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SSC Technical Note No. 40
(SSC-N-114)

BEAM TUBE INTERIOR - CLADDING AND SURFACE SHAPE

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January 7, 1986

The SSC requires a beam tube with a copper interior. Plating the copper on is the first choice but plating may prove to be unacceptable because of cost, non-uniform thickness, surface waviness, surface craters or pimples or blisters.

For the ISABELLE warm bore tubes (beam tubes) we found that drawing a copper tube over the stainless steel bore tube cost less than half the cost of plating an equal thickness of copper onto the outside of the bore tube. The drawn on copper was not bonded to the stainless steel because the magnets quenched slowly enough to make the bond unnecessary. We had a contract to plate 100 tubes, 25 of which were plated before the ISABELLE Project was cancelled. The plating on the outside of an 18 foot long tube was not a simple job but it was much less difficult than plating the inside of a 55 foot long tube. Also, the surface finish for the ISABELLE tube was not important, though easily inspected, while the surface finish of the SSC plating is very important, yet difficult to inspect.

Another method of cladding the beam tube interior with copper is described here along with several proposals for bonding the copper to the stainless steel.

The second part of this note concerns the surface of the copper. Henry Halama and T.S. Chou, in their "Proposal for an Experiment to Study Synchrotron Radiation Desorption from Cold Surfaces ---"[1] states "This experiment should measure the relative merits of various metals, their surface treatments and surface shapes to determine the best solution". Halama asked that I devise methods of producing "various surface shapes" as part of the mechanical design of the experiment. Because further experimentation on the beam tube design is not scheduled in the near future, I offer these ideas for future consideration and/or reference.

I. Cladding the Beam Tube Inside

A copper tube whose O.D. is about .050" smaller than the beam tube I.D. would be slid into the beam tube. The copper I.D. and O.D. and stainless I.D. must be clean. Figure 1 shows the end configuration with the tubes clamped and the alignment plug still in place. After the plug is removed, the tubes are held concentric to each other by the clamp. The clamp I.D. is the same as the expander O.D., thus the expander starts concentric to the tubes and it will maintain that concentricity as it proceeds through the tube. Figure 2 illustrates the expander at work.

The expander will rotate within the tubes and the tubes will be drawn axially through die and over the expander. The rotating part should be fixed axially and the non-rotating part moved axially to avoid having power lines dragged along.

Note that the expander mandrel is in the un-expanded copper and that there are bearings periodically along the mandrel to minimize scratching the copper. The expander wil produce a surface on the copper I.D. which is smoother and less wavy than that of the original tube.

The result will be a copper tube which has an interference fit within the stainless steel tube. This same interference fit, at lower cost, can be obtained by using a solid mandrel instead of the tube expander roller but a heavy lubricant must be used for the operation and then thoroughly removed later.

There are two questions now: 1) During a magnet quench, will the copper be deformed within the beam tube? 2) Will the resistivity of the copper be too high? It is now work-hardened. If"NO" is the answer to both questions, we have a copper clad tube which I am sure will be less expensive than, and have a surface finish superior to a plated tube. There will be minute amounts of gas between the stainless steel and copper but these will not cause a "virtual leak" into the UHV because the gas will be cryo-pumped or frozen in place.

If either question is answered "YES" or "PERHAPS", several variations to the cladding system described above are offered.

1) Seal the tubes together at the flared end and evacuate the space between the tubes with the tubes heated. This will give better metal to metal contact and may cause some cold welding of the metals during expansion of the copper. With such a long and narrow space to be evacuated would the pressure be low enough for this suggestion to be of value? Inexpensive experiments can be done to find out.

2) Fill the space between the tubes with an anaerobic adhesive sealant, as manufactured by Fel-Pro and Loctite, or a thermo-set adhesive as an epoxy. A void-free fit is assured and the copper can be expanded to produce the proper clearance for the adhesive to work best.

3) I called one manufacturer of electro-less nickel plating materials to ask, "Will the electro-less nickel plate both surfaces and bond to itself if those surfaces are brought together during the plating"? The chemist to whom I spoke said that he had not a attempted this but it "surely is an interesting thought". While nickel is magnetic and would not be useable, there may be other electro-less plating materials.

4) The tubes could be soldered, soft or silver, during the expanding process. Powdered metal solder in paste fluxes are available. The paste would be smeared onto the copper as it is pulled into the beam tube. The tubes would be heated in the area of the expanding operation and capillary action will distribute the molten solder around the periphery of the tubes. Excess solder and flux will be squeezed out ahead of the point of contact between the copper and beam tube. Silver soldering would leave the copper annealed , but the copper I.D. must be sealed at the flared end and purged with nitrogen during the silver soldering operation to prevent the copper I.D. from becoming oxidized.

5) The silver soldering can be done in a hydrogen atmosphere as illustrated in Figure 3. A thought here is to eliminate the hydrogen and silver solder in a vacuum but, as in No. 1 above, there is the question of pressure in the small space. Also, the surfaces and silver solder (probably a strip) would have to start out very clean. Hydrogen atmosphere brazing would be acceptable for a cold vacuum system but would the steel absorb enough hydrogen to cause metalurgical problems?

Tools for Cladding

Hardened steel die and expander rollers would be good for cold expanding or soft soldering the copper to the beam tube but they should be "hard chrome" plated to prevent minute particles of steel from being imbedded into the copper and/or stainless steel.

Silver soldering requires tungsten carbide tools, also hard chrome plated. A ceramic die shrink fitted into a steel backing block and ceramic rollers will conduct less heat away from the soldering zone. the soldering zone should be in front of the die and the expander rollers should be long enough to be inside the die and protrude into the soldering zone.

II. Surface Finish and Shapes

The rolling action of the tube expander will leave a smooth surface with a minimum of waviness.

During the preparation of the proposal for "the desorption experiment", Henry Halama discussed "surface shapes" with me. His idea then was to reduce the synchrotron radiation desorption by having the surface upon which the radiation impinges at 90° to the radiation, or as close to 90° as possible, reasoning, 1) that at 90° the least possible area is presented for desorption and 2) that at 90° the reflectivity is "practically nil".[2]

It is pointed out [3] that at 2.5 mr angle of incidence, the reflectivity is about 98% and that the synchrotron radiation eventually would strike the entire inside surface of the beam tube, (the radiation has a vertical angle of divergence and strikes a surface much larger than the beam height) therefore, the entire surface is available for possible desorption. For vacuum, it seems best to capture the synchrotron radiation as soon as possible.

The logic I used to choose the surface shape I recommend as a starting point for experimentation follows:

1. Thread the surface, as a nut, using the thread rolling technique.
2. Use the buttress thread form.
3. The thread must have a sharp peak (minor diameter).
4. At about 3 mr angle of incidence, a .001" radius on the thread peak is too large, as illustrated in Figure 4, rendering the thread useless.
5. Have a very long pitch thread.
6. With .008" thick copper cladding, a thread .008" above the surface could be formed, Figure 5, if 100% metal displacement could be achieved.
7. A thread .008" high would cast a shadow 2.6" long at 3 mr angle of incidence in the horizontal plane. A thread with a pitch of 2.6" in the beam tube I.D will have a helix angle of 57° which would be the angle of incidence in the vertical plane.
8. The thread roller axes would have to be normal to the helix angle (for such a large angle) making the tooling difficult if not impossible.
9. A ridge of the thread shape can be formed square to the tube centerline at spacings easily changed with no tooling change or alteration. Also, the tooling is not difficult even though the forming rolls must be retracted after each ridge is formed. Also, a higher ridge can be produced by moving the tube axially, slowly, during the forming operation.

10. If annular ridges increases the RF impedance too much, the ridges can be formed on one half of the periphery, or less, by oscillating the forming rollers instead of having them rotate completely within the tube.
11. Putting the ridges into the copper requires the copper to be bonded to the stainless steel and it appears that the bond should be as plating or silver soldering.

CONCLUSION

Because the interior surface is so important to the magnet size [4] and perhaps the feasibility of an SSC as proposed, it seems that it would be prudent to have at least two copper cladding systems being tried at the same time. We hear the statement that this is not affordable, but the question is, "Can you afford not to?"

REFERENCES

1. H. Halama, T.S. Chou, March 21, 1984, Proposal for an Experiment to Study Synchrotron Radiation Desorption from Cold Surfaces in Order to Develop SSC Beam Tubes for Maximum Circulating Currents.

2. Private communications with H. Halama and P.A. Thompson.

3. P.A. Thompson, September 23, 1983, Analysis Section Note No. 41, SSC Synchrotron Radiation.

4. M. Tigner, Letter to Dr. N. Samios, August 30, 1984.

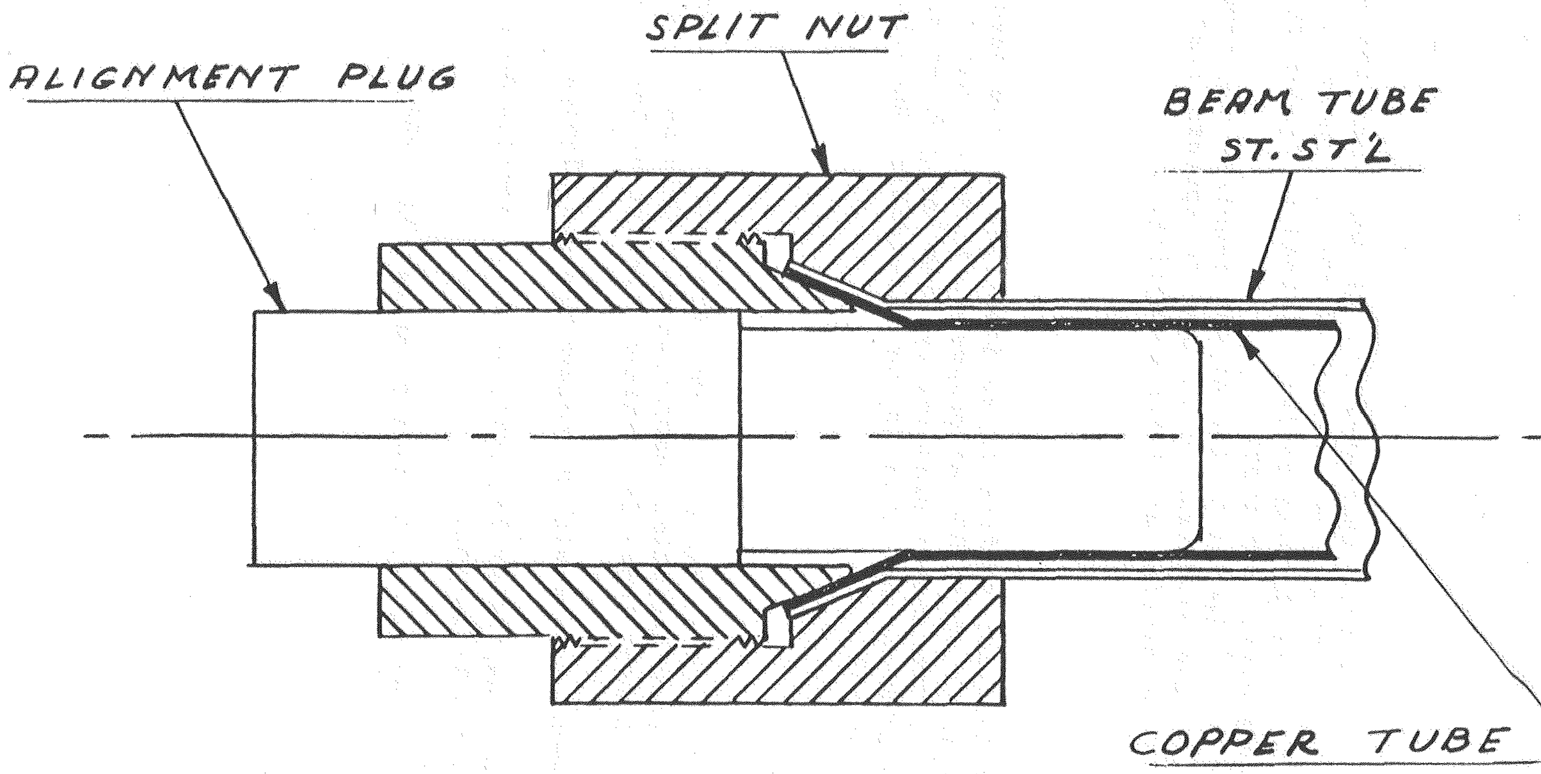

FIG 1

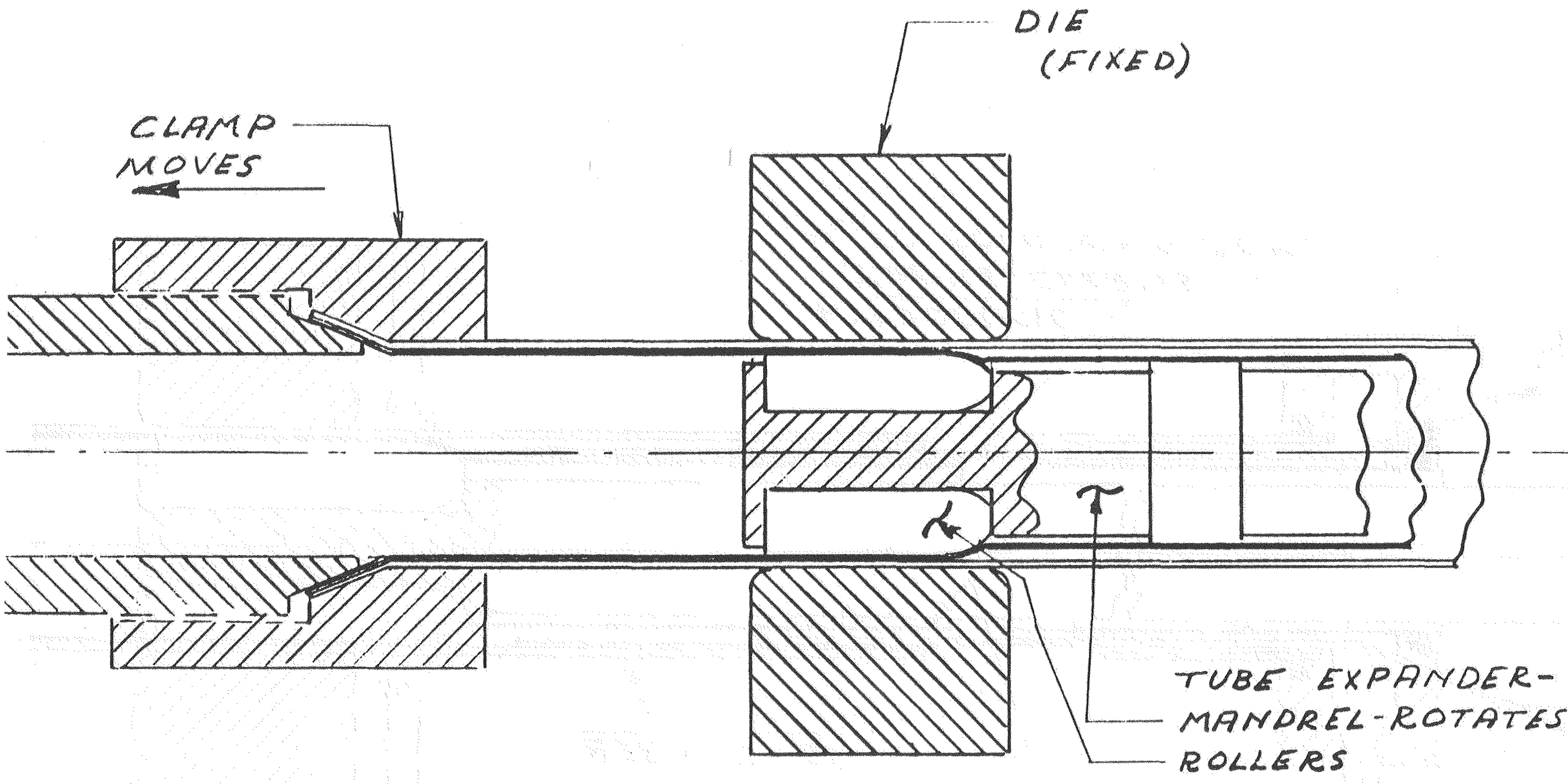
DIE
(FIXED)
CLAMP
MOVES
TUBE EXPANDER-
MANDREL-ROTATES
ROLLERS

FIG 2

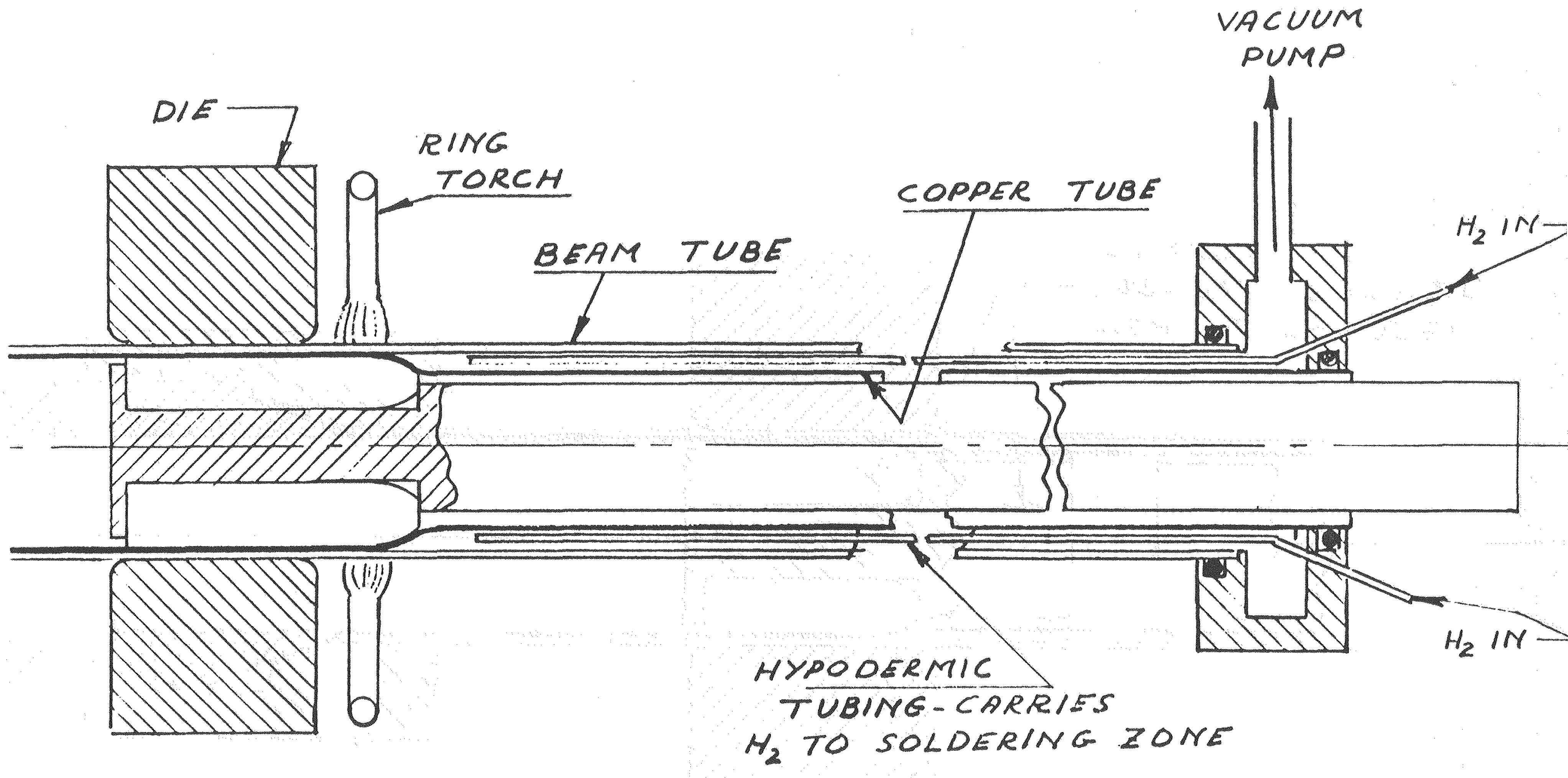
DIE
RING
TORCH
BEAM TUBE
COPPER TUBE
VACUUM
PUMP
H_2 IN
H_2 IN
HYPODERMIC
TUBING-CARRIES
H_2 TO SOLDERING ZONE

FIG 3

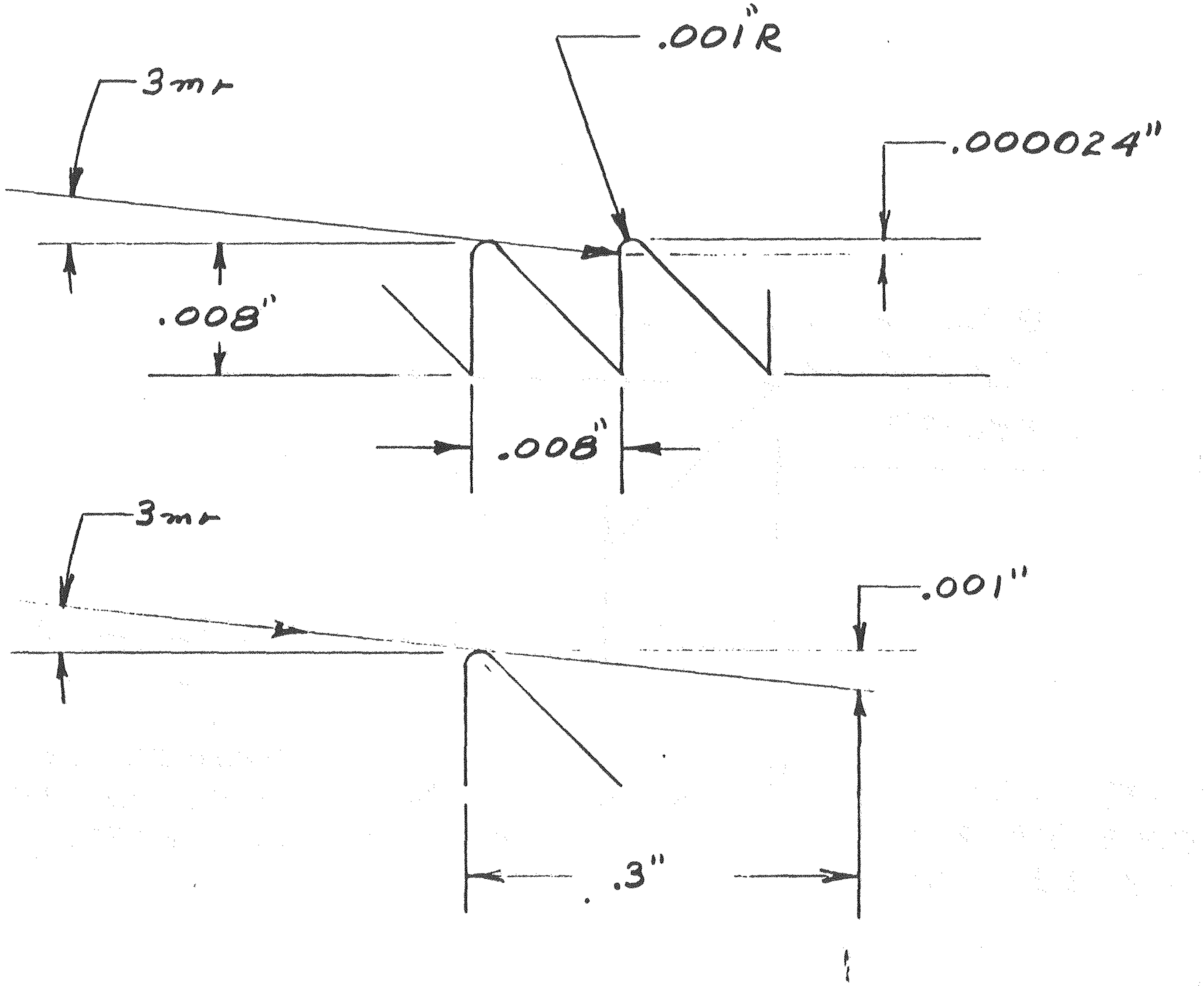

FIG 4

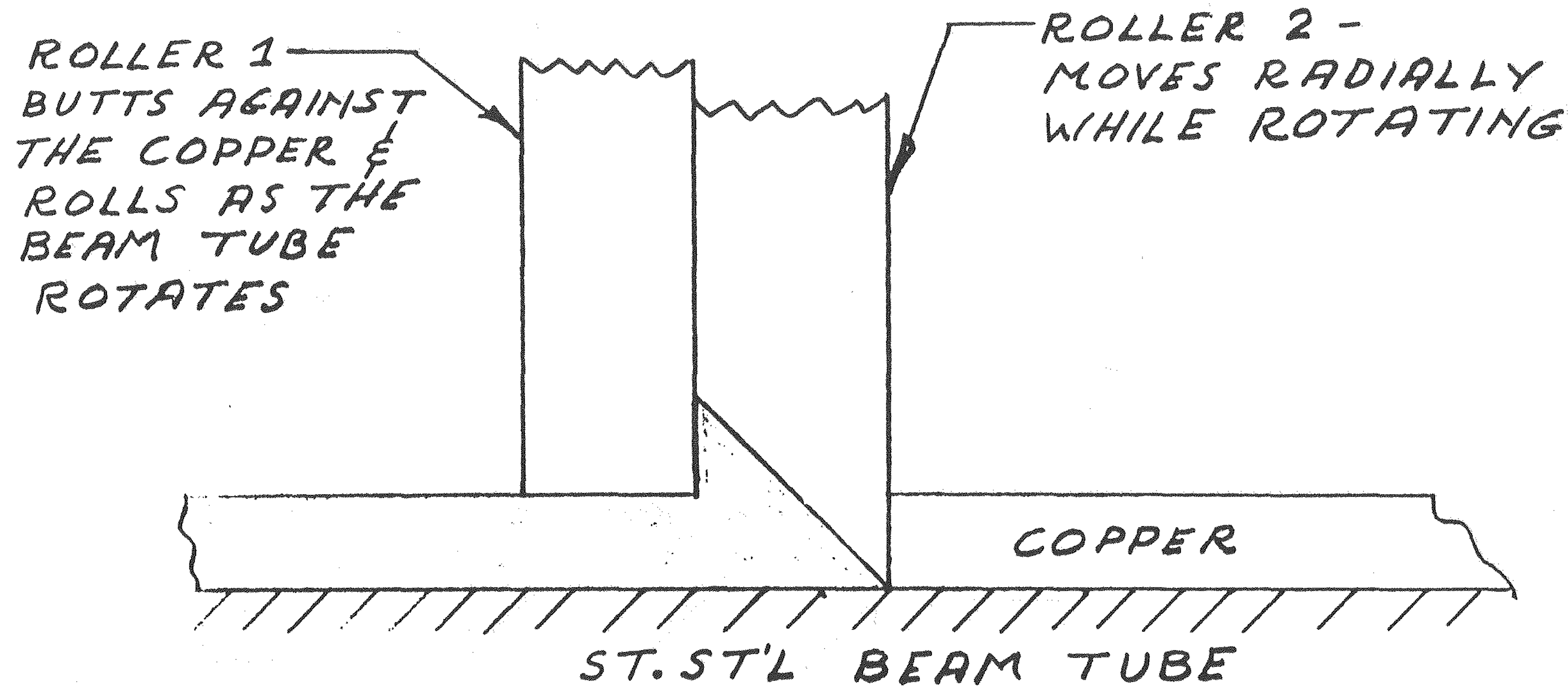
ROLLER 1
BUTTS AGAINST THE COPPER & ROLLS AS THE BEAM TUBE ROTATES
ROLLER 2 -
MOVES RADIALLY WHILE ROTATING
COPPER
ST. ST'L BEAM TUBE

FIG. 5

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