D0 ENGINEERING NOTE

3823.132-EN-502

SAMUS TOROID INSTALLATION FIXTURE

H. Stredde

June 27, 1990
revised July 15, 1998

Approved:
The SAMUS (Small Angle Muon System) toroids have been designed and fabricated in the USSR and delivered to D0 ready for installation into the D0 detector. These toroids will be installed into the aperture of the EF's (End Toroids).

The aperture in the EF's is 72" vertically and 66" horizontally. The Samus toroid is 70" vertically by 64" horizontally by 66" long and weighs approximately 38 tons. The Samus toroid has a 20" by 20" aperture in the center and it is through this aperture that the lift fixture must fit. The toroid must be "threaded" through the EF aperture. Further, the Samus toroid coils are wound about the vertical portion of the aperture and thus limit the area where a lift fixture can make contact and not damage the coils. The fixture is designed to lift along a surface adjacent to the coils, but with clearance to the coil and with contact to the upper steel block of the toroid. The lift and installation will be done with the 50 ton crane at D0.

The fixture was tested by lifting the Samus Toroid 2" off the floor and holding the weight for 10 minutes. Deflection was as predicted by the design calculations.

Enclosed are sketches of the fixture and its relation to both Toroids (Samus and EF), along with hand calculations and an Finite Element Analysis. The FEA work was done by Kay Weber of the Accelerator Engineering Department.

**FIXTURE MODIFICATION- Removal of SAMUS Toroids**

The Samus toroids are to be removed from the EF toroids for run II. These toroids were installed before the B & C-layer PDT’s were installed on top of the EF’s. The original installation fixture was built to clear the top surface of the EF and therefore has to be modified in length in order to clear the top layer PDT’s. This results in a change in length of 64". The fixture will be cut in the center and an appropriate section of material added by welding to provide the needed length.

The fixture will be tested by using a hydraulic cylinder and two columns to fill the gap of the fixture “C” frame. Pressure will be applied to the cylinder to provide a force of 48 tons on the fixture. (38 x 1.25).

Sketches of the modified fixture and test apparatus are included, along with the appropriate calculations that are indicated by * in the revised copy.
6 x 6 x 15 3/4 aluminum blocks
5 Thick plate
8 x 4 x .375 wall structural tubing
Enerpac cy=--4522006, 200 tons @ 10000 psi
6" stroke, 9 3/4 body dia.
Alum. shim stock

Test Load 96,000 LBS.
DEFLECTION = .438"
2-23-99
H. Stredde
**Fermilab Engineering Note**

**Subject:**
Samus Installation Fixture (No Proportional Drift Tubes Installed)

**Scale:** 3/8" = 1.0

**Section 1**

- 53 3/8"
- SECT. 2

- 193 1/2"
- 160" + 64" = 224"
- 176 3/4" ~ 240"
- 28 3/4"
- 14 3/8"
- 16 3/4"

- 33" + 60" = 93"
- 6" + 41" = 47"
- 35"
- 41"

**Est. Fixture Weight:**

- Sect 1 = \( \frac{170}{12} \times 261 \) lb = 3800
- Sect 2 = \( \frac{224}{12} \times 165 \) lb = 3080

**Hook QT =**

\( \approx 550 \) kg

\( \approx 7500 \) lb

**Notes:**
- Fixture modified for removal of toecaps w/ B & C layer (roof) PDT's in place

**References:**
- DWG: 3730.000-M5-294021
- 15" = PDT's
- 9 5/8" = TMDD
- 63.5
- 5" ~ 68"

**Name:** H. Steedos

**Date:** 11-6-89

**Revision Date:** 7-15-98

**Page:** 1
**SECTION 1**

- **W14 x 145**
- **I = 3942 in.**
- **S = 456 in.**
- **A = 76.7 in.**

**SECTION 2**

- **W27 x 84**
- **I = 7470 in.**
- **S = 520 in.**
- **A = 48.8 in.**
DESIGN TO DEFLECTION ORIENTED -

\[ M_{\text{max}} = (40000 \times 108.75) = 4.27 \times 10^6 \text{ in-lb} \]

\[ F_a = 10,000 \text{ psi} \]

\[ S = \frac{4.27 \times 10^6}{100} = 427 \text{ in}^3 > 232 \text{ in}^3 \rightarrow \text{ADD Top & Bottom Plates} \]

TO PROVIDE NEEDED STRENGTH AT LOAD CONTACT POINT

USE 1" THK x 18" WIDE (MIN) PLATE, GUSSETED AT LOAD PTS.

NEW \( I \) → \[ I = 1710 + (1 \times 8)(124) = 3942 \text{ in}^4; \quad a = \frac{14.75 + 2}{2} = 8.375 \]

\[ S = \frac{3942}{8.375} = 471 \text{ in}^3 \]

LOOKING AT DEFLECTION AT FAR END

\[ \Delta_{\text{TOTAL}} = \frac{Pb_1^2}{6EI} (3a - b_1) + \frac{Pb_2^2}{6EI} (3a - b_2) \quad b_1 = 10^\circ \]
\[ = \frac{40000}{6 \times 29 \times 10^4 \times 3942} \left[ (10^2)(3 \times 73 - 10) + (58^2)(3 \times 73 - 58) \right] \]
\[ = 0.33 \downarrow \text{OK} \]

CHECK STRESS:

\[ F_b = \frac{4.27 \times 10^6}{471} = 9,065 \text{ psi} \quad \text{OK} \quad < 21.6 \text{ ksi} \left( \frac{.6F_y}{\sqrt{3}} \right) \]

SHEAR IN WEBS:

\[ \frac{80000 \text{ LBS}}{14.75 \times .688} = 7883 \text{ psi} \quad \text{OK} \quad < 14,400 \text{ ALLOWABLE} \]
**Top Beam:**

SAME SECTION AS BOTTOM, WITH REINFORCEMENT AT LIFTING EYE.  
W14×145  
W/1" PLATES TOP & BOTTOM  
I = 3942 in.²  
S = 471.12 in.³

DEFLECTION AT LOAD:  
\[ \Delta = \frac{PL^3}{3EI} = \frac{80000 \times 39^3}{3 \times 29 \times 10^6 \times 3942} = 0.014'' \]
Vertical Beam:

Equivalent Load:

\[ M = \frac{PL}{8} = \frac{8M}{L} = \frac{(8 \times 9.27 \times 10^6)}{160} = 0.235 \times 10^6 \text{ LBS} \]

\[ \Delta = \frac{PL^3}{92EI} = \frac{0.040}{152500} = 0.041'' \]

Shear thru web:

\[ V = \frac{P}{2} = \frac{152500}{2} = 76,250 \]

\[ \sigma = \frac{76,250}{11.68 \times 10^{-6}} = \sim 6500 \text{ psi} \]
DEFLECTION OF LOADED FIXTURE
(DECELERATING WGT OF FIXTURE)

DEFLECTION: (REF. DESIGN OF WELDMENTS, BUDGET)
Pg 2.11/6

DEFLECTION DUE TO AXIAL ELONGATION: *

\[ \Delta_a = \frac{PL^2}{2E} = \frac{40 \times 2000 \times (53.375)^2}{2 \times 29 \times 10^6} = \frac{0.010}{0.014} \]

DEFLECTION DUE TO BENDING:

Rotation of yield member: *

\[ \Delta_B = \frac{PL^2}{2EI} = \frac{40 \times 2000 \times (53.375)^2}{2 \times 29 \times 10^6 \times 7470} = \frac{0.092}{0.125} \]

Rotation acting as cantilever:

\[ \Delta_C = \frac{PL^3}{3EI} = \frac{40 \times 2000 \times (53.375)^3}{3 \times 29 \times 10^6 \times 3942} = 0.035 \]

DEFLECTION DUE SHEAR:

\[ \Delta_s = \frac{PL \Delta_e}{A_2 E_S} = \frac{40 \times 2000 \times 8.2^{3/2} \times 7.234}{48.2 \times 12 \times 10^6} = 0.082 \]

Total deflection:

\[ \Delta_T = \Delta_a + 2(\Delta_B + \Delta_C + \Delta_s) = (0.010 + 2(0.092 + 0.035 + 0.082)) = 0.428 \]

\[ = 0.428 \times 0.014 + 2(0.125 + 0.035 + 0.082) = 0.498 \]
WELD SIZE, PLATE TO I-BEAM FLANGE (SEC. 1)

\[
S = \frac{V A y}{I} = \frac{40 \times 2000 \times (18 \times 1) \times (7 \frac{3}{8} + \frac{1}{2})}{3942 \times 2} = 1438 \text{ LBS/IN}
\]

FILLET SIZE = \(\frac{1438}{14850} = 0.0968\)

MIN. SIZE DUE TO MATERIAL THICKNESS = \(\frac{1}{4}\)

USING 3/8 WELD, \(\frac{0.097}{0.375} = 26\% \) OF CONTINUOUS WELD

SAY 4" WELD ON 8" Ctrs.

\(\frac{3}{8} \sqrt{4-8}\)

PLATE TO I-BEAM (SEC. 2)

\[
S = \frac{V A y}{I} = \frac{40 \times 2000 \times (12 \times 1) \times (13 \frac{3}{8} + \frac{1}{2})}{7470 \times 2} = 892 \text{ LBS/IN}
\]

FILLET SIZE = \(\frac{892}{14850} = 0.060\"

USING 3/8 FILLET, \(\frac{0.060}{0.375} = 16\%\)

SAY 3" WELD ON 12" Ctrs.

\(\frac{3}{8} \sqrt{4-12}\)
Hook Link - Detail

Dimensions:
- Width: 21 3/4"
- Height: 19"
- Depth: 2 1/4"
- Height: 3 1/8"
- Depth: 7 3/4" RF

Angles:
- 12° R

Details:
- 8" at the top
- 6" at the top
- 10" at the top
- 6" at the top

Areas:
- Shaded areas represent specific sections of the hook link.
Hook Link - Cross Section
Subject: Hook Link Analysis

Link: Mat'l 3" thick H/ES.

Stresses:

Top:

\[ S = \frac{40 \times 2000}{6 \times 3} = 4,444 \text{ psi} \]

Then:

\[ S = \frac{40 \times 2000}{4 \times 3} = 6,667 \text{ psi} \]

Weld Size:

Length of is equal to perimeter of W14 x 145
That distance is about 85".

\[ S = \frac{40 \times 2000}{85} = 941 \text{ lbs/in} \]

Leg size = \[ \frac{941}{14850 \text{ (Allow/1" fillet)}} = 0.11" \]

Mid leg'd based on plate thickness = 5/16

C' FRAME - CORNER CONNECTION (Typ)

W 14 x 145
I = 1710 in.
S = 232 in.

3/4 GUSSET

W 27 x 84
I = 2850 in.
S = 213 in.

14 7/8 REF

26 3/4 REF

1" PLATE TYP

1" PLATE TYP
SUBJECT:
SAMUS INSTALLATION FIXTURE
Bottom Beam

DATE:
4/26/90

REVISION DATE:

NAME:
H. J. Steedoe

DIMENSIONS:

- 66" A - 8" A
- 73" A
- 8" A
- 1/2 A
- 1/2 A
- 4 1/4 x 4 1/2
- 1 1/4 x 1 1/2

W27 x 84

SH1 x 4 1/2
CROSS-SECTION → SAMUS
INSTALLATION BEAM

SECTION A-A
Typ
Corner Analysis

Web Thickness:

$$t_w = \frac{2.63 M}{F_y A}$$

$$F_y = 36 \text{ ksi}$$

$$M = 4.27 \times 10^6 \text{ in-lb} \implies t_w = \frac{4.27 \times 10^3}{2.63 \times 14^{3/8} \times 26^{3/4}}$$

Then

$$t_w = \frac{2.63 \times 4.27 \times 10^3}{36 \times 14^{3/8} \times 26^{3/4}} = 0.784'' > \frac{7/16}{11/16} \implies 1/16 \text{ in.} \times 145$$

To increase web use diagonal stiffener:

Req. Stiffener Area:

$$\phi = 29.079^\circ$$

$$\cos \phi = 0.87396$$

$$\frac{1}{0.87396} \left[ \frac{1.76 M}{d_b F_y} - 0.67 t_w d_c \right]$$

$$= 7.075 \text{ in.}^2$$

Use 3/4 plate, then

$$\frac{7.075}{3/4} = 5'' \text{ plate width }$$

STIFFENER IS 3/4'' x 5'' x (2.85 re=) LG.

Flange Force = $$F_y A = (3.6 \times 9.960 \times 640) = 229 \text{ kip}$$

Weld Capacity = $$(a)(0.707)(21)(2) = 29.7$$

Length Available = 14.875 - 2 = 12.875

Req'd a = $$\frac{229}{(29.7)(12.875)} = 0.599'' \text{ say 5/8'' filler along AB}$$
Weld Size - BC:
40 Tons Load; \( F_a = 0.6 \times 36 = 21.6 \) ksi.

Tensile Load: 40 Tons = 80 Kips.

Shear Load: \( M/N = 0.15 \times 40 \) Tons = 6 Tons = 12 Kips.

TREATING WELD AS A LINE (REF: GREGGERT 6.3.5): 

\[
\sigma = \frac{M}{S} \quad S_W = 2bd + \frac{d^2}{3} \\
= (2)(10)(26^3) + (26^3) \frac{2}{3} \\
= 773.5 \text{ kips}^2
\]

\[
\sigma = \frac{4.08 \times 10^6}{773.5} = 5275 \text{ lbs/ln}.
\]

\[
\sigma = \frac{40 \times 2000}{(2)(10 + 10 + 25.5 + 25 + 9 + 9)} = 899 \text{ lbs/ln}.
\]

\[
\sigma = \frac{12000}{(2)(25.5)} = 235 \text{ lbs/ln}
\]

\[
\sigma_{\text{weld}} = \left[ (899 + 235)^2 + (5275)^2 \right]^{\frac{1}{2}} = 5396 \text{ lbs/ln}.
\]

Allowable force on Weld (1" fillet) = (3 \times 0.707) \times 70 = 14850 \text{ lbs}

Weld size = \( \frac{5396}{14850} = 0.363 \) say \( \frac{3}{8} \) fillet.
BELOW-THE-HOOK LIFTING DEVICE
Engineering Note Cover Page

Lifting Device Numbers:
FNAL Site No.: _____ if applicable
Div. Specific No.: _____ if applicable
Asset No.: _____ if applicable

ASME B30.20 Group:
(check one)
✓ 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: SAMUS MAGNET(S) LIFTING DEVICES ('C' FRAME)

Device was:
Purchased from a Commercial Lifting Device Manufacturer
mfg. name: __________________________

(check all applicable)
✓ Designed and Built at Fermilab
Designed by Fermilab and Built by a Vendor
Assy drawing number: __________________________
Provided by a User or Other Laboratory
Other. Describe: __________________________

Engineering Note Prepared by: __________________________ Date: 6.27.90
Engineering Note Reviewed by: __________________________ Date: 2/26/99

Lifting Device Data:
Capacity: 38 TONS
Fixture Weight: 3.5 TONS
Service: normal heavy severe (refer to B30.20 for definitions)
Duty Cycle: _________ 8, 16 or 24 hour rating (applicable to groups III, and IV)
Inspections Frequency: __________________________
Rated Load Test by FNAL (if applicable): Date: 2.23.99 Load: 48 TONS

Check if Load Test was by Vendor and attach the certificate.
Satisfactory Load Test Witnessed by: __________________________
Signature (of Load Test Witness): __________________________
Notes or Special Information: __________________________