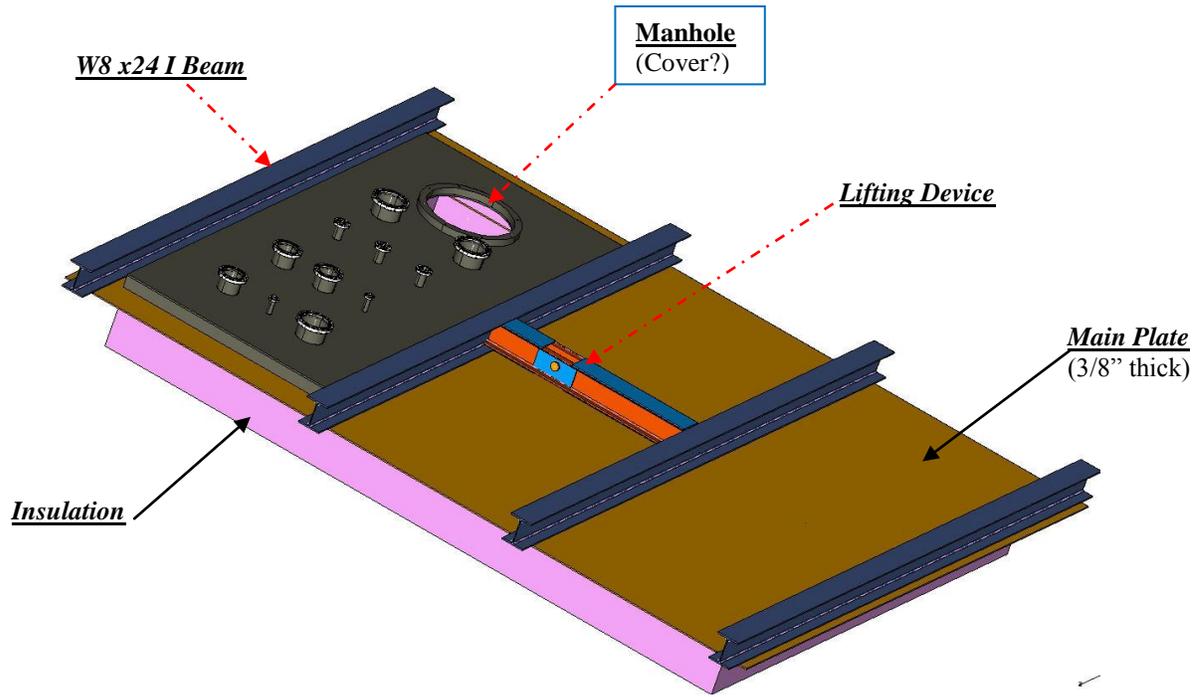


Figure 3, The view of the LBNE 35 ton prototype top structures

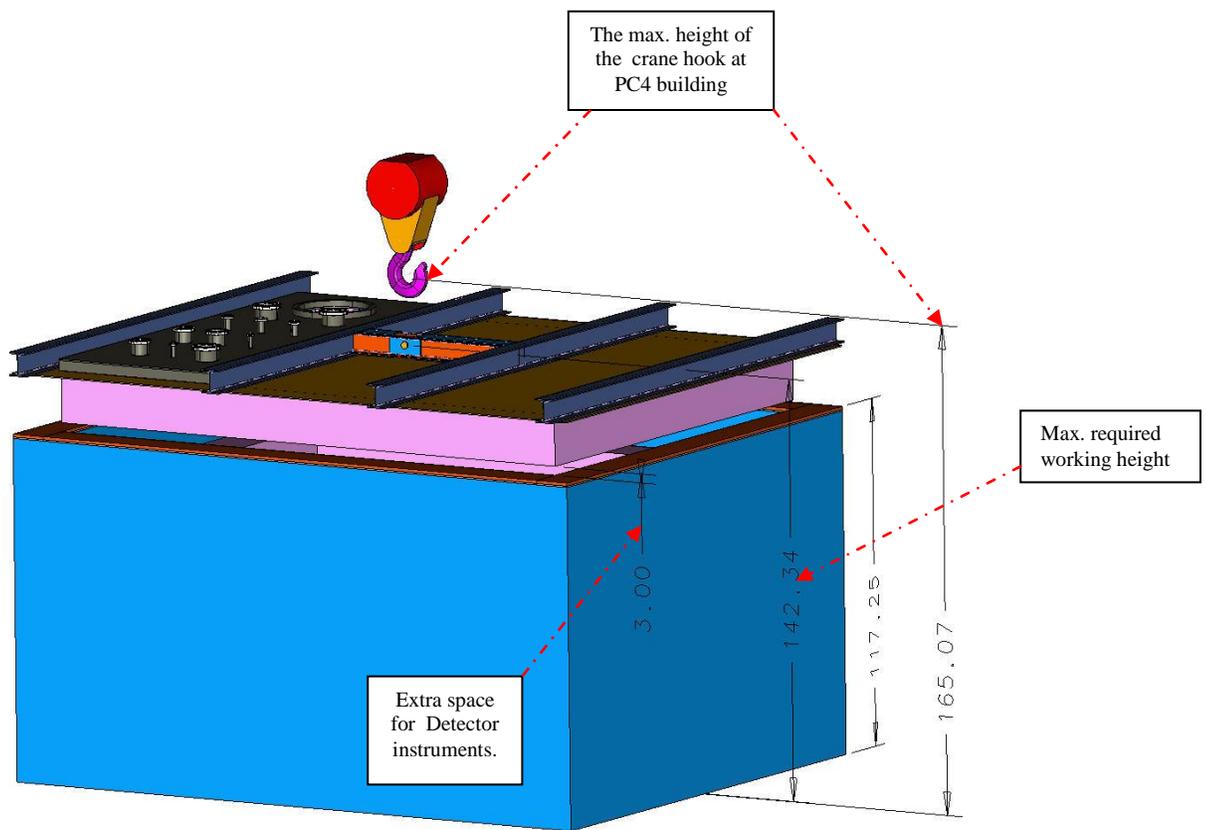


Figure 4, The maximum crane height vs. the max. workable lifting height.

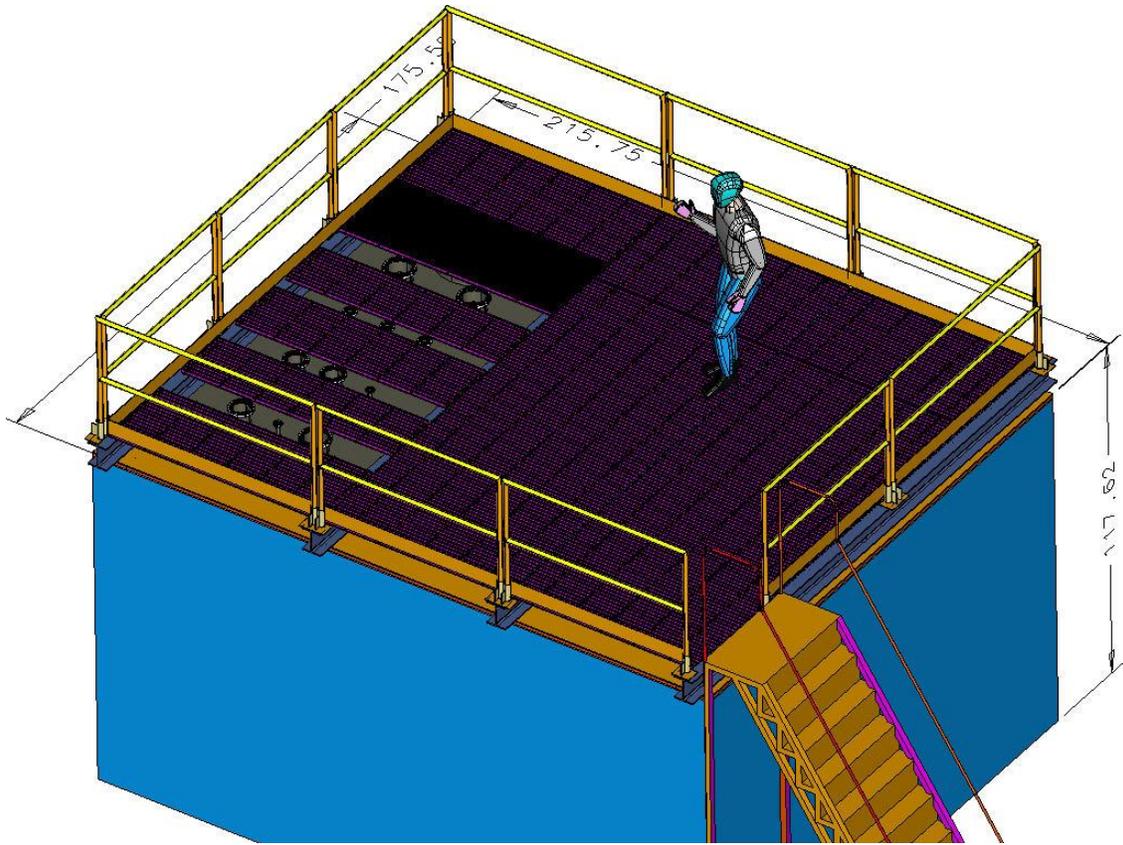


Figure 5, The view of the detector with the platform

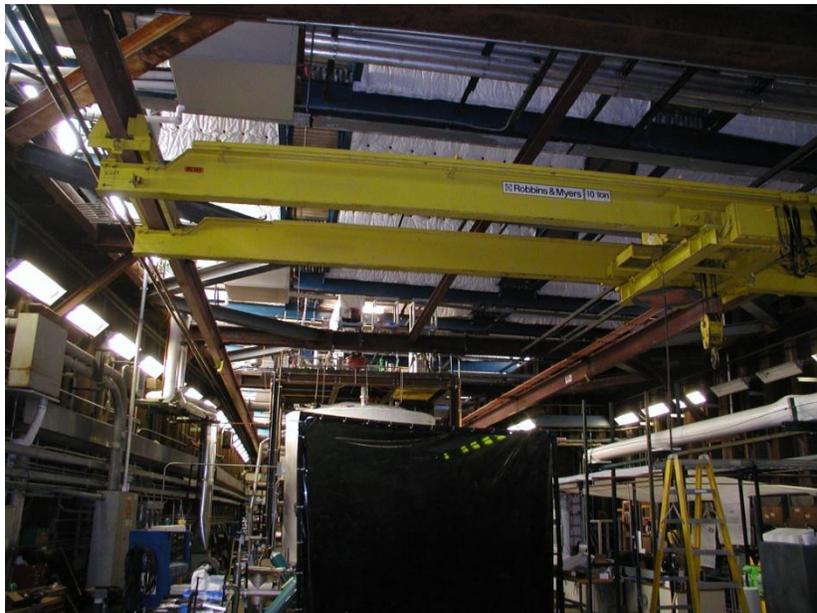


Figure 6, View of crane from PC4 building.

<i>Preliminary Cost Estimates for the Top Structural Components of LBNE</i>							
item	Descriptions	weight (lbs)	material cost	labor			Reference
		length (ft)	(\$)	fab.	weld	tech	(quotation source)
		(pc)		(hrs)			
1	top base plate (plt A) ASTM A36, 3/8" x 10' x 36'	1	\$2,843.97	8	4		Ryerson
2	Structural I beam A36, W8x24 x 20'	4	\$1,516.80	8	4		Action Metals
3	Middle mounting plate A36, 3/4" x 12" x 20'	4	\$1,874.69	16			Ryerson
4	Mtg plt for pumps and manhole (plt B) 304 stainless, 1/2" x 60" x 8'	2	\$3,836.00	8	4		Central Steel & Wire
5	Floor Grating (Duradek T500, 2" ht) (270 SF, including the mounting accessories)	1	\$3,458.87			16	WS Hampshire
7	Safety railings and Kick Plates (65 ft length, including the install accessories)	1	\$3,494.99			24	WS Hampshire
8	Safety Gate	1	\$203.67			2	McMaster
9	Rolling Safety Ladder-13 steps heavy duty serrated grating, shipped unassembled	1	\$1,551.00			8	Global Industrial
10	Medium strength rubber gasket 1/4" x 12 @ 6.03/ft	64	\$385.92			8	McMaster
11	Adapters for railing mounting (using extra materials from Item #1 & #3)			4	2	12	
12	Structural device for handling flip-over the assembled top detector to install		\$1,500.00	16	4	24	
13	Sub assembly, alignment, assembly, and final installation					60	
		<u>Sub-total</u>	\$20,897.74	60	18	154	
14	Miscellaneous Accessories (assuming 5% of total materials)		\$1,033.30				
15	Total material cost with 30% contingency		\$28,510				
Notes:							
1. The estimation is based on the rough preliminary design layout of 04/06/2011.							
2. Estimated engineer's time: 6 weeks; drafter's time: 4 weeks.							
3. Based on the current design layout configurations, it is assumed to use the existing in-house lifting fixture (#151), otherwise, an estimation for the cost of new lifting fixture needs to be added on.							
4. The live load is 100 lbs/sf.(per Mr. Montanari), dead load w/o floor grating is about 33 lbs/sf (per current layout).							
5. Some applicable codes for this design: ASCE Standard, ASD(AISC), ASME B30.20, AWS D1.1.							

Table 1, Preliminary cost estimate for the top structure of the LBNE 35 ton prototype detector.

References:

1. The quotation from Ryerson:

	SALES QUOTATION ACKNOWLEDGEMENT	Page 1 of 2 04/07/2011																																																																						
JOSEPH T. RYERSON RYERSON COIL PROCESSING RYERSON CANADA	QUOTE NBR: 22250279																																																																							
SALES OFFICE: Ryerson Burns Harbor 310 Tech Drive Burns Harbor, IN 46304		ATTENTION: Edward REFERENCE: PHONE NO.: FAX NO.:																																																																						
		FROM: Sammer Refai Email: Sammer.Refai@ryerson.com Phone No. 630-758-2272 Fax No. 999-999-9999																																																																						
SOLD TO: FERMI NATIONAL LAB-PRO CARD CREDIT CARD ACCT KIRK & WILSON RD BATAVIA, IL 60510		SHIP TO: FERMI (SUBURBAN WELDING) 9820 W FRANKLIN AVE FRANKLIN PARK, IL 60131-1913																																																																						
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<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Quote Line No.</th> <th style="width: 10%;">Ord Qty</th> <th style="width: 10%;">Ord Uom</th> <th style="width: 40%;">Item Description</th> <th style="width: 10%;">Estimated Weight Lbs</th> <th style="width: 10%;">Quantity in Price Uom</th> <th style="width: 10%;">Price</th> <th style="width: 10%;">Pro Uom</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">10</td> <td style="text-align: center;">1</td> <td style="text-align: center;">PC</td> <td>CARB PLT A36 0.375" X 120" X 360"</td> <td style="text-align: right;">4,596.000</td> <td style="text-align: right;">4,596.0000</td> <td style="text-align: right;">\$0.6188</td> <td style="text-align: center;">LB</td> </tr> <tr> <td colspan="4"> Pieces: 1 P/N </td> <td style="text-align: right;"> Extended Amount Delivery Date </td> <td colspan="3" style="text-align: right;"> \$2,843.97 04/08/2011 </td> </tr> <tr> <td style="text-align: center;">20</td> <td style="text-align: center;">2</td> <td style="text-align: center;">PC</td> <td>Stnls PLT 304/304L AP 0.5" X 72" X 120"</td> <td style="text-align: right;">2,599.560</td> <td style="text-align: right;">2,599.5600</td> <td style="text-align: right;">\$2.2682</td> <td style="text-align: center;">LB</td> </tr> <tr> <td colspan="4"> Pieces: 2 P/N </td> <td style="text-align: right;"> Extended Amount Delivery Date </td> <td colspan="3" style="text-align: right;"> \$5,870.35 04/12/2011 </td> </tr> <tr> <td style="text-align: center;">30</td> <td style="text-align: center;">1920</td> <td style="text-align: center;">LB</td> <td>WIDE FLANGE BEAM W8 X 24LBS X20"LG</td> <td style="text-align: right;">1,920.000</td> <td style="text-align: right;">1,920.0000</td> <td style="text-align: right;">\$0.7006</td> <td style="text-align: center;">LB</td> </tr> <tr> <td colspan="4"> Pieces: 4 P/N </td> <td style="text-align: right;"> Extended Amount Delivery Date </td> <td colspan="3" style="text-align: right;"> \$1,345.10 04/12/2011 </td> </tr> <tr> <td style="text-align: center;">40</td> <td style="text-align: center;">4</td> <td style="text-align: center;">PC</td> <td>CARB Bar FLT HR A36 0.75" X 12" X 240"</td> <td style="text-align: right;">2,448.000</td> <td style="text-align: right;">2,448.0000</td> <td style="text-align: right;">\$0.7658</td> <td style="text-align: center;">LB</td> </tr> <tr> <td colspan="4"> Pieces: 4 P/N </td> <td style="text-align: right;"> Extended Amount Delivery Date </td> <td colspan="3" style="text-align: right;"> \$1,874.69 04/07/2011 </td> </tr> </tbody> </table>	Quote Line No.	Ord Qty	Ord Uom	Item Description	Estimated Weight Lbs	Quantity in Price Uom	Price	Pro Uom	10	1	PC	CARB PLT A36 0.375" X 120" X 360"	4,596.000	4,596.0000	\$0.6188	LB	Pieces: 1 P/N				Extended Amount Delivery Date	\$2,843.97 04/08/2011			20	2	PC	Stnls PLT 304/304L AP 0.5" X 72" X 120"	2,599.560	2,599.5600	\$2.2682	LB	Pieces: 2 P/N				Extended Amount Delivery Date	\$5,870.35 04/12/2011			30	1920	LB	WIDE FLANGE BEAM W8 X 24LBS X20"LG	1,920.000	1,920.0000	\$0.7006	LB	Pieces: 4 P/N				Extended Amount Delivery Date	\$1,345.10 04/12/2011			40	4	PC	CARB Bar FLT HR A36 0.75" X 12" X 240"	2,448.000	2,448.0000	\$0.7658	LB	Pieces: 4 P/N				Extended Amount Delivery Date	\$1,874.69 04/07/2011		
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Pieces: 4 P/N				Extended Amount Delivery Date	\$1,874.69 04/07/2011																																																																			

2. The quotation from Central Steel & Wire:

Central Steel & Wire Company

OFFICES & PLANTS
Chicago - Detroit
Cincinnati - Milwaukee
Greensboro

P.O. BOX 5100
Chicago, Illinois 60680-5100

3000 West 51st Street
Chicago, Illinois 60632-
2122
1-800-621-8510
Fax: 1-866 332 5150

QUOTATION CONFIRMATION

Phone: 1-630-840-2879
Fax: 1-630-840-3694
To: EDWARD CHI
FERMILAB
MAIL STOP 112
BOX 500
BATAVIA IL 60510-5011

From: DAVID L
Request Date: HENDERSON
Document ID: 04/06/11
Customer: 040611-143104
04372

<u>ITEM</u>	<u>QUANTITY</u>	<u>DESCRIPTION</u>	<u>ESTIMATED QUANTITY</u>	<u>PRICE</u>	<u>ESTIMATED EXTENSION</u>
001	2 PC	3/8" X 120" X 180" HR A-36 PLATE OK TO SCANT CUT SHEAR	4596 #	66.08 CWT	\$3,037.04
002	2 PL	3/4" X 60" X 120" HR A-36 PLATE SHIP DROPS BURN TO 8 PC 12" X 120" FREIGHT	3063 #	79.14 CWT	\$2,424.06
003	4 BR	8" X 24# HR A-992/A-572 GR 50 WF BEAM 60 FT ** DUE 2 WEEKS **	5760 #	73.78 CWT	\$4,249.73
004	1 PL	1/2" X 60" X 120" STAINLESS 304 HR AP PLATE	1083 #	221.48 CWT	\$2,398.63
005	1 SH	1/2" X 60" X 96" STAINLESS 304 HR AP PLATE ** DUE 2 WEEKS **	866 #	221.48 CWT	\$1,918.02
006	1 SH	3/8" X 60" X 120" STAINLESS 304 HR AP PLATE	825 #	219.23 CWT	\$1,808.65
007	1 SH	1/2" X 60" X 96" STAINLESS 304 HR AP PLATE ** DUE 2 WEEKS **	866 #	221.48 CWT	\$1,918.02
Est. Weight Total:			17,059 #	Est. Dollar	\$17,754.15

3. The quotation from Hampshire Inc.

WS Hampshire
 365 Keyes Avenue
 Hampshire IL 60140
 USA



Phone: 847.683.4400
 Fax: 847.683.4407

Quote Number: 25373

Page: 1 of 1

<p>Quote To: Edward Chi FERMI NATIONAL ACCELERATOR LAB KIRK & WILSON RD BATAVIA IL 60510 USA</p> <p>Phone: 630-840-2879 Fax: 630-840-3694</p>	<p>Date: 4/7/2011</p> <p>Sales Person: Ryan Dostal x 261 Fax: 847-683-4407 rdostal@wshampshire.com</p>
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EXCLUSIONS:
 1) Taxes; 2) Installation; 3) Painting/Coating; 4) Freight; 5) Anchorage; 6) Field Measurements;
 7) Design Engineering; 8) Any item not specifically included above
 All Pultrusions and Fabrications are MADE IN THE USA

Line	Part Number	Description	Rev	Drawing	
1	FIBERGLASSLOT	270-sf of Duradek grating & 64-lf of Saffrail handrail Duradek T5000 2in yellow fire retardant uv inhibited polyester, 6ino.c. cross rods with grit. Saffrail handrail: 2x.156 yellow fire retardant uv inhibited polyester square tube posts and rails with kickplate. Grating clips and bolts are 316SS			
<p>Quoting a side mount handrail system to meet OSHA requirements. WSH will need to verify the material used under the grating to determine if a side mount is possible. This would be the grey material in the 3D model submitted.</p>					
		Quantity	Unit Price	UM	Ext. Price
		1.00	\$6,953.69000	EA	\$6,953.69

4. The quotation from Action Metals:

Edward,

Here is what i can quote at this time,i am still waiting for an answer from the mill on the big HRS plates so as soon as i get an answer on those i will advise you right away.

Jim

4 pcs HR BAR 3/4 x 12 x 20' R/L 2450 lbs @ \$0.89 per lb

4 pcs I-beam 8 x 24lb x 20' R/L 1920 lbs @ \$0.79 per lb

1 pc 304 S/S 3/8 x 64 x 180 @ \$4450.00 LOT

1 pc 304 S/S 1/2 x 64 x 180 @ \$5795.00 LOT

Action Metals Co.
1500 Dearborn Ave. Bldg 10A
Aurora, IL 60505
Phone: (630) 585-1000
Fax: (630) 585-5310
Email: actionmetals@sbcglobal.net

5. The quotation from Global Industrial:

The screenshot shows the Global Industrial website interface. At the top, there is a navigation bar with the company logo, contact information (1.888.978.7759), and links for Log In, Your Account, Shopping Cart, and 0 Items - (\$0.00). Below the navigation bar are tabs for Products, Account Tools, and Help Center, along with a search bar. The main content area features a breadcrumb trail: Home > Material Handling > Ladders > Rolling-Steel > Extra Heavy Duty Rolling Safety Ladders > 11 Step Extra Heavy Duty Rolling Safety Ladder - Heavy Duty Serrated Grating. A product image of the ladder is shown with a '9 step shown' label. The product title is '11 Step Extra Heavy Duty Rolling Safety Ladder - Heavy Duty Serrated Grating'. The availability is 'Usually ships in 10 to 13 days' and the stock number is 'WBB190058'. The price is listed as 'Our Price: \$1,115.00'. There are buttons for 'Chat with a Salesperson', 'Add this item to your list', 'E-mail Page', and 'Print Page'. A quantity selector is set to '1' with an 'ADD TO CART' button. Below the product image is a 'Product Information' tab and a 'Customer Reviews' section with a 'Write a review for this product' button. The product description states: 'This extra heavy duty ladder features 600 lb. capacity, 21"D top step and a weight actuated lockstep. The base frame and rear vertical are made with rugged 2" x 1" rectangular tubing for added strength and stability. The 24"W steps have serrated grating tread. High quality wheels are non-marking with roller bearings and dust cover. Rear corner bumpers are standard. Exceeds OSHA and ANSI standards. Gray powdercoat finish. 32"Wx87"D base dimensions. 24"Wx21"Dx110"H top step dimensions.' A 'Product Specifications' table is provided below the description.

Product Specifications	
WIDTH INCHES	32
DEPTH INCHES	87
DEPTH TOP STEP INCHES	21
HEIGHT INCHES	143
HEIGHT INCHES TO TOP STEP	110
CAPACITY LBS	600
COLOR FINISH	Gray
ASSEMBLY	Unassembled
CONSTRUCTION	Steel
HANDRAIL	30
QUANTITY STEPS	11
STEP TYPE	Serrated Grating
STEP WIDTH INCHES	24

On the right side of the page, there is a 'Customers Who Bought This Item Also Bought' section with three recommended products: '44"H CAL-OSHA Handrail Kit for Extra Heavy Duty Rolling Safety Ladders' (From \$203.95), '72" Computer Lan Workstation' (From \$749.00), and 'Mobile Security LCD Computer Cabinet Blue' (From \$229.00). Each product has an 'ADD TO CART' button.

6. Emails related this task:

----- Original Message -----

From: [David Montanari](#)
To: [Dave Pushka](#)
Cc: [Richard Schmitt](#)
Sent: Wednesday, March 30, 2011 11:46 PM
Subject: LBNE 35 ton prototype Top plates Design

Dave,

thanks for your help with the design of the top plates of the LBNE 35 ton prototype.

Following up our conversation, you'll find here some details about the project and particularly the plates which we are looking a design for.

Attached few slides with some dimensions and the positioning of the detector inside PC-4.

Blue is concrete, ~300 mm on the sides and ~100 mm at the bottom to make it flat, because it will seat on a concrete floor.

The concrete thickness is an estimate, it may be a little more or a little less.

Pink is the insulation, 400 mm everywhere, but not under Plate B, for purity reasons.

Dark grey inside is the stainless steel membrane, 1.2 mm thick.

Light grey at the top are the two stainless plates: Plate A is the main one (it includes the neck), Plate B (equipped with several penetrations) covers the neck.

The top of the detector is preassembled upside down: insulation and membrane are attached to Plate A.

Plate A is then flipped and lowered on top of the detector with a crane and internal welds are performed.

Plate B is eventually lowered on top of the neck and the last internal welds are made by going inside through the man-hole.

Insulation density: 125 kg/m³

Top Insulation surface: 16.20 m² (including the 0.1 m tall neck)

Insulation thickness: 0.4 m

Top Insulation weight: ~ 850 kg

Top membrane weight: ~100 kg

Two pumps weight: ~200 kg (total) attached at Plate B.

Among the insulation there are also metal studs and wood panel, I would take 1,200-1,300 kg as design value for the top + the weight of the stainless plate itself.

The two liquid Argon pumps will be anchored to Plate B and they can be mounted anywhere in the plate: the layout of the penetrations is not fixed yet, they can be rearranged to distribute the load of the pumps.

Note: the LAPD filling line that you see in some of the 3-D plots is temporarily there, you can ignore its presence.

Feel free to contact me for additional information.

I am preparing some budgetary numbers, I would very much appreciate some preliminary figures within next Thursday (April 7): thickness, if reinforcement is needed (beams across or trusses) and a rough cost estimate.

I understand there's not so much time, any information you might be able to provide with this short notice would be greatly appreciated.

Thank you very much!

Best

David