Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project: NOvA NDUG Block Weight

Title: NOvA Near Detector Underground

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Reviewer(s):

Key Words: Block Weight Calculation

Applicable Codes: n/a

Abstract Summary:

A good estimate of the NOvA Near Detector Underground (NDUG) Block weight is needed. This note provides that value. Note also includes a preliminary set of calculations on the spreader bar stresses and comparison to ASME B30.20 and ASME BTH.

Fermilab Engineering Manual Requirements:

Chapter 1: No Specifications were provided.

Chapter 2: Risk analysis has not been formally prepared. Weigh calculating engineering notes have been prepared previously and are deemed 'low risk".

Chapter 3: Written requirements and specification reviews by the project have not been formally prepared.

Chapter 4: This engineering note has been specifically prepared to address chapter 4 of the engineering manual.

Chapter 5: The 'reviewed by' signature on the cover page of this document addresses Chapter 5 of engineering manual.

Chapter 6: No materials were purchased as part of the preparation of this document.

Chapter 7: This is a document and no testing is required.

Chapter 8: No release to operations is required for these weight calculations.

Chapter 9: Unless there are lessons learned from this effort, this engineering note and the other material posted in the PPD docdb will be considered the final written Project Report as described in Chapter 9. This note will be placed in the PPD document data bases as a means of Archiving and Control.

Calculations:

Theoretical module weight = ~~283.75~~ 268 lbs each

UMN measures all the material (manifolds, fiber, glue, endplate, etc.) as 8577.1 g. / module (18.91 lbs)

PVC measured weight equals, on average, 514.5 lbs for 610" extrusion. Multiply by two for a module, divide by the 610", multiply by 157" (length of NDUG PVC) = 264.84 lbs

A NDUG module was weighed at CDF and found to be approximately 268 pounds net. Therefore, this is the value to be used.

There will be 24 planes per block

There will be 3 modules per plane.

Theoretical NOvA Near Detector Underground (NDUG) Block Weight, W_{block}:

W_{block} = 24 * 3 * 268 pounds per module = 19,296 pounds

Theoretical NOvA Near Detector Underground (NDUG) 2 by 3 MINI Block Module Weight, $W_{mini\text{-}block}$: (the vertical planes are 2/3rds of the length of a normal near detector module

$W_{mini\text{-}block}$ = 2 * (2/3) * 3 * 268 pounds per module = 1072 pounds 1125 #

Theoretical NOvA Near Detector Underground (NDUG) 2 by 3 Muon Block Module Weight, $W_{muon\text{-}block}$: (the vertical planes are 2/3rds of the length of a normal near detector module. This includes a 4 inch thick steel plate. Steel plate is shown on drawing 493583. Width is 100.5 inches. Length is 150.75 inches. Thickness is 4.00 inches. Weight based on steel at 490 pounds per cubic foot is 17,184 pounds,

$W_{muon\text{-}block}$ = 2 * (2/3) * 3 * 268 pounds per module + 17,284 = 18,256 pounds

Note that the drawing 493583 shows a steel plate weight of 17,176 pounds.

Drawing 493592 shows the steel plate and the muon filter scintillator panels and lists a weight of 19,700 pounds. This assembly includes the structural steel under the plate.

$W_{muon\text{-}block\ assembly}$ = 19,700 pounds 19,800

Lifting Fixture component weights:

Table Top Frame from dwg 493456, dwg indicated weight = 1170 pounds

Spreader Bar from dwg 493316, dwg indicated weight = 570 pounds

ND Pallet Weldment from dwg 493063, dwg indicated weight = 3578 pounds

Table D.S. Frame Weldment dwg 493384, dwg indicated weight = 4325 pounds

Table Vertical U.S. Frame dwg 493454, dwg indicated weight of = 1086 pounds

The Muon Catcher ND MC 3 x 2 weldment dwg 496558, drawing indicated weight of 18567 pounds

Lifting Yoke dwg 493473, drawing indicated weight = 91 pounds (2 req'd)

The assembly of the parts of the spreader bar and NDUG block frame is shown on drawing 493458 and the drawing indicates an assembled weight of 11,511 pounds.

For Lifting the NDUG detector 24 plane block and its frame, the total weight below lifting fixture (spreader bar) is:

19,296 pounds for the block

1170 pounds for the table top

3578 pounds for the pallet

4325 pounds for the D.S. frame weldment

1086 pounds for the Table Vertical U.S. Frame

Sum = 29,455 pounds

For Lifting the NDUG muon catcher 3 by 2 Block Module and its frame, the total weight below lifting fixture (spreader bar) is:

1072 pounds for the 3 x 2 mini-block

18567 pounds for the muon catcher steel weldment

91 pounds for each of 2 lifting yokes

Sum = 19,889 pounds (this is slightly heavier than the 19,700 calculated above – but using the slightly higher value is conservative)

Capacity of the lifting fixture is 15 tons (30,000 pounds).

Capacity of the MINOS shaft crane is 15 short tons (30,000 pounds)

Loading Conditions:

The lifting fixture (spreader bar) shown in drawing 493316 is used for both the block and frame assembly (the sum of the parts listed above and shown in drawing 493520) and the muon catch assemblies.

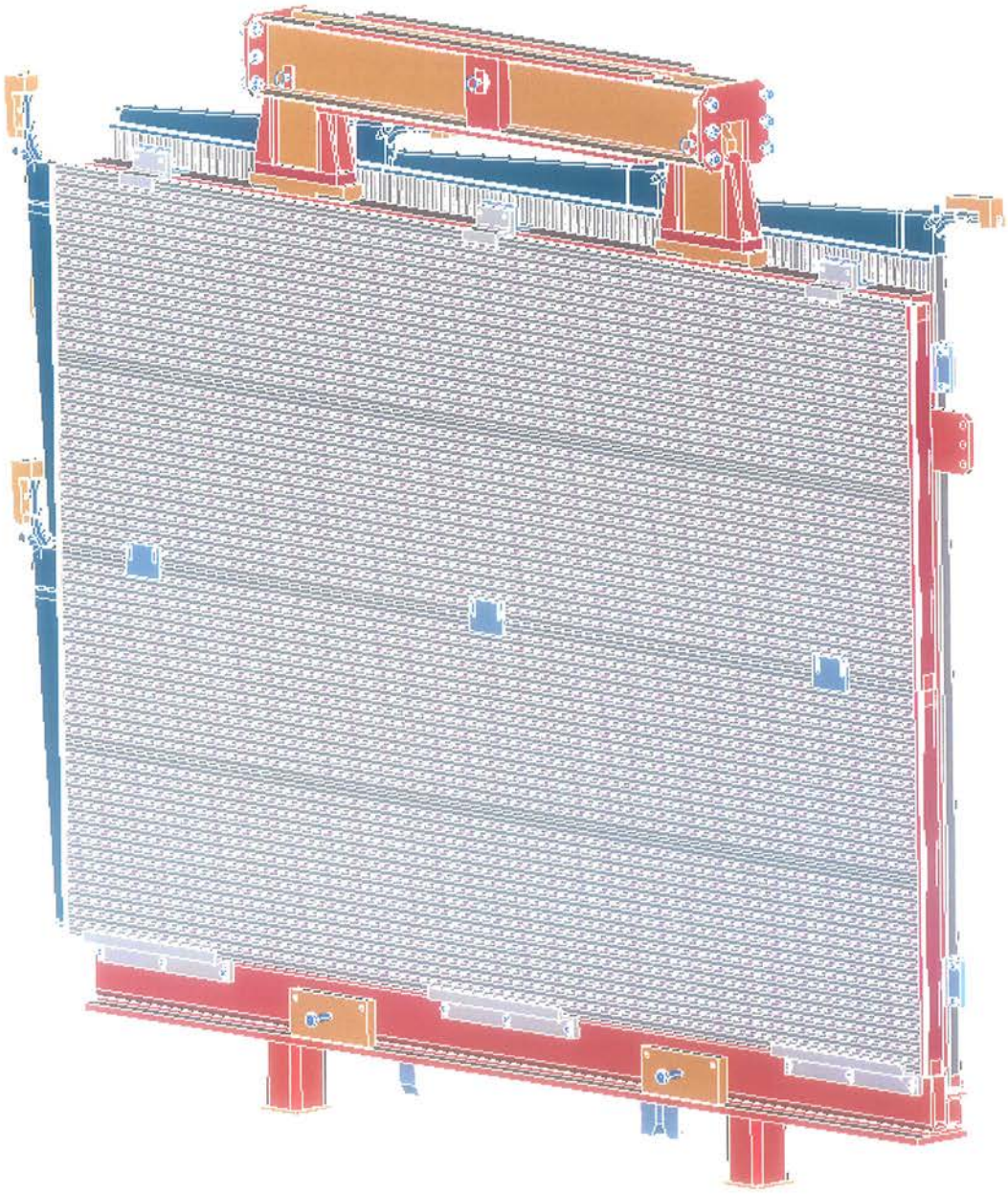
In both cases, the lifting fixture (spreader bar) shown in drawing 493316 is used for a purely vertical lift.

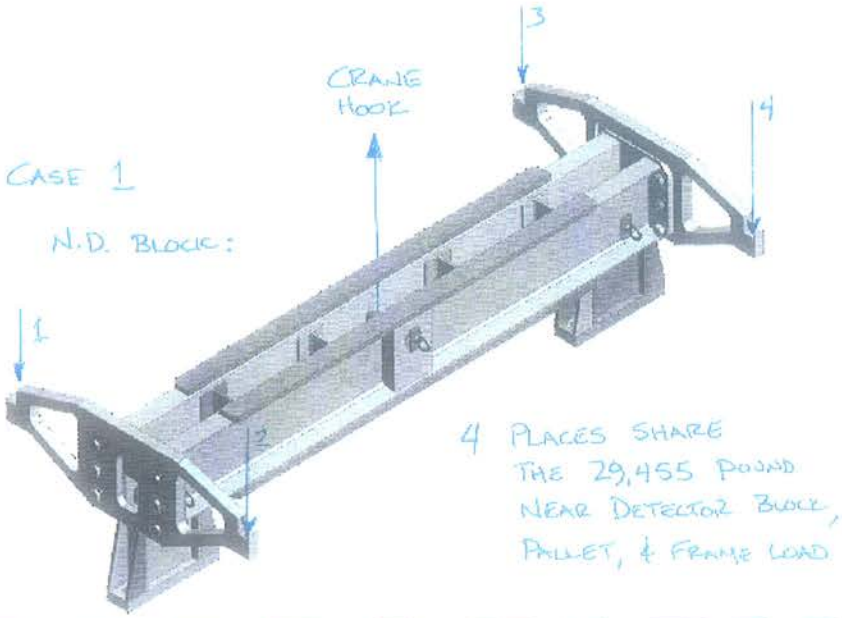
Therefore, the only loading conditions are:

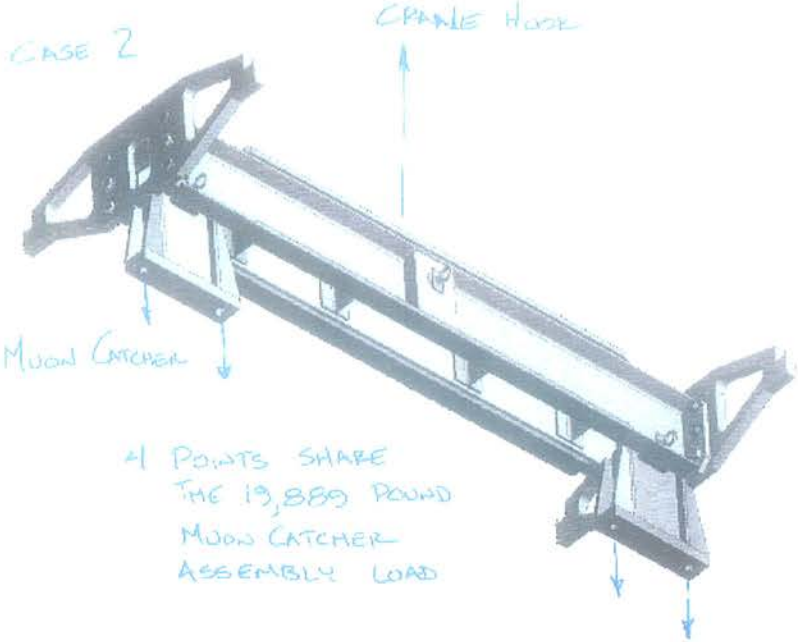
1) 29,455 pounds vertical pick of the block, pallet, table top and D.S. frame:

(Note, the 24 planes of near detector block are suppressed in the above image)

2) 19,889 pounds vertical pick of the muon catcher assembly:




CASE 1
N.D. BLOCK:
CRANE HOOK
1
2
3
4
4 PLACES SHARE THE 29,455 POUND NEAR DETECTOR BLOCK, PALLET, & FRAME LOAD


CASE 2
CRANE HOOK
MUON CATCHER
4 POINTS SHARE THE 19,889 POUND MUON CATCHER ASSEMBLY LOAD

This is a follow up based on Ingrid's review and follow-up meeting (in April 15the and 16th).

1. Both Lifting device and lifting attachments are subject to the code.
2. Both Lifting device and lifting attachments are subject to mild impact loads during routine use.
3. Fillet weld size is specified by the leg width, but the stress is determined by effective throat thickness. The effective weld area of a fillet weld is defined as the effective length of weld multiplied by the effective throat thickness. The minimum effective length of a fillet weld shall be four times the specified weld size, or the weld size shall be considered not to exceed ¼ of the effective weld length. The minimum fillet weld size shall not be less than the size required to transmit calculated forces nor the size required given in the table. The maximum fillet weld size is based on the thickness of the connected parts. Along edges of the materials of thickness less than ¼", the weld size shall not exceed the thickness of the material. Along edges where the material thickness is ¼" or greater, the weld size shall not be greater than the material thickness minus 1/16".
4. Intermittent welds shall be made on both sides of the joint for at least 25% of its length. The maximum spacing of intermittent fillet welds is 12 in.
5. List all the design load for each lifting device and lifting attachment.
6. List all the loading cases for each lifting device and lifting attachment.
7. Verify the applied seismic load based on various codes.
8. Calculate the minimum turn over load of the cart.

Below is the second part of the review.

9. Allowable stresses for flexural member that is not defined as lifting fixture/lifting attachment shall be computed based on compact section or non- compact section.
10. In connection design, bolts shall not be considered as sharing stress in combination with welds. When the gravity axes of connecting, axially stressed members do not intersect at one point, provision shall be made for bending and shear stresses due to eccentricity in the connection.
11. Only ASTM A325 or ASTM A490 bolts shall be used in slip-critical connections.
12. The strength of welds is governed by either the base material or the deposited weld material. The design strength of welds subject to tension or compression shall be equal to the effective area of the weld multiplied by the allowable stress of the base metal. The design strength of welds subject to shear shall be equal to the effective area of the weld multiplied by the allowable stress. If two or more of the general types of welds are combined in a single joint, the effective capacity of each shall be separately computed with reference to the axis of the group in order to determine the allowable capacity of the combination.
13. The effective length of any groove weld is the length over which the weld cross section has the proper effective throat thickness. Intermittent groove welds are not permitted.

This concludes the initial review of 5 Engineering notes.

Ingrid

Calculations for Lifters ID number 188:

ASME BTH Lifter Design Category: Category A

ASME BTH Lifter Service Class: Class 0 (0 to 20,000 load cycles)

ASME BTH Lifter Static Design Basis, $N_d = 2.0$

Beam Section Calculations:

Design Inputs:

Design capacity, P = 30,000 pounds

Span, L = 74 inches and 85 inches

Beam Material: A36 carbon steel

Size: Channel C10 x 20

Qty of C sections: Qty = 2

Allowable stress per ASME B30.20: $\sigma_{allowable} = F_y / 3 = 36{,}000$ psi / 3

Allowable stress from ASME BTH section 3-2.3.1 Strong Axis bending of Compact Sections.

The first paragraph in this section indicates that sections with compact flanges and webs as defined by Table 3-1, with the flanges continuously connected to the webs and loaded in the plane of the minor axis; the allowable bending stress is given by equation (3-6).

Compact Section Check:

b/t = (2.739/.436) = 6.28

0.38 SQRT (E/F_y) = 0.38 * SQRT (29,000/36) = 10.78

b/t < the compact section criteria, therefore, this is a compact section.

Eqn (3-6): $F_b = 1.10 * F_y / N_d$

$F_b = 1.10 * 36{,}000$ psi / 2.0 = 19,800 psi

Therefore, the allowable bending stress from BTH is 19,800 psi. B30.20 requires the bending stress remain less than 12,000 psi.

For BTH, Check that the lateral unbraced length criteria is met:

Eqn (3-8): $L_p = 1.76 * r_y * \text{sqrt}(E / F_y) \leq 0.67* E / (F_y *d/A_f)$

$E = 29{,}000{,}000$ psi

$d = 10.0$

$r_y = 3.66$ in

$F_y = 36{,}000$ psi

$S_x = 15.8$ in^3

$A = 5.88$ in^2

$A_f = 2.739 * .436 = 1.194$ in^2

$L_p = 1.76 * r_y * \text{sqrt}(E / F_y) \leq 0.67* E / (F_y *d/A_f)$

$L_p = 1.76 * 3.66* \text{sqrt}(29000 / 36) \leq 0.67* 29000 / (36 *10/1.194)$

$L_p = 182.8 \text{ in} \leq 64.44$

Use the lesser value (64.44 inches); the actual unbraced length (inches) is far less than this maximum. So the lateral unbraced length criterion is met.

Use the lesser bending stress criteria:

B30.20 criteria is $\sigma_{\text{allowable}} = F_y /3 = 12{,}000$ psi

BTH criteria is $F_b = 1.10 * 36{,}000 \text{ psi} / 2.0 = 19{,}800$ psi

Use bending stress not greater than 12,000 psi

Beam Bending:

Beam Section:	C 10 by 20 (two members connected back to back with 4 *2.75" by ¾" bars added to flanges.
Beam depth,	d = 10 inches
Y =	d/ 2 = 5 inches
Moment of inertia,	I_{xx} = 78.9 in^4 for each section
Span, L =	85 inches
Loading Condition:	Simple beam with concentrated load (case 7 in AISC 9th edition).

Moment of Inertia for bars:

d1 = 10 inches
d2 = 11.5 inches
c = 5.75 inches
b = 2.75 inches
I = (1/12) * 2.75 * (11.5^3 – 10^3)
I = 119.36 in ^4

Combined Moment of Inertia for channels and bars:

I = 119.36 + (2 * 78.9)
I = 277.16 in^4

Reaction R1 =	R1 = P/2
	R1 = 15,000 pounds
Reaction R2 =	R2 = R1 = 15,000 pounds

Maximum bending Moment, M_{max} =

M_{max} = P * l / 4

M_{max} = 30,000 * 85 /4 = 637,500 in - lbs

Bending Stress, σ_{actual} σ_{actual} = M*y/ I_{xx}

σ_{actual} = 637,500 in-pounds*5.75 in / 277 in^4

σ_{actual} = 13,233 psi

σ_{actual} = 13,233 psi; therefore, this is okay. Actual bending stress meets BTH criteria, but not B30.20 criteria.

Calculate the shear stress on the weld between the channel and the 2.75 by ¾ bar:

Vertical shear, V — V = P / 2 = 15,000 pounds

Horizontal shear, τ

$\tau = V * a * y / (I * t)$

I = moment for whole section

I = 277 in^4

a = area of the bars on the top

a = 2* 2.75 * ¾ = 4.12 in^2

y = distance from neutral axis (n.a.) to weld plane

y = 5 inches

t = thickness of section at plane where stress is to be calculated

t = .75 inches

τ = 15,000 * 4.12 *5.0 / (277 * .75)

τ = 1487 psi

Allowable Weld shear per unit length, $P'_{allowable}$ =

$P'_{allowable}$ = 0.707 *w * 0.3 * 70,000 psi

$P'_{allowable}$ = 0.707 *1/2 * 0.3 * 70,000 psi

$P'_{allowable}$ = 7,423 psi

Check Pins:

Main Pin:

2.5 inch diameter

span length = 4.16 inches

Load, P = 30,000 pounds

Shear Stress, τ: τ = (30000/2)/((pi()/4)*2.5^2) = 3055 psi

Bending:

M = P * l /4

M = 30000 * 4.16 / 4

M = 31,200 psi

I = (1/64) * π* d^4

I = 1/64 * 3.14 * 2.5^4 = 1.9175

y = 1.25

σ = My/I = 31,200 * 1.25 / 1.9175

σ = 20,339 psi

End Pins:

1.5 inch diameter

span length = 1.66 inches

Load, P = 15,000 pounds

Shear Stress, τ: τ = (15000/2)/((pi()/4)*1.5^2) = 4244 psi

Bending:

M = P * l /4

M = 15,000 * 1.66 / 4

M = 6225 psi

I = (1/64) * π* d^4

I = 1/64 * 3.14 * 1.5^4 = 0.248

y = .75

σ = My/I = 6225 * .75 / 0.248

σ = 18,787 psi

A PDF of this drawing is available at: http://www-admscad.fnal.gov/MSDMain/cgi-bin/TP_PPDifind-web.pl

Once this page is opened, type in the last six digits of the drawing number (493457) in the search box to access this drawing.

ASME BTH-1-2008 paragraph 1-4.4 addresses analysis methods. The allowable stresses and stress ranges defined in this Standard are based on the assumption of analysis by classical strength of material methods (models), ALTHOUGH OTHER ANALYSIS METHODS MAY BE USED.

This analysis is a sophisticated, computer – aided method of analysis and is not considered a classical strength of material method.