TuP40

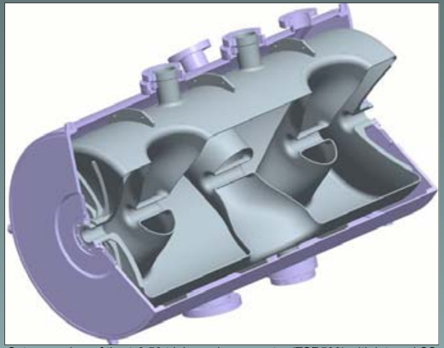
Development of Spoke Cavities for RIA

K.W. Shepard, M.P. Kelly, J.D. Fuerst, M. Kedzie, Z. Conway
Argonne National Laboratory, Argonne, IL 60439, USA

ANL Physics Division

ABSTRACT

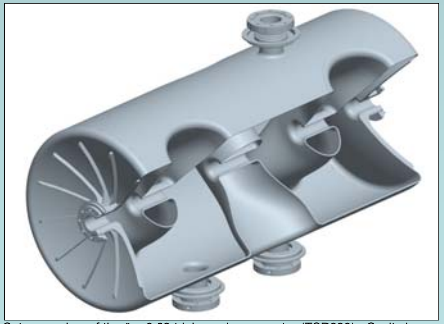
This paper reports the development status of 345 MHz, 4 cm beam aperture, three-spoke-loaded TEM-class superconducting cavities for particle velocities 0.4 < v/c < 0.8. Two prototype cavities have been operated cw at 4.2 K at accelerating gradients above 10 MV/m. Results of cold tests, including mechanical properties and microphonic behavior, are presented.



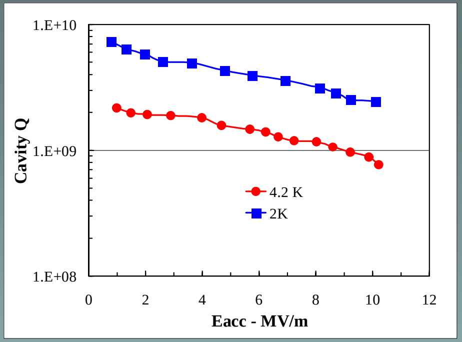
Cut-away view of the β 0.50 triple-spoke resonator (TSR500) with integral SS LHe vessel of length 83 cm and dia. 47 cm. Beam aperture is 4 cm, interior length is 67 cm. Two 5 cm dia. coupling ports and a helium port can be seen at the top of the cavity. Also visible are several niobium ribs welded to the exterior of the niobium shell for mechanical stiffening. The SS jacket is joined to the niobium shell at the beam and coupling ports using a coaxial braze joint made with pure copper in a vacuum furnace.

Table I: Electromagnetic properties

	TSR500	TSR630
Frequency [MHz]	345	345
β_{GEOM}	0.50	0.63
L (3βλ/2) [cm]	65.2	82
QR_s (G) [Ω]	88.5	93
R/Q [Ω]	492	549
Below for E_{acc} = 1.0 MV/m		
RF Energy [J]	0.398	0.565
B_{PEAK} [G]	86	90
E_{PEAK} [MV/m]	2.79	2.93



Cut-away view of the β ≅ 0.63 triple-spoke resonator (TSR630). Cavity beam aperture is 4 cm, transverse diameter is 45.8 cm, and interior length is 85 cm. Coupling ports are 5 cm ID and allow access for high pressure water rinse.



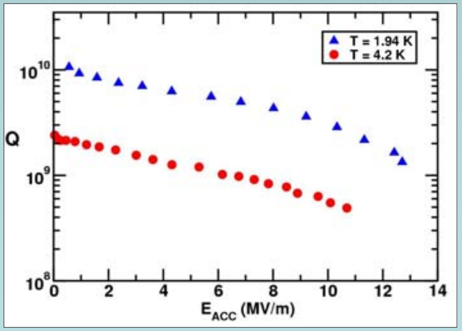
TSR500 cavity Q as a function of accelerating gradient.

DESIGN

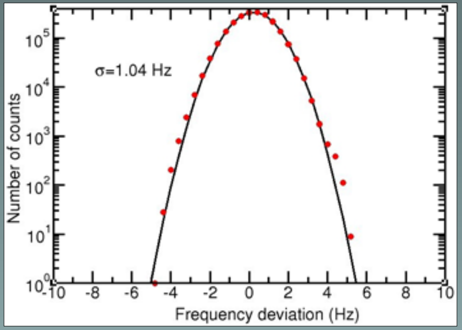
The designs were constrained to provide a 345 MHz three-spoke-loaded cavity of β_{GEOM} = 0.5 and 0.6 with a 4 cm beam aperture. The design priorities were to minimize the peak surface electric and magnetic field and to provide good mechanical stability. The electromagnetic proper-ties were numerically modeled using CST Microwave Studio, Version 5. The mechanical properties were modeled using Pro-E and ANSYS.

The spoke elements are elliptical in cross section in order to minimize the peak surface fields while accommodating a 4 cm beam aperture. The major axis of the ellipse is normal to the beam axis in the center of each spoke to minimize the surface electric field and maximize the beam aperture. The major axis is parallel to the beam axis in the region of the spokes near the outer cylindrical diameter of the cavity in order to minimize the peak surface magnetic field.

Table I details the electromagnetic properties for the accelerating rf eigenmode. The accelerating gradient E_{ACC} in Table I is referenced to an effective length l_{eff} = 62 cm, where we have followed the suggestion of Delayen in taking l_{eff} = $n\cdot\beta_{GEOM}\cdot\lambda/2$, where n is the number of spokes, λ the free-space wavelength at the frequency of the accelerating mode, and β_{GEOM} the reduced velocity at the peak of the transit-time function.



TSR630 cavity Q as a function of accelerating gradient.

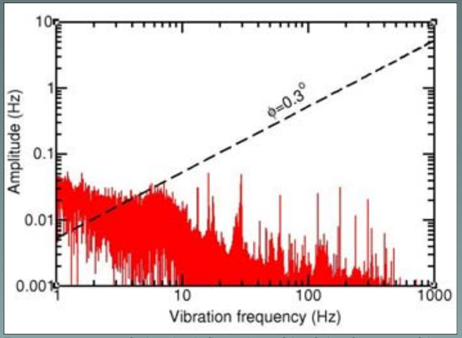


Distribution of frequency errors measured at EACC=9.7 MV/m. The distribution is Gaussian over 5 orders of magnitude, with an RMS fluctuation of 1.1 Hz

TUNING AND PROCESSING

Tuning and preliminary surface processing were performed when the three major sub-assemblies of the cavity were complete: namely, the two spherical end-walls, complete with beam ports and support ribs, and the body of the cavity with coupling ports and all three spokes welded into the cylindrical housing. Tuning was accomplished by clamping the three sections together, using a thin layer of indium to join the sections, and the rf eigenfrequency was measured. The frequency was then brought to design value by machining to adjust the spacing between the end walls and spoke elements.

Prior to welding the three sections together, each was heavily electropolished, removing 150 – 200 microns of material to eliminate any damage caused by forming and machining. After EB welding the three niobium sections together, the SS helium jacket was clam-shelled into place and welded together. The niobium-SS braze transitions were then EB welded to the niobium stub to complete the assembly. The completed cavity was given a light (4-7 micron) buffered chemical polish (BCP). BCP was performed through the 2 inch ID coupling ports with the cavity in a horizontal position. It was found that a bubble could cling to an area roughly 10 cm in diameter at top of the housing, possibly preventing full chemical polishing of this portion of the surface. To ensure a complete BCP, the cavity was rotated 180 degrees and given a second 4-7 micron BCP.



Frequency spectrum of microphonic fluctuations of the rf eigenfrequency of the triple spoke cavity at 9.7 MV/m and 4.2K.

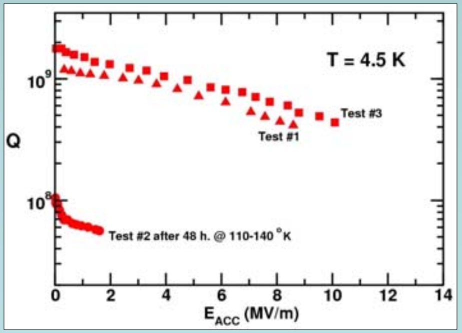
MECHANICAL PROPERTIES AND MICROPHONICS

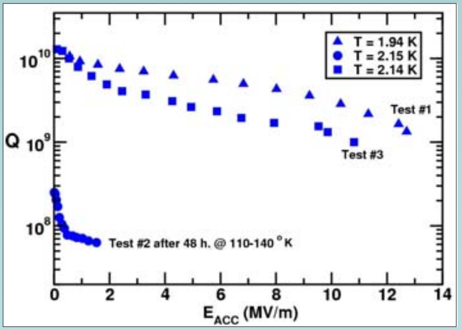
The Lorenz detuning was measured to be 7.3 Hz per (MV/m)². The shift of rf frequency caused by changing the pressure of helium in the cooling jacket was found to be -9.6 kHz/atm, very close to the value of -8 kHz/atm predicted by FEA analysis of the design.

The magnitude of the microphonics is sufficiently small, 1 Hz RMS, that a tuning window of a few tens of Herz would be adequate for phase-control.

HYDROGEN Q-DISEASE

The data show a greater increase of rf loss with increasing field level, so-called Q-slope, than we have observed for the other four types of cavity prototyped at ANL for the RIA driver. We tested the possibility that hydrogen Q-disease may be contributing to the rf loss by warming the cavity and holding it for 48 hours in the temperature range 110 K – 140 K. On then cooling the cavity to helium temperature, we found the cavity Q was severely degraded, by a factor of 10 to 100.





TSR630 cavity Q *vs.*EACC at 4.5 K (left) and 2 K (right) for a sequence of tests described in the text.