Fermi National Accelerator Laboratory
Particle Physics Division

Mechanical Department Engineering Note

Number: *MD-ENG-278* **Date:** *01 October 2010*

Project: *DES*

Project Internal Reference: *DES Docdb 4875*

Title: ***The Support Frame For DES Barrel Shipment From UCL To CTIO***

Author(s): *Greg Derylo* *FNAL/PPD/MD*

Reviewer(s): K. BECZKIEWICZ 10/8/10

Key Words: *DES*

Abstract/Summary:

A support frame has been designed to hold the completed barrel within its shipping crate for transort from UCL in England to the Blanco telescope at CTIO. It is to be fabricated from Maytec aluminum framing system members along with steel adapter plates for mounting of the barrel and fastening to the vibration-isolated floor of the shipping crate. Analysis of the framing members and fastener sizing indicates large factors of safety compared to the anticipated shipping loads.

Applicable Codes: *N/A*

INTRODUCTION

The DES corrector barrel assembly is being sent in pieces to University College London (UCL) for final assembly and alignment of the lenses. UCL will then contract with a vendor to design & build a vibration-isolated shipping container but has asked FNAL to provide a support frame to hold the barrel within this crate. The support frame shall have the following features:

* Barrel to be shipped C1-side down

* Barrel held at the hexapod mounting flange

* Maximum dynamic load = 3 G's [This number has not yet been defined, but DES Docdb 763 p16 indicates applied transport shock loads of 6 G vertical and 3.5 G horizontal. With vibration isolation features designed into the shipping crate, the shocks reaching the payload will be less than this. 3 G's is assumed here for all orientations and the factors of safety found below for this frame are large enough that modest changes in this specification will not invalidate the conclusions on this analysis.]

The support frame being developed (FNAL drawing 4900.123-ME-480500 & MD-480494) is to be contructed from Maytec extruded aluminum framing with steel plates for fastening the frame to the barrel hexapod flange and attachment to the floor of the shipping crate. The vertical support members run from the top to the bottom of the frame, so horizontal members are not compressivey side-loaded but only act to constrain the ends of the verticals. Cross-bracing is added to further provide robustness to the design. The calculations documented below verify the frame's ability to support the load.

BARREL WEIGHT

Lens barrel per Andy S. spreadsheet on 01Oct10 (lb): $Wb_b := 5150$

C5 flange (lb, from docdb 3204): $Wb_c5 := 305$

C5 lens cover (lb, measured): $Wb_cv1 := 13.1 \cdot 2.205$

Shutter & C1 covers estimate per Andy S. (lb): $Wb_cv2 := 250$

Total static weight: $Wb_static := Wb_b + Wb_c5 + Wb_cv1 + Wb_cv2$

$Wb_static = 5.734 \times 10^3$ pounds

Total dynamic weight: $G_dyn := 3$ (g-load discussd above)

$Wb_dyn := G_dyn \cdot Wb_static$

$Wb_dyn = 1.72 \times 10^4$ pounds

FRAMING INPUT DATA

Framing Post Data:

Maytec 90x90 Frame width (m): $width := .090$

Frame vertical post length (m): $L := 1.270$

Number of posts: $N_posts := 8$

Data From Maytec Catalog:

Frame Modulus (Pa, catalog p65): $E := 70 \cdot 10^9$

Frame Yield Stength (Pa, catalog p65): $Yield := 0.2 \cdot 10^9$

Maytec 90x90 Frame Moment (m^4, catalog p30): $I_90 := \frac{282}{100^4}$

90x90 Frame weight (kg/m, catalog p30): $G_90 := 9.5$

Other Input Data

Aluminum Density (kg/m^3): $rho_Al := 2700$

FRAME CALCULATIONS

Frame x-section area (m^2): $XS_area := \frac{G_90}{rho_Al \cdot 1}$

Load limit for N posts: $P_max := N_posts \cdot (Yield \cdot XS_area)$

$P_max \cdot .2248 = 1.266 \times 10^6$ pounds total

$$FOS = \frac{P_max \cdot .2248}{Wb_dyn} = 73.571$$

The limit is several orders of magnitude larger than the dynamic weight of the barrel and therefore acceptable.

Euler's buckling limit: $P_buckle := \frac{\pi^2 \cdot E \cdot I_90}{1^2 \cdot L^2}$

Note: assuming K=1 (pinned ends) is very conservative

$P_buckle \cdot .2248 \cdot N_posts = 2.172 \times 10^6$ pounds

$$\text{FOS} = \frac{P_buckle \cdot .2248 \cdot N_posts}{Wb_dyn} = 126.286$$

The limit is several orders of magnitude larger than the dynamic weight of the barrel and is therefore acceptable

Max bending force (totally ignoring horizontal and diagonal braces -- overly conservative assumption):

Max bending moment: $Mb_max := Yield \cdot \frac{I_90}{0.5 \cdot width}$

R&Y case 1b max moment: $Pb_max := 2 \cdot \frac{Mb_max}{L}$

(1 end fixed / 1 guided)

$Pb_max \cdot .2248 = 4.437 \times 10^{3}$ pounds / post

$$\text{FOS} = \frac{Pb_max \cdot .2248 \cdot N_posts}{Wb_dyn} = 2.064$$

This is marginally greater than the dynamic weight of the barrel but totally ignores the very large structural benefit of the diagonal crossbracing. Due to the overconservatisms assumed the performance is acceptable.

BOLT CONSIDERATIONS

Bolts holding support frame to hexapod flange

* Number of M12 Grade 8.8 HHCS = 11 (but assume users will install only one per plate = 8)
* Stress area of M12 screw = .4039 sqin
* Tensile strength of Grade 8.8 bolt (McMaster 91280A722) = 116 ksi
* Assume preloaded to 80% of tensile strength
* Assume shear stength = 60% of tensile strength

Tensile Load 1: $8 \cdot 0.4039 \cdot 116000 \cdot 0.2 = 7.496 \times 10^{4}$ pounds total

Shear Limit 1: $8 \cdot 0.4039 \cdot 0.6 \cdot 116000 = 2.249 \times 10^{5}$ pounds total

Bolts holding end plates to vertical posts

* Number of M8 Grade 8.8 SHCS = 8 * 4 = 32
* Stress area of M8 screw = .2677 sqin
* Tensile stength of Grade 8.8 bolt (McMaster 95263A633) = 174ksi
* Assume preloaded to 80% of tensile strength
* Assume shear strength = 60% of tensile strength

Tensile Load 2: $32 \cdot 0.2677 \cdot 174000 \cdot 0.2 = 2.981 \times 10^{5}$ unds total

Shear Limit 2: $32 \cdot 0.2677 \cdot 0.6 \cdot 174000 = 8.943 \times 10^5$ pounds total

Screws holding bottom plates to shipping crate base (not part of this assembly, but documented here for reference)

* Number of M12 Grade 8.8 HHCS = 8 * 4 = 32
  (but assume the users will install only half of them, so use 16)
* Stress area of M12 screw = .4039 sqin
* Tensile stength of Grade 8.8 bolt (McMaster 91280A728 assumed) = 116ksi
* Assume preloded to 80% of tensile strength
* Assume shear strength = 60% of tensile strength

Tensile Load 3: $16 \cdot .4039 \cdot 116000 \cdot 0.2 = 1.499 \times 10^5$ pounds total

Shear Limit 3: $16 \cdot .4039 \cdot 0.6 \cdot 116000 = 4.498 \times 10^5$ pounds total

Pull-out force of the M14 threaded insert in the ends of the aluminum posts

* OD of M14 screw = 0.551 inches
* Length of threaded insert = 30mm = 1.18 inches
* Shear strength of aluminum = 0.25 GPa (Maytec catalog p 65) * 60% = 21.7 ksi
* Number of inserts at each end of a vertical post = 4

Pullout limit: $4 \cdot (\pi \cdot 0.551 \cdot 1.18) \cdot 21700 = 1.773 \times 10^5$ pounds / vertical post

These results are much larger than the dynamic weight of the barrel. The fastener performance is therefore acceptable.

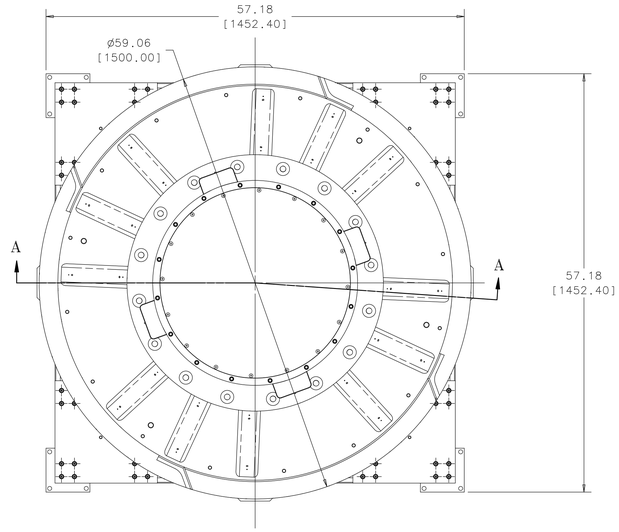
FRAME WEIGHT ESTIMATE

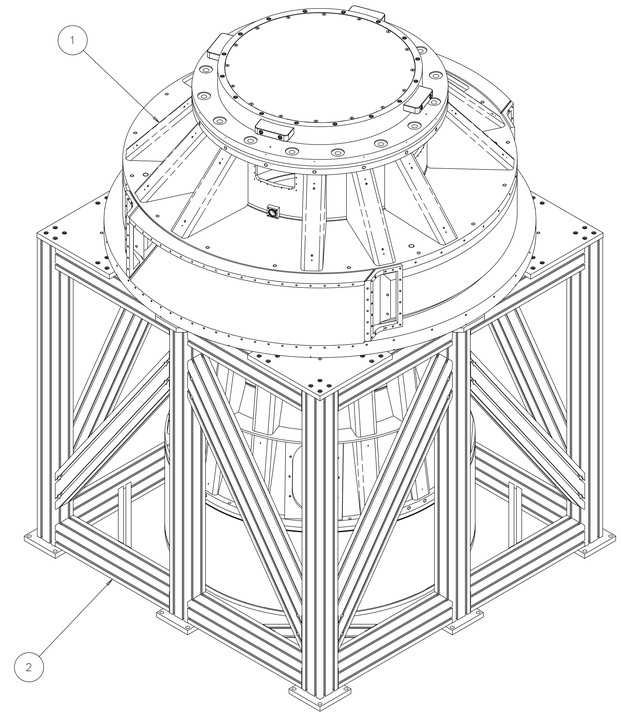
90x90 Weight (kg):	$Wf_a := G_90 \cdot (8 \cdot 1.27 + 16 \cdot 0.56 + 8 \cdot 0.976)$	$Wf_a = 255.816$
45x90 Weight (kg):	$Wf_b := 4.4 \cdot (4 \cdot 0.355)$	$Wf_b = 6.248$
Connectors & Screws (kg):	$Wf_c := 64 \cdot .018 + 48 \cdot .014 + 128 \cdot .05 + 80 \cdot .05 + 5$	$Wf_c = 17.224$
Plates (kg):	$Wf_d := \frac{0.284 \cdot (8 \cdot 25.6 + 4 \cdot 24.8 + 4 \cdot 102.5)}{2.205}$	$Wf_d = 91.962$
Total Weight (kg):	$Wf_tot := Wf_a + Wf_b + Wf_c + Wf_d$	$Wf_tot = 371.25$

$Wf_tot \cdot 2.205 = 818.606$ pounds

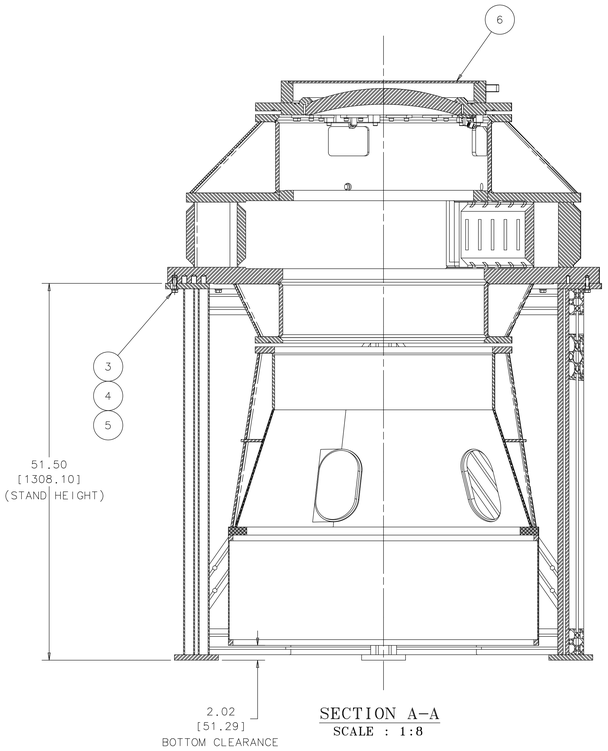
Total weight of barrel plus frame = $Wb_static + (Wf_tot \cdot 2.205) = 6.552 \times 10^3$ pounds

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE

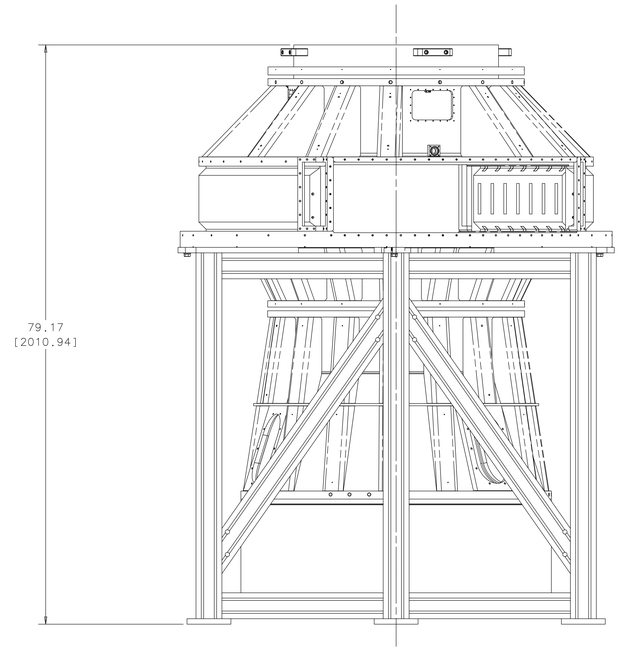


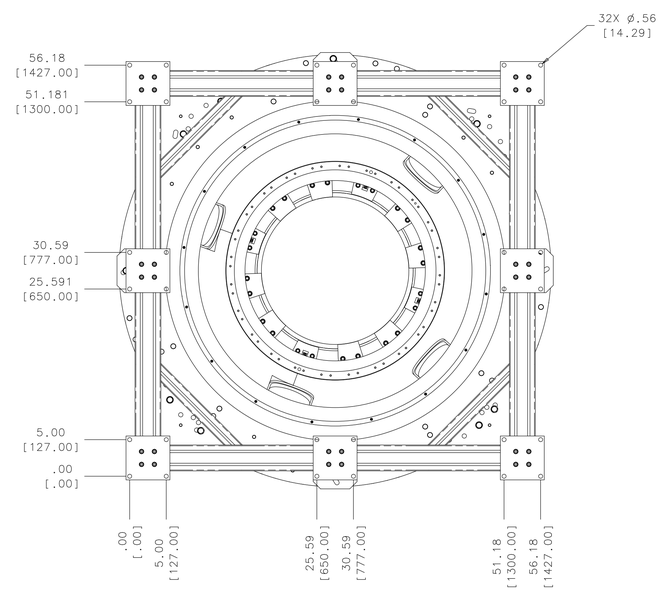


ISOMETRIC VIEW



SECTION A–A
SCALE : 1:8





TOTAL EST. WEIGHT = 6,550 LBS.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
6	MD-436954	C5 FLANGE LENS COVER IMAGER SIDE	1
5	McMASTER CARR 91202A245	M12 LOCK WASHER STEEL	11
4	McMASTER CARR 91455A150	FLAT WASHER FOR M12 SCREW STEEL	11
3	McMASTER CARR 91280A722	HEX HEAD CAP SCREW M12 X 45 mm LG.-STEEL	11
2	MD-480494	BARREL FRAME UCL-CTIO ASSY	1
1	REFERENCE	DES CORRECTOR ASSEMBLY	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	G.DERYLO	23-SEP-2010
.XX	.XXX	ANGLES	DRAWN	G.SMITH	01-OCT-2010
± .06	± ---	± ---	CHECKED	G.DERYLO	04-OCT-2010
			APPROVED	G.DERYLO	04-OCT-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES
5. DRAWING UNITS: U.S. INCH

USED ON

MATERIAL
SEE PARTS LIST ABOVE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

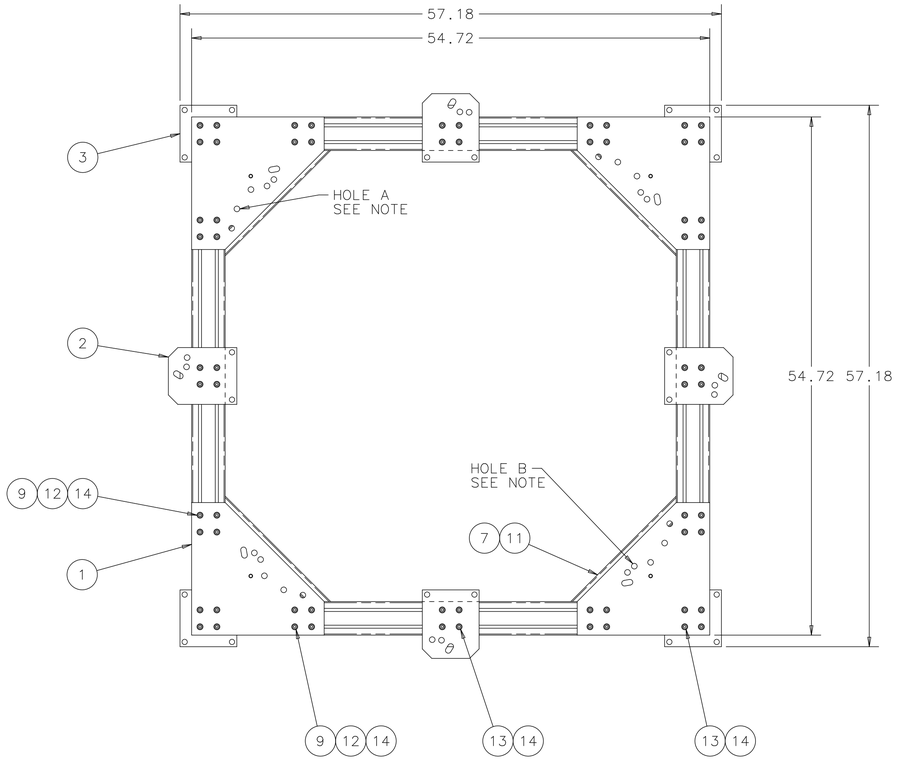
NOTICE: IMAGE OBTAINED FROM FERMILAB WEB SITE
This information is provided for REFERENCE use only.
Not for MANUFACTURE, or DESIGN INFORMATION.
All information contained in this document represents work sponsored by an agency of the U.S. Government.
Neither the U.S. Government nor any agency thereof, nor Universities Research Association, Inc., nor any of their employees or officers, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

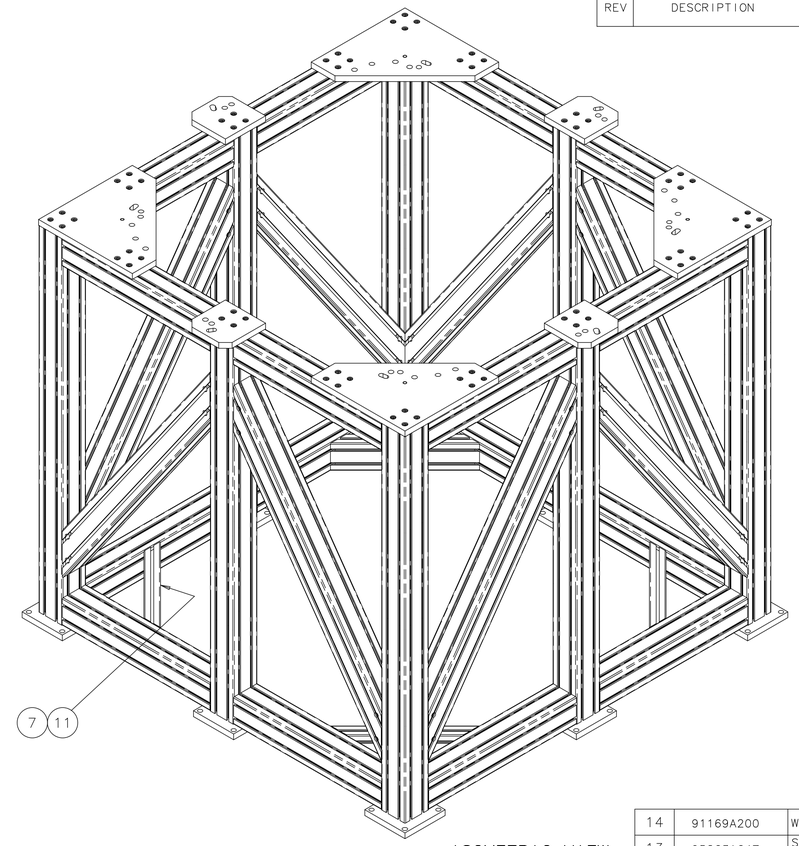
DECAM/CORRECTOR AND CAGE CORRECTOR TRANSPORT BARREL ASSY UCL CTIO

SCALE	DRAWING NUMBER	SHEET	REV
1:8	4900.123-ME-480500	1 OF 1	

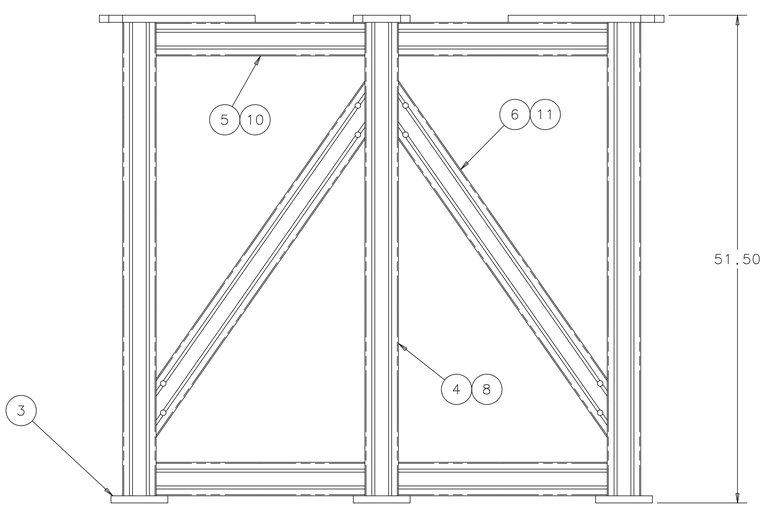
CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

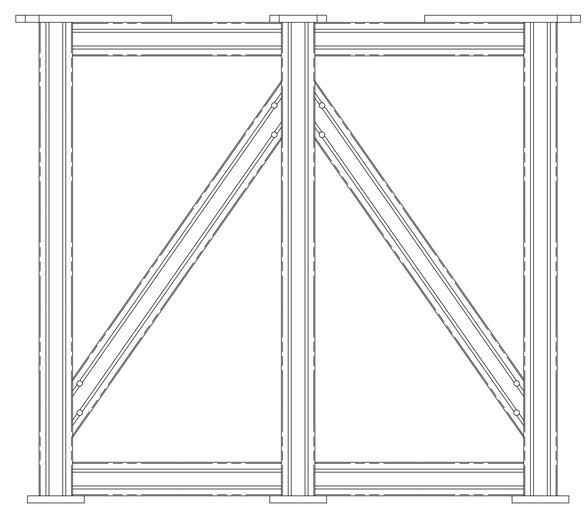
REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE





ISOMETRIC VIEW





NOTE:

BARREL ORIENTATION TO BE SET USING TEMPORARY PINS ALIGNED WITH HOLES "A" AND "B" SHOWN

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
14	91169A200	WASHER, LOCK; M8, McMASTER CARR	96
13	95263A647	SCREW; SOC.HD.CAP, M8X1.25 X 30mm LG. McMASTER CARR	64
12	95263A619	SCREW; SOC.HD.CAP, M8X1.25 X 20mm LG. McMASTER CARR	32
11	1.21.45EK1	HINGED CONNECTOR	80
10	1.21.45E40	SQUARE HEAD CONNECTOR	128
9	1.32.EM8	T-NUT, M8; MAYTEC	32
8	1.35.1140830	THREADED INSERT, M14/M8; MAYTEC	64
7	COML	FRAME, MAYTEC, 45x90 6E SP, 400 mm LG. MACHINING CODE KB1 KB1	4
6	MC-480499	BARREL FRAME UCL CTIO DIAG01	8
5	COML	FRAME, MAYTEC, 90x90 8E SP, 560 mm LG. MACHINING CODE LD2 LD2	16
4	COML	FRAME, MAYTEC, 90x90 8E SP, 1270 mm LG. MACHINING CODE LP0 LP0	8
3	MC-480497	BARREL FRAME UCL-CTIO PLATE L1	8
2	MC-480496	BARREL FRAME UCL-CTIO PLATE U2	4
1	MC-480495	BARREL FRAME UCL-CTIO PLATE U1	4

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	G.DERYLO	23-SEP-2010
.XX	.XXX	ANGLES	DRAWN	V.MAJDANSKI	23-SEP-2010
± .02	± ---	± ---	CHECKED	G.DERYLO	01-OCT-2010
			APPROVED	G.DERYLO	01-OCT-2010

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ASME Y14.5M-1994
4. MAX. ALL MACH. SURFACES 125
5. DRAWING UNITS: US INCHES

USED ON

MATERIAL
SEE PARTS LIST ABOVE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

NOTICE: IMAGE OBTAINED FROM FERMILAB WEB SITE

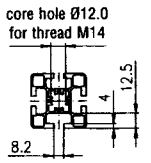
This information is provided for REFERENCE use only. Not for MANUFACTURE, or DESIGN INFORMATION. All information contained in this document represents work sponsored by an agency of the U.S. Government. Neither the U.S. Goverment nor any agency thereof, nor Universities Research Association, Inc., nor any of their employees or officers, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

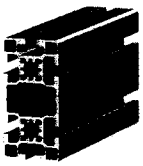
DECAM/CORRECTOR AND CAGE CORRECTOR BARREL FRAME UCL-CTIO ASSY

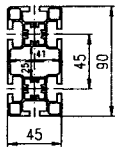
SCALE	DRAWING NUMBER	SHEET	REV
1:8	4900.000-MD-480494	1 OF 1	

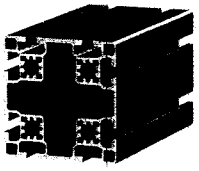
CREATED WITH : Ideas12NXSeries GROUP: PPD/MECHANICAL DEPARTMENT

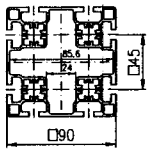
light





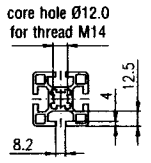


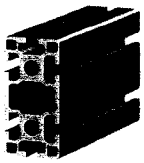


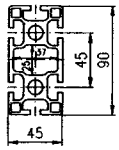


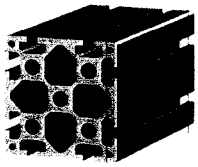
Description	Profile 45×90, 6E, LP	Profile 90×90, 8E, LP		
bar, 6 m	1.11.045090.64LP.60	1.11.090090.83LP.60		
packing unit (number)	1.11.045090.64LP.61 (4)	1.11.090090.83LP.61 (2)		
moment of inertia cm⁴ moment of resistance cm³ weight kg/m	I_x = 98.0 I_y = 27.5 W_x = 21.8 W_y = 12.2 G = 3.3	I_x = 190.5 I_y = 190.5 W_x = 42.3 W_y = 42.3 G = 5.6		

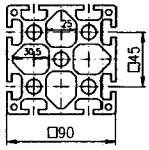
heavy

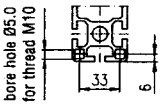


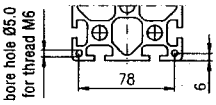












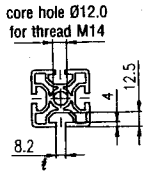
Description	Profile 45×90, 6E, SP	Profile 90×90, 8E, SP		
bar, 6 m	1.11.045090.64SP.60	1.11.090090.83SP.60		
packing unit (number)	1.11.045090.64SP.61 (4)	1.11.090090.83SP.61 (2)		
moment of inertia cm⁴ moment of resistance cm³ weight kg/m	I_x = 126.0 I_y = 34.0 W_x = 28.0 W_y = 15.0 G = 4.4	I_x = 282.0 I_y = 282.0 W_x = 63.0 W_y = 63.0 G = 9.5		

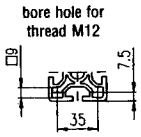
machining data ☞ *Profile machining 1.1A*

MayTec

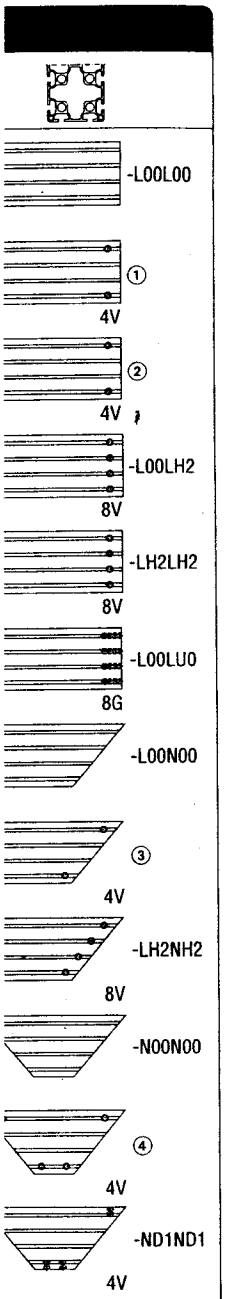
light

heavy





Description	
bar, 6 m	
packing unit (number)	
moment of inertia cm⁴ moment of resistance cm³ weight kg/m	



(additional description)

(additional description)

(additional description)

(additional description)

Extruded profile as per DIN EN 12020

(fine)
(Replacement for DIN 17615)

Aluminium alloy Al Mg Si 0.5 F25
Material Nr. 3.3206.72 (low temp. annealed)

Functional length: 6,000 mm
Delivery length: 6,060 mm + 10 mm

Mechanical data
(Values given in the direction of the press flow)

Tensile strength Rm:	min.	250 N/mm²
Elongation 0.2:	min.	200 N/mm²
Stress point A_5:	min.	10 %
Stress point A_{10}:	min.	8 %
E-Module:	approx.	70,000 N/mm²
Brinell hardness:	approx.	75 HB 2.5/187.5
Co-efficient of elongation:		23.8 x 10^{-6}/K

Surface as per DIN 17611:
E6/EV1 - dull finish and anodised colours
Coat thickness approx. 10 µm
Coat hardness 250-350 HV
Special colours upon request.
The surface area - subject to technical procedure - can show optical changes.

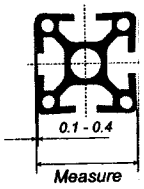
Profile tolerance

(Excerpt from DIN EN 12020-2)

Nominal dimensions:
The dimension deviation depends on the precision with which the tooling is manufactured, the tooling wear and the variation during the extrusion process. For one manufacturing setup the variation within one profile is 0.01 mm.

Profile tolerance		
Dim. range in mm from	to	Tolerance in mm
-	10	± 0.15
10	15	± 0.20
15	30	± 0.25
30	45	± 0.30
45	60	± 0.40
60	90	± 0.45
90	120	± 0.60
120	150	± 0.80
150	180	± 1.00
180	240	± 1.20
240	300	± 1.50

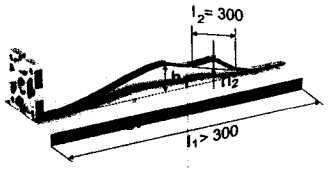
Flatness of profile surfaces



In order to optimize the connection stability, all profile surfaces are designed and manufactured with concave surfaces. This assures that the assembled profiles contact on the outer edges only (line of contact).
When tightening the connectors the slot flanks will be drawn to the mounting profile within the elastic range and will keep the connectors under tension.

Straightness tolerance

of the edge in longitudinal direction

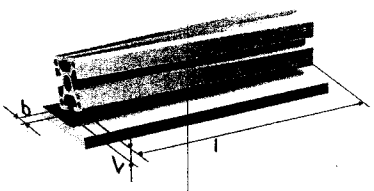


At a certain length l_1 the given tolerance h_1 is not to be exceeded.
For each incremental length of l_2 = 300 mm the deviation h_2 is not to exceed 0.3 mm.

Straightness tolerance		
Length l_1 in m from	to	Tolerance h_1 in mm
-	1	0.7
1	2	1.3
2	3	1.8
3	4	2.2
4	5	2.6
5	6	3.0

Flatness tolerance

(Twist tolerance)



Width *b* in mm		Flatness tolerance					
Dim. range		at length l in m					
from	to	to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6
-	25	1.0	1.5	1.5	2.0	2.0	2.0
25	50	1.0	1.2	1.5	1.8	2.0	2.0
50	75	1.0	1.2	1.2	1.5	2.0	2.0
75	100	1.0	1.2	1.5	2.0	2.2	2.5
100	125	1.0	1.5	1.8	2.2	2.5	3.0
125	150	1.2	1.5	1.8	2.2	2.5	3.0
150	200	1.5	1.8	2.2	2.6	3.0	3.5
200	300	1.8	2.5	3.0	3.5	4.0	4.5