Energy Doubler Tunnel Cryogenic Components

C. Rode

A. Basic Layout

The tunnel cryogenic system is a ring starting at B11 and ending at A49 consisting of 48 cryogenic loops. (See Table IV of Refrigeration System Section for details of number and type of magnets in each loop.) The electrical circuit uses cryogenic feed thrus to interconnect the cryogenic loops; with the buss to coil connections made at B11 (upstream end of dipoles) and at A49 (downstream end of dipoles). The buss is interrupted only by 47 cryogenic feed thrus; the coils are alternately interrupted by a pair of power leads (24) and cryogenic feed thrus (23). Either half or one quarter of the power leads are connected to power supplies while the remainder are shorted together. The shorted power leads would be both for warm up where the electrical circuit has been damaged by a quench etc. and for trouble shooting during initial construction.

The useable cold length as shown in the tables and figures of this section is a mathematical length only. Its exact position varies from 2. to 4. in axial displacement away from the main magnetic element. Its exact position is determined by what the useable cold length is used for, and how the unit is constructed. We will always show it adjacent to the magnet element and the 6 in. of adaptor length as a single unit after it. (Rather than e.g. a 2.45 in. plus 3.55 in. length.)

B. Feed Cans

The satellite refrigerators are connected to two cryogenic loops by the feed cans which are located at station points 15, 25,

35 and 45. These feed cans are welded into the downstream ends of normal quad cryostats, using the 20 inches which is normally available for a special extraction or injection element (see Figure 7).

The feed can in addition to containing a pair of power leads, a cryo feed thru, and a pair of subcoolers also contains half of the instrumentation for the cryogenic control of the refrigerator and magnets.

C. Turnaround Cans

There are 3 types of turnarounds used in the Tevatron: (a) normal double turnaround at station points (S.P.) 21, 29 and 39 (see Figure 8), (b) transfer line double turnarounds at C0, D0, E0, F0 and A0, (c) single turnarounds at B11 and A49 (see Figures 4 and 5). The normal double turnaround box is welded into the quads in the same manner as the feed can. The single turnarounds are welded into the low beta quads at both ends of the B0 interaction region.

The location of the S.P. 21, 29 and 39 was chosen to balance the loads on the refrigerators. (See Refrigeration Report, Section G) Since the refrigerators are on a common compressor system the only effect of shifting these points is to raise the operating temperature of the magnets. We estimate an increase of $.05^{o}$ k per half cell shift. In the two pairs of loops around the low beta region we may need to shift the double turnarounds due to the high power lead requirement for the stand-alone quads. (A39→A42 and B21→B19 or A29→A32, A39→A43, B21→B18, B29→B28)

The double turnaround in addition to containing a pair of special cryogenic feed thrus, a pair of JT valves, a pair of He cooldown vents, and a pair of N_2 vents also contains the second half of the

instrumentation for the cryogenic control of the refrigerator and magnets.

The special cryogenic feed thru has the following design requirement, which preliminary calculations indicate are feasibility:

1. During normal operation, it must make a 5000 amp superconducting connection. Heat load per cryo loop $\frac{1}{2}$ ℓ/hr plus $\frac{1}{2}$ watt max.
2. When one pair of cryoloops are cold and the adjacent pair are warm:
   a. The heat load into the cold loop is less than 5 ℓ/hr plus 10 watts.
   b. No surface in the warm loop will be less than 0^{o} C.
3. During warm up of a pair of cryo loops the feed thru must be able to carry current starting at 1000 amps decreasing to 10 amps over a four hour period. During this period there is no heat load limit on the cold loops.

D. Medium Straight Missing Magnet Spacers

1. S.P. 17 Slot Length 42 ft. 11 in. (See Figure 2)

The quad at S.P. 17 is a normal quad; this is followed by a transfer line adapter box (S.L. 15 in.). We have a useable warm length of 40 ft. 10 in. which includes vacuum pumps and valves. This is followed by the second transfer line adaptor box (S.L. 10 in.)

2. S.P. 18 Slot Length 13 in.

This is upstream of the S.P. 18 quad and is a cold spacer useable only as beam sensor.

E. Normal Long Straight Section (C0, D0 and E0)

(Based T.L. Collins, June 7, 1978)

The cell starts with a short quad at S.P. 48; It contains all the elements of a normal quad, except that its magnetic length is shorter by 25.56 in. and therefore has a slot length of 89.44.

This is followed by a missing magnet transfer line similar to the one at S.P. 17, but with a S.L. of 291.71 in leaving a useable warm length of 266.71 in.

The next group of elements consists of 3 dipoles each with a S.L. of 22 ft.

The next group of elements consists of the long straight together with the doublet at either end. There are three small drift lengths which could be made warm if absolutely necessary, their warm length would be 34.27, 34.27 and 45.86 in. Assuming this option is not taken, the 5 elements are given in Table 1. Careful attention should be noted that the "0 drift" is not centered between the quads; all independent warm regions have a 5 in. longer upstream adaptor then downstream due to the interferences caused by the outer vacuum bellows (see Figure 2).

This is followed by 4 dipoles, a short quad, and another 4 dipoles.

F. Low Beta Long Straight Section (B0)

The cryogenic system is very similar to the normal long straight with four exceptions;

1. The eight quads from A47 to B13 each are powered independently. It is highly desirable that these be low current quads due to the refrigeration load of 8 pairs of power leads.
2. The dipole power is transported thru the quads at A47, A48, B12 and B13; either twisted pair or magnetically shielded.

3. The electrical loop turns around between the last dipole and the doublet. (Coil to buss connection)
4. The cryogenic loops turn around after the doublets (see Figures 4,5).

G. High Beta Long Straight Sections (A0 and F0)

The only cryogenic difference between these and normal long straights is that they have additional warm drifts or bends. See Tables III and IV for lengths.

Table I. Normal Straight Section Elements

Name	Fig.	S.L. Inches	Useable Warm Length	Useable Cold Length
48 F	1	89.44	0	34.15 (Normal Quad)
48 drift	2	291.71	266.71	0
48 dipole	1	264.00	0	0
48 dipole	1	264.00	0	0
48 dipole	1	264.00	0	0
49 F	1	159.20	0	50.27
49 D	1	134.60	0	0
0 drift	2	2074.20	2049.20*	0
11 F	1	184.87	0	50.27
11 D	1	170.79	0	61.86
11 dipole	1	264.00	0	0
11 dipole	1	264.00	0	0
11 dipole	1	264.00	0	0
11 dipole	1	264.00	0	0
12 D	1	89.44	0	34.15 (Normal Quad)
12 dipole	1	264.00	0	0
12 dipole	1	264.00	0	0
12 dipole	1	264.00	0	0
12 dipole	1	264.00	0	0
		6098.25		

*Includes vacuum valves and end of straight section pumps

Table II. Low Beta Straight Section Elements

Name	Fig.	S.L. Inches	Useable Warm Length	Useable Cold Length
A 47	1	115.00	0	34.15
A 47 dipole	1	264.00	0	0
A 47 dipole	1	264.00	0	0
A 47 dipole	1	264.00	0	0
A 47 dipole	1	264.00	0	0
A 48 F	1	98.65	0	34.15
A 48 drift	2	282.50	257.50	0
A 48 dipole	1	264.00	0	0
A 48 dipole	1	264.00	0	0
A 48 dipole	1	264.00	0	0
A 49 F	6	234.00	0	24.00 + 24.00
A 49 D	4	192.00	0	0
B 0 drift	None	1843.34	1843.34	0
B 11 F	5	216.00	0	24.00
B 11 D	1	238.82	0	52.82
B 11 dipole	1	264.00	0	0
B 11 dipole	1	264.00	0	0
B 11 dipole	1	264.00	0	0
B 11 dipole	1	264.00	0	0
B 12 D	1	88.94	0	24.44 (Note: Extra Short)
B 12 dipole	1	264.00	0	0
B 12 dipole	1	264.00	0	0
B 12 dipole	1	264.00	0	0
B 12 dipole	1	264.00	0	0
B 13 F	1	115.00	0	34.15
B 13 dipole	1	264.00	0	0
B 13 dipole	1	264.00	0	0
B 13 dipole	1	264.00	0	0
B 13 dipole	1	260.00	0	0
		6098.25		
		plus		
		2342.00		

Table III. Extraction High Beta Straight Section Elements

Name	Fig.	S.L. Inches	Useable Warm Length	Useable Cold Length
F 48 F	1	74.93	0	34.15
F 48 drift	2	348.43	323.43	0
F 48 dipole	1	264.00	0	0
F 48 dipole	1	264.00	0	0
F 48 short	1	138.00	0	0
F 49 D	1	103.35	0	0
F 49 short	6	162.81	0	24.81*
F 49 F	1	111.43	0	0
A 0 drift	2	2074.20	2049.20	0
A 11 D	1	111.43	0	0
A 11 short	6	162.81	0	24.81*
A 11 F	3	221.93	102.58	0
A 11 short	1	138.00	0	0
A 11 dipole	1	264.00	0	0
A 11 dipole	1	264.00	0	0
A 11 dipole	1	264.00	0	
A 12 D	1	74.93	0	34.15
A 12 dipole	1	264.00	0	0
A 12 dipole	1	264.00	0	0
A 12 dipole	1	264.00	0	0
A 12 dipole	1	264.00	0	0
		6098.25		

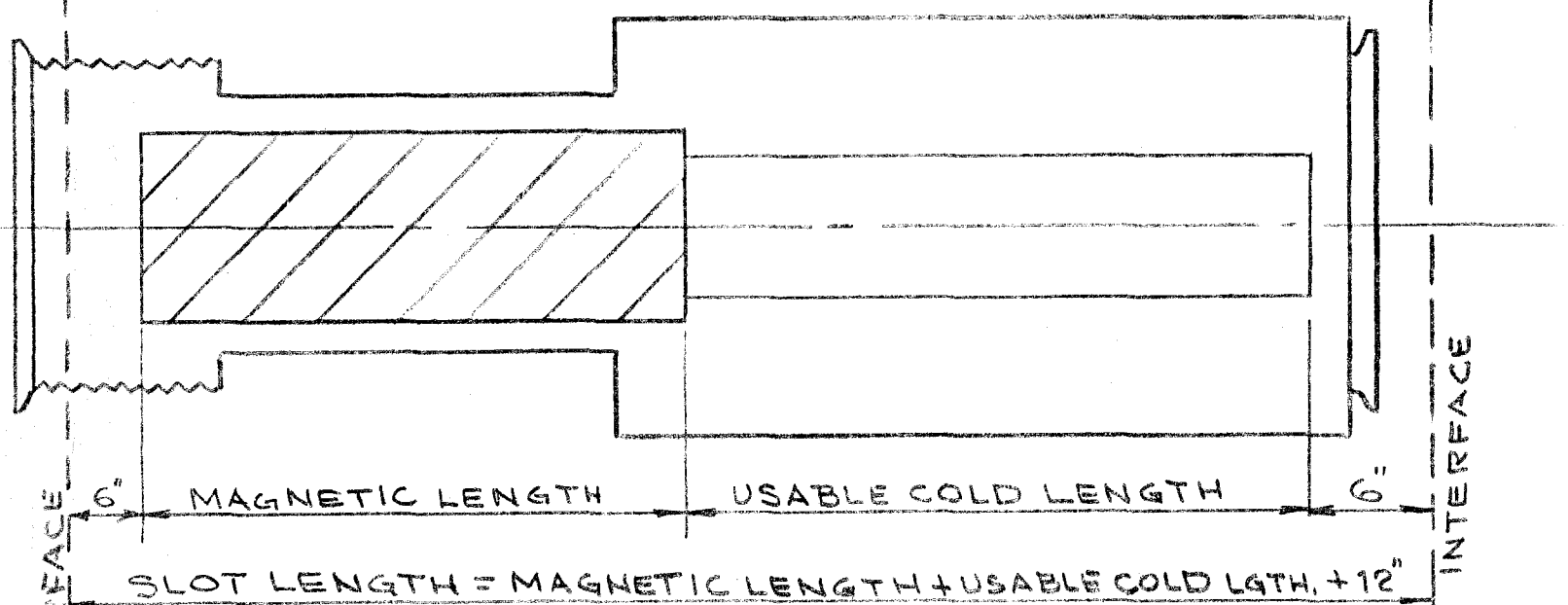
*Split between both ends of short dipole

Table IV. RF High Beta Straight Section Elements

Name	Fig.	S.L. Inches	Useable Warm Length	Useable Cold Length
E 48 F	1	74.93	0	34.15
E 48 drift	2	348.43	323.43	0
E 48 dipole	1	264.00	0	0
E 48 dipole	1	264.00	0	0
E 48 short	1	138.00	0	0
E 49 D	3	266.16	146.81*	0*
E 49 F	1	111.43	0	0
F 0 drift	2	2074.20	2049.20	0
F 11 D	3	274.24	146.81*	0*
F 11 F	3	221.93	102.53	0
F 11 short	1	138.00	0	0
F 11 dipole	1	264.00	0	0
F 11 dipole	1	264.00	0	0
F 11 dipole	1	264.00	0	0
F 12 D	1	74.93	0	34.15
F 12 dipole	1	264.00	0	0
F 12 dipole	1	264.00	0	0
F 12 dipole	1	264.00	0	0
F 12 dipole	1	264.00	0	0
		6098.25		

*Some of the warm length will need to be traded for cold length on a 1 to 1 basis for cold correction elements.

REV.	DESCRIPTION	DRAWN / APPD.	DATE / DATE



BEAM

NOTE:
U.C.L. DIPOLE = 0.00"
U.C.L. NORMAL QUAD = 34.15"

FIG. 1

-10-

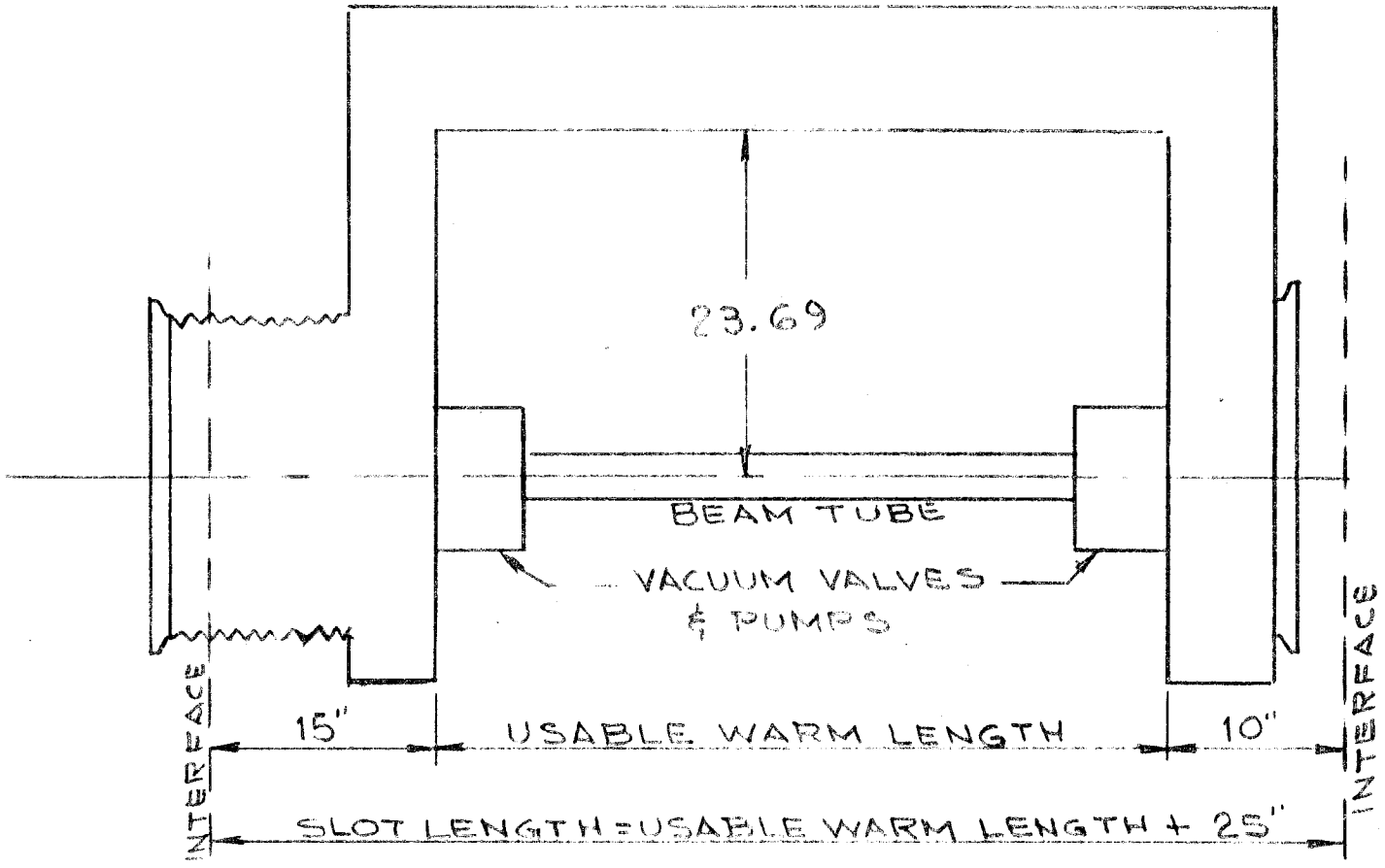
UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	NGA	1-4-79
			CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED	CUK	1-9-79
2. DO NOT SCALE DWG.			USED ON		
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.			MATERIAL-		
√ MAX. ALL MACHINED SURFACES					

FERMI NATIONAL ACCELERATOR LABORATORY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GENERAL DIMENSIONS
MAGNET

SCALE	FILMED	DRAWING NUMBER	REV.
4		1650-MA-103591	

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE



BEAM

FIG. 2

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	NGA	1.4.79
±	±	±	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED	CHR	1.4.79
2. DO NOT SCALE DWG.			USED ON		
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.			MATERIAL-		
√ MAX. ALL MACHINED SURFACES					

FERMI NATIONAL ACCELERATOR LABORATORY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GENERAL DIMENSIONS
MISSING MAGNET TRANSFER LINE
(STATION POINT 0,17,98 EXCEPT B0)

SCALE	FILMED	DRAWING NUMBER	REV.
1/8		1650-MA-103592	

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE

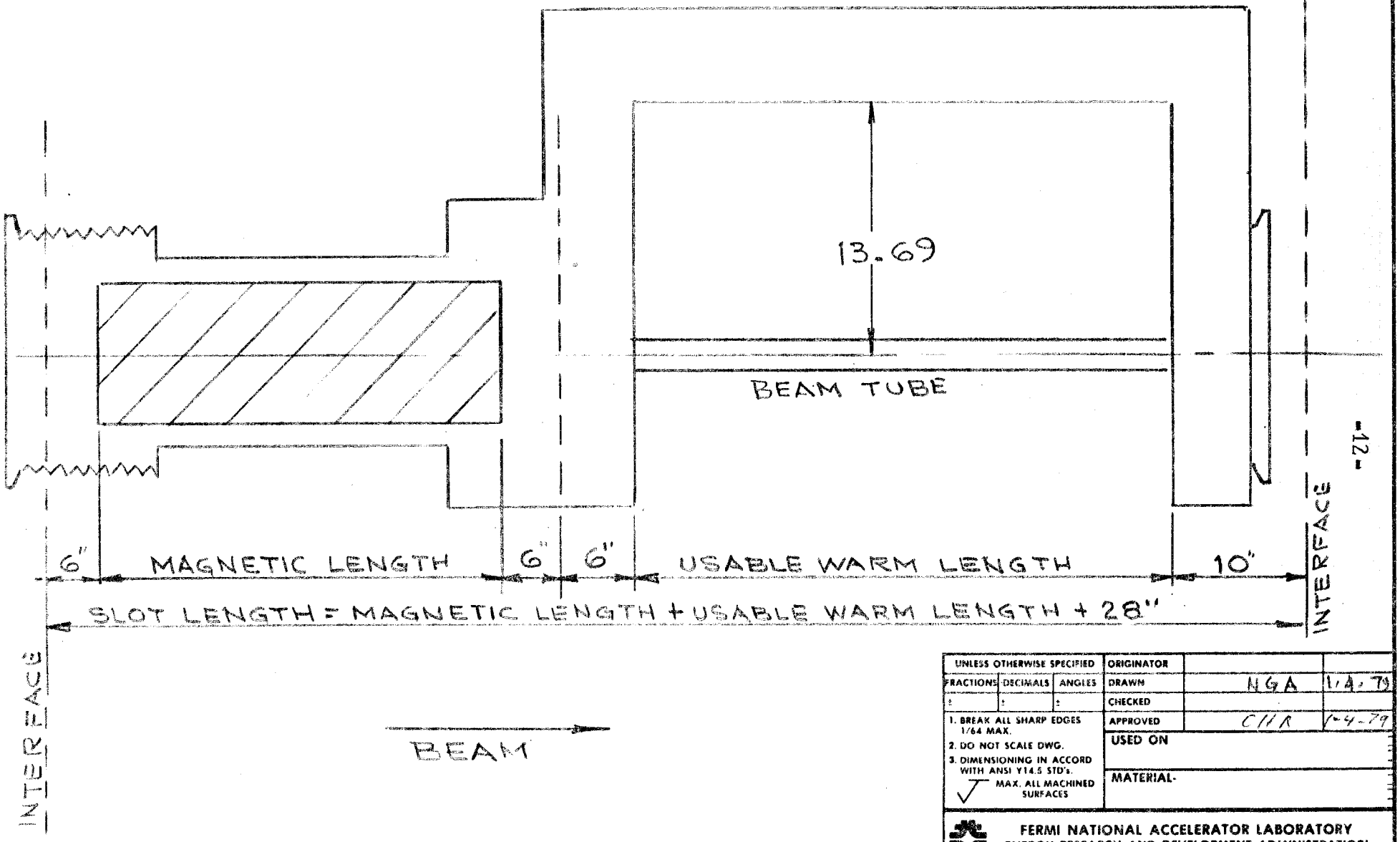


FIG. 3

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	NGA	1-4-79
±	±	±	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED	CHR	1-4-79
2. DO NOT SCALE DWG.			USED ON		
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.			MATERIAL-		
√ MAX. ALL MACHINED SURFACES					

FERMI NATIONAL ACCELERATOR LABORATORY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GENERAL DIMENSIONS
FOR MAGNET WITH
WARM BEAM TUBE

SCALE	FILMED	DRAWING NUMBER	REV.
1/4		1650-MA-103593	A

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE

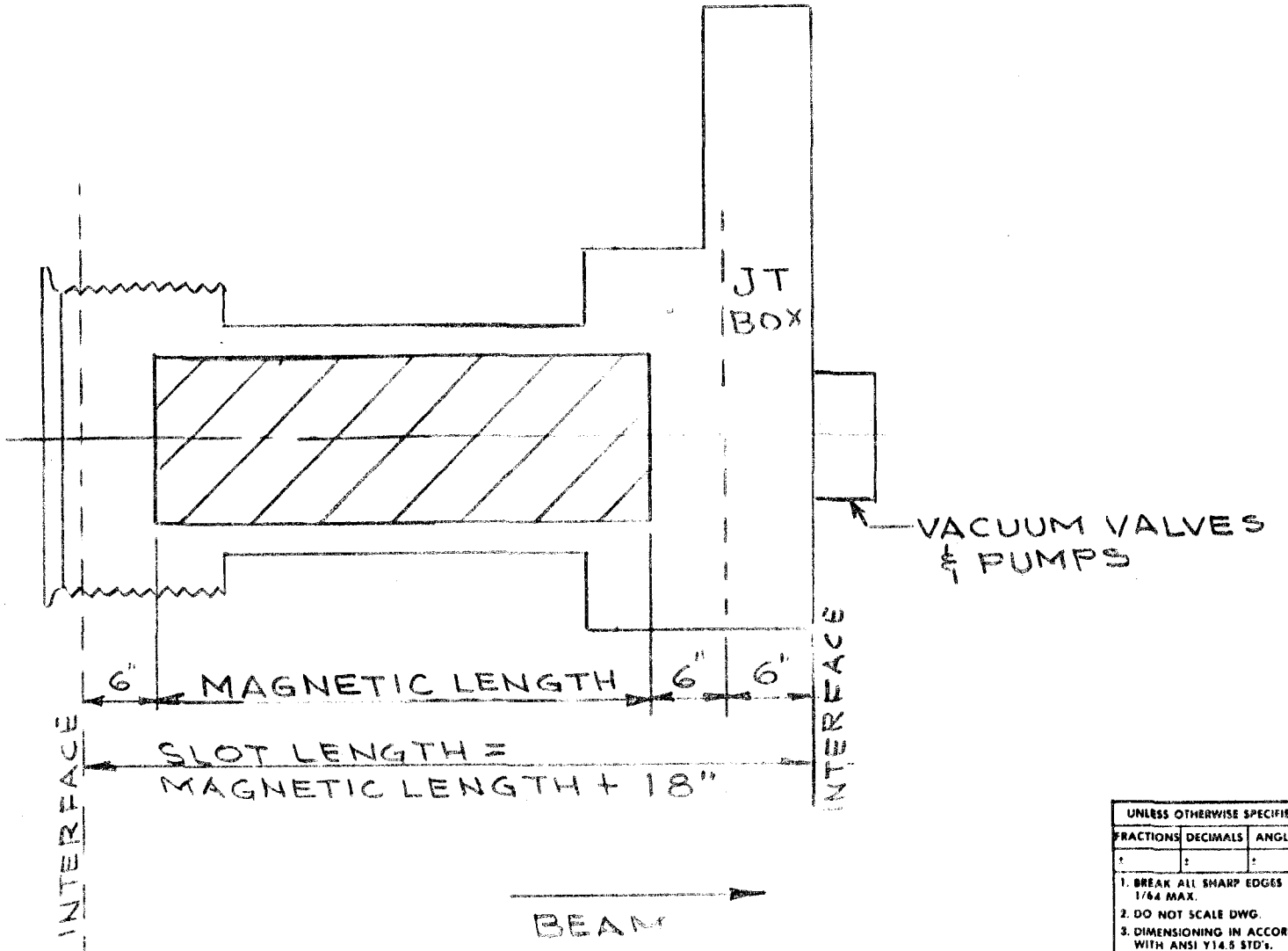


FIG 4

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	NGA	1.5.79
±	±	±	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED	CHR	1-6-79
2. DO NOT SCALE DWG.			USED ON		
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.			MATERIAL-		
√ MAX. ALL MACHINED SURFACES					

FERMI NATIONAL ACCELERATOR LABORATORY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GENERAL DIMENSIONS
A-49 QUAD. JT BOX

SCALE	FILMED	DRAWING NUMBER	REV.
4		1650-MA-103594	A

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE

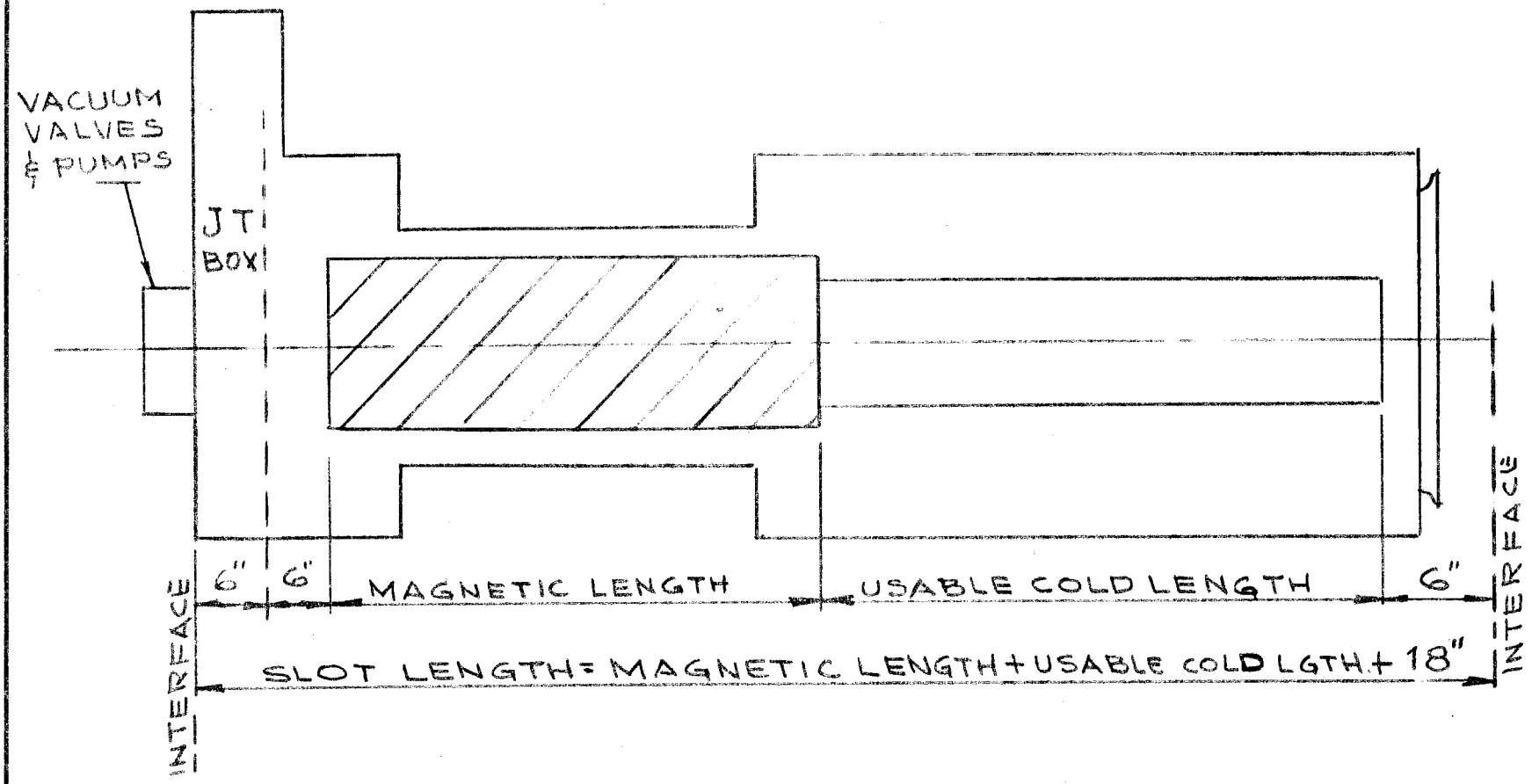


FIG. 5

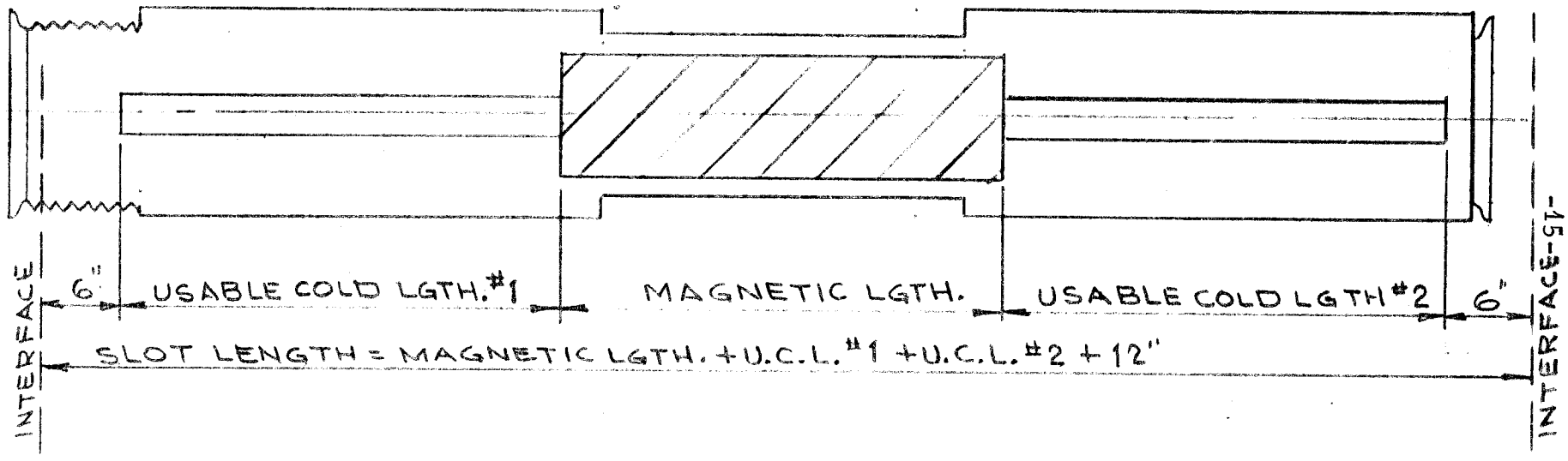
UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	NGA	1-5-79
±	±	±	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED	CHR	1-5-79
2. DO NOT SCALE DWG.			USED ON		
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.			MATERIAL		
√ MAX. ALL MACHINED SURFACES					

FERMI NATIONAL ACCELERATOR LABORATORY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GENERAL DIMENSIONS
B-11 QUAD-JT BOX

SCALE	FILMED	DRAWING NUMBER	REV.
1		1650-MA-103595	A

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE



BEAM

FIG. 6

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	HGA	1-5-79
±	±	±	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED	CMS	1-5-79
2. DO NOT SCALE DWG.			USED ON		
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.			MATERIAL-		
√ MAX. ALL MACHINED SURFACES					

FERMI NATIONAL ACCELERATOR LABORATORY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GENERAL DIMENSIONS
A-49 QUAD
UPSTREAM HALF OF DOUBLET

SCALE	FILMED	DRAWING NUMBER	REV.
1-4		1650-MA-103596	A

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE

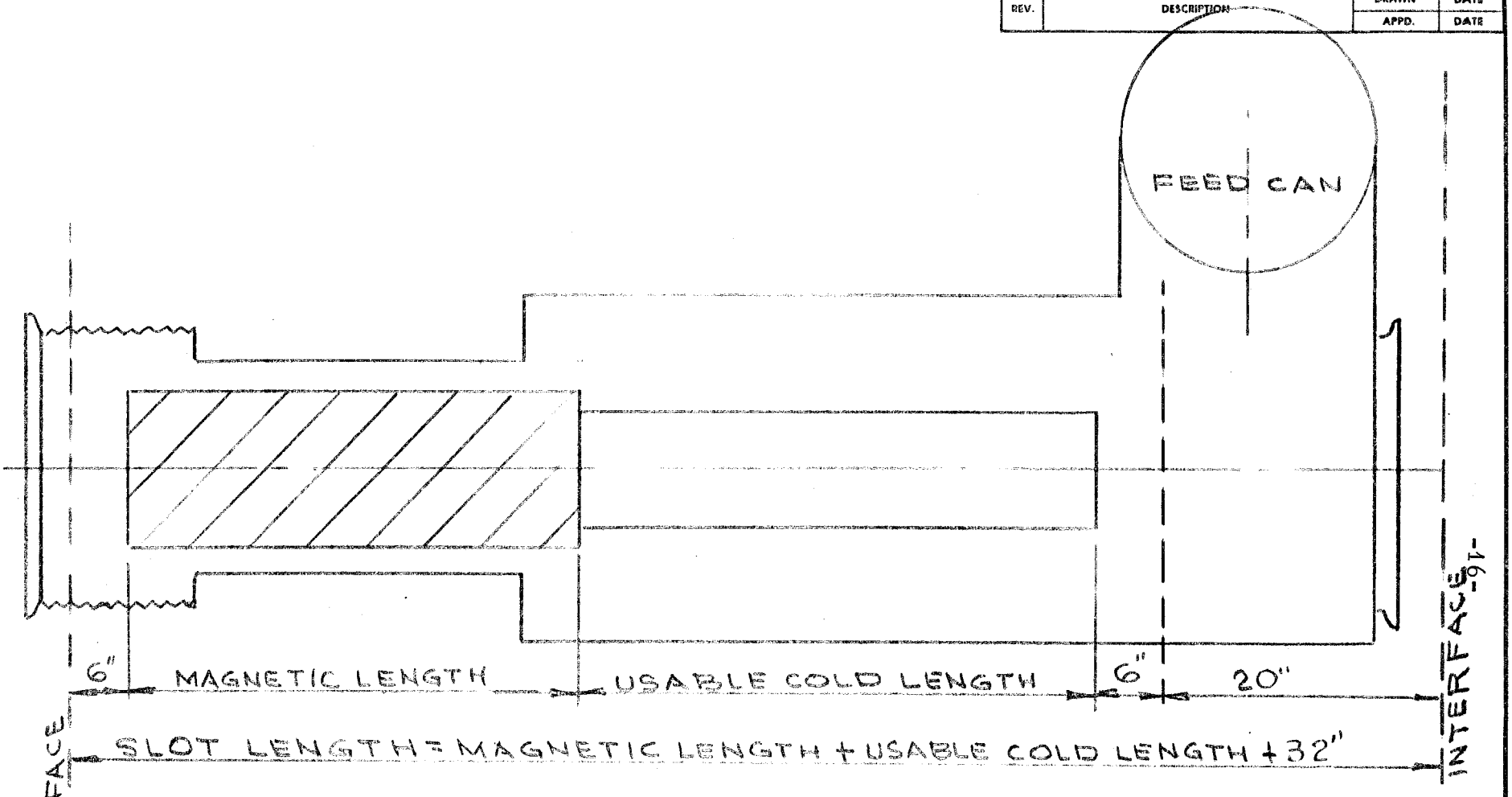


FIG. 7.

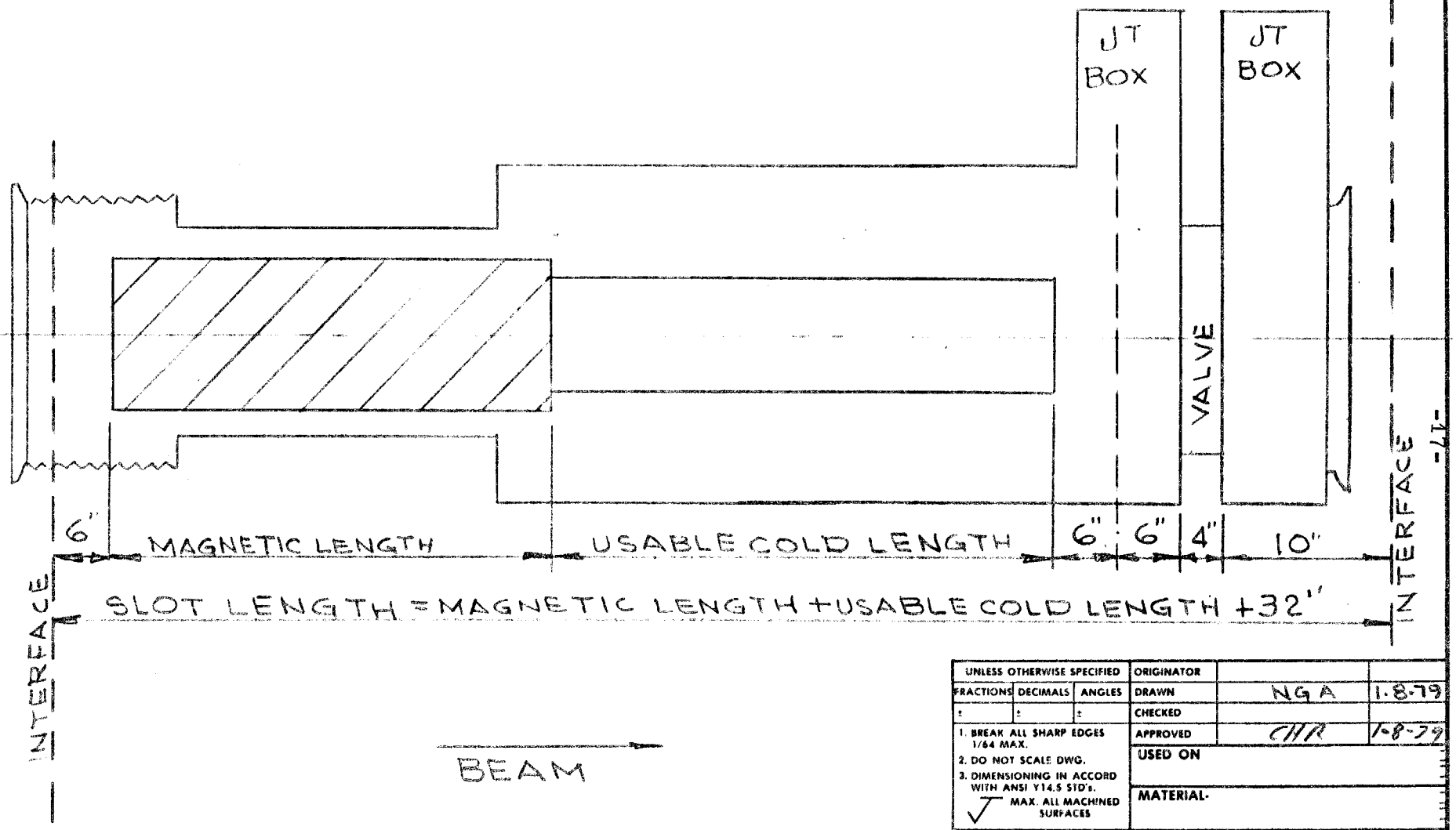
UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	NGA	1-8-79
±	±	±	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED	CNR	1-8-79
2. DO NOT SCALE DWG.			USED ON		
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.			MATERIAL-		
√ MAX. ALL MACHINED SURFACES					

FERMI NATIONAL ACCELERATOR LABORATORY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GENERAL DIMENSIONS
FEED CAN

SCALE	FILMED	DRAWING NUMBER	REV.
1/4		1650-MA-103597	

REV.	DESCRIPTION	DRAWN	DATE
		APPD.	DATE



-17-

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	NGA	1-8-79
±	±	±	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED	CHR	1-8-79
2. DO NOT SCALE DWG.			USED ON		
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.			MATERIAL-		
√ MAX. ALL MACHINED SURFACES					

FERMI NATIONAL ACCELERATOR LABORATORY
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

GENERAL DIMENSIONS
DOUBLE TURN-AROUND

SCALE	FILMED	DRAWING NUMBER	REV.
1/1		1650-MA-103598	

FIG. 8