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LINAC FABRICATION PROBLEMS

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At this time, I would like to discuss any design or fabrication characteristics of our machine that you would like to have my opinion on.

GRAND: One of the things I would like to ask about is the tank fabrication itself. Did you get the same results as Brookhaven did with respect to quality of tolerances in the tanks?

LIVDAHL: I don't remember what the mechanical tolerances were on these tanks, but in fact, they didn't meet them by a considerable bit. No matter whom you go to, you can get into difficulty, if they aren't really conscientious about making required measurements, be they mechanical or otherwise, as they go along, and are not very careful to keep you informed as to the status of the fabrication of any of the particular units.

The cavity design consists of 11 tank sections which join together as shown in Fig. 1. One section pilots into the adjacent section and the rf contact between the sections is made through a contact spring ring which is laid into a groove in the copper of one section. In order to have sufficient copper for this groove, the inside of the cylinder is machined out to

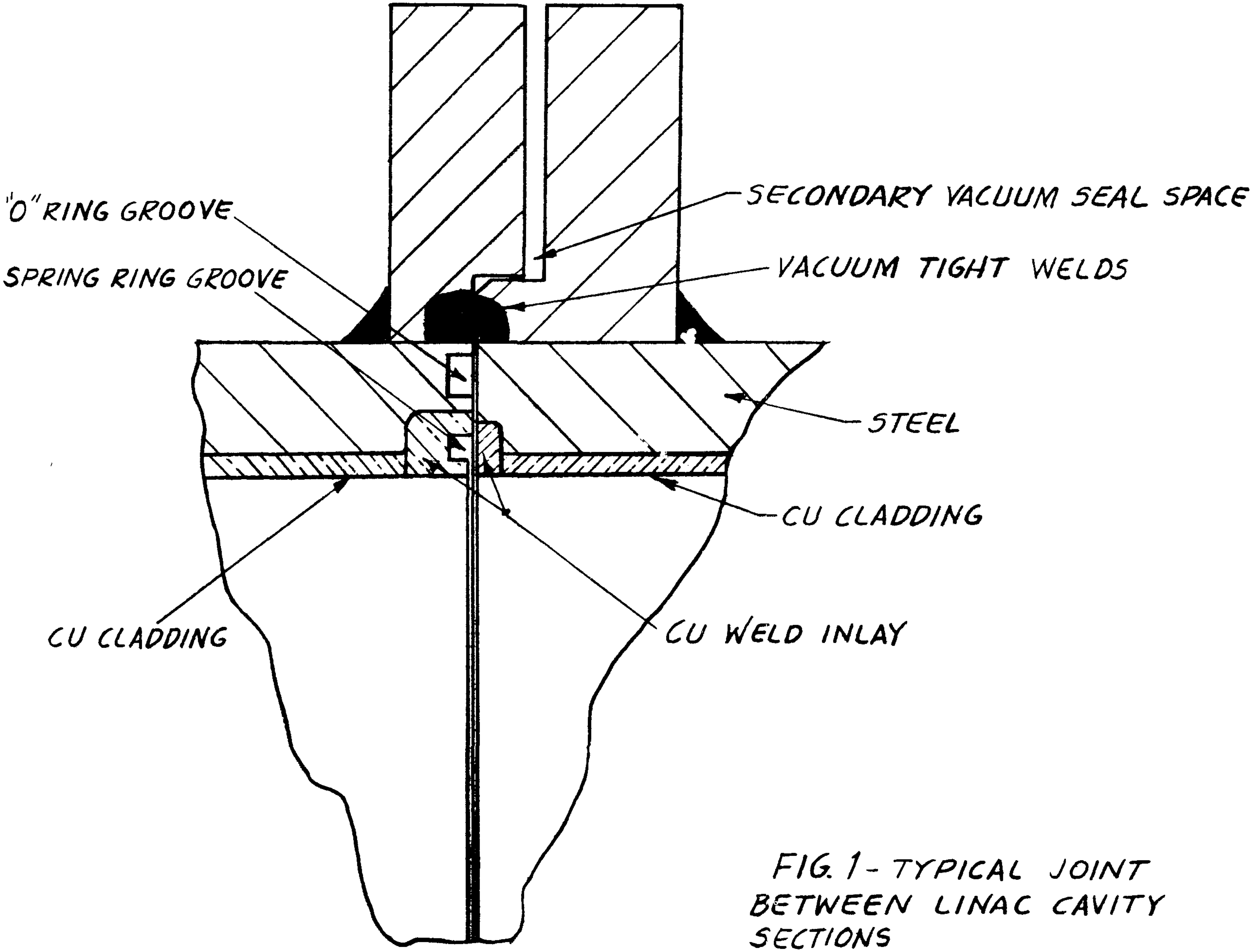

FIG. 1 - TYPICAL JOINT BETWEEN LINAC CAVITY SECTIONS

a depth of about 1/2 inch. This recess is then filled with copper weld to the original thickness of the copper-clad steel to have a thick copper end to work on. This is where the most important problems occurred.

The fabricator applied the copper weld and it was then found that the copper in this weld contained from 30 to 40% iron. This weld extends into the tank about an inch on each side, and we became worried about the conductivity of these areas. The metallurgists found the problem that the fabricator was having in his welding techniques, eliminated these problems, and now the iron concentration is down to about 5% in the welds.

Even more important than the conductivity was the fact that in repeatedly welding the flanges on and then cutting them off again, the ends of the tanks had become badly warped. This resulted in an increased volume of the cavity in these areas. We put rf diaphragms into the cavity in various places and measured the resonant frequency of different parts of the cavity. The frequency of the warped parts of the cavity was drastically changed. However, by this time the fabricator was behind on his delivery schedule by about 9 months or a year, and what could one do? You have to find a way of circumventing the problem, and do the best with what you have. As a consequence we have copper wedges bolted to the inside of the cavity that compensate for this additional volume of the tank at these positions.

Last spring, I decided to see if these wedges made any difference, and we had run enough beam by this time so that I thought that we could tell what the effect was. I took the wedges out and tried to retilt the gradient of the tank so it looked like the same tank tilt. Incidentally, these are all on the end of Tank 1, right where it affects you most. When I retilted the tank and started up, the best I could get was about 10% phase acceptance, instead of the normal 23% that we were used to without the buncher. I concluded that I had done the wrong thing, and put the wedges back in, readjusted the tilt back to where it was and it immediately came back to the acceptance value that we had before. As a consequence, we talked at length to the subcontractor who did all the machining on the tanks about what to do if you had to do it over again. They did a cost estimate for us on the basis of doubling the thickness of the copper on the same thickness of steel, so that now instead of 3/4 of an inch of steel, and 1/4 inch of copper we would have 3/4 of an inch of steel, and 1/2 inch of copper, and their figures indicated that the salvage value that they would get from the copper on machining this cylinder to the right I. D. would offset the additional cost of the operation, and therefore they think we would break even. I think that there are several advantages of doing this. You wouldn't have to go through this nasty operation of rough-tuning the cavities. Putting in the rough-tuning bars is a time-consuming operation.

POLK: I would like to make some comments about thickening the copper cladding on the steel. There is a great problem in getting thick copper skin applied to steel. Basically the difficulty is in the method of making the copper-clad steel itself. The way it is fabricated in the Lukens process is that you start off with a sandwich which consists of a fairly heavy steel plate, a sheet of copper, a parting agent, as shown in Fig. 2, another sheet of copper, another sheet of steel, and steel bars which have been welded in the slots around the edge, so that this forms a sandwich with the interior not exposed to any air. This is heated up in a furnace and run through a set of rolls to reduce the thickness, and it's in this process that you get the metallurgical bond between the copper and the steel. Now the real problem with respect to the copper thickness is, that at the temperature at which this process takes place, the copper is much more fluid than the steel; the copper is very soft and the steel is considerably harder.

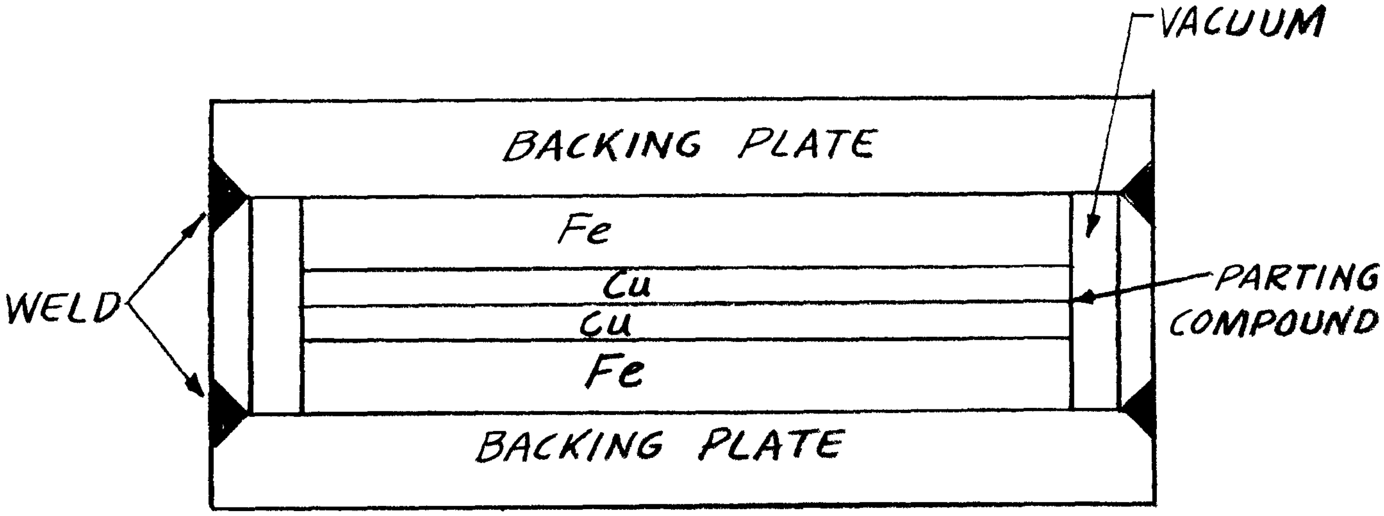

FIG. 2-"SANDWICH" USED IN LUKENS' CLADDING PROCESS

We were informed that one inch was the largest thickness that could be made for us, and I presume it is still the largest that could be made. It is in the proportion of about 0.150 in. of copper, and 0.850 in. of steel. This was a key problem in the initial design, how thick you could make the copper in the cavity. If you want to use ground flanges and mating parts you've got to take into account how much copper you have so you don't end up in the steel. In our case, the calculations for the drift tube shapes were not done very accurately, or to put it another way, I think you've still got a problem in getting the same frequencies for many tanks whether you machine or not.

LIVDAHL: I'm assuming that the present-day techniques for calculating drift tube tables are somewhat more accurate.

POLK: Perhaps. Although you go through the whole business of calculating drift tube shapes, there are still the empirical things, for example, the machining, the stems, the bevels, etc. All these are perturbations on your ability to prejudge the exact resonant frequency of each cell, and my own feeling is that you will still have to apply some rough tuning technique anyway.

HUBBARD: We do have a little bit of experience along this line in that the new Bevatron injector does not have any rough tuners in it. It's only 40 ft. long, however. They calculated the diameter of the cavity that they should have for 200 Mc/sec, and they're not very far off, 160 kc/sec or so.

POLK: Actually, we're not far off either. It turns out that if we had had some more wall tuners, we could have handled it that way. But, in a long tank, of the order of 25 or 30 meters, my own feeling is that you would have to end up with some way of essentially establishing the same resonant frequency all along but this will depend upon the particular decisions you make.

BERINGER: In a multiple cavity machine, you will have to use the same frequency for all cavities. This obviously means you have to do rough tuning of some type. One way of buying rough tuning is by precision machining from drift tube tables. Let me suggest another approach which we used although not as adventurously as I would advocate. You make a lot of components by normal engineering practices and do not try to achieve extreme precision. You have a drift tube table, but you don't take all the dimensions too seriously. Then you do a full-scale perturbation calculation with the components you actually have. You assemble them to give the desired resonant structure. Now I believe, in general, that it will turn out that the effect on beam dynamics is negligible. This only means you have to make some measurements which are a lot cheaper than holding close tolerances in a big fabrication job.

POLK: This is essentially what we did. We took the best fabrication techniques that we could, we measured it, and if we needed any correction, we put it in.