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NOTES ON 1969 PARTICLE ACCELERATOR CONFERENCE

(WASHINGTON D.C.)

AND VISIT TO RUTHERFORD LABORATORY

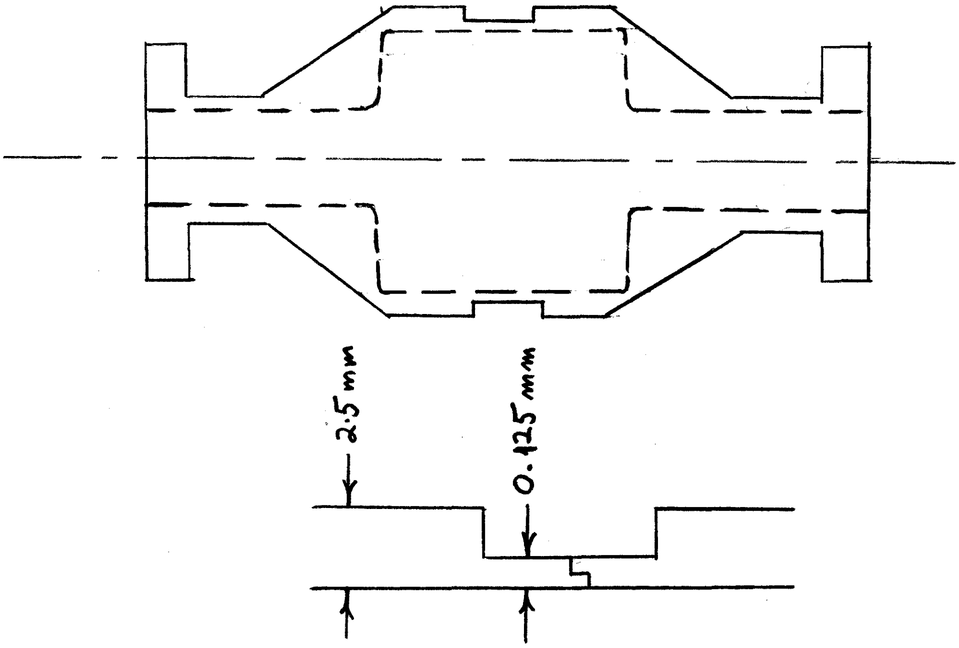
P. Wilson

A. INFORMATION OBTAINED AT PARTICLE ACCELERATOR CONFERENCE

1. Stanford electron beam welded cavity (J. Turneaure)

The TM_{010} cavity, 8.5 GHz, reactor grade niobium, is machined in two halves, polished with 0.3 μ aluminium, then electron beam welded (by Electro-Fusion Co., Menlo Park) in a vacuum of $\approx 10^{-5}$ Torr.

The cavity and joint look like :



The cavity was fired at 2100°C, $p < 10^{-9}$ Torr, for 15 hours.

Before firing :

$H_c = 15$ G

$Q_o = 1 \times 10^8$

After firing :

$H_c > 600$ G

$E_p = 40$ MV/m without loading

$Q = 2 \times 10^9$

At higher fields x-ray emission increased rapidly and Q decreased rapidly. J. Turneaure obtained an absolute maximum field with loading of about 45 MV/m. If the cavity was cycled between high and low power the Q at low power remained the same to within 3 %.

Other tests were made with this cavity, apparently after chemical polishing and re-firing.

a) $Q_o = 5 \times 10^9$ at low power. At $E_p \approx 3$ MV/m the Q decreased to 2.5×10^9 and fields were unstable. At higher fields Q decreased slowly to 5×10^8. J. Turneaure felt there was a small normal area in the cavity that somehow escaped processing during the high temperature treatment.

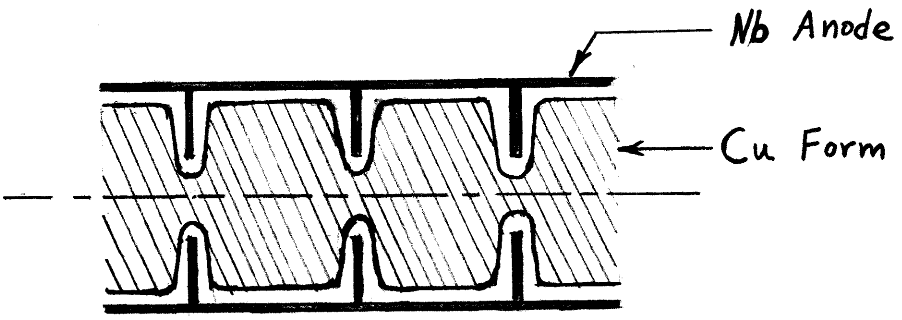
b) After polishing and firing again at low power a Q of 1×10^{10} was obtained. The vacuum window leaked so J. Turneaure could not make high power tests.

These results are slightly disturbing in that they indicate that the procedures for processing and firing the cavities is not yet completely routine, even for these small X-band cavities. The problem may increase in direct proportion to the surface area of structure which is being processed.

2. Stanford Electroformed Cavities (J. Turneaure)

For TE_{011} mode cavities, $Q_0 \approx 10^9 - 10^{10}$ independent of firing temperature as long as the temperature is above 1800° C. H_c increases from 100 G to above 400 G as firing temperature is raised above 1800° C. Chemical polishing after firing is probably a bad idea because no H_c greater than about 430 G has been obtained using this procedure.

Stanford has a contract with Linde* to study electroplating of disk-loaded structures. First attempts were not good because plating was poor in the disk regions. Next they will try a plating anode shaped as shown :



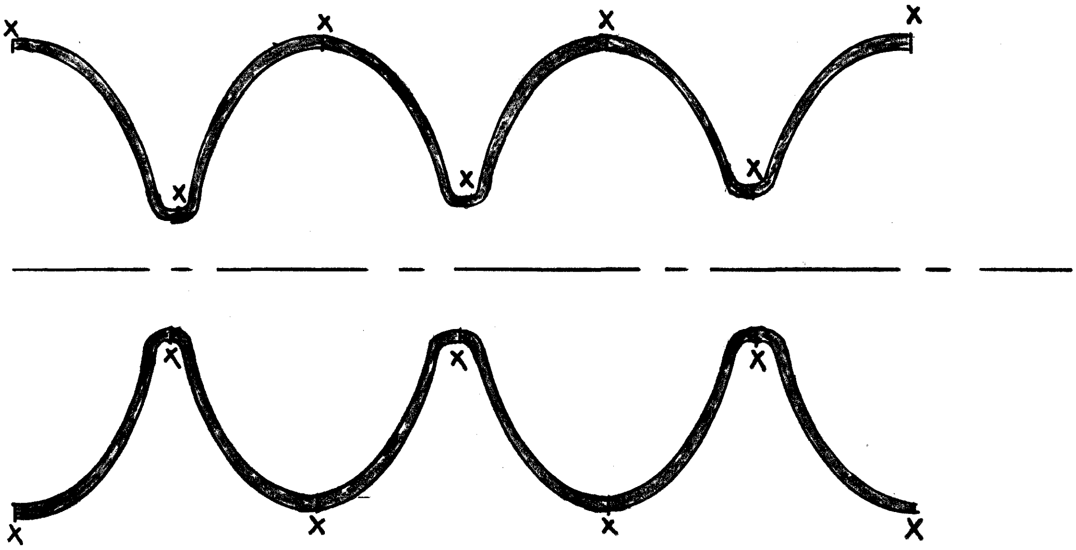
All Stanford niobium cavities are baked at 100° C on a UHV system at about 10^{-7} Torr, and then pinched off.

J. Turneaure thinks that carbon and silicon are the worst impurities in a niobium surface and therefore only oil-free vacuum systems should be used.

3. Stanford Hydroformed structure

At present Stanford plans to build their structure by hydroforming form sheet stock and electron beam welding the sub-assemblies together. The resulting structure looks like the following sketch. One complete period consists of five long cells with π-phase shift, coupled by reduced-length, unexcited, resonant coupling cells. The length of one period is therefore 5π.

*) Division of Union Carbide Co., U.S.A.



Welds are made at locations marked with an x. The structure has good thermal cooling at disks. Strengthening rods are needed and will be welded along the outer diameter. Even so, there is some worry that the structure will not be rigid enough against pressure variations in the helium bath.

Note that a structure could also be built by machining pieces from forgings and then electron beam welding together.

At the present time the use of solid niobium seems the most promising method for building an accelerator or separator structure. Film techniques may work if some way can be found to process the surface, e.g., by means of an electron beam.

4. Stanford Test Accelerator (E. Jones)

The lead-plated structure is about 50 cm long and operates at $\beta = 0.95$. Purpose of the test was to measure the properties of the system as an injector for the planned 500 ft superconducting accelerator. A gradient of 0.8 MV/ft and an accelerated current of 40 μ A were obtained. Stability was 10^{-3} or better, obtained by controlling the klystron output by a feedback loap. Energy spectrum was on the order of 1 %, agreeing with calculations. Bunch length was analyzed by means of a superconducting TM$_{010}$ off-axis cavity, the world's first superconducting "separator".

5. Stanford High Temperature Vacuum Furnace (J. Turneaure)

The hot zone is 28 cm in diameter by 90 cm long. The temperature will be 2300°C at 200 kW, and hopefully 2500°C at a maximum heating power of 1 MW, at a pressure of $10^{-9} - 10^{-10}$ Torr. Tungsten heaters and inner heat shields are used. J. Turneaure thinks a vacuum of 10^{-7} is probably O.K. in a completely oil-free system, but for such a system a better vacuum costs only a little more. The hot zone of the furnace is very expensive and poses a difficult design problem. Mr. J. Heatherington designed the Stanford furnace, and J. Turneaure recommends using him as a consultant on any large-scale furnace project. The furnace will be completed by July.

6. Structures

There was much interest at the conference in N-periodic structures, i.e., an extension of the bi-periodic concept to tri-periodic structures, quadruperiodic structures, and so on (see paper by Epztein at the 1968 Proton Linac Conference, and paper by Knapp, at this Conference). For example, fields in a normal structure for the $3\pi/4$ mode look like :

$$0 \leftarrow \quad \longrightarrow \; \leftarrow 0 \rightarrow \longleftarrow \quad \rightarrow 0$$

Here 0 represents an unexcited cavity. The unexcited cavities can be reduced in length, and by playing with the disk aperture diameter, the fields in the series of three excited cavities can be made equal. The resulting field is :

$$0 \leftarrow \quad \rightarrow \leftarrow 0 \rightarrow \leftarrow \quad \rightarrow 0$$

The structure now looks like three π -mode cells in a row, with each three-cell unit being coupled together by resonant coupling cells. The shunt impedance and ratio E_p/E_0 for such a structure approach that of the π-mode, while the sensitivity to tuning errors is intermediate between that of the $\pi/2$ and π modes. My guess is that detuning will cause a field droop (excited cavities) and a field rise (unexcited cavities):

$$\left(\frac{\delta E}{E}\right)_{\text{droop}} \approx \frac{2N_g(N_1 -1)^2}{k}\left(\frac{\delta\omega}{\omega}\right), \left(\frac{\delta E}{E}\right)_{\text{rise}} \approx \frac{4N_g}{k}\left(\frac{\delta\omega}{\omega}\right)$$

where N_1 is the number of cells in one group, N_g is the number of groups, k is the coupling constant and $\delta\omega/\omega$ the detuning in a cavity near the feed point.

B. VISIT TO RUTHERFORD LABORATORY (A. Carne)

At Rutherford they hope to build a 10 cavity, π mode separator structure operating at 1300 MHz. The hoped-for gradient is 4 MV/m in a lead-plated structure. A two structure system would give useful separation up to about 5 GeV.

At Rutherford they have mastered the art of lead plating over the past year and have reached a Q of 7×10^9 in a S-band TE_{011} mode cavity. They thus become the fifth laboratory to obtain Q's on the order of 10^{10}. They found that their Q increased by a large factor when they de-plated copper from their bath before attempting to plate a cavity. They plate or mask off all exposed copper surfaces and use other standard techniques developed at Stanford, CERN and elsewhere.

They are hoping to electron beam weld the π-mode cavities at the edges of the disks, but preliminary attempts have not been too successful. They are currently working on a lead-to-lead clamped joint. Measurements will be made soon on π-mode model structures at both 1300 MHz and 2850 MHz. They also plan to purchase a 25 W refrigerator in the near future.

At Rutherford they are building much of their electronics within the laboratory. For example, they are now constructing a 200 W power source using 40 W transistors at 433 MHz and step recovery diodes to frequency triple to 1300 MHz. They use home-made strip line couplers and phase shifters to combine the power output of 8 parallel power chains.

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