p̄ Note #402

QUALITY ASSURANCE GUIDELINES FOR THE PRODUCTION OF STOCHASTIC COOLING PICKUPS AND KICKERS

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Introduction

We have been involved in an ongoing collaboration with Argonne Laboratory to perform electron beam studies of the prototype 1-2 GHz and 2-4 GHz LBL stochastic cooling arrays. A summary of those results is contained in Table I.[1] We feel that all the LBL arrays have performed satisfactorily. In addition we have performed similar beam studies at Argonne on the FNAL prototype 1-2 GHz and 2-4 GHz arrays with similar results. Other tests performed on the FNAL prototype arrays included microwave, vacuum, thermal, cryogenic and operation as a kicker.[2]

Technical Support is in the process of fabricating the stochastic cooling arrays for Tev I. As such, we at Tev I must insure that the final products we receive perform at least as well - and hopefully we can make improvements - as the prototypes.

In this note we outline detailed quality assurance guidelines. This is an initial list as more items will be added in the future as they come to mind. The general categories are microwave, electrical, mechanical, cryogenic and vacuum.

I. MICROWAVE

A. Combiner Board S_{11} Measurements

We have modified the beryllium contact blades which attach the SMA connectors to the boards' stripline foils. This gives a slight decrease in microwave reflections from the connectors. The modifications are as follows:

Board	Blade Type	Drawing
1-2 GHz primary	Full Taper	196022-C
1-2 GHz secondary	Full Taper	196022-C
2-4 GHz primary	Half Taper	197489-B
2-4 GHz secondary	Untapered	197686
Quad primary	Untapered	197686
Quad secondary	Untapered	197686

In Figs. I.A.1, I.A.2, and I.A.3 we show drawings of the full, half, and untapered blade types. The last three untapered combiner boards have a modification: the .080" foil to edge of circuit card becomes .110". The secondary combiner output dimension changes from 0.060" to .090". The S_{11} criteria are as follows:

1. 1-2 GHz Primary Boards

Peak $S_{11} \geq$ 13.0 dB. See Fig. I.A.1 for a typical trace.

2. 1-2 GHz Secondary Boards

   a. At output port, vector sum of all S_{21} from the other 4 ports should obey $S_{21} \geq 5.6$ dB at 1.0 GHz decreasing to $S_{21} \geq 5.2$ dB at 2.0 GHz.

   b. Group delays good to ±15 psec.

   c. At output port, peak $S_{11} \geq 15$ dB.

   d. At other ports, average $S_{11} \geq 4.0$ dB.

3. 2-4 GHz Primary Boards

   Peak $S_{11} \geq 10.0$ dB. The main problem is around 4 GHz. See Fig. I.A.3.1 for a typical trace.

4. 2-4 GHz Secondary Boards

   a. At output port, vector sum of all S_{21} from the other 4 ports should obey $S_{21} \geq 5.6$ dB at 2.0 GHz decreasing to $S_{21} \geq 5.2$ dB at 4.0 GHz.

   b. Group delays good to ±10 psec.

   c. At output port, peak $S_{11} \geq 15.0$ dB.

   d. At other ports, average $S_{11} \geq 4.0$ dB.

B. Array S_{11} Measurements

1. 1-2 GHz

   Peak $S_{11} \geq 10.$ dB. See Fig. I.B.1.1 for a typical trace.

2. 2-4 GHz

   Peak $S_{11} \geq 10.0$ dB, except around 3.74-3.92 GHz where coherent reflections from the loop plates give $S_{11} \sim 7.0$ dB. See Fig. I.B.2.1 for a typical trace.

C. Excitation of Each Loop Plate

We have received 1-2 GHz and 2-4 GHz loop plate exciters from LBL. They consist of eight 50Ω stripline probes on teflon boards. The testers were designed to test 8 loop plates with a single positioning of the boards. Each stripline has its own SMA connector, thereby allowing for the excitation of a single loop at a time. A sketch of the LBL testers is shown in Fig. I.C.1. The criteria are as follows:

1. 1-2 GHz

   $S_{21} \sim 15$ dB at mid-band decreasing to ~ 30-40 dB at the band edges. A typical trace is shown in Fig. I.C.1.1.

2. 2-4 GHz

$S_{21} \geq 40$ dB across frequency band.

D. Microwave Attenuation

A vacuum compatible method will probably be needed to attenuate unwanted TE modes in the beampipe. This should improve the performance of the stochastic cooling electrodes. Two methods have been suggested.

1. Resistive Strips

Using the vacuum deposition equipment at Argonne Laboratory we can deposit a thin layer of nicrome or titanium on pyrex glass such that we achieve a resistance of 150-200 ohms/square.[3] The strips would then be loaded in the beampipe as shown in Fig. I.D.1.1. It is convenient that the optimal resistance is the same for both 1-2 GHz and 2-4 GHz beam-pipes.

2. Ferrite Strips

This method is under study at LBL. Preliminary results look encouraging.

E. Coaxial Cables

1. $S_{11} \geq 20$ dB

2. Electrical lengths should be good to 3.4 psec.

F. Ceramaseal SMA Connectors

1. VSWR < 1.06 + $.07f_{GHz}$

2. Should hold microwave quality after 5 cryogenic cycles.

3. Electrical lengths good to ±5 psec.

4. No vacuum leaks after 30 cryogenic cycles.

G. Pre-installation Microwave Check

Once arrays and preamps boxes are installed onto vacuum tanks, check S_{11} of assemblies.

H. In Tunnel Measurements

We must be able to make diagnostic microwave measurements after all vacuum tank/array assemblies are installed in the accumulator and debuncher tunnels.

1. Check d.c. resistances.

2. Measure S_{11} of electrode plates using the network analyzer.

3. Use proton beam to measure total group delay through system.

II. ELECTRICAL

A. Terminating Resistors

99 Ω-102 Ω

B. Solder Joint Resistance

Once installed in array insure that 99 Ω-102 Ω is maintained from heat sink to resistor pin.

C. Beryllium Contact Blade

1. Insure less than 0.3Ω resistance between beryllium and stripline foil of combiner board.

2. Insure that blade is properly centered in top closure bar groove. A short would be disastrous.

D. Mechanical Joint Contact

Resistances should be less than 0.3Ω.

E. Ceramaseal Connectors

Insure less than 0.3Ω resistance through Ceramaseal connectors.

F. Coaxial Cables

Insure less than 0.3Ω resistance through cables.

G. SMA Connectors

Insure less than 0.3Ω resistance through connectors.

H. Array Loop Resistance

1. Eight-way combiners

Insure 12.5Ω - 12.9Ω at SMA connectors.

2. Four-way combiners

Insure 25Ω - 25.7Ω at SMA connectors.

3. Four-way secondary combiners

   Insure 3.1Ω - 3.3Ω

I. Thermocouples

Insure proper operation.

J. Array Alignment on Rails

After mechanically and electrically aligning arrays, no two corners should differ by more than .050". We hope to improve on this number.

III. MECHANICAL

A. Beam Tube Aperture

1. Guarantee 28 mm beam aperture along a 15 meter straight section. Vertical dimensions of riveted beam tubes should be within .010" of design values.

B. Positioning of Electrode Plates

Should be properly positioned on resistor and combiner board so that

1. They are parallel to beam tube.

2. They do not protrude into beam aperture by more than .005".

C. Riveting

1. Insure all designated holes are properly riveted.

2. No loose rivets.

3. Rivet according to designated procedure so as to avoid beam tube distortions.

D. Loop Plate Assemblies

Plates should be properly soldered onto posts, making a good right angle to avoid slanted plates in the arrays.

E. Beryllium Contact Blades

Care must be taken that all blades have the correct dimensions according to the latest design modifications. (See above, under microwave guideline I.A.)

F. Sag in Beam Tubes

Insure no sagging greater than .010". John Marriner calculated the worst case for loose rivets to be .016" and the best case for tight rivets to be .001".

G. Side Plane Positioning

Should be perpendicular to beam tubes and not warped.

H. SMA Connectors

1. Should not be damaged and must be properly positioned according to design specifications.

2. Weld SMA connectors in place only after secondary combiner borads are properly positioned.

I. Cryogenic Shields

Insure proper installation.

J. Cooling Tubes

1. Should not be damaged since they must withstand 600 psig to survive sock waves during cooldown.

2. Must have good solder contact between tubes and cooling clip.

K. Supports for Microwave Attenuators

1. Should be positioned for maximum attenuation.

2. Should not block outgassing holes in beam tubes.

3. Should stay out of beam path.

L. Survey/Alignment

1. Must have plan to align arrays on vacuum tank rails and to transfer array coordinates to outside of vacuum tank. (See alignment document.)

2. Total tolerance including array construction tolerance = ±.040".

M. Straightness of Rails

1. Must be good to ±.005".

2. Check that the ends of the rails relative to the feet of the vacuum tanks are within ±.005".

N. Wheels, Support System

1. Must not be damaged.

2. Must be round and dimensions good to ±.010".

O. Array Wheel Anchor Points

1. Must firmly fix arrays in place.

2. Must be easily removable for possible repairs on arrays.

P. Forces which Change Alignment

Insure that torques and forces of bellows assemblies and microwave, cryogenic, and thermocouple lines do not change array alignment.

Q. Lab 5 Production Traveler

Constantly review traveler to detect any sudden or gradual decline in production quality.

R. Ceramaseal Connectors

Center conductor should not protrude beyond SMA reference plane.

IV. CRYOGENIC

A. Hysteretic Motion

Guard against any such motion which would affect performance of arrays.

B. Breakage, Distortions

Must insure against such damage to

1. Resistors
2. Solder joints
3. Cooling tubes
4. Loop plates
5. Coaxial cables
6. Ceramaseal connectors
7. SMA connectors

8. Combiner boards

9. Side planes

10. Heat sinks

11. Microwave attenuators

etc.

C. Cooling Tubes

1. Tubes and their connections must withstand 600 psig to survive shock waves during cooldown.

2. Absolutely must have no leaks to vacuum.

3. Absolutely must have no flow restrictions so that arrays can maintain proper temperature. In kicker mode, water coolant blockage could damage resistors.

D. Ceramaseal Connectors

Should maintiain good microwave quality. (See above, under microwave guideline I.F.)

E. Arrays

Each completed array half should be cycled 3 times in Lab 5. Monitor d.c. resistance and check for any irregularities.

F. Pre-installation Cool Cycle

Once arrays, pumps and gauges are installed onto vacuum tanks, the completed assemblies should be cooled to LN temperature. Monitor d.c. resistance, S_{11} and temperature. Let up to room temperature and check for hysteretic motion.

V. VACUUM

A. Cleanliness

1. Abolute cleanliness during production must be insured.

2. Every piece of equipment should be properly cleaned.

B. Leaks

1. Each empty vacuum tank on which preamps and gauges are mounted should be leak checked.

2. Ceramaseal connectors should be leak checked.

3. Preamp boxes should be leak checked.

C. Materials

All materials should be compatible with needed pressures in the various systems. This places an important restriction on the choice of microwave attenuators.

D. Pre-installation Pumpdown

Once arrays, pumps, and gauges are installed onto vacuum tanks, the completed assembly should be pumped down to required pressure.

REFERENCES

1. For a complete report of those measurements, see p̄ Note #379.

2. See p̄ Note #371.

3. See p̄ Notes #328 and #358.

Table I

Summary of Argonne Electron Beam Studies of LBL 16 Loop Pair Arrays

Sum Mode

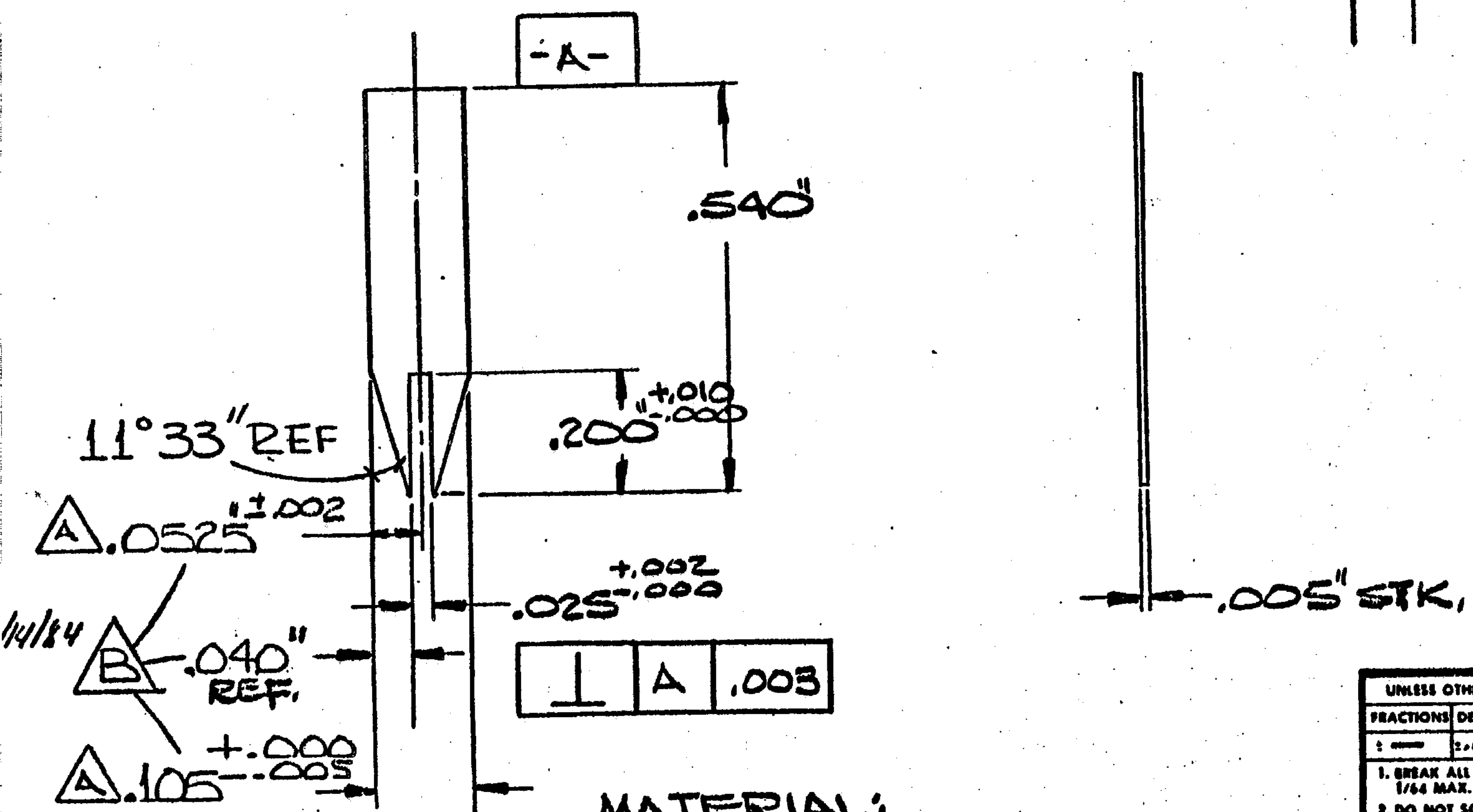
Frequency	s(0,0)theory	Z (0,0) theory	Z (0,0) data
1-2 GHz	0.853	162Ω	170Ω
2-4 GHz	0.593	110Ω	121Ω

Difference Mode

Frequency	d(0,0) theory	Z′ theory	Z′ data
1-2 GHz	1.927	96.1Ω/cm	93.4Ω/cm
2-4 GHz	1.586	89.5Ω/cm	77Ω/cm

FULLY Tapered Contact Blade

REV.	DESCRIPTION	DRAWN / APPD.	DATE
A	ADDED TOL. TO .121 DIM. - ADDED .0605 ±.002 DIM.	JKLJ / ARO	12-14-83 / 12/14/83
B	.105 DIM WAS .121 ADDED NOTCH .0525 WAS .0605	ARO	6/14/84
C	TITLE WAS 1-2 PICK-UP	ARO	8/31/84



MATERIAL:
BERYLLIUM COPPER
CDA ALLOY #175
1/4 TO 1/2 HARD

C

FIG. I.A.1

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	JABLONSKI	10/12/83
± —	±.005	± —	CHECKED	ARO/ck	10/14/83
1. BREAK ALL SHARP EDGES 1/64 MAX. 2. DO NOT SCALE DWG. 3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's. ✓ MAX. ALL MACHINED SURFACES			APPROVED		
			USED ON MB-196023		
			MATERIAL NOTED		

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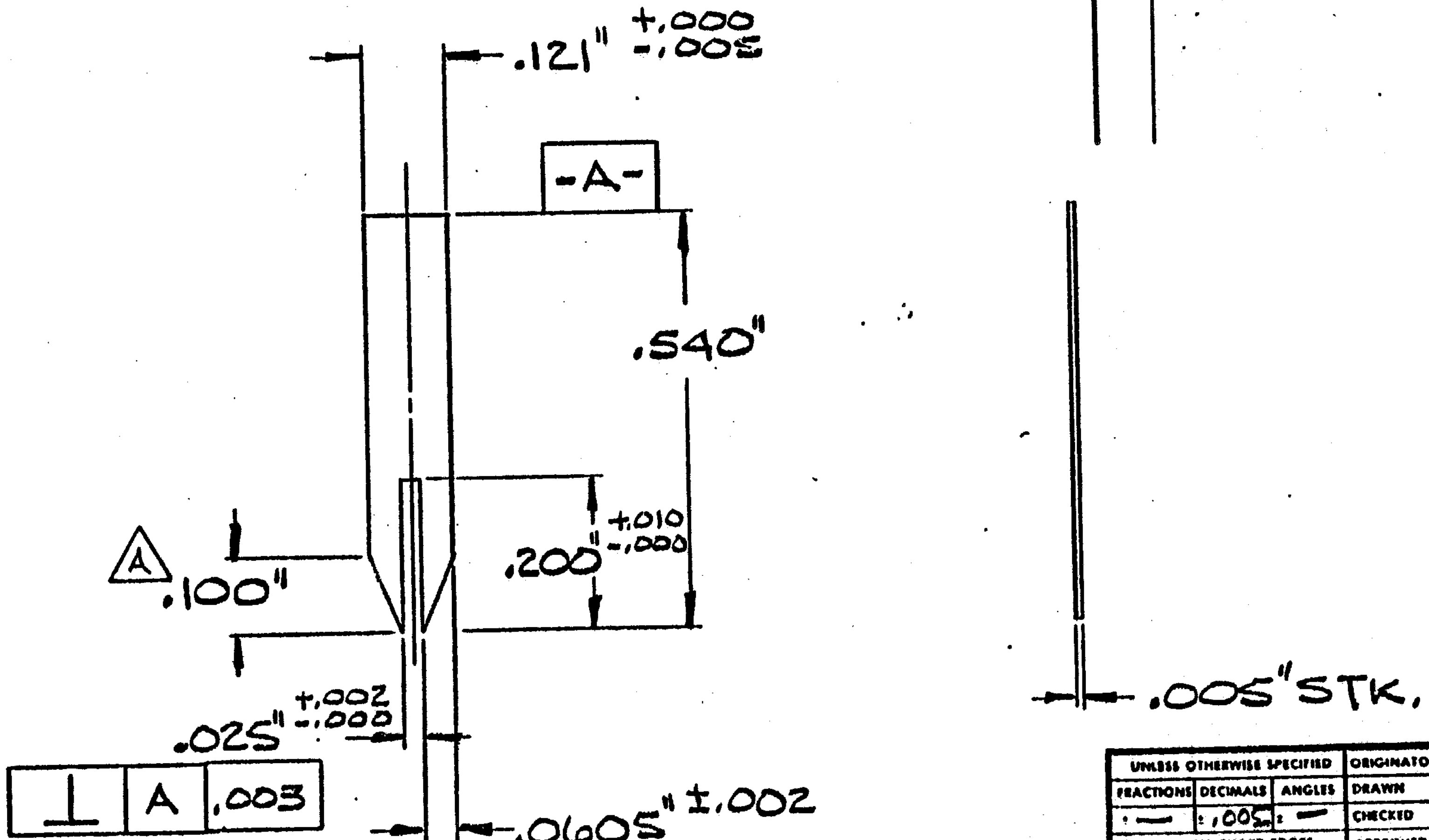
TEV. I STOCHASTIC COOLING 1-2GHz PRIMARY & 2nd COMB. CONTACT

SCALE	FILMED	DRAWING NUMBER	REV.
4X		8020-MA-196022	C

FIG. I. A. 2
Half Tapered Contact Blade

REV.	DESCRIPTION	DRAWN / APPD.	DATE
A	ADDED TAPER	JWJ	8-16-84
		APO	8/16/84
B	ADDED PRIMARY BOARD TO TITLE	APO	9/4/84



MATERIAL:

BERYLLUM COPPER
CDA ALLOY #175
1/4 TO 1/2 HARD

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	OLECK	
FRACTIONS	DECIMALS	ANGLES	DRAWN	JABLONSKI	7-13-84
± —	±.005	± —	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX. 2. DO NOT SCALE DWG. 3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's. 125 MAX. ALL MACHINED SURFACES			APPROVED		
			USED ON		
			MATERIAL: NOTED		

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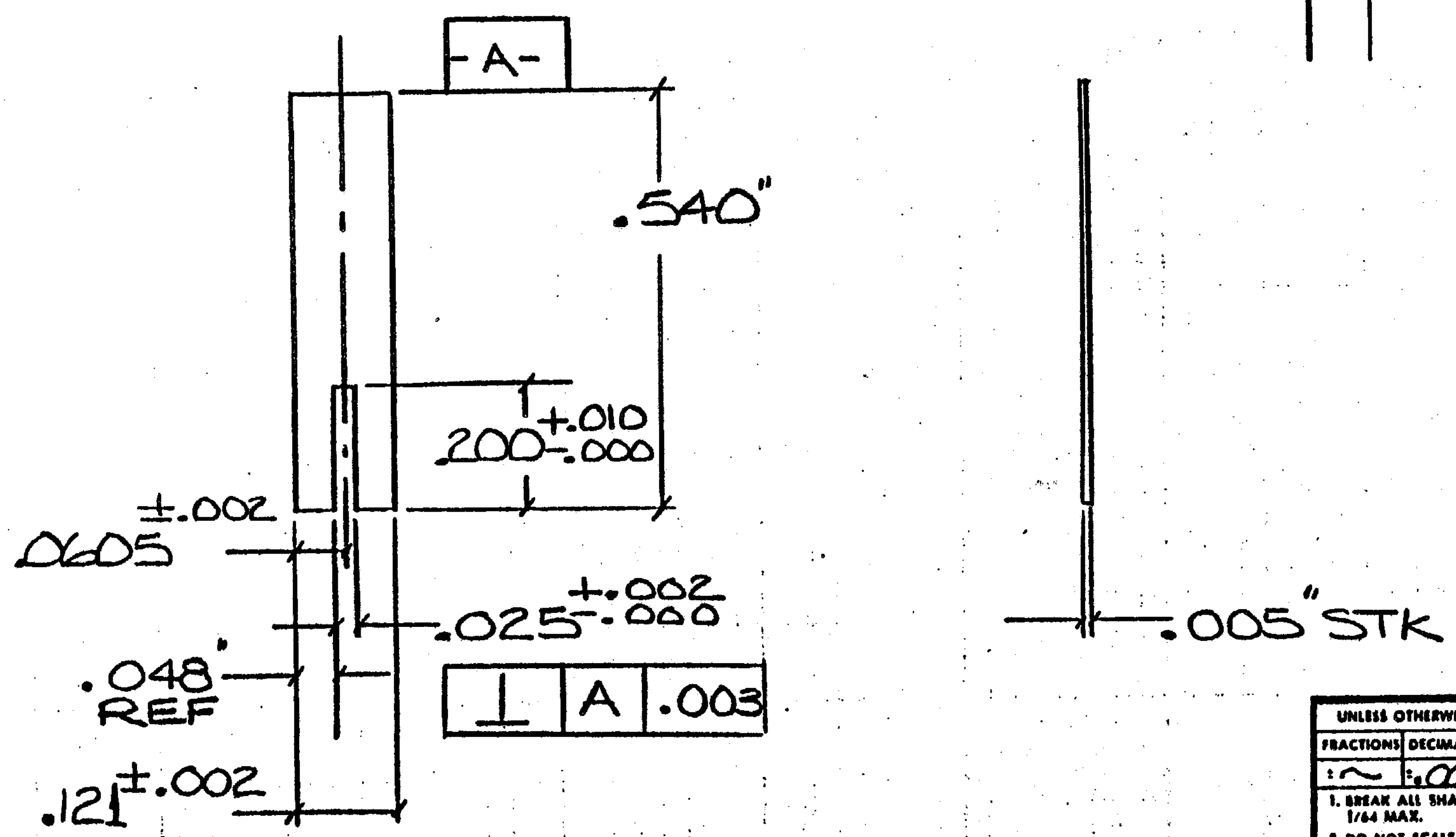
PRIMARY BOARD - (B) TEV. I STOCHASTIC COOLING 2-4 GHz PICK-UP/KICKER CONTACT

SCALE | FILMED | DRAWING NUMBER | REV.

FIG. I. A. 3
Untapered Contact Blade

REV.	DESCRIPTION	DRAWN	DAT
		APPD.	DAT



MATERIAL

BERYLLIUM COPPER
CDA ALLOY #175
1/4 TO 1/2 HARD

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	AR Olack	9/3
± ~	± .005	± ~	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX. 2. DO NOT SCALE DWG. 3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's. √ MAX. ALL MACHINED SURFACES			APPROVED		
			USED ON		
			MATERIAL- NOTED		

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TEV I STOCHASTIC COOLING
2-4GHz 2nd COMB/QUAD-
PRIMARY/QUAD 2nd. CONTACT

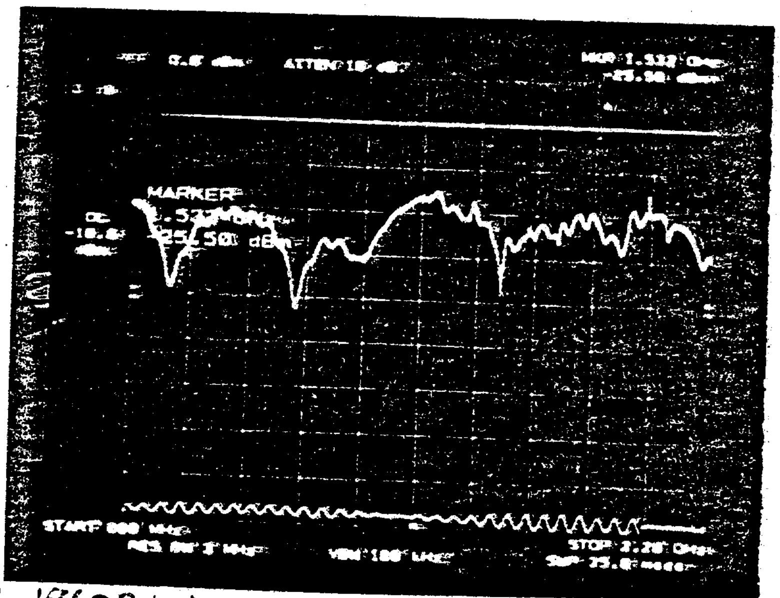
SCALE	FILMED	DRAWING NUMBER
4X		8020-MA-197686

S_{11} of 1-2 GHz Primary Combiner Board

Peak 15.5 dB at 1.532 GHz

10 dB/div

← 0 dB



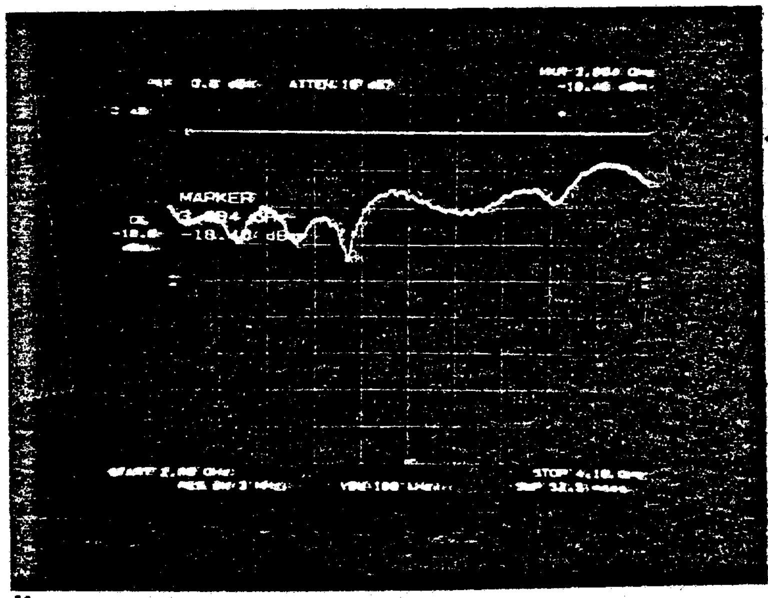
Board # 196034-40

800 MHz

2.2 GHz

FIG. I. A. 1. 1

S_{11} of 2-4 GHz Primary Combiner Board



10 dB/div

← 0 dB

Board #196/99-1

2GHz

4.1 GHz

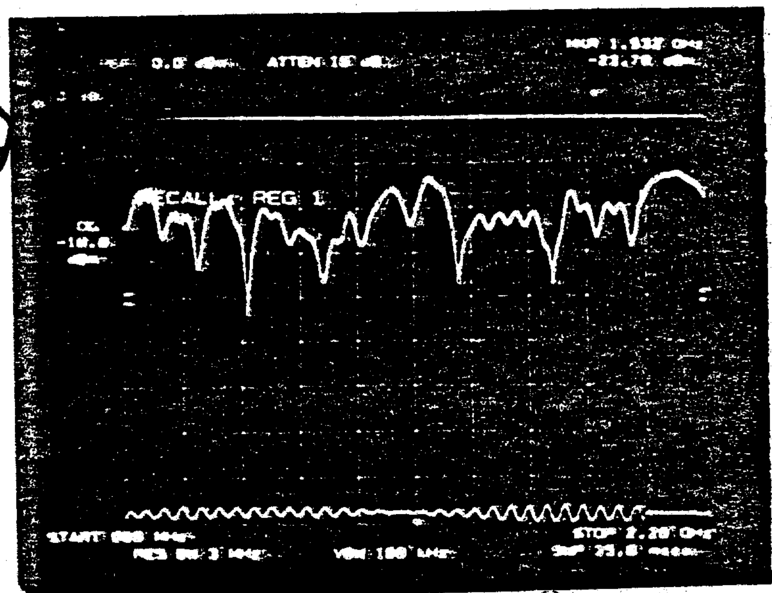
FIG. I.A.3.1

D/S Lower Beamtube

Downstream Peak 13.7 dB at 1.532 GHz

(Resistors are downstream side of plates)

10 dB/div



← 0dB

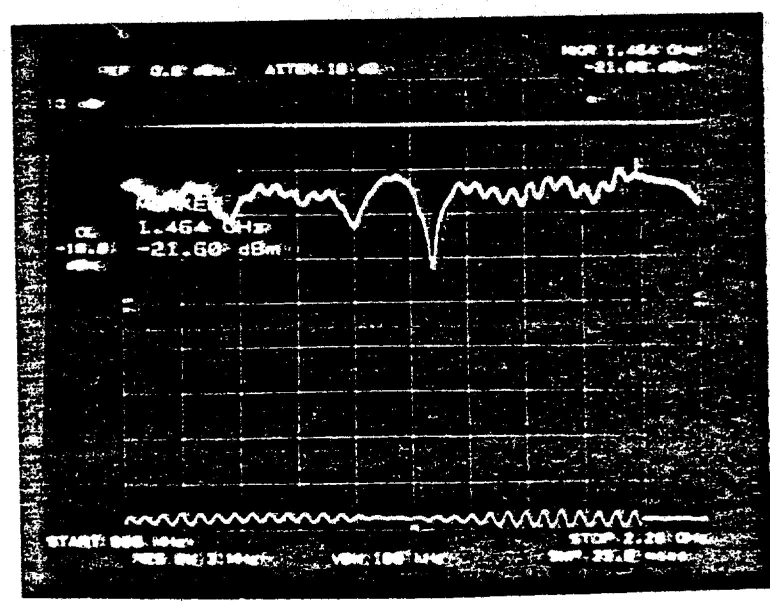
Array # 196225-7 D/S Lower

800 MHz 2.2 GHz

U/S Lower Beamtube

Upstream Peak 11.6 dB at 1.464 GHz

10 dB/div



← 0dB

Array # 196225-7

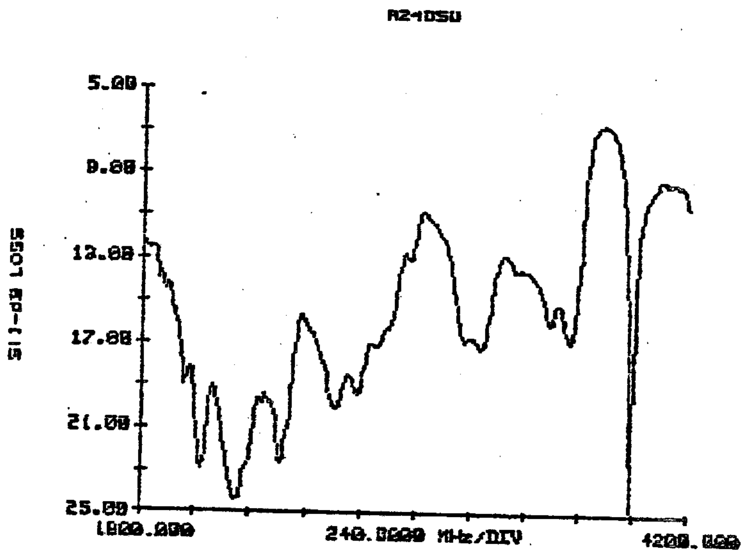
800 MHz 2.2 GHz

S_{11} of 1-2 GHz Array

S11 of 2-4GHz Array

3690.0000	16.64	-51.6
3696.0000	16.08	-47.9
3702.0000	15.65	-45.9
3708.0000	15.13	-42.4
3714.0000	14.40	-39.1
3720.0000	13.57	-36.6
3726.0000	12.61	-34.7
3732.0000	11.49	-34.1
3738.0000	10.42	-35.5
3744.0000	9.47	-39.1
3750.0000	8.69	-44.3
3756.0000	8.19	-49.6
3762.0000	7.74	-53.4
3768.0000	7.39	-57.5
3774.0000	7.13	-61.1
3780.0000	6.95	-65.0
3786.0000	6.89	-68.4
3792.0000	6.80	-71.9
3798.0000	6.73	-75.7
3804.0000	6.69	-79.9
3810.0000	6.64	-84.2
3816.0000	6.62	-88.3
3822.0000	6.67	-91.8
3828.0000	6.69	-94.9
3834.0000	6.72	-97.6
3840.0000	6.73	-100.2
3846.0000	6.75	-103.2
3852.0000	6.81	-106.7
3858.0000	6.88	-110.5
3864.0000	7.00	-114.6
3870.0000	7.16	-118.8
3876.0000	7.35	-123.1
3882.0000	7.62	-127.1
3888.0000	7.91	-131.2
3894.0000	8.28	-135.5
3900.0000	8.72	-140.3
3906.0000	9.23	-145.8
3912.0000	9.88	-152.7
3918.0000	10.68	-161.0
3924.0000	11.74	-171.2
3930.0000	13.36	176.4
3936.0000	15.86	159.0
3942.0000	20.28	126.9
3948.0000	24.70	53.6
3954.0000	20.89	-11.4
3960.0000	18.30	-35.9
3966.0000	16.10	-43.6
3972.0000	14.29	-50.4
3978.0000	12.94	-56.2
3984.0000	11.96	-61.8
3990.0000	11.29	-67.1
3996.0000	10.89	-72.5
4002.0000	10.62	-77.5
4008.0000	10.45	-81.8
4014.0000	10.30	-85.0
4020.0000	10.20	-87.4
4026.0000	10.10	-88.9
4032.0000	9.98	-90.2
4038.0000	9.86	-91.3
4044.0000	9.76	-92.3

Possibly due to coherent reflections from loop plates.



1.8GHz 4.2GH

FNAL Prototype Array

FIG. I.B.2.1

1-2 GHz LBL Loop Exciter

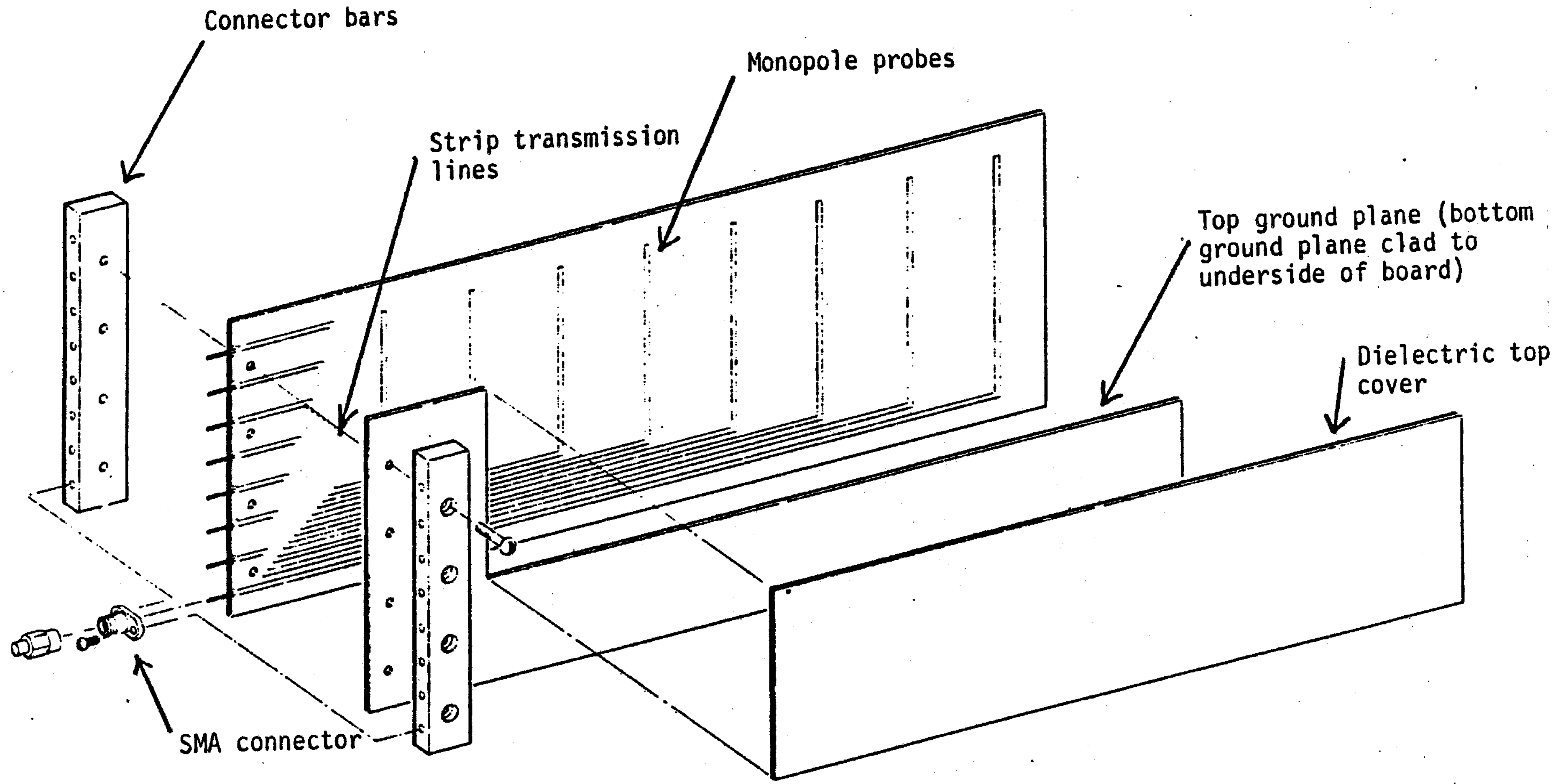
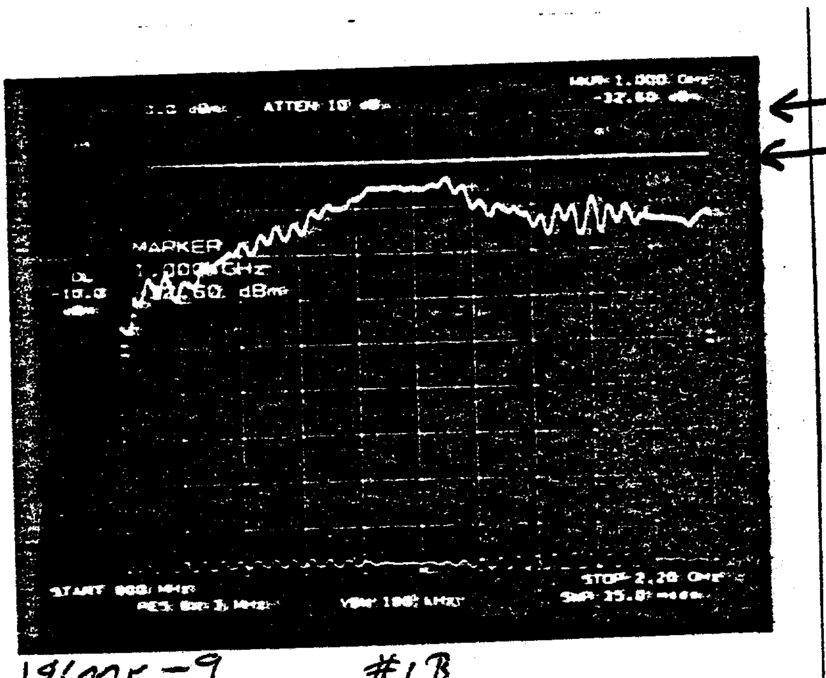


FIG. I.C.1

Exploded View of Monopole Array Board

S_{21} of 1-2 GHz Array



Array # 196225-9 #1B

Bottom beamtube
Loop #1 from downstream end.

FIG. I. C. 1.1

In $\bar{p}$ Note # 328 we set up the mathematical machinery for calculating attenuation lengths of TE modes in rectangular beam chambers. It is hoped that by attenuating such modes, we can improve the performance of the stochastic cooling electrodes.

The proposed method consists of loading the beampipe containing the electrodes with resistive strips of thickness t as shown below.