1302-ENG-0008
Manufacturing Report
& QC Data

1.3 GHz Single Cell Cavities
Part #: 1302G00001-1
S/N's TE1AES001 thru TE1AES006

Approved By:
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9/24/07

Advanced Energy Systems, Inc.

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1.0 Introduction & Overview

This document comprises the quality control data associated with the 1.3 GHz DESY TESLA RF Cavity serial number AES-001. The AES part number for this component is 1247G00001-1. For the most part the data is presented on the FNAL provided traveler documents however in many cases there are also data directly from measurements taken on the coordinate measuring machine.

1.1 Half-Cell Part Numbering

The part numbering system for the cavity half-cells uses the numbering system provided by FNAL with the niobium sheets. The serial number for each cell is engraved at one location approximately 1.25 inches from the equator weld. The format of the serial number starts with the letter "L" designating Long End Cell, followed by the number corresponding to the Nb sheet number provided by FNAL.

The engraving also contains further information. Above the part serial number (closer to the equator) is a straight radial line. This line indicates the direction of the scanning axis per the FNAL specification provided with the material. Below the serial number (further from the equator) appears the number "1" or "2". This number designates the side of the sheet that is engraved. Therefore if the number 2 appears below the serial number it means that side 2 of the sheet is outside and side 1 of the sheet is the RF side. Figure 1 illustrates this system.

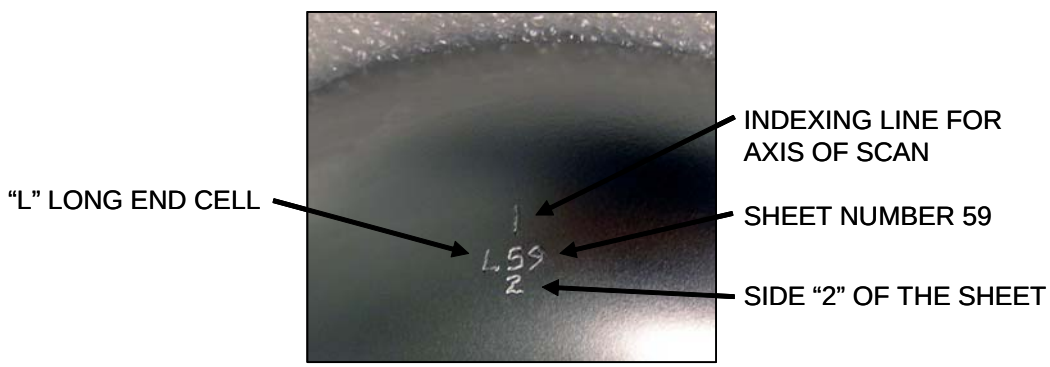

Figure 1 – Part Numbering for Cells

1.2 Beam Tube Part Numbering

The serial numbers for the Beam Tubes follow the same logic as those for the half-cells because they were made from half-cell blank sheets. They are marked with an indexing mark, the sheet number, and the side number that is on the outside. In a couple of cases the indexing mark is not present however the sheet number is placed along the line of the scanning axis. In all cases the flange end of the tube was the center of the original sheet.

1.3 End Group Numbering

The serial numbers for the end groups are simply the combination of the beam tube and cell serial numbers that make up the assembly. Table 1 presents

the pairings for each of the six single cell cavities along with data from the in-process and final inspections.

2.0 Cavity Fabrication Discussion

2.1. Cell Forming and Water Jet Cutting

Cell forming and water jet cutting was performed at Aerotrades Manufacturing, Inc. in Mineola, NY under direct supervision of AES manufacturing personnel. The blanks for hydroforming the cells and for deep drawing the beam tubes were water jet cut. The round NbTi bar for the end flanges was bologna sliced at AES and then water jet cut at Aerotrades to remove the center disk.

In general cell forming went well for this group of cavities with anisotropy of the sheets being about the same as the material used in the first four 9-cell cavities built by AES. As this material was from the same lot as that material and, as far as we understand, went through the same re-heat treatment process as the other sheets this is expected. Post form measurements of the circularity of the equator had variations from .003" to .013" total indicated runout (TIR).

2.2. Beam Tube Manufacturing

The beam tubes were made by deep drawing the flat sheet through a progression of dies using a vertical press. The tubes then undergo a 20 micron BCP operation followed by machining of the weld prep for attachment of the beamline flange. There were no issues with flange welding. A test sample was prepared and sectioned to verify adequate penetration of the face weld.

After welding the final details of the flange faces and seal surfaces were machined as well as the weld preparation for the weld to the cell iris. In this operation an error was made on nine of the twelve beam tubes where the inside lip on the niobium tube was inadvertently machined away flush with the seal surface rather than flush with the bolting surface. A Material Report (MR-07-0017) was prepared and disposition was requested from Fermilab. That disposition was to re-machine the flange faces down by 1 mm to reestablish the proper seal face geometry. The result is that these nine end groups are 1 mm short and the flange is 1 mm thinner than nominal.

2.3. Electron Beam Welding - Irises

EB Welding went well however the parameters for the welds had to be developed because we are using the welder at AES rather than the welder at EBTEC. The beam tube to half-cell welds caused more tilt than we have seen in the past with average results being about .025" out of parallel (TIR) and a worst case of .050" measured at the equator. We have subsequently revised the NC program for that weld to better balance the heat loads between the outside and inside passes and believe it will result in better straightness. Except for the one worst case, the straightness was recovered by machining of the equator weld preparation. For the worst case of .050" we performed some straightening prior to weld prep machining.

2.4. Equator Weld Prep Machining

The equator weld preps were machined to nominal values in all cases. This was done in lieu of measuring the frequency of the end groups and calculating a required cut. Cavities TE1AES001 through TE1AES004 had the weld prep cut by clamping the end flange in the chuck square to the cut and indicating the equator. The high and low points of the equator were averaged and the equator weld prep was machined from that point. Once welded these cavities had an average measured frequency (after temperature, humidity, and barometric pressure correction) of 1300.483 MHz with a spread of +302 kHz, -274 kHz (see section 5 – RF Test Plans & Reports). Cavities TE1AES005 and TE1AES006 had other issues, discussed below, that affected the final measured frequency.

2.5. Cavity Assembly and Pre-Weld BCP

There were two significant issues in cavity assembly with second being a direct result of the first. In the process of performing pre-weld BCP on the equator joints of cavities TE1AES005 and TE1AES006 the end groups were not taken in the correct order resulting in the wrong 2 end groups being assembled into cavity #5. More surprising is the fact that the two end groups assembled for cavity #5 were both female weld preps. The .015" weld prep is difficult to see and the very slight burr at the edges led to the joint aligning very well on assembly. Figure 1 is photograph of the joint as assembled.

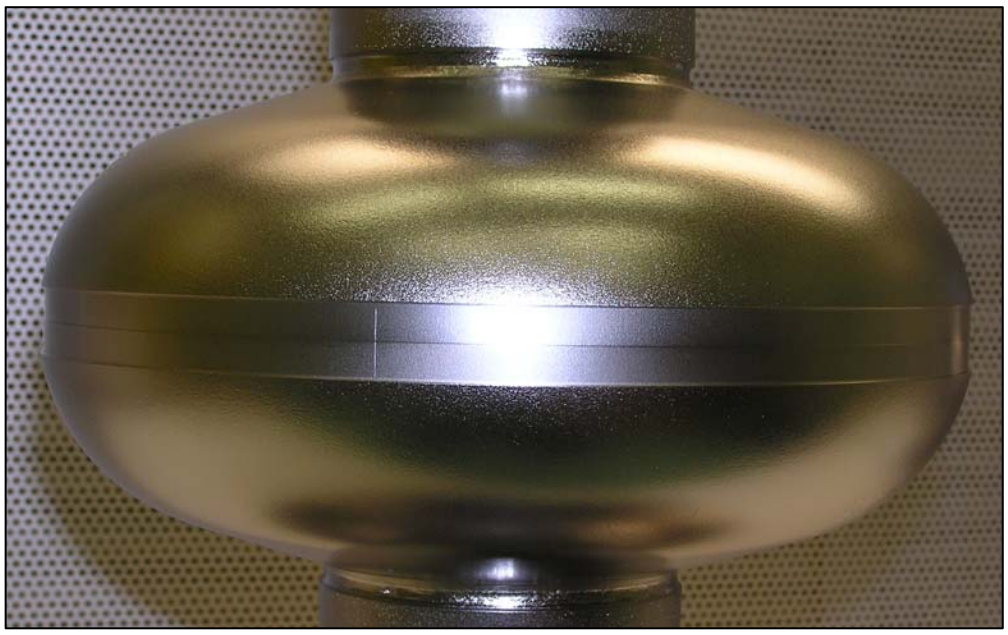

Figure 1 – <u>Assembly of Equator Joint on Cavity TE1AES005</u>

The equator weld went perfectly with no observable difference from the properly assembled joints. The inside of the completed weld was also perfect and undiscernibly different from the other welds. The mistake was caught upon mechanical inspection where the cavity was nominally .015" longer than intended and we observed the part number discrepancy. The problem was also

evident in RF test where the frequency was 1.043 MHz lower than the average of cavities 1 through 4.

The second assembly issue came with cavity TE1AES006 that now had two male weld preps. It was decide to re-machine one end group to the female configuration rather than try to weld 2 males. This was done and the cavity welded perfectly. The result is a cavity which is nominally .015" too short and as with #5 this showed up in RF test where the frequency was 1.45 MHz higher than the nominal of cavities 1 through 4.

Other notes from cavity assembly are that cavity TE1AES004 required a couple of sharp blows by hand to get the joint to snap together and cavity TE1AES006 required a couple of raps with a plastic hammer to engage the joint. All other cavities went together with minimum force. In all cases except cavity #6 the joints were given a 4-5 micron BCP prior to assembly. For cavity 6 we had noted the tight fit prior to chemistry so we performed a 15 micron BCP prior to assembly. Even with that the joint required the hammer blows to engage.

Finally, we observed some apparent effect during pre-weld BCP that seemed to stem from our system of supporting the end group on a Teflon post in the BCP bath. The top of the post sits above the level of the acid and ensures that the joint gets immersed approximately 1.5" but does not contact the bottom of the tank. Because it is solid, the post also blocks the iris and beam tube such that vapor forming during the etch does not easily escape up the beam tube. We speculate that this seems to have resulted in some residue forming on the beam tube side of the Teflon. This was quite subtle after chemistry but became apparent after welding. Cavity #1 did not have this problem but cavities 2, 3, 4, and 5 all have some discolored areas. After performing a heavier 10 micron BCP on the halves of cavity 6 we noticed the discolored area as described above. We then performed a further 5 micron BCP on the complete end group immersing up to just below the NbTi flange to remove this residue. Figure 2 shows a photograph of cavity #6 end groups after the first 10 micron etch.

Figure 2 – <u>Residue from BCP Operation on Cavity 6 Halves</u>

Subsequent to our discovery if this discoloration on the cells we tested our ultrapure water system. We had the manufacturer perform bacteria tests and we performed evaporation tests on mirrored surfaces. Both test returned negative results and the water continues to measure a resistivity of 18 MΩ in the delivery loop. It is our speculation that this "deposit" is coming from the vapor of the reaction because of the apparent relationship to the contact zone of the Teflon but we cannot be sure. These Teflon posts have been used many times in the acid. The Teflon has no unusual appearance at all and we have never observed this effect before. This is possibly because in the past we moved the parts around more frequently during the etch rather than just agitating the acid as was done here.

2.6. Electron Beam Welding - Equators

The equator weld parameter worked extremely well giving less shrinkage than we had seen at EBTEC (.027" vs. .031") and excellent straightness. Parallelism between end flanges was good to a few thousandths of an inch in all cases. Even in the case where 2 female weld preps were assembled the weld worked perfectly with shrinkage and straightness being the same as for male-female joints.

The only cavity that showed significant activity during equator welding was cavity #4 that had sparking in many areas and one spit on the seal pass. The spit came at 1:13 into the seal pass which corresponds to about 170 degrees around the joint. Since the seal pass begins 180 degrees away from the alignment marks on the cells the spit point should be about 10 degrees from the alignment marks. The weld pass on cavity #4 was completely clean with no activity at all.

Movies of the equator welds for cavities 3 through 6 have been submitted to Fermilab for review.

3.0 Inspection Data

Table 1 is a compilation of the dimensional inspections performed on the cavity assemblies and subassemblies. Of note is the final column indicating the length discrepancy for each cavity. With the exception of cavities 5 and 6 that had other issues with respect to assembly, cavities 1 thru 4 all came within .008" of the expected length after accounting for beam tube issues.

Single Cell Cavity Assembly Data

Cavity S/N	Tube ID	Cell ID	Prep Gender	End Group Length Before Eqtr Prep	End Group Length After Eqtr Prep	End Group dL From Machining	Total dL Machining	Target dL Machining	Equator Prep Machining Error	Predicted Stack Height	Measured Pre-Weld Stack Height	Measured Post-Weld Stack Height	dL Welding	Sum of Weld dL & Machining Error	Cavity Design Length	Length Error
TE1AES001	183	213	F	7.75543	7.69586	0.05957	0.11715	0.116	0.00115	15.37778	15.376	15.349	0.027	0.0281	15.4330	-0.0840
	204	206	M	7.7545	7.69692	0.05758										
TE1AES002	181	210	F	7.78679	7.75017	0.03662	0.11377	0.116	-0.00223	15.45234	15.452	15.426	0.026	0.0238	15.4330	-0.0070
	178	218	M	7.79432	7.71717	0.07715										
TE1AES003	202	216	F	7.75496	7.69968	0.05528	0.11195	0.116	-0.00405	15.38646	15.385	15.359	0.026	0.0219	15.4330	-0.0740
	180	219	M	7.75845	7.70178	0.05667										
TE1AES004	182	208	F	7.74949	7.69434	0.05515	0.11077	0.116	-0.00523	15.37596	15.373	15.346	0.027	0.0218	15.4330	-0.0870
	184	207	M	7.75224	7.69662	0.05562										
TE1AES005	176	209	F	7.78499	7.72455	0.06044	0.11638	0.116	0.00038	15.41846	15.416	15.390	0.026	0.0264	15.4330	-0.0430
	205	215	F	7.74985	7.69391	0.05594										
TE1AES006	201	220	F	7.79604	7.71945	0.07659	0.13395	0.116	0.01795	15.39931	15.397	15.371	0.026	0.0436	15.4330	-0.0616
	177	211	M	7.75222	7.69486	0.05736										

RED Indicates Beam Tube Assemblies that are nominally 1 mm shorter than design due to machining error.
Indicates the Gender error on assembly of Cavity #5 and the resulting extra machining on End Group 201/220 in Cavity #6

Table 1 – Dimensional Inspection data for Cavities and Subassemblies

Section 4.0

Vacuum Leak Test Reports

Advanced Energy Systems, Inc.
Leak Test Report

TEST REPORT NUMBER (1)	1302-TR –sn-1
TEST PLAN NUMBER (2)	AES-ENG-0001
PROJECT NAME	GC1302
TEST ARTICLE PART NUMBER	1302G00001-1
TEST ARTICLE DESCRIPTION	1.3 GHz Single Cell S/C Cavity
TEST ARTICLE SERIAL NUMBER	TE1AES001
ALLOWABLE LEAK RATE	See Comments
MSLD MODEL NO.	Varian model 979
MSLD SERIAL NO.	LLD80035
CALIBRATED LEAK ID	Model SD-8D; S/N 6205
CALBRATED LEAK VALUE SCC/S	1.88 x E-8

TEST RESULTS: No measurable leak detected. Sensitivity 1.6E-10

COMMENTS: **Allowable leak rate: No leak detectable on the most sensitive scale of a Helium Mass Spectrometer Leak Detector with a minimum sensitivity of $2x10^{-10}$ atm-CC/sec for helium.**

DATE	**9/19/07**	**TEST PERFORMED BY**	**Jack Ditta**

Advanced Energy Systems, Inc.
Leak Test Report

TEST REPORT NUMBER (1)	1302-TR –sn-2
TEST PLAN NUMBER (2)	AES-ENG-0001
PROJECT NAME	GC1302
TEST ARTICLE PART NUMBER	1302G00001-1
TEST ARTICLE DESCRIPTION	1.3 GHz Single Cell S/C Cavity
TEST ARTICLE SERIAL NUMBER	TE1AES002
ALLOWABLE LEAK RATE	See Comments
MSLD MODEL NO.	Varian model 979
MSLD SERIAL NO.	LLD80035
CALIBRATED LEAK ID	Model SD-8D; S/N 6205
CALBRATED LEAK VALUE SCC/S	1.88 x E-8

TEST RESULTS: No measurable leak detected. Sensitivity 1.5E-10

COMMENTS: **Allowable leak rate: No leak detectable on the most sensitive scale of a Helium Mass Spectrometer Leak Detector with a minimum sensitivity of $2x10^{-10}$ atm-CC/sec for helium.**

DATE	**9/19/07**	**TEST PERFORMED BY**	**Jack Ditta**

Advanced Energy Systems, Inc.
Leak Test Report

TEST REPORT NUMBER (1)	1302-TR –sn-3
TEST PLAN NUMBER (2)	AES-ENG-0001
PROJECT NAME	GC1302
TEST ARTICLE PART NUMBER	1302G00001-1
TEST ARTICLE DESCRIPTION	1.3 GHz Single Cell S/C Cavity
TEST ARTICLE SERIAL NUMBER	TE1AES003
ALLOWABLE LEAK RATE	See Comments
MSLD MODEL NO.	Varian model 979
MSLD SERIAL NO.	LLD80035
CALIBRATED LEAK ID	Model SD-8D; S/N 6205
CALBRATED LEAK VALUE SCC/S	1.88 x E-8

TEST RESULTS: No measurable leak detected. Sensitivity 2.4E-10

COMMENTS: **Allowable leak rate: No leak detectable on the most sensitive scale of a Helium Mass Spectrometer Leak Detector with a minimum sensitivity of $2x10^{-10}$ atm-CC/sec for helium.**

DATE	**9/19/07**	**TEST PERFORMED BY**	**Jack Ditta**

Advanced Energy Systems, Inc.
Leak Test Report

TEST REPORT NUMBER (1)	1302-TR –sn-4
TEST PLAN NUMBER (2)	AES-ENG-0001
PROJECT NAME	GC1302
TEST ARTICLE PART NUMBER	1302G00001-1
TEST ARTICLE DESCRIPTION	1.3 GHz Single Cell S/C Cavity
TEST ARTICLE SERIAL NUMBER	TE1AES004
ALLOWABLE LEAK RATE	See Comments
MSLD MODEL NO.	Varian model 979
MSLD SERIAL NO.	LLD80035
CALIBRATED LEAK ID	Model SD-8D; S/N 6205
CALBRATED LEAK VALUE SCC/S	1.88 x E-8

TEST RESULTS: No measurable leak detected. Sensitivity 1.5E-10

COMMENTS: **Allowable leak rate: No leak detectable on the most sensitive scale of a Helium Mass Spectrometer Leak Detector with a minimum sensitivity of $2x10^{-10}$ atm-CC/sec for helium.**

DATE	**9/19/07**	**TEST PERFORMED BY**	**Jack Ditta**

Advanced Energy Systems, Inc.
Leak Test Report

TEST REPORT NUMBER (1)	1302-TR –sn-5
TEST PLAN NUMBER (2)	AES-ENG-0001
PROJECT NAME	GC1302
TEST ARTICLE PART NUMBER	1302G00001-1
TEST ARTICLE DESCRIPTION	1.3 GHz Single Cell S/C Cavity
TEST ARTICLE SERIAL NUMBER	TE1AES005
ALLOWABLE LEAK RATE	See Comments
MSLD MODEL NO.	Varian model 979
MSLD SERIAL NO.	LLD80035
CALIBRATED LEAK ID	Model SD-8D; S/N 6205
CALBRATED LEAK VALUE SCC/S	1.88 x E-8

TEST RESULTS: No measurable leak detected. Sensitivity 1.8E-10

COMMENTS: **Allowable leak rate: No leak detectable on the most sensitive scale of a Helium Mass Spectrometer Leak Detector with a minimum sensitivity of $2x10^{-10}$ atm-CC/sec for helium.**

DATE	**9/19/07**	**TEST PERFORMED BY**	**Jack Ditta**

Advanced Energy Systems, Inc.
Leak Test Report

TEST REPORT NUMBER (1)	1302-TR –sn-6
TEST PLAN NUMBER (2)	AES-ENG-0001
PROJECT NAME	GC1302
TEST ARTICLE PART NUMBER	1302G00001-1
TEST ARTICLE DESCRIPTION	1.3 GHz Single Cell S/C Cavity
TEST ARTICLE SERIAL NUMBER	TE1AES006
ALLOWABLE LEAK RATE	See Comments
MSLD MODEL NO.	Varian model 979
MSLD SERIAL NO.	LLD80035
CALIBRATED LEAK ID	Model SD-8D; S/N 6205
CALBRATED LEAK VALUE SCC/S	1.88 x E-8

TEST RESULTS: No measurable leak detected. Sensitivity 1.5E-10

COMMENTS: **Allowable leak rate: No leak detectable on the most sensitive scale of a Helium Mass Spectrometer Leak Detector with a minimum sensitivity of $2x10^{-10}$ atm-CC/sec for helium.**

DATE	**9/19/07**	**TEST PERFORMED BY**	**Jack Ditta**

Section 5.0

RF Test Plans and Reports

RF Measurement and Test Plan

M. Cole

September 6, 2007

1302-ENG-0004

Post Weld Measurement of Frequencies for Single Cell FNAL Cavities

Test Objective:

Measure the RF resonant frequencies of the fundamental mode for single cell FNAL Cavities immediately following welding.

Test Method and Procedure:

1) Fixturing and Setup: The cavity will be setup in the cavity test fixture for RF measurement.
2) RF Frequency Measurements: RF probes will be inserted in the measuring fixture and connected to the network analyzer. Probe penetration will be kept to a minimum to avoid perturbing the cavity frequency. Frequencies will be measured using an S21 measurement with the network analyzer.
3) Frequency Correction: Using the LANL code ConvertF.EXE the measured frequencies will be corrected for temperature and the dielectric constant of the air in the cell. The frequencies will be corrected to a value at 20C with no air in the cell.

Anticipated Test Results:

The results of the tests will be the fundamental mode frequency for each of the single cell cavities.

RF Measurement and Test Report
M. Cole
September 13, 2007
1302-ENG-0007
Post Weld Measurement of Frequencies for Single Cell FNAL Cavities

We have completed the Fundamental Mode RF frequency measurements on the six FNAL Single Cell Cavities. The measurements where performed as per the test plan "1302-ENG-0004 Post Weld Frequency Test Plan".

The frequency results are shown in the table below. The table shows the measured lab frequency along with the test conditions. The frequencies are then corrected to a standard 20C Vac (no air in cell) frequency as well as 2K Vac.

Cavity ID	Test Date	Bench Measured Frequency (MHz)	Cavity Temp (C)	Air T (C)	RH (%)	BP (inHg)	20C No Air Frequency (MHz)	2K No Air Frequency (MHz)
TE1AES001	9/7/2007	1300.343	21.9	21.5	51.0	30.33	1300.785	1302.689
TE1AES002	9/10/2007	1300.190	20.6	21.5	50.0	30.06	1300.617	1302.520
TE1AES003	9/11/2007	1299.886	21.4	22.0	51.0	30.00	1300.321	1302.224
TE1AES004	9/11/2007	1299.781	21.0	21.5	50.0	29.97	1300.209	1302.112
TE1AES005	9/12/2007	1299.007	22.3	22.0	50.0	29.71	1299.446	1301.348
TE1AES006	9/13/2007	1301.500	20.7	21.0	45.0	30.21	1301.921	1303.827

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