D0 ENGINEERING NOTE

3823.111-EN-485

SOLENOIDAL MAGNET INSTALLATION

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Approved: _____

A handwritten signature in dark ink, appearing to read "Kurt Kempf", is written over a horizontal line. The signature is fluid and cursive, with a long horizontal stroke extending to the right.

The major modification to the D0 detector for the next physics collider run is the upgrade of the central tracking system. The first component to be installed will be the solenoid magnet, with the central pre-shower attached. This engineering note is directed to the installation of the solenoid magnet and the equipment needed to accomplish this task.

As part of the installation process, the main detector must undergo a change in position of one of its major components, namely the South End Calorimeter(SEC). This calorimeter must be completely decoupled from the main detector, i.e. all cabling and cryo lines removed. The equipment used for installing all calorimeters(bridge and support structures) will be put into position and the calorimeter (SEC) will be pulled off of the detector center beam and parked on the south sidewalk of the D0 Assembly Hall. The necessary cryo lines will re-connected in order to keep the cryostat cold. This calorimeter will remain here during the greater portion of the upgrade reconfiguration schedule. When this task is finished, the old central tracking system and its mounts will be removed from the bore of the Central Calorimeter (CC). The main detector is now ready to receive the new tracking system, starting with the solenoid magnet.

The basic scheme for this task is to install an I-beam through the bore of the Central Calorimeter on which the solenoid can be rolled into position. Brackets added at each end of the solenoid provide mounts for Hilman rollers which allow the solenoid to roll on the I-beam. The I-beam is then inserted through the solenoid and placed in contact with the Hilman rollers. The solenoid will be secured to the I-beam solidly so as to prevent any relative motion between the I-beam and the magnet. This package will then be lifted and moved onto a transfer cart positioned on the Calorimeter installation bridge immediately in front of the parked SEC. At this point the I-beam will be partially into the CC bore. The transfer cart supports the I-beam at the end of the magnet. The north support is removed during final transfer of the magnet into CC. The transfer cart will be moved north on the installation bridge to within ~6" of the CC face. The north end of the installation I-beam will now extend through the CC and will be supported by a weldment mounted between the NEC and CC on the center beam. This weldment will be anchored horizontally to the CC and has both horizontal and vertical adjustment capabilities. After the I-beam is engaged and supported by this weldment, the transfer cart's north I-beam support is removed and the solenoid package is now supported by the south transfer cart support and the weldment at the north end of the CC. The solenoid is aligned with the center line of the CC bore. The dimensional limits on the solenoid/pre-shower package provide a nominal radial clearance of 1/4" with CC bore. The security locks are removed from the solenoid/I-beam package and the solenoid is rolled along the I-beam into position within the CC. When the proper Z location has been reached the solenoid will be lowered onto fixed mounts on the CC vacuum shell. The I-beam will be removed by reversing the installation support procedure. Final X and Y alignment will be done by optical survey methods.

The solenoid with the pre-shower attached is estimated to weigh ~10,000 lbs. One piece of the equipment used in removing the SEC is a bridge which spans the distance from the end of the center beam to a support structure on the south sidewalk (this bridge has been used in the installation of all Calorimeters). A transfer cart, used in positioning the solenoid, will be mounted on this bridge. This cart will be a welded steel structure of 8 x 4 x 1/4 wall box section, mounted on four (4) Hilman rollers. There are two removable support assemblies on top of the cart base structure. These assemblies consist of saddles which seat the installation I-beam, and include vertical and horizontal adjusting devices. The adjusters consist of screw jacks for the vertical and simple jack screws for the horizontal. Using these adjusters proper alignment of the solenoid package with the CC bore will be made. The installation I-beam is a composite structure consisting of a W18 X 86 beam with 3/4" thick x 12" wide cap plates, top and bottom. Since deflection of the I-beam is our main concern for insertion of the solenoid into the CC bore, the member stresses are quite small. The deflection analysis shows that the beam deflects .046", with the solenoid package at the mid-point of the beam(worst case). The max. bending moment is 4.29E4 lb-ft and thus the max. bending stress is 1720 psi., well below acceptable the limit of 20ksi. A load test of the beam will be conducted with a 125% load factor and the expected deflection should be .055".

An independent analysis was performed by Ang Lee and a copy of his work is attached.

The Stress & Deflection Calculation for the Cross
Beam (W18x86) and the Vertical Column Used in the D0 Solenoid Installation

Ang Lee

Introduction

The structure used to install the solenoid for D0 upgrade consists of a cross beam_W18x86 and several box beam frames. The purpose of this calculation is to determine the stress level as well as the deflection which the structure will be possible experienced during the installation procedure. Only the worst case is considered for the purpose of the analysis. The AISC,9th Edition is used as a guideline to determine the allowable stress for the structure in question. The calculation result is summarized on the Table 1. Even for the very conservative approach, the stress level is very low compared with its allowable. The maximum deflection will be less than 70 mils.

Table 1 The Stress and Deflection

	Max. Stress (ksi)	Allowable Stress (ksi)	Max. Def. (in)
I Beam (W18x86)	2.2	21.6 ⁽¹⁾	0.043
Top Tubing (8x4x1/4)	7.1	27.6 ⁽²⁾	0.018
Vertical Column (8x4x1/4)	1.07	14.6 ⁽³⁾	0.003
Total Def. <			0.070

Note:

- 1) Also checked with AISC, 9th edition, Eq F1-2, F1-8, K1-1, K1-3, K1-4, K1-6 and K1-8.
- 2) Also checked with AISC,9th edition , Table 5.1 and F3-3
- 3) Also checked with AISC, 9th edition,Eq E2-1 and H1-3
- 4) The stress in the jack stand is less than above calculated stress for top tubin and vertical column since the jack stand uses the same 8x4x1/4 tube with a much small dimension.

Calculation details: (see next page)

CALCULATION DETAILS

- 1) Consider a simply supported case with a concentrated load in the middle of the I-Beam (the worst case)

$$M = \frac{10,000}{2} \times \frac{270}{2} = 675,000 \text{ lbf-in}$$

$$I_{\text{Total}} = I_{\text{(EXTRA plate)}} + I_{\text{(W18x86)}}$$

$$I_{\text{(W18x86)}} = I_2 = 1530 \text{ in}^4$$

$$I_{\text{EXTRA plate}} = I_1 = \frac{12}{12} (19.875^3 - 18.375^3) = 1646 \text{ in}^4$$

So:

The max. bending stress σ_b

$$\sigma_b = \frac{M \cdot \frac{y}{2}}{I_{\text{Total}}} = \frac{675,000 \times \frac{19.875}{2}}{1530 + 1646} = 2200 \text{ PSI}$$

$$\sigma_b = 2.2 \text{ ksi}$$

2). Allowable stress followed AISC guide line

CHECK (I-2)

$$\frac{76 \text{ k}}{\sqrt{F_y}} = \frac{76 \times 11.09}{\sqrt{36}} = 140 \text{ in}$$

OK

$$\frac{20,000}{\left(\frac{d}{A_f}\right) \cdot F_y} = \frac{20,000}{\left[\frac{19.875}{(11.09 \times 0.77) + (0.75 \times 12)} \right] \times 36} = 490''$$

$$L = 270'' > L_c = 140''$$

Then (F1-8) will be used

$$F_b = \frac{12 \times 10^3 C_b}{\frac{L \cdot d}{A_f}} \leq 0.60 F_y$$

$$\frac{12 \times 10^3 \cdot C_b}{\frac{L \cdot d}{A_f}} = \frac{12 \times 10^3 \times 1.75}{\frac{270 \times 19.875}{17.54}} = 68 \text{ ksi.}$$

Then:

F_b will be taken as $0.6 \times F_y$

$$\boxed{F_b = 0.6 \times 36 = 21.6 \text{ ksi}} \Rightarrow \tau_b = 2.2 \text{ ksi.}$$

3) CHECK WITH THE "SECTION K, AISC, 9th EDITION"

a) LOCAL FLANG BENDING (K1-1)

$$0.4 \sqrt{\frac{P_{bf}}{F_{ye}}} : \text{ WHERE } P_{bf} = \frac{4}{3} \times 10 \text{ kips}$$

$$0.4 \sqrt{\frac{\frac{4}{3} \times 10}{36}} = 0.24 < t_f = 0.75'' + 0.77''$$

(ok)

b) LOCAL WEB YIELDING (K1-3)

$$\frac{R}{t_w(N+2.5K)} = \frac{10}{0.5(1+2.5) \times 1\frac{7}{8}} = 3.97 \text{ kips}$$

$$< 0.66 F_y = 23 \text{ kips}$$

where: $N=1K$ (worst case)

(ok)

c) WEB CRIPPLING (K1-4)

$$R = 67.5 t_w^2 \left[1 + 3 \left(\frac{N}{d} \right) \left(\frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{\frac{F_y w t_f}{t_w}}$$

$$= 67.5 \times 0.5^2 \left[1 + 3 \left(\frac{10}{18.375} \right) \left(\frac{0.5}{0.77} \right)^{1.5} \right] \sqrt{\frac{36 \times 0.77}{0.5}}$$

$$= 31.291 \times 7.445 = 232 \text{ kip} \gg 10 \text{ kips}$$

(ok)

d) SIDESWAY WEB BUCKLING
(14-6) OR K11-7)

$$\frac{d_c/t_w}{l/b_f} = \frac{15.51/0.5}{0.5} = 62.04 > \frac{2.3}{1.7} \text{ OR}$$

Where: $d_c = d - 2k = 18.39 - 2 \times 1.44 = 15.51$

(OK)

e) COMPRESSION BUCKLING OF WEB (K1-2)

$$\frac{4100 t_w c^3 \sqrt{F_{wc}}}{P_{bf}} = \frac{4100 \times 15^3 \sqrt{36}}{\frac{4}{3} \times 10 \text{ (kips)}} = 230'' \gg d_c = 15.51''$$

(OK)

4) possible an axial force due to the SOLENOID moving along the Beam.

$$F_{axial} = 5\% \cdot P = 0.05 \times 10,000 = 500 \text{ lbf}$$

Compressive $\sigma_{cp} = \frac{F_{axial}}{A} = \frac{500}{25.3 + 18} = 11 \text{ psi, (VERY small)}$

5) Deflection at middle (WORST CASE) Negligible!

$$\delta_I = \frac{P L^3}{48 E I} = \frac{10,000 \times 270^3}{48 \times 30 \times 10^6 \times 3176} = 0.043''$$

SECTION 2 BOX BEAM FRAME

THIS SECTION WILL COVER BOX BEAM FRAME
AS WELL AS JACK STAND WHICH USES A SAME STRUCTURE
TUBING WITH A MUCH SMALLER SIZE OF THE FRAME.

1). TOP TUBING AND THE VERTICAL COLUMN

* ASSUMING ALL WEIGHT
OF SOLENOID IS LOADED
ON ONE FRAME.

a). TOP TUBE 8x4x1/4"

$$R_2 = \frac{5 \times 12.5 + 5 \times 33.5}{40} = 5.75 \text{ kips}$$

$$R_1 = 10 - 5.75 = 4.25 \text{ kips}$$

$$M_{\max} = 54 \text{ kip-in}$$

The maximum stress σ_b

$$\sigma_b = \frac{54 \times 2}{15.3} = 7.1 \text{ ksi}$$

Allowable From AISC

CHECK TABLE B5.1

$$\frac{23^2}{\sqrt{F_y}} > \frac{b}{t} = \frac{8''}{0.25} = 32 > \frac{190}{\sqrt{F_y}} = 28$$

NON COMPACT SECTION :

$$F_b = 0.6 F_y = 0.6 \times 46 = 27.6 \text{ ksi (F3-3)}$$

$$>> J_b = 7.1 \text{ ksi (WORST CASE)}$$

Deflection (Assuming 10,000 lb Loaded in middle) ^(2k)

$$\delta_{max} = \frac{10 \times 10000 \times 40^3}{48 \times 30 \times 10^6 \times 15.3} = 0.03'' \text{ Very STIFF}$$

OR TAKE FEA RESULT

$$\delta_{max} = 0.018''$$

ANSYS 5.3
JAN 14 1998
14:49:20
PLOT NO. 1
DISPLACEMENT
STEP=1
SUB =1
TIME=1
RSYS=0
DMX = .018678
F

DSCA=107.076
ZV =1
DIST=22
XF =20
YF =-1
Z-BUFFER

b) THE VERTICAL COLUMN

SINCE one Reaction Force
is 5.75 kips BASED ON THE
ASSUMPTION THAT 10,000 lb
LOADED ON ONE FRAME ONLY.

LET'S SAY: $P = 6 \text{ kips}$ FOR VERTICAL COLUMN

$$f(\text{compressive}) = \frac{6 \text{ kips}}{A} = \frac{6}{5.59} = 1.07 \text{ (KSI)}$$

$$\boxed{\sigma_c = 1.07 \text{ ksi}}$$

CHECK AISC, CHAPTER E. (E2-1).

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}} = \sqrt{\frac{2 \times 3.14^2 \times 30 \times 10^3}{46}} = 113$$

$$\frac{Kl}{r} = \frac{2 \times 82.25}{1.65} = 99.67 < 113$$

THEN

$$F_a = \frac{\left[1 - \frac{(Kl/r)^2}{2C_c^2}\right] F_y}{\frac{5}{3} + \frac{3(Kl/r)}{8C_c} - \frac{(Kl/r)^3}{8C_c^3}}$$

$$= \frac{\left[1 - \frac{99.67^2}{2 \times 113^2}\right] \times 46}{\frac{5}{3} + \frac{3}{8} \frac{99.67}{113} - \frac{99.67^3}{8 \times 113^3}}$$

$$= \frac{(1 - 0.3889)}{(1.67 + 0.33 - 0.085)} \cdot 46 = 0.32 \times 46 = 14.6 \text{ ksi}$$

$$F_a = 14.6 \text{ ksi} \gg \sigma_c = 1.07 (\text{ksi})$$

(OK)

Reflection:

$$\delta = \frac{F}{AE} \cdot L = \frac{6,000}{5.59 \times 30 \times 10^6} \times 82.5$$

$$= 0.003 \text{ (inch)} \approx 3 \text{ (mils)}$$

NOTHING

Assuming THERE WILL BE A CASE WHERE THE SOLENOID IS MOVED TOWARDS ITS BEAM LINE POSITION, AN EXTRA FORCE WILL BE ADDED BESIDE THE COMPRESSIVE Force:

$$\begin{aligned} * F_{ex} &= 5\% * P = 300 \text{ lbf} \\ &= 0.3 \text{ kips.} \end{aligned}$$

$$\sigma_b = \frac{300 \times 82.25'' \times \frac{8''}{2}}{45.1}$$

$$= 2.2 \text{ (ksi)}$$

FOR A NON-COMPACT SECTION, THE Allowable is given

$$F_b = 0.6 * F_y = 0.6 \times 46 = 27.7 \text{ ksi}$$

$$\boxed{\frac{\sigma_c}{F_c} + \frac{\sigma_b}{F_b} = \frac{1.07}{14.6} + \frac{2.2}{27.7} = 0.15 \ll 1} \quad (H 1.3)$$

OK

W SHAPES Dimensions

Designation	Area <i>A</i>	Depth <i>d</i>		Web			Flange				Distance		
				Thickness <i>t_w</i>		$\frac{t_w}{2}$	Width <i>b_f</i>		Thickness <i>t_f</i>		<i>T</i>	<i>k</i>	<i>k₁</i>
	In. ²	In.	In.	In.	In.	In.	In.	In.	In.	In.			
W 18×311 ^a	91.5	22.32	22%	1.520	1½	¾	12.005	12	2.740	2½	15½	3¾	1¾
×283 ^a	83.2	21.85	21½	1.400	1¾	1½	11.890	11½	2.500	2½	15½	3¾	1¾
×258 ^a	75.9	21.46	21½	1.280	1¾	¾	11.770	11½	2.300	2½	15½	3	1½
×234 ^a	68.8	21.06	21	1.160	1½	¾	11.650	11½	2.110	2½	15½	2¾	1
×211 ^a	62.1	20.67	20%	1.060	1½	¾	11.555	11½	1.910	1½	15½	2¾	1
×192	56.4	20.35	20%	0.960	1	½	11.455	11½	1.750	1¾	15½	2½	1½
×175	51.3	20.04	20	0.890	¾	¾	11.375	11½	1.590	1½	15½	2¼	¾
×158	46.3	19.72	19¾	0.810	¾	¾	11.300	11½	1.440	1¾	15½	2½	¾
×143	42.1	19.49	19½	0.730	¾	¾	11.220	11½	1.320	1¾	15½	2	1½
×130	38.2	19.25	19¼	0.670	¾	¾	11.160	11½	1.200	1¾	15½	1¾	1½
W 16×119	35.1	18.97	19	0.655	¾	¾	11.265	11¼	1.060	1½	15½	1¾	1½
×106	31.1	18.73	18¾	0.590	¾	¾	11.200	11¼	0.940	1½	15½	1¾	1½
×97	28.5	18.59	18%	0.535	¾	¾	11.145	11¼	0.870	¾	15½	1¾	¾
×86	25.3	18.39	18¾	0.480	½	¾	11.090	11¼	0.770	¾	15½	1¾	¾
×76	22.3	18.21	18¼	0.425	¾	¾	11.035	11	0.680	1½	15½	1¾	1½
W 18×71	20.8	18.47	18½	0.495	½	¾	7.635	7¾	0.810	1¾	15½	1½	¾
×65	19.1	18.35	18¾	0.450	¾	¾	7.590	7¾	0.750	¾	15½	1¾	¾
×60	17.6	18.24	18¼	0.415	¾	¾	7.555	7½	0.695	1½	15½	1¾	1¾
×55	16.2	18.11	18½	0.390	¾	¾	7.530	7½	0.630	¾	15½	1¾	1¾
×50	14.7	17.99	18	0.355	¾	¾	7.495	7½	0.570	¾	15½	1¼	1¾
W 18×46	13.5	18.06	18	0.360	¾	¾	6.060	6	0.605	¾	15½	1¼	1¾
×40	11.8	17.90	17¾	0.315	¾	¾	6.015	6	0.525	½	15½	1¾	1¾
×35	10.3	17.70	17¾	0.300	¾	¾	6.000	6	0.425	¾	15½	1¾	¾
W 16×100	29.4	16.97	17	0.585	¾	¾	10.425	10¾	0.985	1	13¾	1½	1¾
×89	26.2	16.75	16¾	0.525	½	¾	10.365	10¾	0.875	¾	13¾	1½	¾
×77	22.6	16.52	16½	0.455	¾	¾	10.295	10¼	0.760	¾	13¾	1½	¾
×67	19.7	16.33	16¾	0.395	¾	¾	10.235	10¼	0.665	1½	13¾	1¾	1¾
W 16×57	16.8	16.43	16¾	0.430	¾	¾	7.120	7¾	0.715	1½	13¾	1¾	¾
×50	14.7	16.26	16¼	0.380	¾	¾	7.070	7¾	0.630	¾	13¾	1¾	1¾
×45	13.3	16.13	16½	0.345	¾	¾	7.035	7	0.565	¾	13¾	1¼	1¾
×40	11.8	16.01	16	0.305	¾	¾	6.995	7	0.505	½	13¾	1¾	1¾
×36	10.6	15.86	15¾	0.295	¾	¾	6.985	7	0.430	¾	13¾	1¾	¾

*For application refer to Notes in Table 2.

Shapes in shaded rows are not available from domestic producers.

W SHAPES Properties

Nominal Wt. per Ft	Compact Section Criteria				r_T	$\frac{d}{A_f}$	Elastic Properties						Plastic Modulus	
	$\frac{b_f}{2t_f}$	F_y'	$\frac{d}{t_w}$	F_y''			Axis X-X			Axis Y-Y			Z_x	Z_y
							I	S	r	I	S	r		
Lb.		Ksi		Ksi	In.	In. ⁴	In. ³	In.	In. ⁴	In. ³	In.	In. ³	In. ³	In. ³
311	2.2	—	14.7	—	3.26	0.68	6960	624	8.72	795	132	2.95	753	207
283	2.4	—	15.6	—	3.23	0.74	6160	564	8.61	704	118	2.91	676	185
258	2.6	—	16.8	—	3.19	0.79	5510	514	8.53	628	107	2.88	611	166
234	2.8	—	18.2	—	3.16	0.86	4900	466	8.44	558	95.8	2.85	549	149
211	3.0	—	19.5	—	3.13	0.94	4330	419	8.35	493	85.3	2.82	490	132
192	3.3	—	21.2	—	3.10	1.02	3870	380	8.28	440	76.8	2.79	442	119
175	3.6	—	22.5	—	3.07	1.11	3450	344	8.20	391	68.8	2.78	398	106
158	3.9	—	24.3	—	3.05	1.21	3060	310	8.12	347	61.4	2.74	356	94.8
143	4.2	—	26.7	—	3.03	1.32	2750	282	8.09	311	55.5	2.72	322	85.4
130	4.6	—	28.7	—	3.01	1.44	2460	256	8.03	278	49.9	2.70	291	76.7
119	5.3	—	29.0	—	3.02	1.59	2190	231	7.90	253	44.9	2.69	261	69.1
106	6.0	—	31.7	—	3.00	1.78	1910	204	7.84	220	39.4	2.66	230	60.5
97	6.4	—	34.7	54.7	2.99	1.92	1750	188	7.82	201	36.1	2.65	211	55.3
86	7.2	—	38.3	45.0	2.97	2.15	1530	166	7.77	175	31.6	2.63	186	48.4
76	8.1	64.2	42.8	36.0	2.95	2.43	1330	146	7.73	152	27.6	2.61	163	42.2
71	4.7	—	37.3	47.4	1.98	2.99	1170	127	7.50	60.3	15.8	1.70	145	24.7
65	5.1	—	40.8	39.7	1.97	3.22	1070	117	7.49	54.8	14.4	1.69	133	22.5
60	5.4	—	44.0	34.2	1.96	3.47	984	108	7.47	50.1	13.3	1.69	123	20.6
55	6.0	—	46.4	30.6	1.95	3.82	890	98.3	7.41	44.9	11.9	1.67	112	18.5
50	6.6	—	50.7	25.7	1.94	4.21	800	88.9	7.38	40.1	10.7	1.65	101	16.6
46	5.0	—	50.2	26.2	1.54	4.93	712	78.8	7.25	22.5	7.43	1.29	90.7	11.7
40	5.7	—	56.8	20.5	1.52	5.67	612	68.4	7.21	19.1	6.35	1.27	78.4	9.95
35	7.1	—	59.0	19.0	1.49	6.94	510	57.6	7.04	15.3	5.12	1.22	66.5	8.06
100	5.3	—	29.0	—	2.81	1.65	1490	175	7.10	186	35.7	2.51	198	54.9
89	5.9	—	31.9	64.9	2.79	1.85	1300	155	7.05	163	31.4	2.49	175	48.1
77	6.8	—	36.3	50.1	2.77	2.11	1110	134	7.00	138	26.9	2.47	150	41.1
67	7.7	—	41.3	38.6	2.75	2.40	954	117	6.96	119	23.2	2.46	130	35.5
57	5.0	—	38.2	45.2	1.86	3.23	758	92.2	6.72	43.1	12.1	1.60	105	18.9
50	5.6	—	42.8	36.1	1.84	3.65	659	81.0	6.68	37.2	10.5	1.59	92.0	16.3
45	6.2	—	46.8	30.2	1.83	4.06	586	72.7	6.65	32.8	9.34	1.57	82.3	14.5
40	6.9	—	52.5	24.0	1.82	4.53	518	64.7	6.63	28.9	8.25	1.57	72.9	12.7
36	8.1	64.0	53.8	22.9	1.79	5.28	448	56.5	6.51	24.5	7.00	1.52	64.0	10.8

frictional
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STRUCTURAL TUBING

Rectangular

Dimensions and properties

Dimensions				Properties**									
Nominal* Size	Wall Thickness		Weight per Ft	Area	X-X Axis				Y-Y Axis				J
	In.	In.			I_x	S_x	Z_x	r_x	I_y	S_y	Z_y	r_y	
In.	In.	Lb.	In. ²	In. ⁴	In. ³	In. ³	In.	In. ⁴	In. ³	In. ³	In.	In. ⁴	In. ⁴
8x6	0.5625	3/16	46.51	13.7	112	27.9	35.2	2.86	70.8	23.6	28.8	2.28	147
	0.5000	1/2	42.05	12.4	103	25.8	32.2	2.89	65.7	21.9	26.4	2.31	135
	0.3750	3/8	32.58	9.58	83.7	20.9	25.6	2.96	53.5	17.8	21.0	2.36	107
	0.3125	5/16	27.59	8.11	72.4	18.1	21.9	2.99	46.4	15.5	18.0	2.39	91.3
	0.2500	1/4	22.42	6.59	60.1	15.0	18.0	3.02	38.6	12.9	14.8	2.42	74.9
	0.1875	3/16	17.08	5.02	46.8	11.7	13.9	3.05	30.1	10.0	11.4	2.45	57.6
8x4	0.5625	3/16	38.86	11.4	80.5	20.1	26.9	2.65	26.2	13.1	16.2	1.51	69.0
	0.5000	1/2	35.24	10.4	75.1	18.8	24.7	2.69	24.6	12.3	15.0	1.54	64.1
	0.3750	3/8	27.48	8.08	61.9	15.5	19.9	2.77	20.6	10.3	12.2	1.60	52.2
	0.3125	5/16	23.34	6.86	53.9	13.5	17.1	2.80	18.1	9.05	10.5	1.62	45.2
	0.2500	1/4	19.02	5.59	45.1	11.3	14.1	2.84	15.3	7.63	8.72	1.65	37.5
	0.1875	3/16	14.53	4.27	35.3	8.83	11.0	2.88	12.0	6.02	6.77	1.68	29.1
8x3	0.5000	1/2	31.84	9.36	61.0	15.3	21.0	2.55	12.1	8.05	10.1	1.14	35.7
	0.3750	3/8	24.93	7.33	51.0	12.7	17.0	2.64	10.4	6.92	8.31	1.19	29.9
	0.3125	5/16	21.21	6.23	44.7	11.2	14.7	2.68	9.25	6.16	7.24	1.22	26.3
	0.2500	1/4	17.32	5.09	37.6	9.40	12.2	2.72	7.90	5.26	6.05	1.25	22.1
	0.1875	3/16	13.25	3.89	29.6	7.40	9.49	2.76	6.31	4.21	4.73	1.27	17.3
	0.3750	3/8	22.37	6.58	40.1	10.0	14.2	2.47	3.85	3.85	4.83	0.765	12.6
8x2	0.3125	5/16	19.08	5.61	35.5	8.87	12.3	2.51	3.52	3.52	4.28	0.792	11.4
	0.2500	1/4	15.62	4.59	30.1	7.52	10.3	2.56	3.08	3.08	3.63	0.819	9.84
	0.1875	3/16	11.97	3.52	23.9	5.97	8.02	2.60	2.52	2.52	2.88	0.847	7.94
	0.3750	3/8	22.37	6.58	40.1	10.0	14.2	2.47	3.85	3.85	4.83	0.765	12.6
7x5	0.5000	1/2	35.24	10.4	63.5	18.1	23.1	2.48	37.2	14.9	18.2	1.90	79.9
	0.3750	3/8	27.48	8.08	52.2	14.9	18.5	2.54	30.8	12.3	14.6	1.95	64.2
	0.3125	5/16	23.34	6.86	45.5	13.0	15.9	2.58	26.9	10.8	12.6	1.98	55.3
	0.2500	1/4	19.02	5.59	38.0	10.9	13.2	2.61	22.6	9.04	10.4	2.01	45.6
	0.1875	3/16	14.53	4.27	29.8	8.50	10.2	2.64	17.7	7.10	8.10	2.04	35.3

*Outside dimensions across flat sides.

**Properties are based upon a nominal outside corner radius equal to two times the wall thickness.