FERMILAB-LU-212

LINAC CAVITY UPGRADE TUNING STEPS

LU - 212

H.W. MILLER

Rev. 4/29/91

LINAC CAVITY UPGRADE

PRE-BRAZE TUNING STEPS

H.W. MILLER

Rev. 4/10/91

Pre-braze Tuning Steps

A.Introduction

This note describes the tuning steps listed on the pre-braze tuning check list and pre-braze tuning chart. (Check List 1 &2). The check list is to be filled out for each module/section and a record kept in the corresponding log book. Beside each task check indicating that data is entered in the log book and to disk file where appropriate. Date and sign each step after completion. Bill Miller, Rene Padilla or Tom Jurgens must verify data where indicated and initial the authorized to proceed column.

B.Description of Steps

1.Test 1st Part. Measure the 1st sample segment from the machine shop before authorizing full production. Verify that the cell length CL and Section number from Table 1 agree. The SF frequency is measured against a flat copper plate. Correct the frequency for vacuum at 25 degC using spreadsheet 1, Frequency Correction Cu. (note that there is a similar spreadsheet for aluminum. don't use it). Compare the measured frequency to the SF goal tabulated in Table 1 for the particular module/section. If the frequency agrees within ±0.250 MHz. authorize production. If out of range, ask Bill Miller or Tom Jurgens for a decision and have them initial the log book.

Caution The segment may be narrower in the region where there is no watertube groove (Where the slot is to be cut later). This is because of the method of clamping with the water tube groove when machining the parts. We have noted errors of 0.0002 inches in some parts which causes a low Q when measured.If the Q is low, use **aluminum oxide paper only**, and lap lightly (< 10 passes at a time with 600 grit paper on a granite flat plate) to remove irregularities. Do not lap more than 0.0005 inchs from each side. Q increases with the length of the the segment (CL). From Module 3 where we are now Q's > 14500 will give an adequate frequency measurement.

2.Lap SF Parts.

Lap all segments. Pay attention to the caution in step 1. Check the rim frequently so that you take the minimum amount of material off of each edge. When the low spot just cleans up stop and proceed to the step 3.

3.Measure SF Frequency.

Measure all of the segments and enter corrected data (Vac@ 25 degC) on a copy of the Main Cavity Cells (Spread Sheet 2). Necessary statistical data is automatically calculated.

4.Accept SF Machining

An average frequency of ±0.250 MHz. with a spread of 0.350 MHz. can usually be paired adequately for final stacking. If a few cells are way out of range (>0.500 MHz.) they may need re-machining. Ask Bill Miller or Tom Jurgens for a judgement in such cases.

5.Determine Stacking Order.

Rene Padilla has a program for finding all possible stacking combinations. The idea is to pick the best order as determined by a pairing of half cells. Try to keep the spread of paired cells ±0.025 MHz. Put any half cells with large deviations at the ends where their errors can be adjusted with the end terminations. The two spares will be used later if a segment is damaged. Fill out and enter the data on Final Stacking and Tuning (Spreadsheet 3),columns A and C.

6.Slot 1st Five Segments.

a)The slot depth for the 1st five segments in the stacking order.is cut in two or three steps. A first cut slot depth is determined and made in each of the 1st five segments. The slotted segments, with side cells clamped in place, are stacked in order adding one at a time from one thru five and the progression of five $\pi/2$ frequencies is measured. Enter the corrected (Vac@25C) data into Spreadsheet 3 , column F. Adjusted frequencies will appear in column G which correct for half cell errors about an average value. Data are plotted and a projected $\pi/2$ frequency determined, Step 7(up to three iterations may be necessary).

The SF Goal Frequency is calculated so that for a ctr=7.264 inches in sections 1 thru 3 and ctr= 7.188 inches in sections 4 thru 7 the projected $\pi/2$ frequency will be 804.900 MHz. ("ctr" is the spacing between the center of an accelerating module and the center of the cutter sweeping a radius of 3.4091 inches that makes the slot cut. See sketch on Slotting, Data Sheet 1.)

Caution: After each slotting, carefully inspect the slot and pin holes for burrs and remove as necessary. During machining, the segment length can increase a few tenths of a mil in the region near the slot. It can be brought back into flatness with the rest of the rim by slight lapping.

b)**Determine the first cut depth**. Determine the SF paired average frequency of the stack (Row 56 Column D) with the SF Goal. If the frequency is low, the usual case, then increase the center spacing.(ctr). The estimated coefficient ($\Delta f/\Delta ctr$) for the adjustment comes from Table 1. Raise the frequency an additional 0.250 MHz. using the same coefficient and add the additional Δctr to the ctr spacing. Enter this dimension on Data Sheet 1 and in the logbook. Send a copy to Dan Snee and with the parts to the machine shop.after having Bill Miller or Tom Jurgens initial and date the entry. Test the returned five slotted segments per Step 7.

c) **Determine the 2nd cut depth.** If the π/2 projection with the 1st cut is 805.150±0.050 MHz then the 2nd cut can be the final cut so proceed to step d). Experience to date has been that the SF values are only reliable to about 0.250 MHz. but that the Δf/Δ ctr values have been accurate to a few percent. If the π/2 frequency is outside the desired range than estimate and machine a second slot ctr to get 805.000 MHz. Determine a corrected Δf/Δ ctr. Measure the segments per Step 7.

d) **Final Cut Depth.** Using either the published Δf/Δctr or the corrected one in step c), determine the final slot depth for π/2 =804.900 MHz. and machine the parts.

7.Project π/2 Frequency

Plot the adjusted frequencies determined in the step 6, π/2 vs 1/n (number of half cells) and project the intercept for 1/n= 0 (an infinite stack). This will be the π/2 frequency of the stack when it is properly tuned. Use Cricket graph,scatter plot and 2nd order curve projection. A logbook sample document is shown in Data Sheet 2. The goal is for corrected π/2=805.900 ±0.020 MHz. The first slot projection will be about 0.250 MHz. high. With the π/2 frequency correct for the first five segments, machine the final slots in the remaining middle cells and bridge ends. Have the bridge ends done first so that tuning cut outs on the ends can be done at the same time the ends are being machined. Note that the slots in bridge ends are not the same width as side cells nor centered. To avoid confusion at the machine shop, give a dimensioned Fig. 1 to the shop with the final slot depth entered.

8. Machine end terminations.

As machined, the terminating and bridge (bridge ends are measured with a bridge coupling cell with gap shorted clamped in place) end cell frequencies will be too high. The amount is determined by placing them on the original five cell stack and tuning them lower with a probe in their gap for minimum energy in their adjacent side cell. The cell frequency shift Δf with and without the probe determines the correction. A frequency decrease of 2xΔf is made in the end half cell by removing the correct amount of material. If there are two bridge ends (section 2&3) the averaged Δf of the two is used. Tom Jurgens will make the cutout calculation and provide a sketch similar to fig.2 for bridge ends and fig.3 for terminating ends. Take an initialed and dated copy to the shops with the parts and make sure a copy is in the logbook. All mechanical machining needs to be finished at this time (Pin holes & probe holes).

9.Slot Remaining Segments.

Slot remaining segments and finish holes for pins while the end terminations are being measured as per step 8. Return to tuning area before end terminations are available if possible. Record final CL from the machine shop measured data and enter it into spread sheet 3 column B.

10. Stack full structure.

a) Stack the full structure with half cell terminations (flat plates). Measure the π/2 frequency and enter corrected value on spreadsheet 3 (CFR52). Add the data point to the projected $\pi/2$ graph (step 7) and enter the projected $\pi/2$ frequency into spreadsheet 3 (CGR62). Note: we use to stack the segments adding one at a time and measure each $\pi/2$ frequency. This is not necessary now unless the projection with the full stack does not agree with the five stack projection to ± 0.02 MHz.

b) Stack the full structure with terminating ends. Short bridge coupling cells. tune the ends for minimum energy in the adjacent side cells. Measure $\pi/2$ frequency and Q. Enter data into spreadsheet 3 (CIR62 and CIR63).

11. Measure Individual Cell Frequencies.

Short side cells adjacent to a cell to be measured with drive and pickup loop shorting probes. Short all accelerating cells not to be measured with the precision ground rod. One cell at a time, measure the individual cell frequency and enter the data into spreadsheet 3 Pre Braze column I. Caution: Always use the same probe on the top and the same probe on the bottom rows of side cells. On a sketch in the log book, indicate the probe number. Seat the probe onto the vacuum flange fully and without a gasket. If a probe is damaged (e.g. a finger breaks off) repair it and clearly mark in the log book what action took place. The goal is consistency and we intend to use the same probes in the section after brazing to estimate frequency shifts during brazing.

12. Measure $\pi/2$ Frequency

Measure the $\pi/2$ frequency and Q of the structure with the bridge coupling cells shorted. Enter the data into spreadsheet 3 (CIR62 and CIR63).

The section is ready to pack and ship for brazing!

LINAC CAVITY UPGRADE

Post-BRAZE TUNING STEPS

H.W. MILLER

3/27/91 Rev.

Post-braze Tuning Steps

A.Introduction

This note describes the tuning steps listed on the post-braze tuning check list. (Check List 3). The check list is to be filled out for each module/section and a record kept in the corresponding log book. Beside each task check indicating that data is entered in the log book and to disk file where appropriate. Date and sign each step after completion. Bill Miller or designated person must verify data where indicated and initial the authorized to proceed column.

All Measurements made in air are quoted corrected for vacuum at 25 deg. C. All vacuum measurements are corrected for 25 deg.C. Recorded data is to be corrected.

B.Description of Steps

1. Mechanical Preparation. (mechanical group)

a)Weld on all flanges and verify that the section is vacuum tight. Make sure no welds protrude into the beam bore or vacuum pump-out that will obstruct probe travel.

b) While still on the shipping crate tune side coupling cells to 805.290±.010 MHz. (Tuning Checklist 3 step 1)

c) Mount section on it's cradle and wheel around cart. Prior to final tuning of the section, install all water manifolding to the cavity. Inspect and complete any mechanical work that needs to be done.

2. Measure Individual Accelerating Cell Frequencies.

Measure each accelerating cell frequency with shorts placed in adjacent cells (See pre-braze tuning, step 11.) For consistency in the measurement, make sure the same probe is used in the side cells that was used in the pre-braze step. If that is not possible clearly indicate the reason why in the log book(e.g. a broken or lost probe). Enter the corrected measurement data on Spread Sheet 3, column J. Tune the end cells for zero energy in their adjacent side cells and measure the $\pi/2$ frequency and Q for the Structure. Enter the measurement in Spread Sheet 3, Column J , Rows 62 & 63. Bridge coupling cells are shorted during this measurement. The object in this step is to track shifts in tuning due to the brazing and shipping.

3.Tune Accelerating Cell Frequency

Determine the frequency adjustment required for the accelerating cells. The goal is for $\pi/2$= 805.000 ± 0.001 MHz. when corrected for vacuum at 25 deg. C. All cells should be low and the $\pi/2$ average will need to increase by about 0.100 MHz. If any cell has increased too high during the brazing or mechanical work, treat it as a special case and have Miller decide how to handle it. The $\pi/2$ frequency will increase in proportion to an increase in the accelerating cells average if there is little coupling cell stored energy. (Which is the case if the interior accelerating cells are all tuned identical and if the end cells are tuned to minimum energy in the adjacent side cells)

The cell frequencies are increased by denting the sides of the cells in the detents provided. Three or four tuning passes are required. (no more that 0.06 MHz. per pass). We found on proto-type R that too large a shift on any one cell can affect the tuning on several other cells. by about 20%. Tapping hard gives bigger errors and tapping lightly gives smaller errors. As the average $\pi/2$ frequency of the section is raised the spread in individual cell frequencies will decrease.

1st. Pass- Start with the $\pi/2$ frequency and interior 14 cell average frequency measured in step B-2. Find the Δf to increase the $\pi/2$ frequency to 804.960 MHz. add the Δf to the 14 cell average and determine the incremental change each cell must be tuned to raise the average. Tune only those cells that must be increased upward. Ignore any cells that must decrease. The average will move up less than projected which is ok and safe. Tune the appropriate cells upward. Tune the end cells for zero adjacent side cell energy. Measure the individual cell frequencies, $\pi/2$ frequency and Q. Record data on the appropriate rows and column of Spreadsheet 3. Note that only the 1st and Final tuning columns are listed on the sample spreadsheet. Depending upon the number of passes required additional columns are needed.

2nd. Pass- Determine the Δf required to increase the $\pi/2$ frequency to 804.990 MHz. add the incremental change to the interior cell average and determine the amount each cell must increase. Tune all cells that need to increase up the determined amount. Note that if any cell will need to decrease more that .010 MHz. it might be too high for the final pass and special tuning will be required. Record data in an appropriate column of Spreadsheet 3.

3rd. Pass-Repeat the steps in the 2nd. Pass with a target $\pi/2$ frequency of 804.998 MHz. If some cells are too high, i.e. they must be reduced, leave cells adjacent to them low. Bring other cell frequencies up to the target. average. Record data in an appropriate column of Spreadsheet 3.

4th Pass- If it is necessary to make a fourth pass in tuning to achieve 805.000 ± .001 MHz. it can be accomplished simply by tapping the individual cells up while watching the $\pi/2$ frequency and increasing it about 1/16 of the required amount with each cell. Experience with proto-type R indicates that re-inserting the probes for better than 0.010MHz. accuracy is difficult. While not desired, variations of cell to cell tuning of ±.020 MHz. are tolerable. Check end tuning and verify that adjacent side cell energy is small (<.5 db). Record final tuning in an appropriate colunm of Spreadsheet 3.

4 Check Coupling Cell Frequency

Minor coupling cell frequency shift may occur during tuning of the accelerating cells. Check and retune the coupling cells to 805.290±.010 MHz.

5. Measure Structure Parameters.(air)

Measure and record $\pi/2(a)$, Q(a), $\pi/2(c)$ and Q(c). Measure all modes (31) and run Disper. Record parameters on the Summary Data Sheet . Make sure that all values are corrected for vacuum at 25 deg. C.

6. Measure Structure Parameters. (Vacuum)

Measure and record $\pi/2(a)$ and Q(a). Measure all modes (31) and run Disper. Record parameters on the Summary Data Sheet . Make sure that all values are corrected for 25 deg. C.

Note that $\pi/2(c)$ is not measured directly at vacuum. That is because, while the end accelerating cells could be shorted to make the measurement, it would require an additional vacuum cycle. Experience is that an adequate value for $\pi/2$ (c) is calculated from Disper.

7. Adjust Coupling Cells (Stop Band)

We want the stop band to be between +50 and +100 KHz with the structure under vacuum. The side cell tuning in step 1 should put the stop band in the correct range. Due to differences in the side cell gap spacing and hence frequency variation with changes in gap spacing and due to the variations in copper hardness the side cells may need to be adjusted. If that is the case, make a Δf adjustment to place the stop band at +90 KHz.

8. Tune Bridge Ends.

As tuned, with the Bridge Coupling Cell (BCC) Shorted, the accelerating cells at Bridge ends will be tuned too low when the Bridge couplers are in place. This is because the shorted BCC raises the accelerating cell frequency. The amount, refered to the $\pi/2$ frequency is between 9 and 11 KHz. Increase the $\pi/2$ frequency + 10 KHz. with each Bridge accelerating cell.

9. Mount Tuning Cell(s)

Unshort the Bridge Coupling Cell(s) and mount a Tuning Cell on the Bridge Coupling flange.

10. Tune Bridge Coupling Cell(s).

Short the posts of the Tuning Cells and the gap in the end accelerating cells. Tune the Bridge Coupling Cell to 810.00± .050 MHz. A convenient way is to measure S11 with a capacitive probe in the Bridge Coupling Cell monitor port. Make sure it is not coupling enough to shift the frequency.

11. Tune Bridge Accelerating Cells.

Separate the posts on the tuning cells equally until the section is tuned near the correct $\pi/2(a)$ frequency (same frequency as in step 5). Check For minimum energy in adjacent side coupling cells. Note that the $\pi/2$ frequency could be correct if one end is low and one end high but that would not have minimum energy in the side cells.

Now check one end at a time. If there is energy in the Bridge Coupling Cells the end accelerating cell needs a small adjustment. Iteratively adjust the tuning cell and accelerating cell until there is no energy in either the Bridge Coupling Cell or the adjacent side coupling cell. Go slow , there should not be more that a couple of KHz change in $\pi/2$ frequency. Tune both ends.

Measure and record the two modes introduced by each tuning and Bridge Coupling Cell. They do not couple well through the structure so drive and pick up at the end being measured. Label the modes with the Bridge Accelerating cell number.

Short the posts in the tuning cells. Measure and record.the $\pi/2(bc)$ of all the coupling cells. This will be higher than $\pi/2(c)$ since the bridge coupling cells were tuned to 810 MHz.

12. Short Bridge Coupling Cells.

Measure and record $\pi/2(a)$, $Q(a)$. Cover all vacuum ports and give to mechanical group to mount on girder.

Note

A list of tuning steps for module 3, section 4 dated 2/24/199, first pass tuning example and final stacking and tuning data sheet of module 2, section 4 are attached as Appendix A Different modules and sections are shown as examples because the procedures were in a continuous state of evolution and these presentations were avalilable at the time.

Module Final Tuning Steps

1. Mount tuning cell(s) on each section and adjust end accelerating cell frequency. Tune each section to 805.000 ± .001 MHz. at 25 degrees C. Keep coupling cell energy to ± 2db Max in coupling cells.

Mount bridge couplers 1-2 and 3-4

2. Tune Bridge couplers 1-2 and 3-4. and balance coupling with nose position. Mark nose for welding.

Weld noses in bridge coupler 1-2 and 3-4. Mount all three bridge couplers.

3. Final Tune Bridge couplers 1-2 and 3-4. Tune frequency and balance coupling with nose position on Bridge Coupler 2-3. Mark nose position for welding.

Weld noses in bridge coupler 2-3. Mount bridge coupler.

4. Final tune module and adjust coupling slot for beam loading. Make a bead pull and record field distribution. Adjust bridge coupling cells for proper phase balance.

5. Calibrate probes for -57db attenuation between the waveguide input and the co-ax panel at the center of the module.

6. Power Test the Module.

7. Varify that all pre-installation items on Check List 4 are completed

8. The module is ready for installation.

9. Details of the final tuning will be available in a Final Linac Tuning Summary

Section	CL (inches)	SF Goal (MHz.)	Δf/Δctr (KHz./mil*
1	3.3991	820.80	27.26
2	3.49776	820.59	26.37
3	3.59397	820.39	25.55
4	3.68775	820.20	24.78
5	3.77783	819.77	24.08
6	3.86429	819.40	23.44
7	3.94852	819.05	22.85
8	4.03053	818.72	22.31
9	4.10939	818.49	21.81
10	4.18516	818.22	21.36
11	4.25906	817.97	20.94
**12	4.33075	817.74	20.56
13	4.39985	819.13	20.21
14	4.46633	818.90	19.90
15	4.53104	818.69	19.61
16	4.59403	818.50	19.35
17	4.65477	818.31	19.11
18	4.71331	818.15	18.90
19	4.77032	817.99	18.71
20	4.82614	817.85	18.53
21	4.87934	817.72	18.38
22	4.93095	817.59	18.24
23	4.98121	817.48	18.12
24	5.03018	817.38	18.01
25	5.07751	817.28	17.91
26	5.12326	817.19	17.83
27	5.16784	817.11	17.76
28	5.21129	817.03	17.69
*One mil=0.001 inches.			
Sections, 1-12 Design ctr=7.264 & 13-28 Design ctr=7.188			

Table 1, SF Δf/Δctr Vs CL

Freq. Correct. Copper

Enter:			
Temp Deg.C=	18.19	Absolute Temp=	291.19
Bar. Pressure (mBar)=	970.2	Partial Pressure Air=	722.7692986
Rel. Humidity(%)=	30.8	Partial Press. Water=	4.880719583
Frequency	807.322	Vapor Pressure=	15.84649215
		Dielectric Const. K=	1.000582077
Bar. Pressure (mmHg.)=	727.6500182	K^1/2=	1.000290996
Adjusted Freq. (Vacuum)=	807.5572279		
Adjust Freq. (Vacuum @25C)	807.463737		
Ref Freq.		**Freq. Correction.**	
807.322300		-0.141437	
Errors	**Δf (MHz.)**		
0.1Deg. C	-0.001369		
5 mBar	-0.001063		
1% Rel Humid.	-0.001074		
Temp. Deg.C	Vapor Pressure	Calc. from D5 Equation	
15	12.67	13.09749022	
20	17.5	17.65560198	
25	23.8	23.80000107	
30	31.8	32.0827379	
35	42.2	43.24798426	
40	55.1	58.29889418	

Spead Sheet 1

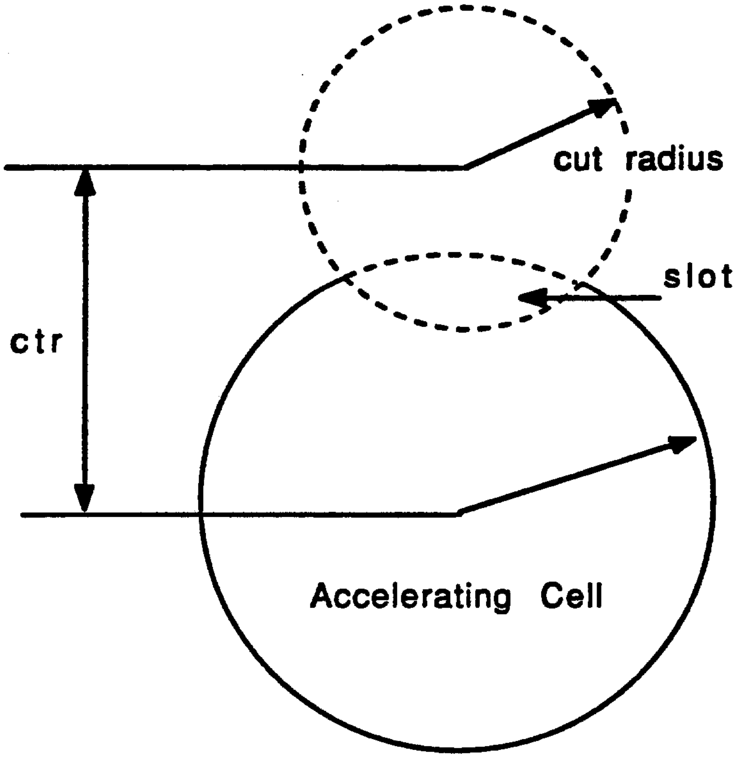
	A	B	C	D	E	F
1	Main Cavity Cells, Module		Section		Date:	
2	Vendor ·	, SF=			Tested By:	
3	,					
4	Cell #	Q	Freq. Vac @25	PairAVG Vac@25	Freq-SF (avg)	Comments
5						
6	M				#DIV/0!	
7	M			0.000	#DIV/0!	
8						
9	M				#DIV/0!	
10	M			0.000	#DIV/0!	
11						
12	M				#DIV/0!	
13	M			0.000	#DIV/0!	
14						
15	M				#DIV/0!	
16	M			0.000	#DIV/0!	
17						
18	M				#DIV/0!	
19	M			0.000	#DIV/0!	
20						
21	M				#DIV/0!	
22	M			0.000	#DIV/0!	
23						
24	M				#DIV/0!	
25	M			0.000	#DIV/0!	
26						
27	M				#DIV/0!	
28	M			0.000	#DIV/0!	
29						
30	M				#DIV/0!	
31	M			0.000	#DIV/0!	
32						
33	M				#DIV/0!	
34	M			0.000	#DIV/0!	
35						
36	M				#DIV/0!	
37	M			0.000	#DIV/0!	
38						
39	M				#DIV/0!	
40	M			0.000	#DIV/0!	
41						
42	M				#DIV/0!	
43	M			0.000	#DIV/0!	
44						
45	M				#DIV/0!	
46	M			0.000	#DIV/0!	
47						
48	M				#DIV/0!	
49	M			0.000	#DIV/0!	
50						
51	M				#DIV/0!	
52	M			0.000	#DIV/0!	
53						
54	M				#DIV/0!	
55	M			0.000	#DIV/0!	
56						
57	Interior Cells					
58	AVERAGE	#DIV/0!	#DIV/0!	0.000	#DIV/0!	
59	STD DEV	#DIV/0!	#DIV/0!	0.000	#DIV/0!	
60	MIN	0	0.000	0.000	#DIV/0!	
61	MAX	0	0.000	0.000	#DIV/0!	
62	SPREAD	0	0.000	0.000	#DIV/0!	
63						
64	B					
65	B				#DIV/0!	
66	B				#DIV/0!	

Spread Sheet 2

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Final Stacking and Tuning					Date:							
2	Module Section		Target SF=			Tested By:							
3													
4													
5	Acc. Cell #	Length	SF Freq.	Paired Freq.	Pair- PairAvg.	π/2 vs 1/n	adj. π/2 vs 1/n				Acc. cell Frequency		
6						Ctr.			Pre Braze	Post Braze	Braze Δf	1st. tuning	Final tuning
7	B												
8											0.000		
9	M												
10	M						0.000						
11				0.000	0.000						0.000		
12	M												
13	M						0.000						
14				0.000	0.000						0.000		
15	M												
16	M						0.000						
17				0.000	0.000						0.000		
18	M												
19	M						0.000						
20				0.000	0.000						0.000		
21	M												
22	M						0.000						
23				0.000	0.000						0.000		
24	M												
25	M						0.000						
26				0.000	0.000						0.000		
27	M												
28	M						0.000						
29				0.000	0.000						0.000		
30	M												
31	M						0.000						
32				0.000	0.000						0.000		
33	M												
34	M						0.000						
35				0.000	0.000						0.000		
36	M												
37	M						0.000						
38				0.000	0.000						0.000		
39	M												
40	M						0.000						
41				0.000	0.000						0.000		
42	M												
43	M						0.000						
44				0.000	0.000						0.000		
45	M												
46	M						0.000						
47				0.000	0.000						0.000		
48	M												
49	M						0.000						
50				0.000	0.000						0.000		
51	M												
52	M						0.000						
53											0.000		
54	B												
55													
56	AVERAGE	#DIV/0!	#DIV/0!	0.0000	0.000				#DIV/0!	#DIV/0!	0.000	#DIV/0!	#DIV/0!
57	STD DEV	#DIV/0!	#DIV/0!	0.000	0.000				#DIV/0!	#DIV/0!	0.000	#DIV/0!	#DIV/0!
58	MIN	0	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000
59	MAX	0	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000
60	SPREAD	0	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000
61													
62	π/2 Freq.												
63	O												
64													
65	Spares												
66													
67	M												
68	M												
69													
70	M												
71	M												
72													
73	B												

Spread Sheet 3

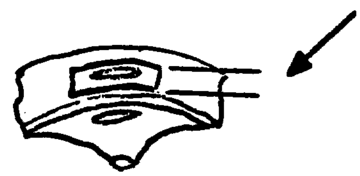
Module___, Section___ Slotting Data



Cut radius= 3.4091"

Acc Cell radius= 5.2972"

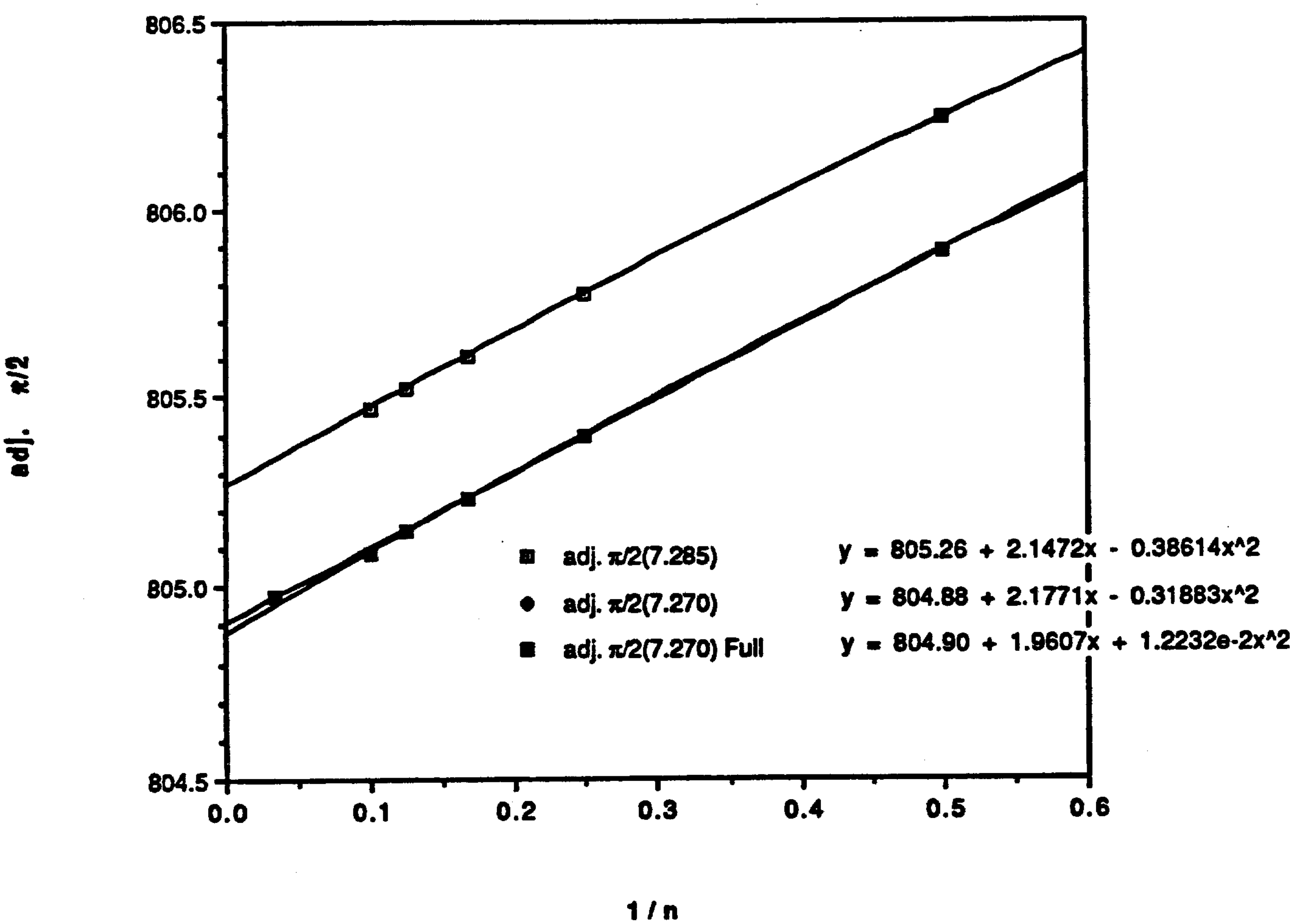
Slot width= ________"



Slot Cut Number	Slot Depth ctr (inches)	Checked By	Date
1st	____________	________	_____
2 nd	____________	________	_____
Final	____________	________	_____

Data Sheet 1

	1/n	adj. π/2(7.285)	adj. π/2(7.270)	adj. π/2(7.270) Full
1	0.500	806.240	805.886	805.886
2	0.250	805.774	805.400	805.400
3	0.167	805.612	805.233	805.233
4	0.125	805.526	805.145	805.145
5	0.100	805.472	805.090	805.090
6	0.083			
7	0.071			
8	0.062			
9	0.056			
10	0.050			
11	0.045			
12	0.042			
13	0.038			
14	0.036			
15	0.033			804.976



DATA SHEET 2

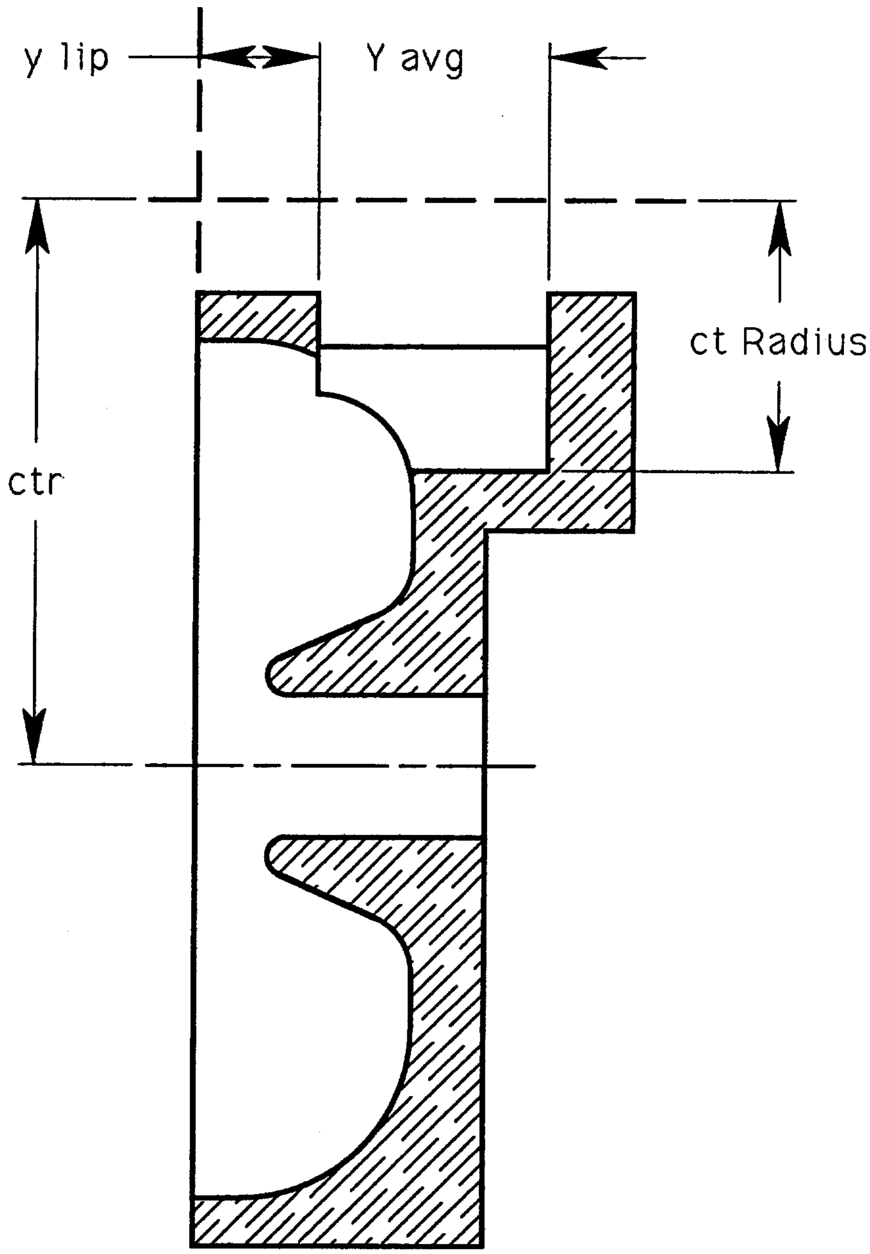
Bridge Slotting

Module ________ Section ________

y lip ________

Y avg ________

ctr ________



Chkd By ________

Date ________

Figure - 1

Bridge End Frequency Adjustment

Module: 2 **Section:** 2

Cell # : B0602 , B0603 **Freq. Shift: Δfx2=** 4.824 MHz

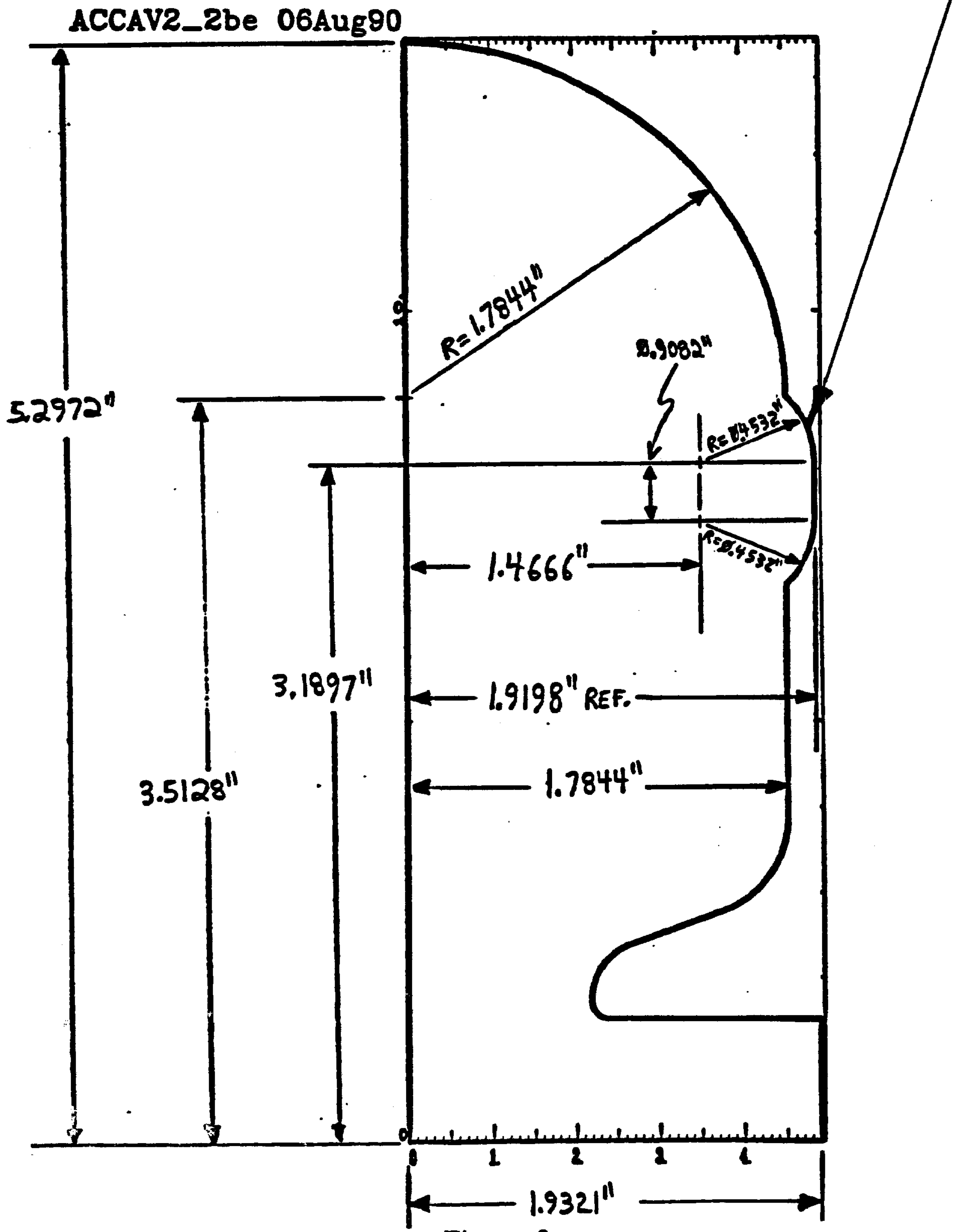


Figure 2

Terminating End Frequency Adjustment

Module: 2 **Section:** /

Cell # : B0503 **Freq. Shift: Δfx2=**

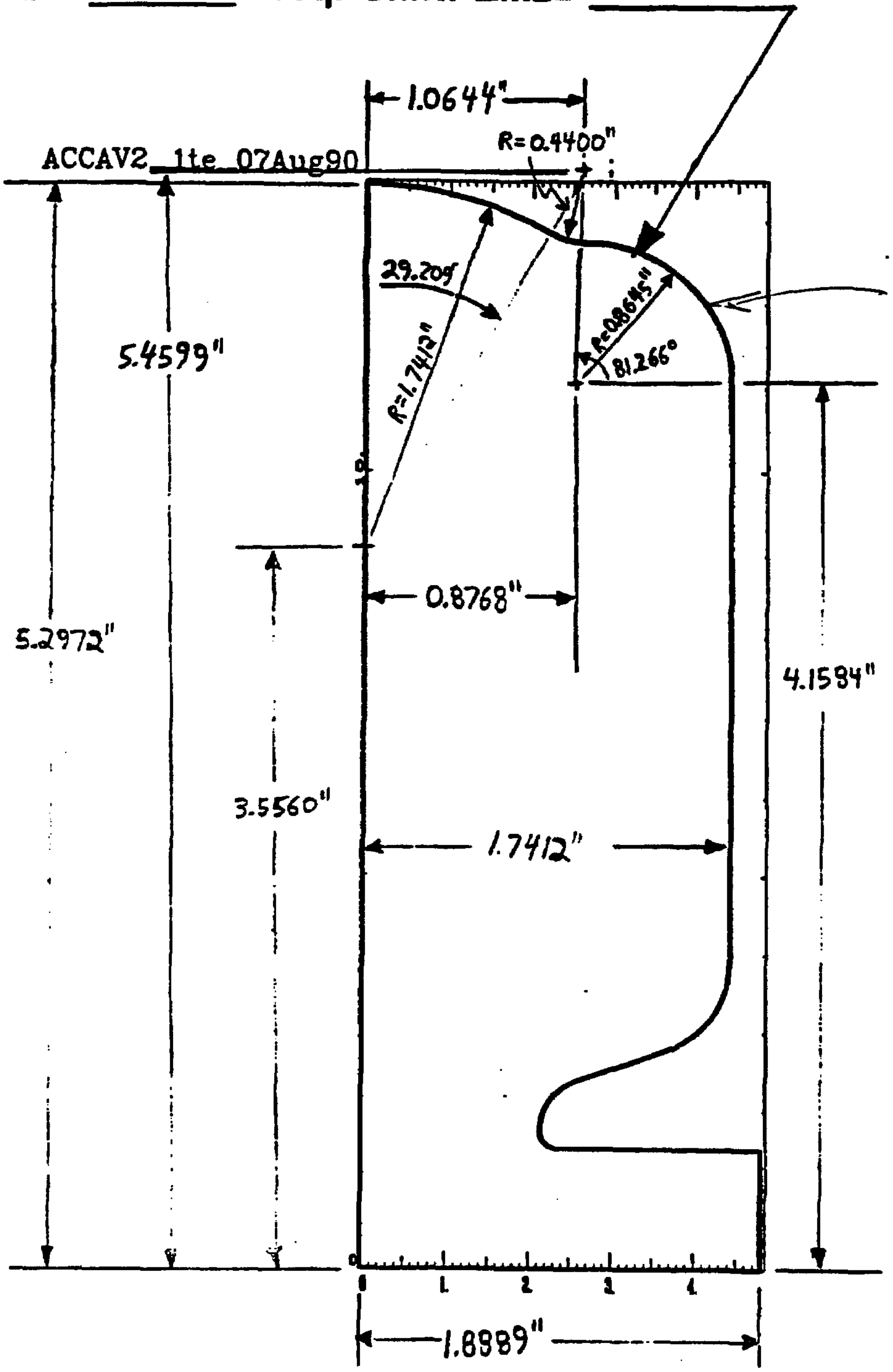


Figure 3

Pre-Braze Tuning Check List					
Module____ Section____					
TASK	DATA ENTERED		DATE TESTED	TESTED BY	Completed*
	Log Book	Disk File			
Test 1st Part					
Lap SF Parts					
Measure SF Frequency					
Accept SF Machining					
Determine Stacking Order					
Slot 1st Five Segments					
Project $\pi/2$ Frequency					
Machine End Terminations					
Slot Remaining Segments					
Stack Full Structure					
Measure Individual Cell Freq.					
Measure $\pi/2$ Frequency					

* Complete column must be signed by H. Miller or designee before continuing to next step.

Check List 1

Pre-braze Tuning Chart

	Test 1st part.	Lap SF Parts	Measure SF Frequency	Accept SF Machining	Determine Stacking Order.	Slot 1st five Segments	Project π/2 Frequency	Machine end Terminations	Slot Remaining Segments	Stack Full Structure	Measure Individual Cell Frequencies	Measure π/2 Frequency
Mod 1 Section 1												
Mod 1 Section 2												
Mod 1 Section 3												
Mod 1 Section 4												
Mod 2 Section 1												
Mod 2 Section 2												
Mod 2 Section 3												
Mod 2 Section 4												
Mod 3 Section 1												
Mod 3 Section 2												
Mod 3 Section 3												
Mod 3 Section 4												
Mod 4 Section 1												
Mod 4 Section 2												
Mod 4 Section 3												
Mod 4 Section 4												
Mod 5 Section 1												
Mod 5 Section 2												
Mod 5 Section 3												
Mod 5 Section 4												
Mod 6 Section 1												
Mod 6 Section 2												
Mod 6 Section 3												
Mod 6 Section 4												
Mod 7 Section 1												
Mod 7 Section 2												
Mod 7 Section 3												
Mod 7 Section 4												

	Post Braze Tuning Check List					
	Module____Section____					
	TASK	DATA ENTERED		DATE TESTED	TESTED BY	Completed*
		Log Book	Disk File			
1	Tune Coupling cells					
2	Measure Accelerating Cells					
3	Tune Accelerating Cells					
4	Check Coupling Cell Frequency					
5	Measure Parameters (Air)					
6	Measure Parameters (Vac)					
7	Adjust Coupl. Cells (Stop Band)					
8	Tune Bridge Ends					
9	Mount Tuning Cell					
10	Tune Bridge Coupling Cell					
11	Tune Bridge Accelerating Cells					
12	Short Bridge Coupling Cells					
	* Complete column must be signed by H. Miller or designated person before continuing to					

Check List 3

MODULE PRE-INSTALLATION CHECK LIST, MECHANICAL

MODULE NUMBER ______ INITIAL & DATE

BRIDGE COUPLERS

1. CLEANED & PAINTED CLEAR ________
2. FLANGES LAPPED & COVERED ________
3. ION PUMP ON CENTER BRIDGE COUPLER ________
4. WINDOW ASSEMBLY ON CENTER BRIDGE COUPLER ________
5. BLANK OFF ION PUMP PORTS ON END BRIDGE COUPLERS ________

CAVITIES & GIRDER

1. REMOVE ION GAUGES FROM CONDITIONING CONFIGURATION ________
2. REMOVE BRIDGE COUPLERS & BLANK OFF CAVITY FLANGES ________
3. REMOVE BEAM TUBES & BLANK OFF B. T. FLANGES (USE HELIOCOFLEX SEALS & WIREBRUSH HANDLES) ________
4. INSTALL ION GAUGE ON CENTER OF SECTION 3 (INSTALL NEW ION GAUGE PROTECTOR) ________
5. INSTALL QUADS ________
6. SNUG DOWN ALL CAVITY "Z" ADJUSTERS ________
7. INSTALL ALUMINUM HOLD DOWN BAR ON EACH CAVITY ________
8. PURGE & BACKFILL WITH DRY NITROGEN ________
9. REMOVE GIRDER STANDS ________
10. QUAD WATER MANIFOLD ________

CHECK LIST, ELECTRICAL

1. HIGH POWER TESTING IS COMPLETE ________
2. VERIFY FINAL TUNING IS COMPLETED & BEAM LOADING SLOT IS CORRECT ________
3. MODE MEASUREMENTS ARE IN LOGBOOK ________
4. BEAD-PULL DATA IS IN LOG BOOK ________
5. VERIFY THAT PHASE BALANCE HAS BEEN MADE ________
6. PROBES ARE CALIBRATED TO -57 db (TARGET VALUE) & ACTUAL CALIBRATION IS LISTED IN THE LOGBOOK ________
   PROBE TYPE: TEFLON____, GLASS SEALED____
   BRIDGE COUPLERS MAY BE REMOVED
7. ALL ACCELERATING FIELD MONITOR CABLES ARE INSTALLED ________
8. INSTALLED 8-WAY COMBINER & PADS ________
9. IF POSSIBLE, MEASURE MODULE UNDER VACUUM ________

Check List 4

Feb. 24, 1991

Tuning of Module 3-4

1. Measure individual post braze cell and $\pi/2$ frequencies. Record corrected values on the final stacking order data sheet.

2. Compare the shift in the average cell frequency (excluding ends.) with the shift in the $\pi/2$ frequency. If they are not in agreement it is probably due to probe changes. Base any cell frequency changes on the new average.

3. Keep the end cells tuned for zero energy in their adjacent side cells as the $\pi/2$ frequency is increased. Do so by probes inserted into the gap to lower the frequency or by moving the ends. Prior to tests with vacuum, tune the ends physically so that a relative Δf measurement with and with out vacuum is made under the same conditions.

4. Tune the side cells to 805.150 MHz. corrected prior to starting the accelerating cell tuning.

5. Find the amount the $\pi/2$ frequency is low. Assume that the average cell frequency must be raised that amount. If any cells are above that frequency we need to decide what to do. If they are all lower as they should be then proceed. We want the final average cell frequency to be achieved with the minimum spread in cell frequencies

6. Move toward the final cell average in steps. Find the average cell goal frequency to move $\pi/2$ up 30 KHz. or 1/3 of Δf, which ever is smallest. Remember, until all cells are below the goal average, the average can move up higher without tuning all cells.

Bring any extra low cells up to the average starting frequency. Do not increase more than 30KHz at a time without checking other cells.and $\pi/2$. This is because a 20% shift in adjacent cells has been seen when tuning any particular cell. Establish the cell goal average.

7. Re-evaluate the cell average, $\pi/2$ and establish a new average cell goal. Move $\pi/2$ up 20 KHz. of 1/3 Δf similar to the steps in 6.

8. Repeat 7 until $\pi/2$ is within 10 KHz. of $\pi/2$. Then move cells up to the final cell average. Check atmospheric conditions frequently and work with corrected values only.

9. Keep ends tuned at each step for zero adjacent side cell energy. Bridge coupling cells are shorted.

10 Record frequencies of internal cells at each pass on the final stacking order data sheet. Record $\pi/2$ frequency and Q for each step.

11. Measure $\pi/2$ for the accelerating and side cells, Q, individual cell frequencies and modes. Calculate disper and record data.

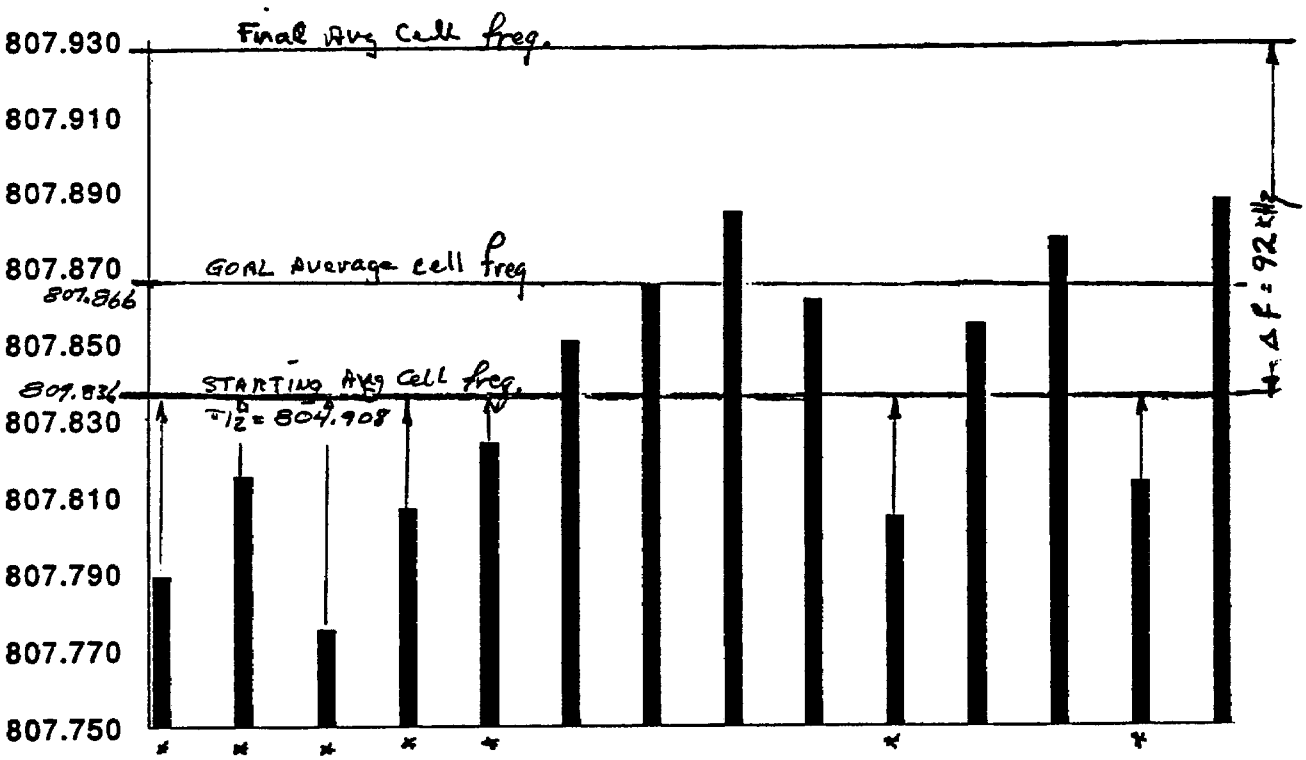
12. Repeat step 11 under vacuum. Check that stop band is between 50 and 100 KHz. If not, adjust side cells and repeat steps 11 and 12.

13. Tune bridge ends with tuning cell installed. Proper tuning is zero energy in the bridge and adjacent side cell. Tune the bridge coupling cell to get the same side cell $\pi/2$ frequency as the average side cell frequency measured in 11. Record $\pi/2$ of accelerating and side cells and Q.

14. Short BCC and measure $\pi/2$ and Q.

15. Repeat 14 under vacuum.

Example First pass from Z-4



** first pass Then adjust Goal.*

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	2-4 Final Stacking and Tuning					Date: 8-15-90										
2	*removed 810/811 (dented)					Tested By: RENE' P.										
3																
4																
5	Acc. Cell #	Length	SF Freq.	Paired Freq.	Pair- PairAvg	π/2 vs 1/n	adj. π/2 vs 1/n					Acc. cell Frequency				
6						Ctr. 7.270			Pre Braze	Post Braze	Braze Δf	1st. tuning	2nd. tuning	Final tuning	f-avg. f	
7	B0801	2.867/4.034	818.429											(3rd)		
8									806.760	806.589	-0.171					
9	M0829	4.035	818.606													
10	M0828		818.575			805.945	805.879									
11				818.531	0.007				807.968	807.789	-0.179	807.8584	807.869	807.916		
12	M0816	4.030	818.487													
13	M0817		818.520			805.440	805.424									
14				818.530	0.006				807.934	807.815	-0.119	807.8576	807.868	807.916		
15	M0807	4.030	818.540													
16	M0806		818.386			805.241	805.254									
17				818.506	-0.018				807.939	807.775	-0.164	807.858	807.869	807.916		
18	M0837	4.031	818.627													
19	M0836		818.617			805.190	805.166									
20				818.530	0.006				807.985	807.807	-0.178	807.858	807.867	807.917		
21	M0824	4.029	818.442													
22	M0825		818.535			805.130	805.121									
23				818.532	0.008				807.984	807.824	-0.160	807.8581	807.865	807.916		
24	M0813	4.030	818.530													
25	M0812		818.363			805.086	805.094									
26				818.494	-0.030				807.973	807.851	-0.122	807.8665	807.866	807.916		
27	M0833	4.030	818.626													
28	M0832		818.599			805.085	805.070									
29				818.532	0.008				807.989	807.865	-0.124	807.8591	807.865	807.916		
30	M0814	4.030	818.464													
31	M0815		818.416			805.047	805.047									
32				818.520	-0.004				807.977	807.884	-0.093	807.874	807.865	807.916		
33	M0838	4.029	818.625													
34	M0839		818.621			805.051	805.039									
35				818.527	0.003				807.988	807.861	-0.127	807.8576	807.864	807.917		
36	M0819	4.030	818.433													
37	M0818		818.530			805.038	805.032									
38				818.533	0.009				807.964	807.805	-0.159	807.858	807.864	807.917		
39	M0821	4.030	818.535													
40	M0820		818.472			805.023	805.021									
41				818.528	0.004				807.981	807.855	-0.126	807.8582	807.868	807.916		
42	M0830	4.030	818.583													
43	M0831		818.623			805.021	805.013									
44				818.521	-0.003				807.977	807.877	-0.100	807.8873	807.868	807.916		
45	M0809	4.030	818.420													
46	M0808		818.550			805.008	805.004									
47				818.529	0.005				807.966	807.814	-0.152	807.8577	807.867	807.916		
48	M0822	4.030	818.508													
49	M0823		818.540			805.001	804.998									
50				818.525	0.001				808.003	807.887	-0.115	807.8633	807.867	807.916		
51	M0827*	4.031	818.509													
52	M0826		818.609			805.003	804.997									
53									806.554	806.182	-0.371					
54	E/B0802	2.866	818.518													
55																
56	AVERAGE	4.030	818.530	818.5240	0.000				807.973	807.836	-0.137	807.861	807.867	807.916	#DIV/0!	
57	STD DEV	0.001	0.078	0.011	0.011				0.019	0.037	0.028	0.005	0.002	0.000	#DIV/0!	
58	MIN	4.029	818.363	818.494	-0.030				807.934	807.775	-0.179	807.858	807.864	807.916	0.000	
59	MAX	4.035	818.627	818.533	0.009				808.003	807.887	-0.093	807.874	807.869	807.917	0.000	
60	SPREAD	0.006	0.264	0.038	0.038				0.069	0.112	0.086	0.016	0.005	0.001	0.000	
61																
62	π/2 Freq.						804.930		804.913	804.908		804.945	804.863	804.999		
63	Q						n/a		n/a	20705		20,779	20,789	20,759		
64																
65	Spares															
66																
67	M0834		818.612													
68	M0835		818.613													

Appendix A-3