Testing of the Broadband HOM Absorber*

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A higher order mode absorber is needed to remove higher order mode power disposed by the beam, and to damp these modes sufficiently. Within the HOM absorber, an assortment of tiles are used to absorb the higher order modes over a wide frequency range. In the Cornell ERL, these tiles have to be operated at 77K to simplify thermal transition from the cavities to the absorbers. Brazed ferrite tiles were tested using a heat plate and infrared camera, to find any defects in the brazing of the tiles. A new procedure for testing was then developed. Each tile sample was thermocycled from room temperature to 77K, to simulate thermal stress during cool down. During this process the thermal expansion rates were recorded and documented. These experiments will be used in finding the optimal brazing recipe for the absorber tiles used in the Cornell ERL Higher Order Mode absorber.

I. INTRODUCTION

The Higher Order Mode (HOM) absorber is a system used in conjunction with superconducting RF cavities. Figure 1 shows an HOM absorber and its components. For the proposed Energy Recovery Linac (ERL) at Cornell University [1, 2], an HOM load is detrimental to the projects success. The HOM absorber is used to remove HOM's from the cavities as efficiently as possible [3]. HOM's in a cavity can create beam instability, and significant energy losses. With the design of the cavities, the HOM's propagate in the beam pipes at the ends of the superconducting cavities. The HOM absorbers are placed in the beam pipes between the cavities to intercept the HOM power at a well defined location. The absorbers are operated at about 80K. A higher temperature would complicate the thermal transition to the cavities at 2K, whereas a lower temperature would significantly reduce the efficiency of the power interception. Ferrite has shown to be a excellent absorber of RF waves at certain frequencies, and ceradyne is used for others [4]. The absorber tiles are brazed to a metal plate, and then installed to the HOM absorber, see Figure 1. Each of these absorbing tiles need to be to exact specifications and quality, and to be tested for imperfections prior to use in the absorber. A procedure was developed to test, and analyze each tile, in a timely and precise fashion.

The physical characteristics of the materials used proved to be of high importance. Each absorbing tile needs to with stand high and low temperatures. Each tile must also be able to survive rapid temperature changes. Thermocycling was used to examine the reactions of the material combinations used in the tiles, brazes, and plates. The goal of this experiment is to decide which material combinations work best together.

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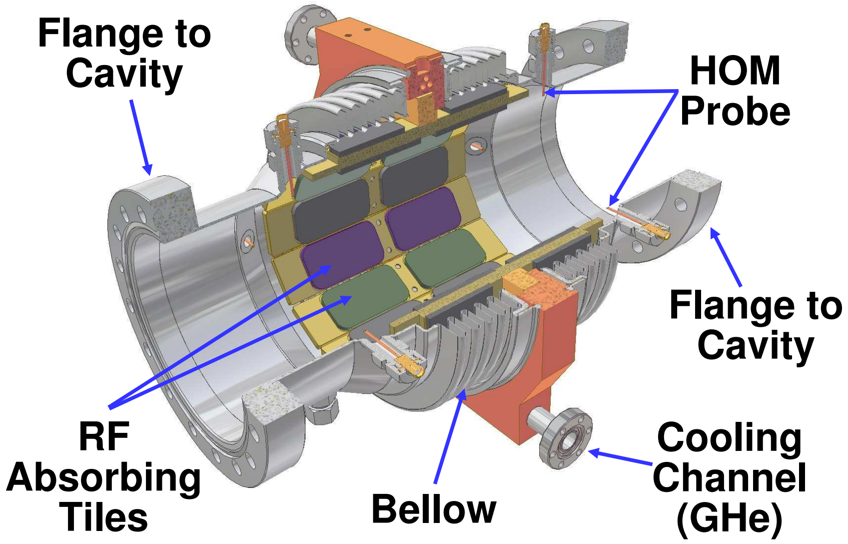

FIG. 1: HOM Absorber

II. A NEW HEAT TESTING PROCEDURE

Each absorbing tile must be flawless prior to being installed into the load. Some tiles may have defects in the brazing to the plate. Others may have small fractures in the material itself. Each tile must be examined in such a way as to see these defects readily. The process previously used is the Radio Frequency test. A tile is put in the path of a standing RF wave and watched for heating/cooling irregularities. This test proved time consuming, and only worked if the material is lossy at the given RF frequency, so a replacement was needed.

Use of a heat plate as opposed to an RF wave would solve the lengthy testing time dilemma. The set-up is illustrated in Figure 2 . The procedure is as follows:

Thermo Testing Procedure For Ferrite Tiles Using Heat-Plate

- *Use of a heat-plate as opposed to RF waves is much more efficient when testing multiple tiles. A hot plate with smooth surface is ideal. If surface is not level, a level piece of conducting metal over the heat-plate is also efficient. Begin by stabilizing the heat-plate temperature at 73-77° Celsius. With each trial the plate will drop in temperature, so be sure to allow for stabilization time. Mount the Infrared camera close enough for a smooth and timely transition from heat-plate to viewing area. Provide sufficient heat shielding between camera lens and heat-plate. A mounting surface is needed for the viewing area. Aluminum blocks, (or any other conductive metal.) should be placed so as to quickly maneuver tiles from heat-plate to viewing area.*

- *Place each tile ferrite down on the heat-plate for 7 seconds. Quickly remove and place on viewing mounts. At 5 seconds after removal from heat-plate, capture image. This time frame allows for optimal viewing of defects (if any) in the sample. Between each sample test, a cool down period for the tiles is needed of 7-12 minutes, depending on environmental conditions. A tile at room temperature prior to testing is recommended*

FIG. 2: Testing Setup. Front: heat plate, Middle: tile sample, Back: infrared camera

for optimal results. When testing several samples, one can begin another while others are cooling back to room temperature.

- *If the Elkonite plate is warped, the ferrite tiles may not touch the heat surface evenly. If this occurs, each tile must be treated as a separate trial. When placing sample for viewing, note which tile was being tested. The location of the ferrite tile may affect its cool down, and should be taken into consideration.*
- *A series of three trials is recommended for each tile to clearly show defects. If a flaw is visible, one needs to confirm with consistent images, showing the same results.*
- *Software provided with the Infrared camera can be used in analysis. Defects in the tiles are more visible through the software, rather than the camera display itself. Specific location temperature readings are also available in the software program.*

Each test was then documented. The documenting format is meant to be a hard copy, quick reference tool. An example is given in Figure 3.

The software included with the infrared camera, IRPro, is used to examine the resulting images. An example of a processed IR picture is given in Figure 3. Various color schemes can be chosen to examine an image. The scheme shown in Figure 3 shows high heat areas as white, and low heat areas as black. Along with imaging, the software allows the user

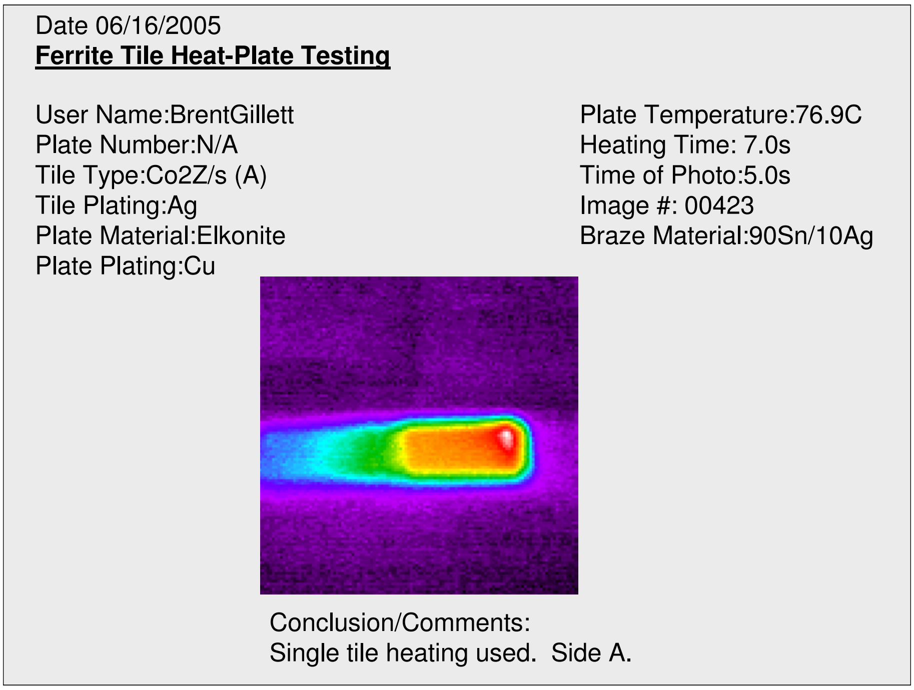

FIG. 3: Testing template

to find exact temperature readings at specific locations on the image. This can be used to determine how drastic the temperature differences are, should one find a defective area on a sample.

The tile samples that were tested include the Co2Z/s, TT2-111R/s, tiles which are ferrite with silver plating, and Co2Z and TT2-111R which are ferrites with Cu/CuTi/Ti three level plating. All samples tested were brazed using 90%Sn/10%Ag braze onto Elkonite plates. The Co2Z/s tile, as shown in Figure 3 showed serious defects in the brazing after analysis of the infrared image.

III. THERMOCYCLING

Each tile sample was thermocycled up to ten times each. Going from room temperature, 300K, to liquid nitrogen at 77K, and back to room temperature to complete one cycle. The samples of special interest were the ones found to be defective in the heat testing. The results can be found in Figure 4.

Each tile sample was tested for ten cycles, or until separation from plate. The samples were allowed time to raise their temperature back to room temperature between cycles to assure consistent findings. The silver plated Co2Z/s and TT2-111R/s tiles failed the thermo cycling tests within ten cycles. The TT2-111R and Co2Z plates showed no visible changes after the full ten cycles.

By thermocycling the tiles, we are testing their integrity on very extreme scales. The tiles will be cooled down to 77K, but will not experience such rapid temperature changes in the absorber. These tests are to prove that the samples are more than capable of withstanding such conditions. If a sample has passed the thermocycling procedure, and the subsequent heat plate test, it is a promising sample for use in the load.

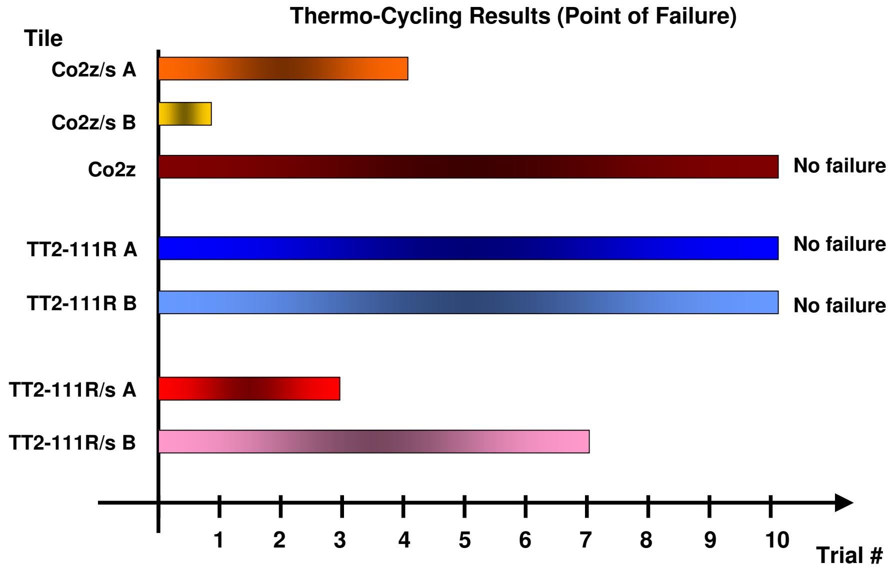

FIG. 4: Thermocycling Results For Different Tile Types. A and B used to designate two tiles per plate. All samples use Sn/Ag braze, and Elkonite plates

Shown in Figure 5 is a picture taken after one thermocycle of the Co2Z/s sample. In this sample the tile separated from the Elkonite tile due to poor brazing. Pockets, or voids can be seen, where the braze was not in contact with the tile. During thermocycling, the tile and Elkonite plate contracted at slightly different rates. With the braze not in contact throughout the surface of the tile, the bond was weakened and eventually failed.

The results of the procedure showed that the three-layer plating of the tiles was ideal. Each silver plated sample (those tiles denoted "/s") failed the thermocycling. The tiles that were plated with the Cu/CuTi/Ti survived all ten cycles.

IV. THERMAL EXPANSION

Thermal expansion coefficients are needed to choose plate materials which have closely matching thermal expansion rates to the tiles. Similar expansion properties are important for successful brazing and cool down to 77K. Six types of samples, the Co2Z/s, TT2-111R, Ceradyne, Elkonite, Molybdenum, and Tungsten , were all examined. The tiles, plates and brazes need to act as one unit during extreme changes in temperature. A large difference in expansion rates would result in forces, and would prove detrimental to the system. Figure 6 shows the measured normalized integral thermal expansion from 77K to room temperature.:$\Delta L/L_0 = L(300\text{ K}) - L(77\text{ K})/L_0$

The Co2Z tile will be best brazed to an Elkonite plate since the thermal expansion rates are very similar. The TT2-111R tile has shown effective in combination with the Elkonite, but thermal expansion results show that Molybdenum would also be a good match. A Ceradyne tile will need to be brazed to a Molybdenum or Tungsten plate. The Ceradyne thermal expansion rate is roughly half that of Molybdenum, as opposed to 1/4 that of

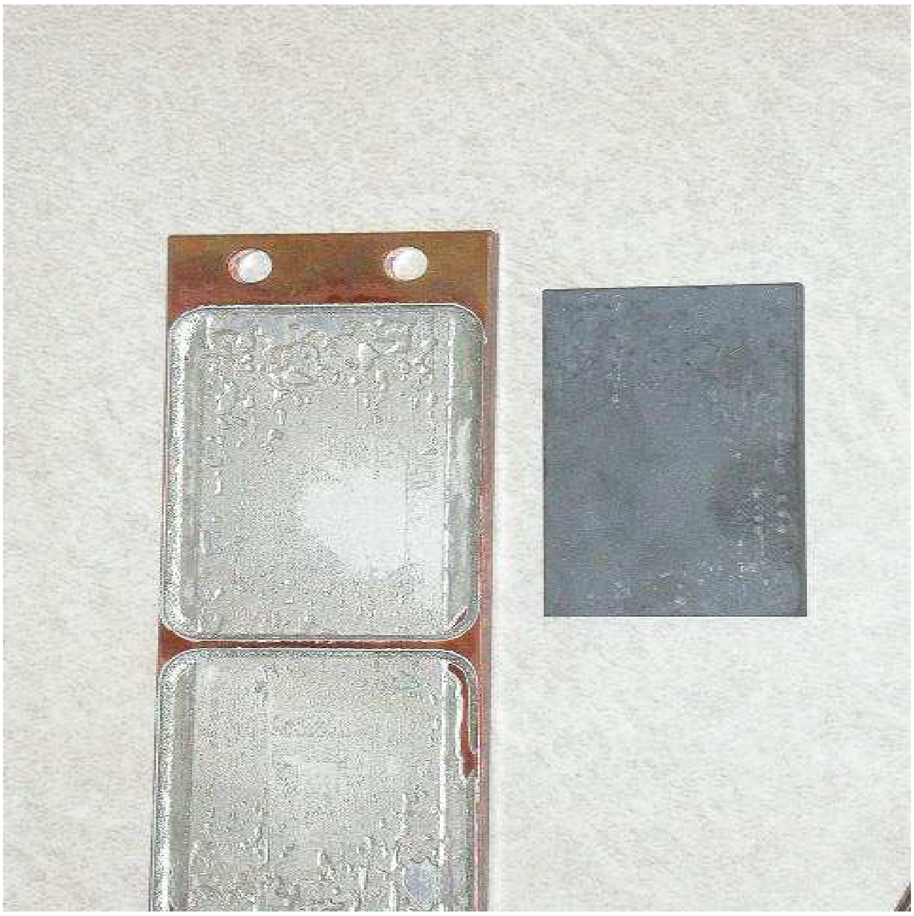

FIG. 5: Braze Failure

Elkonite. A new plate material may be needed for the Ceradyne sample.

V. CONCLUSION

The procedure developed for heat testing the tile samples has proved effective. Though some samples may require several trials, it is an efficient method to analyze the integrity of the components. The tile samples that were tested were brazed to Elkonite plates using 90% Sn and 10% Ag braze. This recipe proved effective in the Co2Z and TT2-111R samples. Each of these samples passed both heat testing, and thermocycling procedures. The silver plated tiles did not pass the thermocycling procedure, and therefore rendering Silver as an insufficient treatment for the tiles.

The thermal expansion analysis gave insight as to what materials will be most compatible for use in the absorber. Sample testing concluded that Co2Z and TT2-111R are good matches with the Elkonite plate. Though not tested, one can conclude that the two samples would also work well with Molybdenum and Tungsten. The Ceradyne tile will most likely work well with the Molybdenum or Tungsten, but not so much with Elkonite, due to larger differences in expansion rates.

The work completed so far is the starting point for further ventures. The data taken by myself and others must be carefully considered before the final assembly in any absorber.

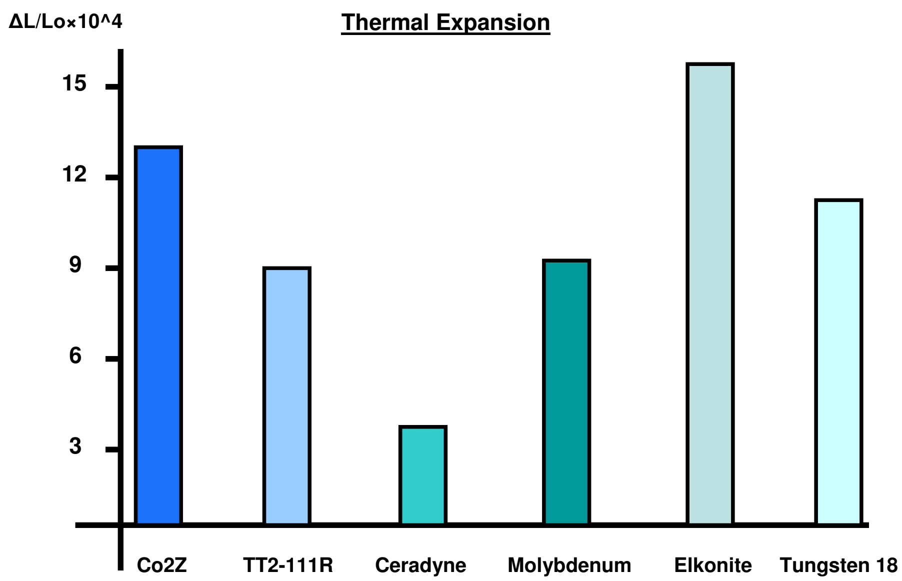

FIG. 6: Thermal Expansion Results

The efforts of this project will benefit many facilities including the proposed ERL here at Cornell University.

VI. ACKNOWLEDGMENTS

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[1] Study for a proposed phase IERL Synchrotron Light Source at Cornell University, ed. by S. Gruner and M. Tigner, CHESS Tech. memo 01-003, (July 2001).

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