**ANALYSIS
of the
SAMUS COLLIMATOR CART**

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D-Zero Engineering Note

#3740.225-EN-314

Approved by:

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TABLE of CONTENTS

INTRODUCTION	1
ANALYSIS	2
TEST	5
TEST RESULTS	6
CONCLUSION	10
CALCULATIONS	Apdx. A
TESTING	Apdx. B
ASSEMBLY PROCEDURE	Apdx. C
DRAWINGS AND SPECS	Apdx. D

INTRODUCTION

The SAMUS collimator cart is a support for shielding blocks and the vacuum assembly of the Tevatron beam tube as it passes through the D0 End Iron. It slides on linear bearings mounted in the SAMUS toroid as the End Iron moves in and out. There are two collimators designed for the D0 experiment, designated North and South, each identical except for the shimming of the tungsten center blocks, and thereby the relative position of the Tevatron tube.

This report contains calculations of the stresses during installation as well as the installed configurations. To support the analysis of the installation case, loads were simulated on the cart held in a mock-up of the lifting fixture.

ANALYSIS

The cart is designed to meet two major criteria: all stresses must be below the appropriate AISC standard, and deformations must be small enough not to interfere with the End Iron as it rolls out. Also, for the linear bearings to roll smoothly, the loads must be kept within the manufacturer's specifications.

During installation, the cart is cantilevered by the lifting fixture described in D0 engineering note 3740.225-EN-315. Under these conditions the cart will not be fully assembled; certain shielding plates will be removed to allow easier installation, thus reducing the weight of the collimator. Though it is preferable to install the cart from the front end (the end nearest the collision point), it is designed and shown to be safe when installed from either the front or back.

The support rails upon which the bearing tracks are mounted are also stressed. The rails will be under maximum stress when the cart is rolled out to touch either the front or back rail stops. When the Tevatron tube is fully connected, and the End Iron is being rolled in and out, the cart is constrained and will not move to either extreme. The critical configurations may only occur during installation or maintenance, when the cart is disconnected from the Tevatron beamline.

Since the cart is supported by three pairs of bearings, the weight distribution is indeterminate. The bearings are positioned so that if any two pairs of bearings are supporting the load, only one pair will be supported by part of the rail overhanging the SAMUS Toroid.

The loading on the cart is due to the weight of the shielding blocks and the vacuum assembly. There are no horizontal or axial loads. Presently, some blocks are made of tungsten and some of lead. Since, in the future, the lead blocks may be replaced with tungsten blocks of the same shape but greater density, the cart is designed for the all-tungsten case. The shielding blocks actually act as a distributed load across the cart, but for the purpose of the stress calculations, the top, middle, and intermediate plates are considered to be supported at the midpoint of the flange, and the center and bottom plates by the cart bottom.

The moment of inertia of the cart is smallest where the ion pump is to be installed. As a conservative simplification for many of the

calculations herein, the cart is considered to have this limiting moment of inertia along its entire length.

When calculating the shear flow through the welds, the additional strength given to the joint by the bolts is ignored. The bolts give more strength to the welded joint, and also serve to hold the parts together during welding. They are high tension alloy bolts, torqued to 65 ft-lbs prior to welding.

The vacuum assembly within the collimator is held in place by several brackets mounted to the flanges. The shielding blocks are aligned by 1/4" stainless steel guide rods, which are placed in slightly oversized slots in both the shield blocks and the cart itself. There are three End Plates bolted to the cart, one at each end and one about halfway through the shielding. Three 1/2" threaded stainless steel rods pass through the shielding and are secured to the End Plates. These, along with the guide rods, ease the assembly process and keep the blocks from moving around during installation and End Iron roll-out.

TABLE ONE
RESULTS

Stress	Condition	Calculated Stress (psi)	AISC Allowable	Factor of Safety	Apdx. A Page
CART:	Bending	4375	18000	4.1	8
	Beam Shear	314	12000	38.2	8
	Weld shear	3720	24000	6.5	9
	Cart shear along Weld	2246	12000	5.3	10
	Bending in Flange Weld	136	18000	132.4	16
	Bending in Flange	43	18000	418.6	16
	Shear in Flange	23	12000	521.7	16
	Axial Force	0	0	-	-
	Horizontal Force	0	0	-	-
SUPPORT RAIL:	Bending, case 1	5551	18000	3.2	12
	case2	12884	18000	1.4	13
BEARINGS:	Moment:				
	Six bearings	1610	3211*	2.0	14
	Four bearings	2643	3211*	1.2	15
	Vertical force:				
	Six bearings	1381	6746*	4.9	14
	Four bearings	2267	6746*	3.0	15

* Manufacturer's Allowable Limit

TEST

This test of the cart is to determine whether or not the cart will yield under the loads subjected during its installation. The conditions of the lifting procedure will be simulated using a test fixture (ME-295097) loaded with a hydraulic jack to simulate the weight of the shielding blocks and other contents of the fully assembled cart.

The cart may be installed from either the front or back end. Because the "I" of the cart is not constant along the length (though the hand calculations assume this for simplicity), the cart will be tested from both ends. To determine if either of the two carts have major defects, one cart will be used to test lifting from the back, and the other, lifting from the front.

The values used for testing are based on all shielding blocks made from tungsten. Though the actual weight is distributed, for simplicity the test will use a point load placed approximately at the centroid of the distributed load. The force of the point load is adjusted to match the moment of the distributed load, which directly affects the most critical criteria of the cart's strength: the bending stress.

It is anticipated that during the testing the cart will experience a small amount of local yielding, which will result in work-hardening of the steel. There may also be evidence of shakedown (slight yielding due to surface roughness at points of contact) and elastic deformation in the test fixture. With each iteration, the cart may not return to its original position due to this yielding. If, however, during any iteration significant yielding is observed, the test will be discontinued.

TEST RESULTS

The deflections were larger than expected. The majority of the deflection seems to be due to the bending of the actual test fixture. The values of loads and deflections are tabulated in tables B1 and B2, and charted in graphs B1, B2, B3, and B4.

Assuming a constant moment of inertia, the stress is directly proportional to the force applied, and the strain directly proportional to the deflection. The graphs included here are load vs. deflection, and should theoretically have the same shape as the traditional stress vs. strain diagrams.

The deflections are nonlinear. It is believed that this is due to the shakedown in the surface of the "I" beams and the settling of the shims under the pressure pad. The shape of the graphs appears parabolic, but as the loads increase, the slopes of the lines approaches the theoretical linear model. The initial part of the curve has a smaller slope, which represents the bending of the test structure. As the shims and "I" beams settle, the slope of the deflection increases to that of the theoretical model.

The last two iterations for each case are consistent and repeatable to within four thousandths of an inch. This shows that the cart is still in the elastic range at values 25% greater than the worst case it is designed to experience. According to conservative hand calculations, the actual stress at 125% of the design load is only 25% of the AISC maximum allowable stress.

The actual load on the cart will be distributed, but for simplicity, the test was done with a point load. According to formulas from Roark & Young, the deflection under the same weight will be 4% higher when the load is distributed than when it is considered a point load. This must be taken into consideration during the design of the lifting fixture.

TEST PLOTS

**TABLE B1:
LIFTING FROM FRONT**

**TABLE B2:
LIFTING FROM BACK**

**TABLE B3:
STRUCTURE DEFORMATION
LIFTING FROM FRONT**

**TABLE B4:
STRUCTURE DEFORMATION
LIFTING FROM BACK**

CONCLUSION

The stress calculations have shown that the cart and its associated components have met AISC design criteria or the manufacturer's specifications for all modes of possible failure.

The test data has shown that the cart remains elastic at loads up to 125% of the all-tungsten case, and that the deflection of the cart is small.

According to both the calculations and the testing, the cart is shown to resist deflection, remain elastic, and be operationally repeatable.

APPENDIX A

DESIGN CALCULATIONS

Note #3740.225-EN-314

All Tungsten Cart

Item	Z Coord. (In)	Moment Arm (In)	Weight (lb)	Weight on Flange (lb)	Weight on Bottom (lb)	Moment (In lb)
72" Cart	236	36	713	76	637	25668
Front Edge of Cart	200	0	0	0	0	0
2" Gage Blocks	201	1	184	154	30	184
2" Gage Blocks	203	3	184	154	30	552
2" Gage Blocks	205	5	184	154	30	920
2" Gage Blocks	207	7	184	154	30	1288
2" Pump blocks	209	9	100	100	0	900
2" Pump blocks	211	11	100	100	0	1100
2" Pump blocks	213	13	100	100	0	1300
2" Pump blocks	215	15	100	100	0	1500
2" Pump blocks	217	17	100	100	0	1700
2" Pump blocks	219	19	100	100	0	1900
2" Pump blocks	221	21	100	100	0	2100
2" center blocks	223	23	366	222	144	8418
2" center blocks	225	25	366	222	144	9150
2" center blocks	227	27	366	222	144	9882
2" center blocks	229	29	366	222	144	10614
2" center blocks	231	31	366	222	144	11346
2" center blocks	233	33	366	222	144	12078
2" center blocks	235	35	366	222	144	12810
2" center blocks	237	37	366	222	144	13542
2" center blocks	239	39	366	222	144	14274
2" center blocks	241	41	366	222	144	15006
2" center blocks	243	43	366	222	144	15738
2" center blocks	245	45	366	222	144	16470
2" center blocks	247	47	366	222	144	17202
2" center blocks, lg bore	249	49	363	222	141	17787
2" center blocks, lg bore	251	51	363	222	141	18513
2" center blocks, lg bore	253	53	363	222	141	19239
6" conflat flange (3)	210	10	18	0	18	180
tube cluster w/flanges	210	10	25	0	25	250
flange support	210	10	10	0	10	100
ion pump	214	14	100	0	100	1400
8" spool flange	256	56	14	0	14	784
P&E valve	256	56	64	0	64	3584
valve support	256	56	10	0	10	560
front end plate	200	0	10	0	10	0
middle end plate	222	22	17	0	17	366
back end plate	255	55	21	0	21	1145
Total Moment (in lb)						261711
Total Weight (lb)			8285	4944	3341	
Center of Gravity (in)	232	32				

Note: Calculations are for all shield blocks made of tungsten.
Substitution of lead results in less severe loads.

Ali Tungsten Cart, Lifting Case

Item	Z Coord. (in)	Moment Arm (in)	Weight (lb)	Weight on Flange (lb)	Weight on Bottom (lb)	Moment (in lb)
72" Cart	236	36	713	76	637	25679
Front Edge of Cart	200	0	0	0	0	0
2" Gage Blocks	201	1	0	0	0	0
2" Gage Blocks	203	3	0	0	0	0
2" Gage Blocks	205	5	158	128	30	790
2" Gage Blocks	207	7	158	128	30	1106
2" Pump blocks	209	9	48	48	0	432
2" Pump blocks	211	11	48	48	0	528
2" Pump blocks	213	13	48	48	0	624
2" Pump blocks	215	15	48	48	0	720
2" Pump blocks	217	17	48	48	0	816
2" Pump blocks	219	19	48	48	0	912
2" Pump blocks	221	21	48	48	0	1008
2" center blocks	223	23	340	196	144	7820
2" center blocks	225	25	340	196	144	8500
2" center blocks	227	27	340	196	144	9180
2" center blocks	229	29	340	196	144	9860
2" center blocks	231	31	340	196	144	10540
2" center blocks	233	33	340	196	144	11220
2" center blocks	235	35	340	196	144	11900
2" center blocks	237	37	340	196	144	12580
2" center blocks	239	39	340	196	144	13260
2" center blocks	241	41	340	196	144	13940
2" center blocks	243	43	340	196	144	14620
2" center blocks	245	45	340	196	144	15300
2" center blocks	247	47	340	196	144	15980
2" center blocks, lg bore	249	49	337	196	141	16513
2" center blocks, lg bore	251	51	337	196	141	17187
2" center blocks, lg bore	253	53	337	196	141	17861
6" conflat flange (3)	210	10	18	0	18	180
tube cluster w/flanges	210	10	25	0	25	250
flange support	210	10	10	0	10	100
ion pump	214	14	100	0	100	1400
8" spool flange	256	56	14	0	14	784
P&E valve	256	56	64	0	64	3584
valve support	256	56	10	0	10	560
front end plate	200	0	10	0	10	0
middle end plate	222	22	17	0	17	366
back end plate	255	55	21	0	21	1145
Total Moment (in lb)						239406
Total Weight (lb)			7085	3804	3281	
Center of Gravity (in)	234	34				

Note: Calculations are for all shield blocks made of tungsten.
Substitution of lead results in less severe loads.

SUBJECT

Calculation of "I" through cart

NAME

DATE

REVISION DATE

$$A_1 = 3.375 \cdot 1 \cdot 2 = 6.75 \text{ in}^2$$

$$A_2 = 3.325 \cdot 1 \cdot 2 = 6.65 \text{ in}^2$$

$$A_{\text{Total}} = 31.838 \text{ in}^2$$

$$A_3 = 1.25 \cdot 14.75 = 18.438 \text{ in}^2$$

$$y_1 = 1.25 + 3.325 + .5 = 5.075 \text{ in}$$

y measured from bottom of cart.

$$y_2 = 1.25 + \frac{3.325}{2} = 2.913 \text{ in}$$

$$y_3 = \frac{1.25}{2} = .625 \text{ in}$$

$$\bar{y} = \frac{A_1 y_1 + A_2 y_2 + A_3 y_3}{A_1 + A_2 + A_3} = 2.046 \text{ in}$$

$$\bar{y}_1 = y_1 - \bar{y} = 3.029 \text{ in}$$

$$\bar{y}_2 = .867 \text{ in}$$

$$\bar{y}_3 = 1.421 \text{ in}$$

$$I_1 = \frac{1}{12} \cdot 2 \cdot 3.375 \cdot 1^3 + 6.75 (3.029)^2 = 62.493 \text{ in}^4$$

$$I_2 = \frac{1}{12} \cdot 2 \cdot 1 \cdot 3.325^3 + 6.65 (.867)^2 = 11.125 \text{ in}^4$$

$$I_3 = \frac{1}{12} \cdot 14.75 \cdot 1.25^3 + 18.438 (1.421)^2 = 39.631 \text{ in}^4$$

$$I = 113.25 \text{ in}^4$$

SUBJECT

Lifting Configuration

NAME

DATE

REVISION DATE

DURING LIFTING, THE CART CONFIGURATION IS AS SHOWN ABOVE, AND IT IS MODELED AS A SIMPLE BEAM IN THE "Z" DIRECTION, SHOWN BELOW.

SUBJECT

BEAM Calculations

NAME

DATE

REVISION DATE

Lifting from Front, (15.81)

$$R_b = 7085 \frac{15.81}{14.07} = 7961 \text{ lb}$$

$$R_a = 7085 + 7961 = 15046 \text{ lb}$$

$$M_{\max} = 7085 \cdot 15.81 = 112,000 \text{ lb-in}$$

Lifting from Back, (19.81)

$$R_b = 7085 \frac{19.81}{14.07} = 9975 \text{ lb}$$

$$R_a = 7085 + 9975 = 17,060 \text{ lb}$$

$$M_{\max} = 7085 \cdot 19.81 = 140,400 \text{ lb-in}$$

BEAMAC II beam name: Lift_from_Front

Last modified at 5:21:51 PM on Thu, Aug 8, 1991

All distances are given in inch from the left end of the beam.
 Maximum shear is 7964.01 lb; it occurs from $x=53.81$ inch to $x=67.88$ inch.
 Minimum shear is -7085.00 lb; it occurs from $x=38.00$ inch to $x=53.81$ inch.
 Minimum moment is -112013.85 lb-in; it occurs at $x=53.81$ inch.
 The maximum upward deflection is approximately 0.2970 mil.
 The maximum downward deflection is approximately 14.9170 mil.

BEAMAC II beam name: Lift_from_Back

Last modified at 5:34:44 PM on Thu, Aug 8, 1991

All distances are given in inch from the left end of the beam.
 Maximum shear is 9978.94 lb; it occurs from $x=53.81$ inch to $x=67.88$ inch.
 Minimum shear is -7085.00 lb; it occurs from $x=34.00$ inch to $x=53.81$ inch.
 Minimum moment is -140353.85 lb-in; it occurs at $x=53.81$ inch.
 The maximum upward deflection is approximately 0.3721 mil.
 The maximum downward deflection is approximately 21.1560 mil.

SUBJECT

Beam Calculations

NAME

DATE

REVISION DATE

Bending: The maximum moment is 140,400 lb-in,
when lifted from back end.

$$I = 113.25 \text{ in}^4 \quad c = 3.53 \text{ in}$$

$$\sigma = \frac{M_c}{I} = \frac{140,400 \cdot 3.53}{113.25} = 4,375 \text{ psi}$$

using AISI code, $\sigma_{\max}(\text{bending}) = .6 \sigma_y$
 $\sigma_y = 30,000 \text{ psi}$ for SS304

$$\sigma_b = 18,000 \text{ psi}$$

Shear: The maximum shear is found to be 9980 lb.
The smallest cross-sectional area is:

$$A = 31.84 \text{ in}^2$$

$$\sigma = \frac{F}{A} = \frac{9980}{31.84} = 314 \text{ psi}$$

AISI allows max shear to be $.4 \sigma_y$:

$$\sigma_v = .4 \cdot 30,000 = 12,000 \text{ psi}$$

SUBJECT

Beam Calculations

NAME

DATE

REVISION DATE

WELD SHEAR: There is a z-axis shear in the joints between the side supports and the top and bottom supports. These joints are secured by bolts and partial penetration groove welds on each side. This conservative calculation will ignore the strength of the bolts and show that the welds alone are adequate to resist the shear.

$$\text{average shear} = \tau_v = \frac{VQ}{Ib}$$

$$Q \text{ (for top support)} = A_1 \bar{y}_1 = 6.75 \cdot 3.029 = 20.45 \text{ in}^3$$

$$Q_{\text{Bottom}} = A_3 \bar{y}_3 = 18.438 \cdot 1.421 = 26.20 \text{ in}^3$$

- bottom is critical.
- maximum shear is 9980 lb.

Both $\frac{1}{8}$ " welds

$$\begin{aligned} \text{total effective throat (shear area)} \\ b &= 2 \left(\frac{1}{8} + \frac{3}{4} \cdot \frac{1}{8} \right) \\ &= .427 \text{ in} \end{aligned}$$

$$\sigma_v = \frac{9,980}{164.68} \frac{26.20}{.427} = 3,720 \text{ psi}$$

$$\text{using } \sigma_{\text{max}} (\text{shear}) = .3 \sigma_{\text{tension}} \quad (\text{AISC code})$$

$$\text{and } \sigma_{\text{tension}} = 80,000 \text{ psi}$$

$$\sigma_v (\text{max}) = 24,000 \text{ psi}$$

SUBJECT

Beam Calculations

NAME

DATE

REVISION DATE

Z-axis shear of the core material along the welds:

$$\text{shear area } A_s = 2 \cdot 0.2 \left(\frac{1}{8} + \frac{1}{8} \right)$$
$$c = .707$$

$$\bar{\sigma}_v = \frac{VQ}{Ib} = \frac{9.980}{164.68} \frac{26.2}{.707} = 2246 \text{ psi}$$

AISC allows .4 σ_y , or 12,000 psi

SUBJECT

WEIGHT DISTRIBUTION

NAME

DATE

REVISION DATE

FRONT

The distribution of the cart weight is indeterminate, but in the worst case, one pair of bearings is unloaded. There are three possible configurations:

1) R_a and R_b loaded $\Sigma M_b \Rightarrow W \cdot 1 = -R_a \cdot 14$
 $W = 8285 \text{ lb}$
 $R_a = -592 \text{ lb}$

$\Sigma F_y = 0 \Rightarrow R_b = 8877 \text{ lb}$

2) R_a and R_c loaded $\Sigma M_c \Rightarrow W \cdot 9 = R_a \cdot 24$
 $R_a = 3107 \text{ lb}$

$\Sigma F_y = 0 \Rightarrow R_c = 5178 \text{ lb}$

3) R_b and R_c loaded $\Sigma M_c \Rightarrow R_b \cdot 10 = W \cdot 9$
 $R_b = 7457 \text{ lb}$

$\Sigma F_y = 0 \Rightarrow R_c = 829 \text{ lb}$

- values are for bearing pairs

ENGINEERING NOTE

A12

SUBJECT

Support Rail Strength

NAME

DATE

REVISION DATE

The support rails will be under maximum stress when the SAMUS cart is rolled out to either end (up or downstream) and the bearings are touching the rail stops. There are two cases:

Case One: Cart rolled downstream till back bearings hit back rail stop.

ACTUAL MODEL

The point of contact between the support rail and the SAMUS toroid is rounded and inexact, so in the model the moment arm is .911" longer than actual.

Through this section, $I = 9.093 \text{ in}^4$ $c = 2.166 \text{ in}$

$$R_a (\text{maximum}) = 1554 \text{ lb}$$

$$\sigma = \frac{Mc}{I} = \frac{1554 \cdot 15 \cdot 2.166}{9.093}$$

$$\sigma = 5551 \text{ psi}$$

and in Bending, SS 304 can take 18,000 psi.

SUBJECT

Support Rail Strength

NAME

DATE

REVISION DATE

Case Two: Car is so upstream that front carings touch front rail steps.

Again, the point of contact is rounded, so the moment arm is slightly exaggerated (.911").
The critical stresses are found at the notch.

Through this section; $I = 3.73 \text{ in}^4$ $c = 1.342 \text{ in}$

R_b and R_c share the load: $R_b = 0$, $R_c = 2589 \text{ lbs}$

$$\sigma = \frac{2589 \cdot 13.832 \cdot 1.342}{3.73} = 12,884 \text{ psi}$$

R_b and R_c share the load: $R_b = 3729$, $R_c = 415 \text{ lb}$

$$M = 3729 \cdot 3.832 + 415 \cdot 13.832 = 20,023 \text{ lb-in}$$

$$\sigma = \frac{20,023 \cdot 1.342}{3.73} = 7,204 \text{ psi}$$

ENGINEERING NOTE

A 14

SUBJECT

Bearing Strength

NAME

DATE

REVISION DATE

$$F_{top} = 2472 \text{ lb}$$

$$F_{Bot} = 1671 \text{ lb}$$

$$\Rightarrow F_{Bg} = 4143 \text{ lb}$$

$$\Sigma M: M = 2472 \cdot 7.938 + 1671 \cdot 4.083 - 4143 \cdot 7.396$$

$$M = -4196 \text{ lb-in}$$

F_{Bg} acts on the innermost edge of the bearing mount plate, 1.166" from the bearing center.

$$M_{Bz} = 4143 \text{ lb} \cdot 1.166 = 4831 \text{ lb-in}$$

this moment is supported by 3 bearings axially, for each of which

$$M_{max} = 37 \text{ Kgf-m} = 3211 \text{ lb-in}$$

and

$$F_{max} = 3060 \text{ Kgf} = 6746 \text{ lb}$$

SUBJECT

Bearing Strength

NAME

DATE

REVISION DATE

In this case, the middle bearings are not in contact, and the front and rear bearings each take loads from half of the cart.

Front Bearing: $F_{f1} = 1454 \text{ lb}$ $F_{b1} = 813 \text{ lb}$

$$F_{Brg} = 2267 \text{ lb}$$

$$M_{Brg} = 2267 \cdot 1.166 = 2643 \text{ lb-in}$$

Back Bearing: $F_{f2} = 1018 \text{ lb}$ $F_{b2} = 857 \text{ lb}$

$$F_{Brg} = 1875 \text{ lb}$$

$$M_{Brg} = 1875 \cdot 1.166 = 2186.25 \text{ lb-in}$$

ENGINEERING NOTE

A16

SUBJECT

Cross - Section Stresses

NAME

DATE

REVISION DATE

Bending on the Flange weld:

- assuming entire cart is composed of section with smallest I (conservative).

$$I = 2 \cdot \frac{1}{12} \cdot 72 \cdot (.125)^3 + 2 \cdot 72 \cdot .125 \cdot (.5 - .063)^2$$

$$= 3.461 \text{ in}^4$$

$$M_{\text{weld}} = F_{\text{sla}} \cdot 1.063 - F_{\text{brg}} \cdot .521$$

$$F_{\text{sla}} = 2472 \text{ lb}$$

$$F_{\text{brg}} = 4143 \text{ lb}$$

$$= 470 \text{ lb-in}$$

$$\sigma = \frac{Mc}{I} = 136 \text{ psi}$$

Bending on the flange:

$$I = \frac{1}{12} \cdot 72 \cdot 1^3 = 6 \text{ in}^4$$

$$M = F_{\text{sla}} \cdot .563 - F_{\text{brg}} \cdot .21$$

$$\sigma = \frac{Mc}{I} = 43 \text{ psi}$$

$$M = 522 \text{ lb-in}$$

Shear through flange:

$$\sigma = \frac{F_{\text{brg}} - F_{\text{sla}}}{72 \cdot 1} = 23 \text{ psi}$$

APPENDIX B

STRESS TESTING

Note #3740.225-EN-314

TEST PROCEDURE

- 1) Install and position cart in testing fixture, with the upstream end 4.12" from the center of the first "I" beam.
- 2) Position the pressure pad under the furthestmost "I" beam, centered 32.87" from the upstream end of the cart.
- 3) Use "C" clamps, secure a 2" x 2" box beam to the top "C" channels, allowing it to protrude over the free end of the cart.
- 4) Place a hydraulic jack between the pressure pad and the "I" beam above it. Verify that it is secure and the loading is perpendicular to the cart.
- 5) Attach a pair of dial indicators to the free end of the box beam in position to measure the vertical deflection of the free end of the cart.
- 6) Attach two additional dial indicators to the cart at the two points of its support, also in position to measure vertical displacement.
- 7) With the hydraulic jack at zero load, record the position of the dial indicators.
- 8) Pressurize the jack to the following loads, recording the pressure of the jack and position of all indicators at each point:
25%-50%-75%-50%-25%-0
- 9) Analyze the results as described in this report, checking for yielding of the cart and shakedown in the test fixture. If at any time the cart shows evidence of substantial yielding, discontinue testing.
- 10) Repeat steps 8) and 9) for the following load procedures:
 - a) 25%-50%-75%-100%-75%-50%-25%-0
 - b) 25%-50%-75%-100%-125%-100%-75%-50%-25%-0
 - c) 25%-50%-75%-100%-125%-100%-75%-50%-25%-0
- 11) Remove the jack and all dial indicators from the testing assembly.
- 12) Remove the cart. Install the other cart and position in the testing fixture, with the downstream end 4.12" from the center of the first "I" beam.

- 13) Position the pressure pad under the nearer "I" beam, centered 37.12" from the downstream end of the cart.
- 14) Repeat steps 4) through 10) for this configuration.

DATA
Table B1; Lifting from Front

Load %	Pres	Load	Rear	Middle	Fr. Ave	A	B	C	C Exp
0	0	0	0.510	0.549	0.679	0.000	0.000	0.000	0.000
25	600	1656	0.517	0.547	0.648	0.007	0.001	0.032	0.003
50	1200	3312	0.523	0.544	0.602	0.013	0.004	0.078	0.006
75	1825	5037	0.535	0.537	0.536	0.025	0.012	0.144	0.010
50	1225	3381	0.533	0.539	0.551	0.023	0.010	0.128	0.006
25	600	1656	0.527	0.542	0.583	0.017	0.007	0.096	0.003
0	0	0	0.512	0.547	0.650	0.002	0.001	0.029	0.000
0	0	0	0.512	0.547	0.650	0.000	0.000	0.000	0.000
25	625	1725	0.524	0.544	0.600	0.012	0.004	0.050	0.003
50	1190	3284	0.531	0.541	0.563	0.019	0.007	0.087	0.006
75	1810	4996	0.536	0.538	0.530	0.024	0.010	0.120	0.010
100	2400	6624	0.539	0.536	0.514	0.027	0.011	0.136	0.013
75	1800	4968	0.538	0.537	0.520	0.026	0.011	0.130	0.010
50	1200	3312	0.535	0.538	0.536	0.023	0.009	0.114	0.006
25	600	1656	0.529	0.541	0.567	0.017	0.007	0.083	0.003
0	0	0	0.510	0.547	0.643	-0.003	0.000	0.007	0.000
0	0	0	0.510	0.547	0.643	0.000	0.000	0.000	0.000
25	600	1656	0.527	0.543	0.582	0.018	0.004	0.062	0.003
50	1200	3312	0.535	0.540	0.542	0.026	0.007	0.102	0.006
75	1800	4968	0.540	0.538	0.509	0.031	0.009	0.134	0.010
100	2400	6624	0.543	0.537	0.493	0.033	0.011	0.151	0.013
125	3025	8349	0.545	0.536	0.485	0.035	0.011	0.158	0.016
100	2425	6693	0.543	0.536	0.489	0.034	0.011	0.154	0.013
75	1825	5037	0.542	0.537	0.495	0.033	0.011	0.148	0.010
50	1225	3381	0.539	0.538	0.513	0.030	0.009	0.130	0.006
25	600	1656	0.533	0.541	0.550	0.024	0.006	0.093	0.003
0	0	0	0.511	0.548	0.633	0.002	0.000	0.010	0.000
0	0	0	0.511	0.548	0.633	0.000	0.000	0.000	0.000
25	600	1656	0.529	0.543	0.565	0.018	0.004	0.068	0.003
50	1200	3312	0.538	0.540	0.523	0.027	0.008	0.110	0.006
75	1825	5037	0.543	0.538	0.497	0.032	0.010	0.137	0.010
100	2425	6693	0.544	0.537	0.486	0.033	0.011	0.147	0.013
125	3025	8349	0.545	0.537	0.480	0.034	0.011	0.154	0.016
100	2425	6693	0.545	0.537	0.483	0.034	0.011	0.150	0.013
75	1825	5037	0.545	0.537	0.490	0.034	0.011	0.143	0.010
50	1200	3312	0.541	0.539	0.508	0.030	0.009	0.125	0.006
25	600	1656	0.533	0.542	0.545	0.022	0.006	0.088	0.003
0	0	0	0.512	0.549	0.629	0.001	-0.002	0.004	0.000

DATA
Table B2: Lifting from Back

Load%	Press	Load	Rear	Middle	Fr. Ave	A	B	C	C Exp
0	0	0	0.501	0.491	0.517	0.000	0.000	0.000	0.000
25	600	1656	0.519	0.488	0.437	0.018	0.003	0.080	0.005
50	1200	3312	0.534	0.485	0.371	0.033	0.006	0.146	0.009
75	1800	4968	0.537	0.483	0.310	0.036	0.008	0.207	0.014
50	1200	3312	0.545	0.484	0.320	0.044	0.007	0.197	0.009
25	625	1725	0.537	0.485	0.358	0.036	0.006	0.159	0.005
0	0	0	0.510	0.488	0.467	0.009	0.003	0.050	0.000
0	0	0	0.510	0.488	0.467	0.000	0.000	0.000	0.000
25	610	1684	0.528	0.486	0.392	0.018	0.002	0.075	0.005
50	1200	3312	0.539	0.485	0.345	0.029	0.003	0.122	0.009
75	1750	4830	0.548	0.483	0.298	0.038	0.005	0.169	0.014
100	2400	6624	0.553	0.481	0.233	0.043	0.008	0.234	0.019
75	1825	5037	0.553	0.481	0.266	0.043	0.008	0.201	0.014
50	1225	3381	0.548	0.482	0.292	0.038	0.006	0.175	0.009
25	625	1725	0.540	0.483	0.335	0.030	0.005	0.132	0.005
0	0	0	0.512	0.487	0.447	0.001	0.001	0.020	0.000
0	0	0	0.512	0.487	0.447	0.000	0.000	0.000	0.000
25	610	1684	0.531	0.484	0.369	0.020	0.003	0.078	0.005
50	1200	3312	0.542	0.483	0.318	0.031	0.005	0.128	0.009
75	1790	4940	0.550	0.482	0.280	0.039	0.005	0.167	0.014
100	2375	6555	0.554	0.480	0.256	0.043	0.007	0.191	0.019
125	3000	8280	0.555	0.479	0.244	0.044	0.008	0.202	0.023
100	2425	6693	0.555	0.479	0.250	0.043	0.008	0.197	0.019
75	1800	4968	0.553	0.480	0.258	0.042	0.008	0.189	0.014
50	1200	3312	0.544	0.480	0.284	0.033	0.007	0.163	0.009
25	625	1725	0.540	0.482	0.328	0.029	0.005	0.119	0.005
0	0	0	0.513	0.485	0.436	0.001	0.002	0.010	0.000
0	0	0	0.513	0.485	0.436	0.000	0.000	0.000	0.000
25	600	1656	0.533	0.483	0.357	0.020	0.002	0.080	0.005
50	1150	3174	0.543	0.482	0.308	0.030	0.004	0.128	0.009
75	1775	4899	0.551	0.480	0.265	0.039	0.005	0.171	0.014
100	2450	6762	0.554	0.479	0.250	0.042	0.006	0.186	0.019
125	3000	8280	0.556	0.479	0.241	0.043	0.006	0.195	0.023
100	2425	6693	0.555	0.479	0.247	0.043	0.006	0.189	0.019
75	1800	4968	0.554	0.479	0.255	0.041	0.006	0.181	0.014
50	1225	3381	0.550	0.480	0.278	0.038	0.005	0.158	0.009
25	600	1656	0.541	0.481	0.322	0.029	0.004	0.115	0.005
0	0	0	0.512	0.486	0.438	0.000	-0.001	-0.001	0.000

APPENDIX C

ASSEMBLY PROCEDURE

Note #3740.225-EN-314

ASSEMBLY PROCEDURE

The SAMUS Collimators will be assembled in the A-Zero High Bay, then stored and later shipped to D-Zero assembly building in plastic containers previously used to transport the End Calorimeter modules. Assembly will conform to drawing ME-294969. Part numbers referred to in this report correspond to those listed in the parts list on the assembly drawing.

The north and south collimators will be assembled identically with the exception of the placement the shims around the ion pump and around the tungsten center blocks as noted below.

Many of the shielding blocks are made of lead and tungsten, which are hazardous materials. When working with these materials, at least one person present must be approved to handle lead and tungsten by Accelerator Safety department. When handling, personnel are prohibited from eating, drinking, and smoking and must wear protective clothing (gloves are adequate). The gloves and any other material that has had prolonged contact with the lead is to be considered Hazardous Waste, and must be disposed of as directed by Accelerator Safety. Workers are to prevent the generation of airborne dust from the hazardous materials and must wash their hands when the work is completed.

- Assemble all the vacuum components:
 - a) Granville-Phillips valve and its assembly (23, 25, 51, 52)
 - b) Electropolished and insulated 2.5" stainless steel beamtube (35)
 - Note: Through the tungsten, this tube to be wrapped with Kapton tape, 2 layer overlap minimum.**
 - c) Perkin-Elmer ion pump (26)
 - d) Tube cluster with thermocouples and ion gages (21, 24, 44)
 - e) Strainert load cell and assembly (36-40, 42, 47)
 - f) All bellows and flanges (27-32)
- Leak test vacuum components according to Accelerator Division standard procedure.
- Install sixteen center block bottom plates (6).

- Install four ion gage bottom plates (14). Put the modified block (two holes drilled for the flange support bracket) furthestmost downstream, aligned over the holes in the cart.
- Install bottom layer of center block shim plates (7-10) as dictated by the survey:
North collimator- .060" (1) and .120" (1), total of .180"
South collimator- .120" (1)
- Lay three of the large bore tungsten center plates (1) and thirteen of the small bore tungsten center plates (2) on top of the shims, spaced one inch apart with the semicircular hole facing up.
- Mount the flange support brackets (34) to the cart.
- Lay G-10 shims under location of the ion pump to support its weight.
- Lower the vacuum assembly into place on the cart, and secure flanges into their brackets and the large valve with its clamps (33, 43).
- Install G-10 shims to position the ion pump horizontally in the cart.
- Install remaining tungsten center blocks (small and large bore) onto the beamtube. The cracks should be alternately placed horizontally and vertically.
- Lay the 1/4" stainless steel guide rods (45) fifty-three inches long into the grove along the cart, flush with the upstream end.
- Install the center block middle plates (5) onto the cart aligned by the stainless steel guide rods.
- Insert shims (7-10) to center the center blocks horizontally:
North collimator- .120" (1) and .060" (2), total of .240" each side
South collimator- .120" (1) on the right (East) side; .120" (1) and .060" (4), total of .360" on left (West) side.
- Place the remaining shims (7-10) on top of the center block plates:
North collimator- .120" (1) and .060" (3), total of .300"
South collimator- .120" (1) and .060" (4), total of .360"
- Lay two more stainless guide rods (45) thirty-one inches long on top of the center block middle plates (5).

- Install the center block intermediate plates (4) aligned on the stainless guide rods.
- Attach the middle shield end plate (17) and back shield end plate (18) to the cart.
- Install the ion pump middle plates (11) aligned by the stainless steel guide rods. Place the four modified plates furthest upstream and all on the right side.
- Install the ion gage middle plates (13) onto the cart aligned by the stainless steel guide rods. Place the four plates with the larger bore hole furthest upstream.
- Lay two more stainless guide rods (45) seven inches long on top of the ion gage middle plates (13).
- Install the ion gage intermediate plates (12) aligned on the stainless guide rods. Place the two plates with the cut groove for the ion pump electrical connection furthest downstream.
- Attach the front shield end plate (16) to the cart.
- Insert two 1/2" stainless steel threaded rods (41) fifty-six inches long through the two lower holes in the shielding. Secure loosely to the front and back shield end plates using nuts and washers (43).
- Lay two stainless steel guide rods (45) fifty-three inches long into the grooves on the middle and intermediate lead plates.
- Secure all vacuum component wiring into the provided notches in the lead.
- Install twenty-seven top plates (3) aligned on the stainless steel guide rods.
- Insert one 1/2" stainless steel threaded rod (41) fifty-six inches long through the hole in the top shielding blocks. Secure to the front and back shield end plates using nuts and washers (43).
- Tighten the nuts on the threaded rods through the two lower holes in the shielding.

APPENDIX D

DRAWINGS
and
SPECIFICATIONS

Note #3740.225-EN-314

THK type SR-W/SR-V

Model No	LM block dimensions mm													Grease nipple
	Width			Length		Height								
	W	B	B ₁	L	L ₁	C	M	S×I	T	K	N	E		
*SR 15W	34	26	4	57	39.5	26	24	M 4 × 7	6	19.5	6	5.5	Drive-in nipple	
*SR 15V	34	26	4	40.5	22.9	—	24	M 4 × 7	6	19.5	6	5.5	Drive-in nipple	
*SR 20W	42	32	5	66.5	46.7	32	28	M 5 × 8	7.5	22	5.5	12	B-M6F	
*SR 20V	42	32	5	48	27.8	—	28	M 5 × 8	7.5	22	5.5	12	B-M6F	
*SR 25W-Y	48	35	6.5	83	59	35	33	M 6 × 9	8	26	7	12	B-M6F	
*SR 25V-Y	48	35	6.5	60	35.2	—	33	M 6 × 9	8	26	7	12	B-M6F	
*SR 30W	60	40	10	97	69.3	40	42	M 8 × 12	9	32.5	8	12	B-M6F	
*SR 30V	60	40	10	68	40.9	—	42	M 8 × 12	9	32.5	8	12	B-M6F	
SR 35W	70	50	10	111	79.0	50	48	M 8 × 12	13	36.5	8.5	12	B-M6F	
SR 35V	70	50	10	78	45.7	—	48	M 8 × 12	13	36.5	8.5	12	B-M6F	
SR 45W	86	60	13	126	90.5	60	60	M10 × 15	15	47.5	11.5	16	B-PT 1/8	
SR 55W	100	75	12.5	156	117	75	68	M12 × 20	17	54.5	12	16	B-PT 1/8	
SR 70T	126	90	18	195	147.6	90	85	M16 × 25	25	70	12	16	B-PT 1/4	

Note 1: The grease nipple for the type SR15W/V is a straight drive-in type.

Note 2: The mounting holes of the rails of the type SR25W/V-Y use M6 mounting bolts. (The symbol Y is listed after the symbol for the total length of the LM rail in the model number.) Please note that M5 mounting holes will be provided when the symbol Y is not listed.

Example: SR25W2UUC1 + 460 LYP - II

Symbol for M6 mounting holes

*: Stainless steel-made products are also available for the sizes marked with an asterisk in the table.

Width W_1 ± 0.05	LM rail dimensions: mm					Basic load rating		Static permissible moment Note 3			Weight		Model No
	W_2	B_2	Height M_1	$d \times D \times h$	Pitch F	C kgf	C_0 kgf	M_A kgf·m	M_B kgf·m	M_C kgf·m	LM block kgf	LM rail kgf/m	
15	9.5	7.5	12.5	$3.5 \times 6 \times 4.5$	60	970	1970	5.2	4.4	6.8	0.18	1.2	*SR 15W
15	9.5	7.5	12.5	$3.5 \times 6 \times 4.5$	60	550	1130	12.6	11.0	3.9	0.12	1.2	*SR 15V
20	11	10	15.5	$6 \times 9.5 \times 8.5$	60	1280	2570	8.7	7.5	9.8	0.3	2.1	*SR 20W
20	11	10	15.5	$6 \times 9.5 \times 8.5$	60	730	1470	17.8	15.4	5.6	0.2	2.1	*SR 20V
23	12.5	11.5	18	$7 \times 11 \times 9$	60	2070	4030	14.8	12.9	21.6	0.4	2.7	*SR 25W-Y
23	12.5	11.5	18	$7 \times 11 \times 9$	60	1190	2300	38.4	33.2	12.4	0.3	2.7	*SR 25V-Y
28	16	14	23	$7 \times 11 \times 9$	80	3060	5790	25.7	22.2	37.0	0.8	4.3	*SR 30W
28	16	14	23	$7 \times 11 \times 9$	80	1750	3310	54.9	56.2	21.1	0.5	4.3	*SR 30V
34	18	17	27.5	$9 \times 14 \times 12$	80	4250	7870	40.8	35.4	60.8	1.2	6.4	SR 35W
34	18	17	27.5	$9 \times 14 \times 12$	80	2430	4500	101.6	88.0	34.8	0.8	6.4	SR 35V
45	20.5	22.5	35.5	$11 \times 17.5 \times 14$	105	5640	10300	60.8	52.6	106.8	2.2	11.3	SR 45W
48	26	24	38	$14 \times 20 \times 17$	120	9090	16000	118.9	103.0	175.0	3.6	12.8	SR 55W
70	28	35	47	$18 \times 26 \times 22$	150	15900	27100	265.2	229.7	422.8	7.0	22.8	SR 70T

Note 3: M_A , M_B , and M_C shown in the figure on the right are the permissible moment values for one LM block in case of the type SR...W. For the type SR...V, M_A and M_B show the permissible moment for two LM blocks in close contact and M_C shows the permissible moment for one LM block.

Type SR...W
(for one LM block)

Type SR...V
(for two LM blocks)

TESTING ORIENTATION

SECTION D-D
SCALE 1:4

NO.	DESCRIPTION	QTY.	UNIT	REMARKS
1	FLANGE	1	EA	
2	FLANGE	1	EA	
3	FLANGE	1	EA	
4	FLANGE	1	EA	
5	FLANGE	1	EA	
6	FLANGE	1	EA	
7	FLANGE	1	EA	
8	FLANGE	1	EA	
9	FLANGE	1	EA	
10	FLANGE	1	EA	
11	FLANGE	1	EA	
12	FLANGE	1	EA	
13	FLANGE	1	EA	
14	FLANGE	1	EA	
15	FLANGE	1	EA	
16	FLANGE	1	EA	
17	FLANGE	1	EA	
18	FLANGE	1	EA	
19	FLANGE	1	EA	
20	FLANGE	1	EA	
21	FLANGE	1	EA	
22	FLANGE	1	EA	
23	FLANGE	1	EA	
24	FLANGE	1	EA	
25	FLANGE	1	EA	
26	FLANGE	1	EA	
27	FLANGE	1	EA	
28	FLANGE	1	EA	
29	FLANGE	1	EA	
30	FLANGE	1	EA	
31	FLANGE	1	EA	
32	FLANGE	1	EA	
33	FLANGE	1	EA	
34	FLANGE	1	EA	
35	FLANGE	1	EA	
36	FLANGE	1	EA	
37	FLANGE	1	EA	
38	FLANGE	1	EA	
39	FLANGE	1	EA	
40	FLANGE	1	EA	
41	FLANGE	1	EA	
42	FLANGE	1	EA	
43	FLANGE	1	EA	
44	FLANGE	1	EA	
45	FLANGE	1	EA	
46	FLANGE	1	EA	
47	FLANGE	1	EA	
48	FLANGE	1	EA	
49	FLANGE	1	EA	
50	FLANGE	1	EA	
51	FLANGE	1	EA	
52	FLANGE	1	EA	
53	FLANGE	1	EA	
54	FLANGE	1	EA	
55	FLANGE	1	EA	
56	FLANGE	1	EA	
57	FLANGE	1	EA	
58	FLANGE	1	EA	
59	FLANGE	1	EA	
60	FLANGE	1	EA	

1. 100 2. 100 3. 100 4. 100 5. 100 6. 100 7. 100 8. 100 9. 100 10. 100
 11. 100 12. 100 13. 100 14. 100 15. 100 16. 100 17. 100 18. 100 19. 100 20. 100
 21. 100 22. 100 23. 100 24. 100 25. 100 26. 100 27. 100 28. 100 29. 100 30. 100
 31. 100 32. 100 33. 100 34. 100 35. 100 36. 100 37. 100 38. 100 39. 100 40. 100
 41. 100 42. 100 43. 100 44. 100 45. 100 46. 100 47. 100 48. 100 49. 100 50. 100
 51. 100 52. 100 53. 100 54. 100 55. 100 56. 100 57. 100 58. 100 59. 100 60. 100
 61. 100 62. 100 63. 100 64. 100 65. 100 66. 100 67. 100 68. 100 69. 100 70. 100
 71. 100 72. 100 73. 100 74. 100 75. 100 76. 100 77. 100 78. 100 79. 100 80. 100
 81. 100 82. 100 83. 100 84. 100 85. 100 86. 100 87. 100 88. 100 89. 100 90. 100
 91. 100 92. 100 93. 100 94. 100 95. 100 96. 100 97. 100 98. 100 99. 100 100. 100

#10 24 U.N.C. 2H TAP X 1-2" DEEP
1221 PLACES AS SHOWN

REV.	DESCRIPTION	DATE	BY
1	ORIGINAL REVISED	12-12-72	WHS
2	REVISIONS	12-12-72	WHS
3	REVISIONS	12-12-72	WHS

1/8" X 45° CHAMFER
131 EDGES AS SHOWN

3/16" X 45° CHAMFER
AS SHOWN

-.005
A

1/21.005 A

FEDERAL NATIONAL ACCELERATOR LABORATORY		ME-294924	
U.S. DEPARTMENT OF ENERGY		2014 STAINLESS STEEL	
FACILITY: FERMILAB		PROJECT: 1000	
SUBJECT: 1000		DATE: 12-12-72	
DRAWN: 1000		CHECKED: 1000	
APPROVED: 1000		DATE: 12-12-72	
FEDERAL NATIONAL ACCELERATOR LABORATORY		ME-294924	
U.S. DEPARTMENT OF ENERGY		2014 STAINLESS STEEL	
FACILITY: FERMILAB		PROJECT: 1000	
SUBJECT: 1000		DATE: 12-12-72	
DRAWN: 1000		CHECKED: 1000	
APPROVED: 1000		DATE: 12-12-72	

1/8" X 45° CHAMFER
EXT. EDGES AS SHOWN

3/16" X 45° CHAMFER
AS SHOWN

5/16" DIA. TAP DRILL X 1 1/8" DEEP
5/16" DIA. TAP X 3/4" DEEP
EXT. EDGES AS SHOWN

1/8" X 1/2" L-PILE X 45°
CHAMFER AS SHOWN

1.710
.000

ITEM	PART NO.	DESCRIPTION OR SIZE
PARTS LIST		
1	ME-294924	1.710 X .000
2	ME-294924	1.710 X .000
3	ME-294924	1.710 X .000
4	ME-294924	1.710 X .000
5	ME-294924	1.710 X .000
6	ME-294924	1.710 X .000
7	ME-294924	1.710 X .000
8	ME-294924	1.710 X .000
9	ME-294924	1.710 X .000
10	ME-294924	1.710 X .000
11	ME-294924	1.710 X .000
12	ME-294924	1.710 X .000
13	ME-294924	1.710 X .000
14	ME-294924	1.710 X .000
15	ME-294924	1.710 X .000
16	ME-294924	1.710 X .000
17	ME-294924	1.710 X .000
18	ME-294924	1.710 X .000
19	ME-294924	1.710 X .000
20	ME-294924	1.710 X .000
21	ME-294924	1.710 X .000
22	ME-294924	1.710 X .000
23	ME-294924	1.710 X .000
24	ME-294924	1.710 X .000
25	ME-294924	1.710 X .000
26	ME-294924	1.710 X .000
27	ME-294924	1.710 X .000
28	ME-294924	1.710 X .000
29	ME-294924	1.710 X .000
30	ME-294924	1.710 X .000
31	ME-294924	1.710 X .000
32	ME-294924	1.710 X .000
33	ME-294924	1.710 X .000
34	ME-294924	1.710 X .000
35	ME-294924	1.710 X .000
36	ME-294924	1.710 X .000
37	ME-294924	1.710 X .000
38	ME-294924	1.710 X .000
39	ME-294924	1.710 X .000
40	ME-294924	1.710 X .000
41	ME-294924	1.710 X .000
42	ME-294924	1.710 X .000
43	ME-294924	1.710 X .000
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96	ME-294924	1.710 X .000
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98	ME-294924	1.710 X .000
99	ME-294924	1.710 X .000
100	ME-294924	1.710 X .000

DATE: 11/1/81

FIGURE 1

FERMILAB		FERMILAB	
FERMILAB NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY			
D. D. SAMIS COLLIMATOR SAMIS (ART SIDE SUPPORT (LEFT)			
DATE	BY	DATE	BY
11/1/81	ME-294924	11/1/81	ME-294924
3740.220-MD-295280			
CREATED WITH: CPAS 4.1 USER NAME: GOTTEN			

[illegible][illegible]

FEDERAL BUREAU OF INVESTIGATION		U. S. DEPARTMENT OF JUSTICE	
LABORATORY REPORT			
Q101	Q102	Q103	Q104
Q105	Q106	Q107	Q108
Q109	Q110	Q111	Q112
Q113	Q114	Q115	Q116
Q117	Q118	Q119	Q120
Q121	Q122	Q123	Q124
Q125	Q126	Q127	Q128
Q129	Q130	Q131	Q132
Q133	Q134	Q135	Q136
Q137	Q138	Q139	Q140
Q141	Q142	Q143	Q144
Q145	Q146	Q147	Q148
Q149	Q150	Q151	Q152
Q153	Q154	Q155	Q156
Q157	Q158	Q159	Q160
Q161	Q162	Q163	Q164
Q165	Q166	Q167	Q168
Q169	Q170	Q171	Q172
Q173	Q174	Q175	Q176
Q177	Q178	Q179	Q180
Q181	Q182	Q183	Q184
Q185	Q186	Q187	Q188
Q189	Q190	Q191	Q192
Q193	Q194	Q195	Q196
Q197	Q198	Q199	Q200
Q201	Q202	Q203	Q204
Q205	Q206	Q207	Q208
Q209	Q210	Q211	Q212
Q213	Q214	Q215	Q216
Q217	Q218	Q219	Q220
Q221	Q222	Q223	Q224
Q225	Q226	Q227	Q228
Q229	Q230	Q231	Q232
Q233	Q234	Q235	Q236
Q237	Q238	Q239	Q240
Q241	Q242	Q243	Q244
Q245	Q246	Q247	Q248
Q249	Q250	Q251	Q252
Q253	Q254	Q255	Q256
Q257	Q258	Q259	Q260
Q261	Q262	Q263	Q264
Q265	Q266	Q267	Q268
Q269	Q270	Q271	Q272
Q273	Q274	Q275	Q276
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Q293	Q294	Q295	Q296
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Q301	Q302	Q303	Q304
Q305	Q306	Q307	Q308
Q309	Q310	Q311	Q312
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Q385	Q386	Q387	Q388
Q389	Q390	Q391	Q392
Q393	Q394	Q395	Q396
Q397	Q398	Q399	Q400
Q401	Q402	Q403	Q404
Q405	Q406	Q407	Q408
Q409	Q410	Q411	Q412
Q413	Q414	Q415	Q416
Q417	Q418	Q419	Q420
Q421	Q422	Q423	Q424
Q425	Q426	Q427	Q428
Q429	Q430	Q431	Q432
Q433	Q434	Q435	Q436
Q437	Q438	Q439	Q440
Q441	Q442	Q443

ITEM		STATUS	DESCRIPTION OR SIZE	
PARTS LIST				
1	ORIGINATOR	K	PRIMEVAL	07-
2	EXAMINER		TERMANSEN	07-
3	CHECKED			
4	APPROVED			
LISTED ON				
ME-279493				
MATERIAL				
#304 STAINLESS STEEL
FEDERAL BUREAU OF INVESTIGATION UNITED STATES DEPARTMENT OF JUSTICE LABORATORY				
D-D CALORIMETER SHIELD CART				
SAMUEL CART				
SUPPORT RAIL-LEFT SIDE				
NAME	DATE	LABORATORY NUMBER		
1	4	1	3740 220-MD-295097	

NO.	DESCRIPTION	QTY	UNIT	PRICE	TOTAL
1	STEEL PLATE 1/2" THICK	10	SQ. FT.	1.25	12.50
2	STEEL PLATE 1/4" THICK	20	SQ. FT.	0.75	15.00
3	STEEL PLATE 1/8" THICK	40	SQ. FT.	0.40	16.00
4	STEEL PLATE 1/16" THICK	80	SQ. FT.	0.20	16.00
5	STEEL PLATE 1/32" THICK	160	SQ. FT.	0.10	16.00
6	STEEL PLATE 1/64" THICK	320	SQ. FT.	0.05	16.00
7	STEEL PLATE 1/128" THICK	640	SQ. FT.	0.025	16.00
8	STEEL PLATE 1/256" THICK	1280	SQ. FT.	0.0125	16.00
9	STEEL PLATE 1/512" THICK	2560	SQ. FT.	0.00625	16.00
10	STEEL PLATE 1/1024" THICK	5120	SQ. FT.	0.003125	16.00
11	STEEL PLATE 1/2048" THICK	10240	SQ. FT.	0.0015625	16.00
12	STEEL PLATE 1/4096" THICK	20480	SQ. FT.	0.00078125	16.00
13	STEEL PLATE 1/8192" THICK	40960	SQ. FT.	0.000390625	16.00
14	STEEL PLATE 1/16384" THICK	81920	SQ. FT.	0.0001953125	16.00
15	STEEL PLATE 1/32768" THICK	163840	SQ. FT.	0.00009765625	16.00
16	STEEL PLATE 1/65536" THICK	327680	SQ. FT.	0.000048828125	16.00
17	STEEL PLATE 1/131072" THICK	655360	SQ. FT.	0.0000244140625	16.00
18	STEEL PLATE 1/262144" THICK	1310720	SQ. FT.	0.00001220703125	16.00
19	STEEL PLATE 1/524288" THICK	2621440	SQ. FT.	0.000006103515625	16.00
20	STEEL PLATE 1/1048576" THICK	5242880	SQ. FT.	0.0000030517578125	16.00
21	STEEL PLATE 1/2097152" THICK	10485760	SQ. FT.	0.00000152587890625	16.00
22	STEEL PLATE 1/4194304" THICK	20971520	SQ. FT.	0.000000762939453125	16.00
23	STEEL PLATE 1/8388608" THICK	41943040	SQ. FT.	0.0000003814697265625	16.00
24	STEEL PLATE 1/16777216" THICK	83886080	SQ. FT.	0.00000019073486328125	16.00
25	STEEL PLATE 1/33554432" THICK	167772160	SQ. FT.	0.000000095367431640625	16.00
26	STEEL PLATE 1/67108864" THICK	335544320	SQ. FT.	0.0000000476837158203125	16.00
27	STEEL PLATE 1/134217728" THICK	671088640	SQ. FT.	0.00000002384185791015625	16.00
28	STEEL PLATE 1/268435456" THICK	1342177280	SQ. FT.	0.000000011920928955078125	16.00
29	STEEL PLATE 1/536870912" THICK	2684354560	SQ. FT.	0.0000000059604644775390625	16.00
30	STEEL PLATE 1/1073741824" THICK	5368709120	SQ. FT.	0.00000000298023223876953125	16.00
31	STEEL PLATE 1/2147483648" THICK	10737418240	SQ. FT.	0.000000001490116119384765625	16.00
32	STEEL PLATE 1/4294967296" THICK	21474836480	SQ. FT.	0.0000000007450580596923828125	16.00
33	STEEL PLATE 1/8589934592" THICK	42949672960	SQ. FT.	0.00000000037252902984619140625	16.00
34	STEEL PLATE 1/17179869184" THICK	85899345920	SQ. FT.	0.000000000186264514923095703125	16.00
35	STEEL PLATE 1/34359738368" THICK	171798691840	SQ. FT.	0.0000000000931322574615478515625	16.00
36	STEEL PLATE 1/68719476736" THICK	343597383680	SQ. FT.	0.00000000004656612873077392578125	16.00
37	STEEL PLATE 1/137438953472" THICK	687194767360	SQ. FT.	0.000000000023283064365386962890625	16.00
38	STEEL PLATE 1/274877906944" THICK	1374389534720	SQ. FT.	0.0000000000116415321826934814453125	16.00
39	STEEL PLATE 1/549755813888" THICK	2748779069440	SQ. FT.	0.00000000000582076609134674072265625	16.00
40	STEEL PLATE 1/1099511627776" THICK	5497558138880	SQ. FT.	0.000000000002910383045673370361328125	16.00
41	STEEL PLATE 1/2199023255552" THICK	10995116277760	SQ. FT.	0.0000000000014551915228366851806640625	16.00
42	STEEL PLATE 1/4398046511104" THICK	21990232555520	SQ. FT.	0.00000000000072759576141834259033203125	16.00
43	STEEL PLATE 1/8796093022208" THICK	43980465111040	SQ. FT.	0.000000000000363797880709171295166015625	16.00
44	STEEL PLATE 1/17592186044416" THICK	87960930222080	SQ. FT.	0.0000000000001818989403545856475830078125	16.00
45	STEEL PLATE 1/35184372088832" THICK	175921860444160	SQ. FT.	0.00000000000009094947017729282379150390625	16.00
46	STEEL PLATE 1/70368744177664" THICK	351843720888320	SQ. FT.	0.000000000000045474735088646411895751953125	16.00
47	STEEL PLATE 1/140737488355328" THICK	703687441776640	SQ. FT.	0.0000000000000227373675443232059478759765625	16.00
48	STEEL PLATE 1/281474976710656" THICK	1407374883553280	SQ. FT.	0.00000000000001136868377216160297393798828125	16.00
49	STEEL PLATE 1/562949953421312" THICK	2814749767106560	SQ. FT.	0.000000000000005684341886080801486968994140625	16.00
50	STEEL PLATE 1/1125899906842624" THICK	5629499534213120	SQ. FT.	0.0000000000000028421709430404007434844970703125	16.00
51	STEEL PLATE 1/2251799813685248" THICK	11258999068426240	SQ. FT.	0.00000000000000142108547152020037174224853515625	16.00
52	STEEL PLATE 1/4503599627370496" THICK	22517998136852480	SQ. FT.	0.000000000000000710542735760100185871124267578125	16.00
53	STEEL PLATE 1/9007199254740992" THICK	45035996273704960	SQ. FT.	0.0000000000000003552713678800500929355621337890625	16.00
54	STEEL PLATE 1/18014398509481984" THICK	90071992547409920	SQ. FT.	0.00000000000000017763568394002504646778106689453125	16.00
55	STEEL PLATE 1/36028797018963968" THICK	180143985094819840	SQ. FT.	0.000000000000000088817841970012523233890533447265625	16.00
56	STEEL PLATE 1/72057594037927936" THICK	360287970189639680	SQ. FT.	0.0000000000000000444089209850062616169452667236328125	16.00
57	STEEL PLATE 1/144115188075855872" THICK	720575940379279360	SQ. FT.	0.00000000000000002220446049250313080847263336181640625	16.00
58	STEEL PLATE 1/288230376151711744" THICK	1441151880758558720	SQ. FT.	0.000000000000000011102230246251565404236316680908203125	16.00
59	STEEL PLATE 1/576460752303423488" THICK	2882303761517117440	SQ. FT.	0.0000000000000000055511151231257827021181583404541015625	16.00
60	STEEL PLATE 1/1152921504606846976" THICK	5764607523034234880	SQ. FT.	0.00000000000000000277555756156289135105590767022705078125	16.00
61	STEEL PLATE 1/2305843009213693952" THICK	11529215046068469760	SQ. FT.	0.000000000000000001387778780781445675527953835113525390625	16.00
62	STEEL PLATE 1/4611686018427387904" THICK	23058430092136939520	SQ. FT.	0.0000000000000000006938893903907228377639769175567626953125	16.00
63	STEEL PLATE 1/9223372036854775808" THICK	46116860184273879040	SQ. FT.	0.00000000000000000034694469519536141888198845877838134765625	16.00
64	STEEL PLATE 1/18446744073709551616" THICK	92233720368547758080	SQ. FT.	0.000000000000000000173472347597680709440994229389190673828125	16.00
65	STEEL PLATE 1/36893488147419103232" THICK	184467440737095516160	SQ. FT.	0.0000000000000000000867361737988403547204971146945953369140625	16.00
66	STEEL PLATE 1/73786976294838206464" THICK	368934881474191032320	SQ. FT.	0.00000000000000000004336808689942017736024855734729766845703125	16.00
67	STEEL PLATE 1/147573952589676412928" THICK	737869762948382064640	SQ. FT.	0.000000000000000000021684043449710088680124278673648834228515625	16.00
68	STEEL PLATE 1/295147905179352825856" THICK	1475739525896764129280	SQ. FT.	0.0000000000000000000108420217248550443400621393368244171142578125	16.00
69	STEEL PLATE 1/590295810358705651712" THICK	2951479051793528258560	SQ. FT.	0.000000000000000000005421010862427522170031069668412208571115625	16.00
70	STEEL PLATE 1/1180591620717411303424" THICK	5902958103587056517120	SQ. FT.	0.000000000000000000002710505431213761085001534833420610355578125	16.00
71	STEEL PLATE 1/2361183241434822606848" THICK	11805916207174113034240	SQ. FT.	0.0000000000000000000013552527156068805425007674167103051777890625	16.00
72	STEEL PLATE 1/4722366482869645213696" THICK	23611832414348226068480	SQ. FT.	0.00000000000000000000067762635780344027125038370835515258889453125	16.00
73	STEEL PLATE 1/9444732965739290427392" THICK	47223664828696452136960	SQ. FT.	0.000000000000000000000338813178901720135625191854177576294447265625	16.00
74	STEEL PLATE 1/18889465931478580854784" THICK	94447329657392904273920	SQ. FT.	0.0000000000000000000001694065894508600678125959270887881472236328125	16.00
75	STEEL PLATE 1/37778931862957161709568" THICK	188894659314785808547840	SQ. FT.	0.00000000000000000000008470329472543003390629796354439407361181640625	16.00
76	STEEL PLATE 1/75557863725914323419136" THICK	377789318629571617095680	SQ. FT.	0.000000000000000000000042351647362715016953148981772197036805908203125	16.00
77	STEEL PLATE 1/151115727451828646838272" THICK	755578637259143234191360	SQ. FT.	0.0000000000000000000000211758236813575084765744908860985184029541015625	16.00
78	STEEL PLATE 1/302231454903657293676544" THICK	1511157274518286468382720	SQ. FT.	0.00000000000000000000001058791184067875423828724544304925920147705078125	16.00
79	STEEL PLATE 1/604462909807314587353088" THICK	3022314549036572936765440	SQ. FT.	0.000000000000000000000005293955920339377119143622721524629600738525390625	16.00
80	STEEL PLATE 1/1208925819614629174706176" THICK	6044629098073145873530880	SQ. FT.	0.0000000000000000000000026469779601696885595718113607623148003692626953125	16.00
81	STEEL PLATE 1/2417851639229258349412352" THICK	12089258196146291747061760	SQ. FT.	0.00000000000000000000000132348898008484427797890568038115740018463134765625	16.00
82	STEEL PLATE 1/4835703278458516698824704" THICK	24178516392292583494123520	SQ. FT.	0.000000000000000000000000661744490042422138989452840190578700092315673828125	16.00
83	STEEL PLATE 1/9671406556917033397649408" THICK	48357032784585166988247040	SQ. FT.	0.0000000000000000000000003308722450212110694947264200952893500461578369140625	16.00
84	STEEL PLATE 1/19342813113834066795298816" THICK	96714065569170333976494080	SQ. FT.	0.00000000000000000000000016543612251060553474736321004764467502307891845703125	16.00
85	STEEL PLATE 1/38685626227668133590597632" THICK	193428131138340667952988160	SQ. FT.	0.000000000000000000000000082718061255302767373681605023822337511539459228515625	16.00
86	STEEL PLATE 1/77371252455336267181195264" THICK	386856262276681335905976320	SQ. FT.	0.0000000000000000000000000413590306276513836868408025119111687557697296142578125	16.00
87	STEEL PLATE 1/154742504910672534362390528" THICK	773712524553362671811952640	SQ. FT.	0.00000000000000000000000002067951531382569184342040125595558437888486480712890625	16.00
88	STEEL PLATE 1/309485009821345068724781056" THICK	1547425049106725343623905280	SQ. FT.	0.000000000000000000000000010339757656912845921710200627977792189442432403644403125	16.00
89	STEEL PLATE 1/618970019642690137449562112" THICK	3094850098213450687247810560	SQ. FT.	0.0000000000000000000000000051698788284564229608551003139888959472212162018222015625	16.00
90	STEEL PLATE 1/1237940039285380274899124224" THICK	6189700196426901374495621120	SQ. FT.	0.000000000000000000000000002584939414228211480427550156994479736110608100911103125	16.00
91	STEEL PLATE 1/2475880078570760549798248448" THICK	12379400392853802748991242240	SQ. FT.	0.00000000000000000000000000129246970711410574021377507849723