HIGH POWER RF TESTS OF 433 MHZ SINGLE-CELL ACCELERATOR CAVITIES AND ASSOCIATED FEED SYSTEM*

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Abstract.

We describe an accelerator module consisting of four single-cell accelerator cavities powered through WR1800 waveguide by a single Thomson-CSF Model 2120 klystron at 433 MHz, for use in the Boeing Modular Components Technology Development (MCTD) electron linac. We discuss planned peak and average accelerating field limitation tests and report on the status of the testing program.

Introduction.

The objective of the Boeing MCTD electron linac program is to develop and demonstrate high brightness, high average power RF electron linac components. The specific parameters of the MCTD linac (in its initial configuration) appear in Table 1.

Frequency	433.3	MHz
Beam energy	10.	MeV
Beam current	.5	A
Number of cavities/klystron	4	
Number of klystrons	2	
Klystron peak output power	4.	MW
Klystron average output power	1.	MW
Accelerating Gradient	1.25	MV/cell

Table 1. Initial parameters of MCTD linac.

The RF feed system (Fig. 1) will allow four cavities to be driven by a single klystron with no circulator required to protect the klystron from power reflected by the cavities. The cavities are arranged in pairs, with the second cavity 270 degrees in phase behind the first. When the pair is powered through a quadrature hybrid splitter, and the difference in path lengths between the hybrid and cavities is suitably set, power reflected from the cavities will be diverted through the fourth port of the hybrid and into a load. The power from the klystron will be split between two such pairs, with an adjustable waveguide phase shifter in one leg to allow the fields of one pair to be set at any desired phase relative to the other pair.

Accelerating cavities for MCTD.

The accelerating cavities are loosely modeled on the PETRA cavity geometry (Fig. 2). They have a shunt impedance R of 13 Mohm, defined in terms of the accelerating voltage V (including transit time factor) and cavity wall losses P_c by $R = V^2/P_c$. The measured unloaded Q is 40,000 (Fig. 3). At an operating gradient of 1.25 MV/cavity, the losses will be about 120 kW/cavity peak. With the accelerating gradient and average beam current in Table 1, the coupling coefficient should be about 6.2 for an optimal match. The coupling coefficient realized in the cavities to be tested is slightly lower, about 5.6. (At 0.5 A average beam current, the reflected power will still be only 2 kW.)

CW cavities operating at 1.25 MV/cavity would reject 120 kW of heat. Such a high thermal load is expected to result in appreciable detuning of the cavity, in spite of an aggressive cooling design. Finite element numerical modeling of the thermal distortion indicates that the outside of the cavity will bulge outward, while the end plates bow inward, bringing the nose cones closer together. Both these effects act to reduce the frequency of the cavity, so we have fitted the cavities with generous plunger tuners which have approximately 1 MHz tuning range, most of which will be in the upward direction. Adapted from the PEP cavity tuner design, the MCTD tuners are water-cooled, with graphite blocks to damp RF resonances in the coaxial structure comprising the plunger stem and vacuum bellows.

The cavities are evacuated through a roughly circular port in the outside wall opposite the coupling aperture. Two copper bars containing cooling water channels screen the pumping port. An additional screen will be located at the pump flange. The pumps are 4-inch cryopumps, which can be isolated from the cavity by a gate valve.

A loop probe is placed on the outer wall opposite the tuner. The penetration and orientation of this probe are chosen to provide a signal about 50 dB below the forward power level when there is no beam in the cavity. The signal from this probe will be used for a cavity tuning indication and for stabilization of the cavity fields.

High power cavity tests.

Gradients in high duty factor cavities can be limited by either peak or average field. We will test the peak and average field limitations of a single pair of cavities driven by a single klystron through a quadrature hybrid. The klystron will be capable of producing 4 MW peak pulses at up to 25% duty factor. There will be no electron beam present for these tests.

The cavity code URMEL shows that the cavity has a strongly enhanced electric field on the nose cone, so that the peak electric field is 13 /m times the accelerating voltage. The Kilpatrick limit on electric field at 433 MHz is about 21 MV/m, corresponding to an accelerating voltage of 1.6 MV. The forward cavity power P_f in a cavity with no beam loading is given by

$$P_f = \frac{(1+B)^2}{4\,B} P_c ,$$

where B is the coupling coefficient, so that the 2 MW peak forward power available from the klystron can produce approximately 1 MW wall power dissipation, peak field limitations in the cavity permitting. This would corre-

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spond to an accelerating voltage of 3.6 MV per cavity, or over twice the Kilpatrick limit. We therefore expect there will be sufficient peak klystron power to explore the peak field limitations of the cavity.

Although the MCTD accelerator will be limited to 25% duty factor by the RF power supply, we would like to demonstrate that accelerator cavities can be operated at the thermal loads encountered in CW operation. Since maximum duty factor is 0.25, the peak wall loss power must be four times the CW value in order to achieve the same average power, implying field levels of twice the nominal CW fields, or 2.5 MV/cavity. This is roughly half again the Kilpatrick limit, and it is questionable whether this gradient can be achieved for the long (10 ms) pulses available.

Even if the Kilpatrick limit cannot be exceeded, the peak wall loss power will be nearly 200 kW, for a 50 kW average. We expect this will suffice to give a good indication of tuning sensitivity to average power dissipation. An array of thermocouples and strain guages in the cavity (Fig. 4) will allow us to plot thermal and distortion maps which can be compared with the finite element model results.

Status of test program.

As of early March, 1989, the klystron high voltage power supply, series regulator, and associated crowbar circuitry operate reliably. The klystron has been tested up to 4 MW peak. and is being conditioned to high average power. The waveguide load system used to test the klystron will soon be dismantled and the waveguide feed system for the cavity pair installed. The cavities are under vacuum, and are being baked out at 150 C. We expect to bring the cavities under RF power before the end of March, 1989.

Acknowledgements.

We would like to acknowledge the efforts of the Boeing Free Electron Laser Design Group staff and the Boeing Physical Sciences Research Center machine shop personnel, who designed and built the accelerator cavities. We are further indebted to the technicians of the Boeing FEL program, who have mounted the experiment on a very ambitious schedule.

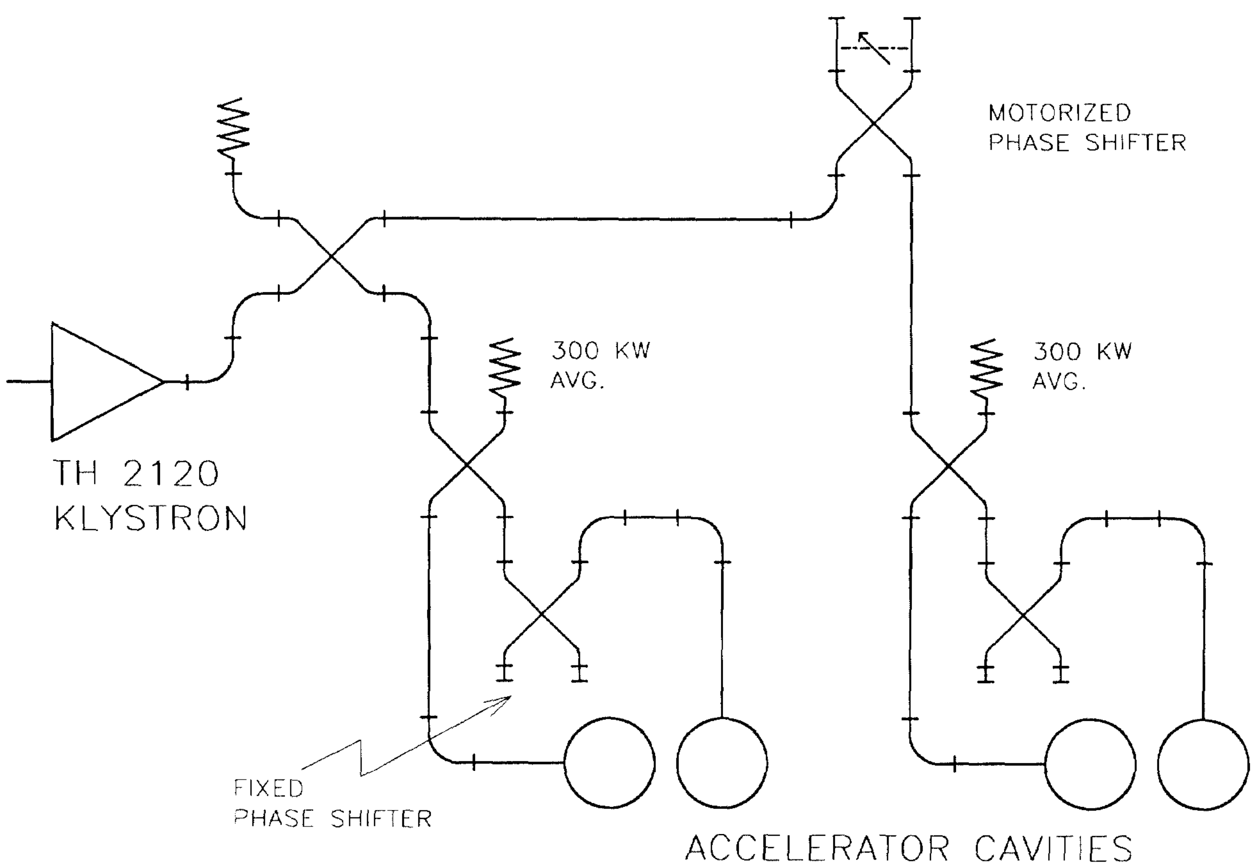

Figure 1. Schematic of RF feed system for MCTD accelerator module.

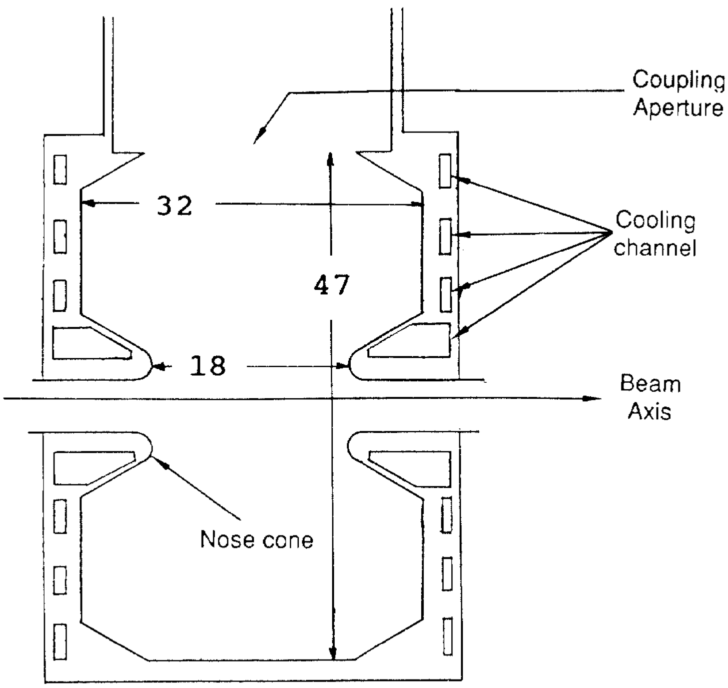

Figure 2. Cross section of MCTD cavity showing important dimensions (cm).

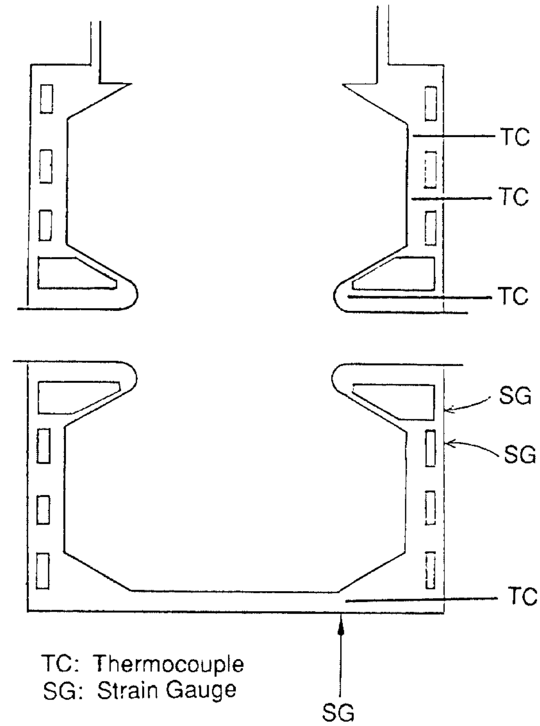

Figure 4. Deployment of some of the thermocouples and strain gauges to be used in MCTD cavity high power test.

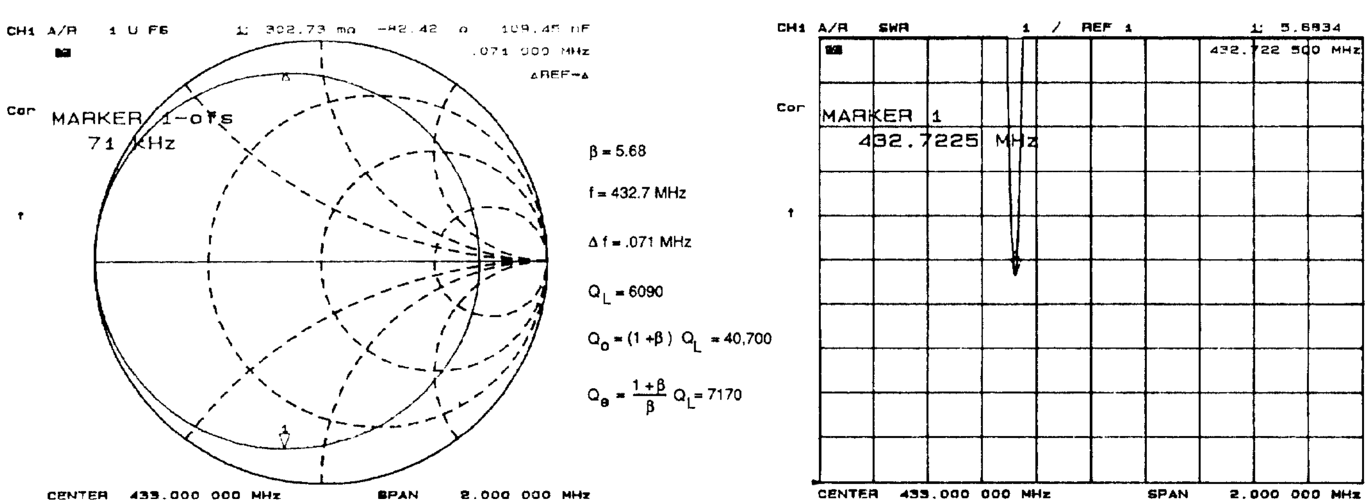

Figure 3. Network analyzer traces for finished MCTD cavity, from which a coupling coefficient of 5.6 and Q_o of 40,000 can be determined.