FCC Week 2015

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Marriott Georgetown Hotel
US/Eastern timezone

Cavity fabrication concepts: rapid forming

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and University of Padua

Outline: a 4W-Talk

- **What** we do now;
- **What** else the Technology offers;
- **What** kind of R&D INFN does;
- **What** it could be needed for FCC

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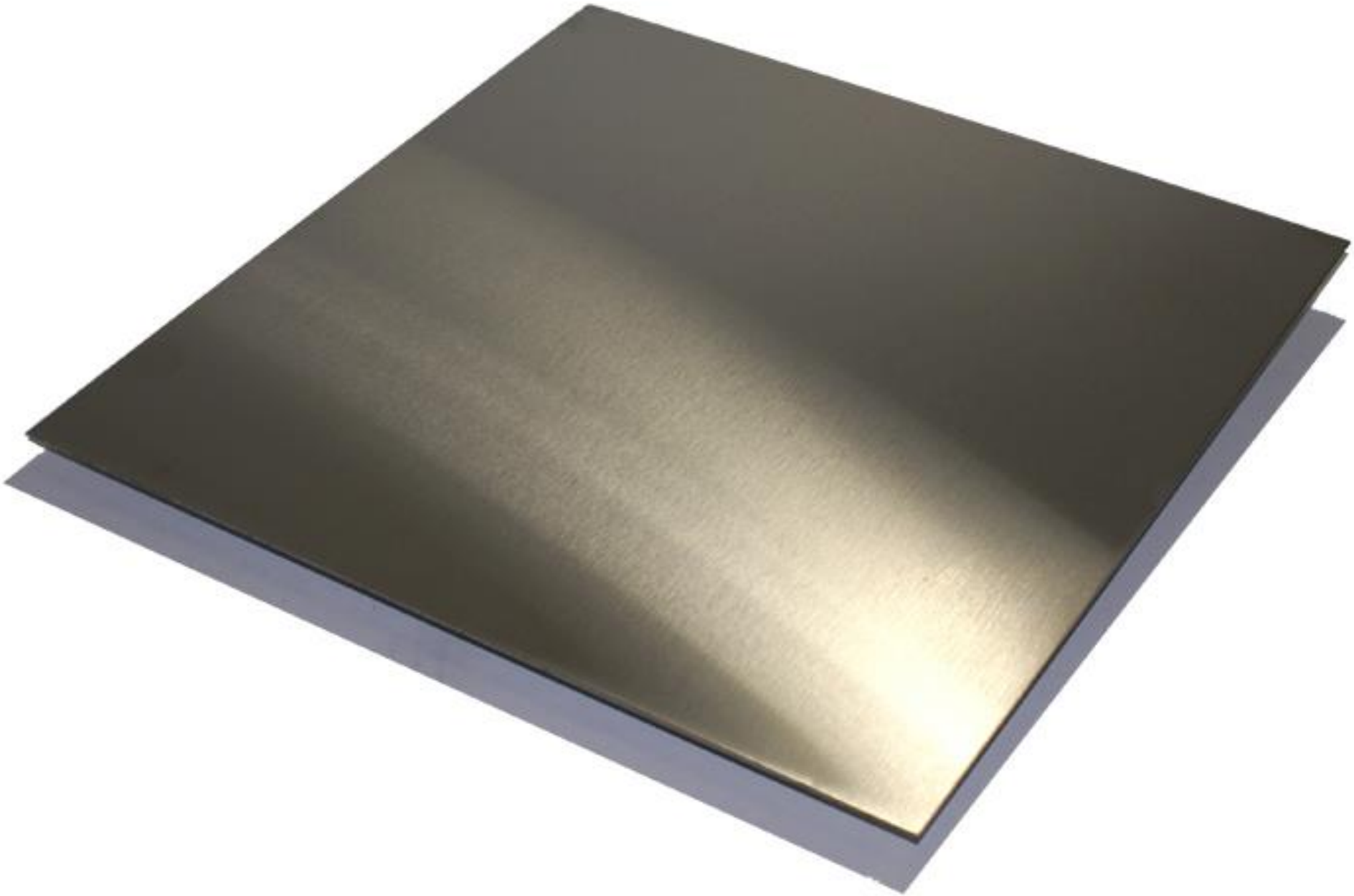
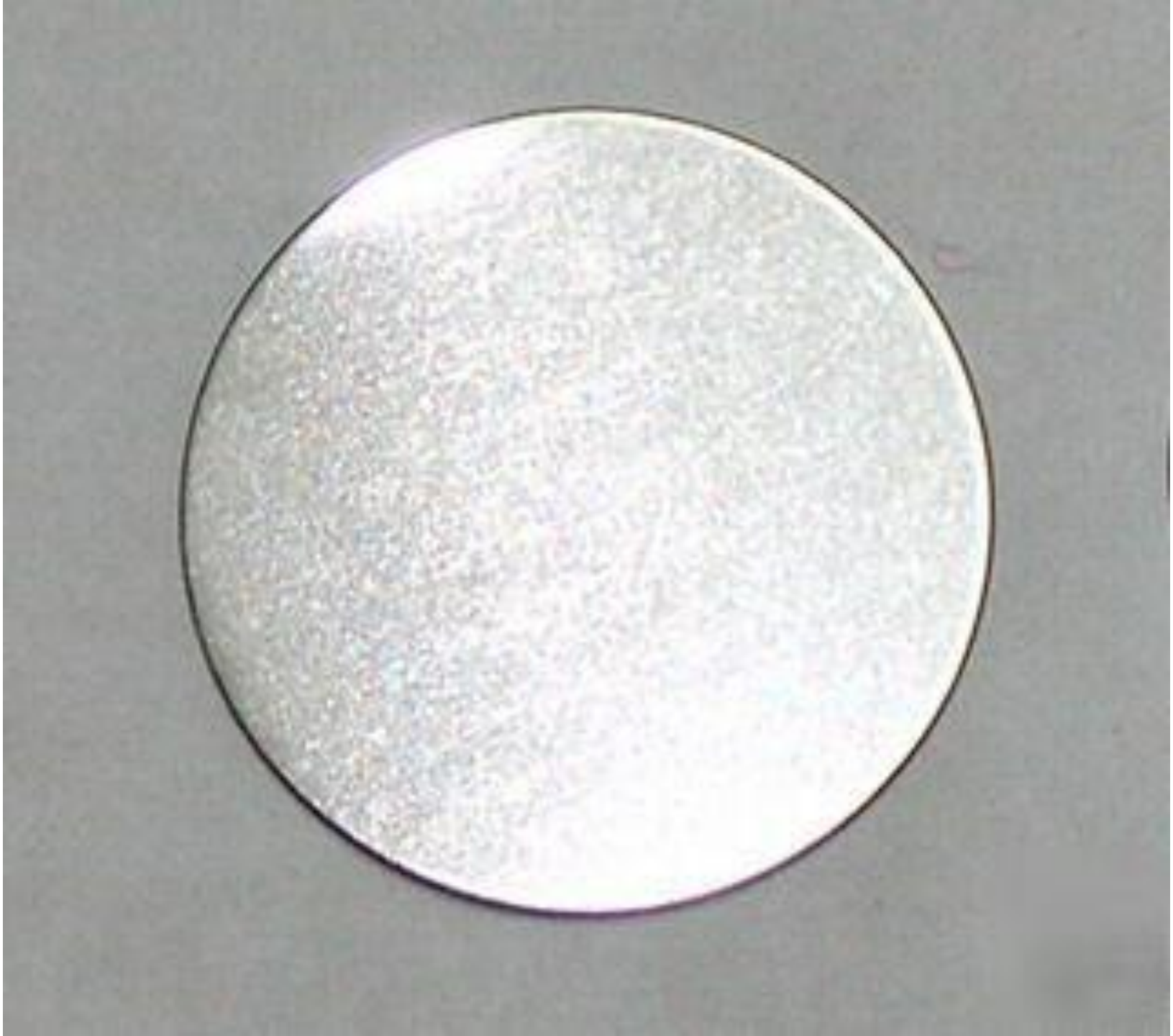
TESLA Technology: 1,3 GHz 9-cell





Courtesy K. Ueno Sensei


2011 6 1

The Standard technology has prooven to be extremely reliable even for mass production at the European X-ray Free Electron Laser

Now! If you think that for FCC ….

- **We have already the fabrication technology.**
- **EB welding technology works already as it is**
- **Nothing needs to be changed**

Then ...

THANK YOU FOR ATTENTION!

If instead You believe that ...

the hystory of SRF does not end just with bulk Nb,

... then a serious and deep R&D is mandatory

The cavities we'll consider in this talk

1,3 GHz

400 MHz

Drawbacks of the EB technology

- Long time of fabrication
- Risk of failure of the EB-weld
- Cost of the high-RRR Nb material

Time of Fabrication

- **UHV required for EB welding**
- **(RRR straightforwardly depend on vacuum pressure)**

- **400MHz 2-cells require a large EB machine**

- **9 welds/cavity; 2 welds/day/machine**

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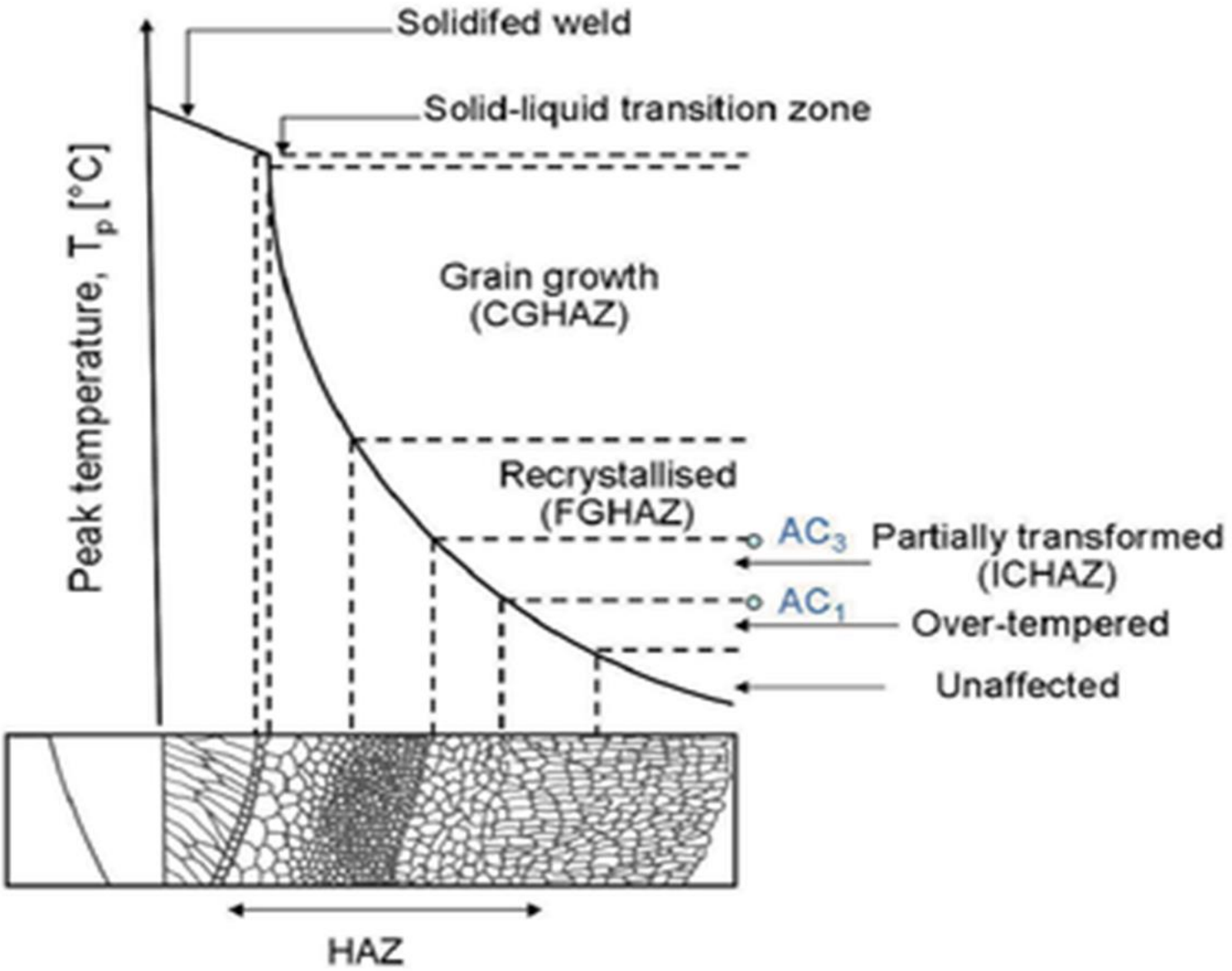
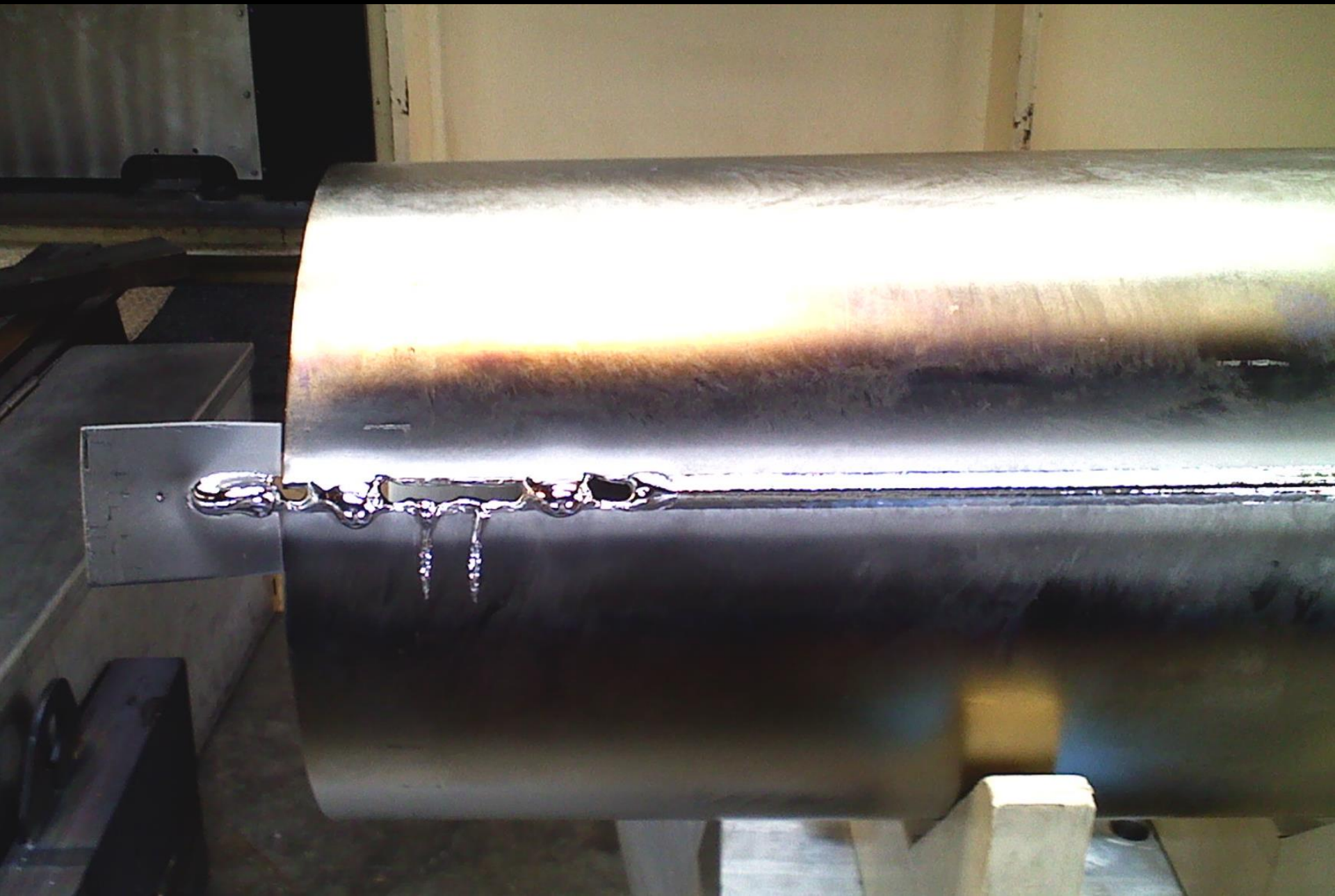
12 years of fabrication with 1 EB Machine

Heat Altered Zone (HAZ)



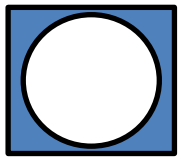
Failure Risk

Failure Risk



Cost evaluation of a bulk Nb 400 MHz 2-cell cavity

Costs

- **Weight of a 400MHz 2-cell = 100 Kg**
- **Weigth of Nb Swarf**  **= 27 Kg**
- **Cost of 250 RRR bulk Nb = 500-600 €/Kg**
- **Number of cavities = 1200**

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76 M€ only for the bare Nb material

Costs

- **Cost of the bare Nb material = 76 M€**
- **Cost of Welding (incl. Trimming, calibration ~ 12 K€/cavity) = 14 M€**
- **Flanges, Stiffening, Nb-Ti, brazing = 10 M€**
- **BCP and/or EP + acid recovery (at least 20.000 lt of HFa) = 10 M€**

Total = 110 M€ (without tuners, HOMS, etc)

So, ...

any alternative way ?!?

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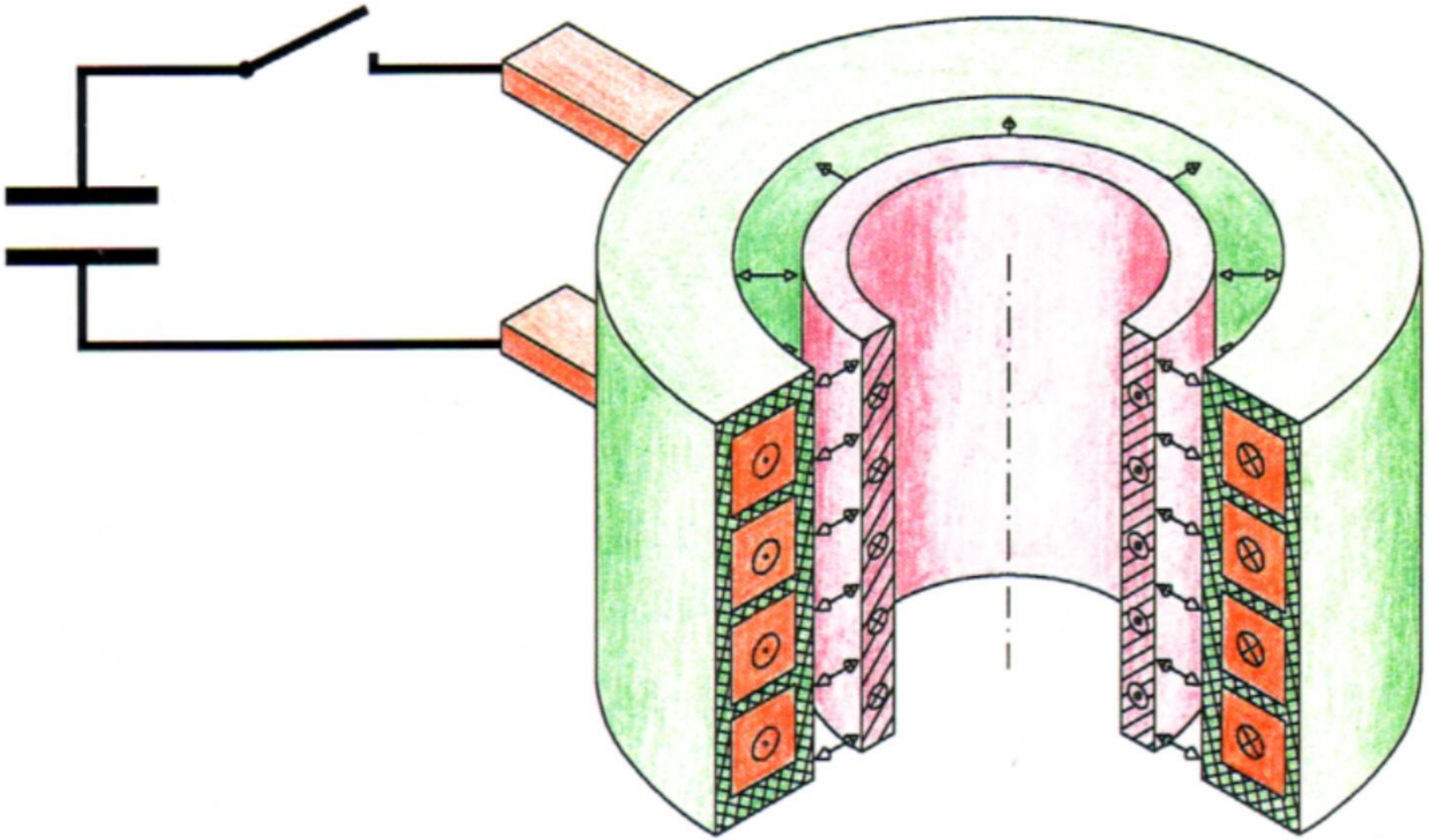
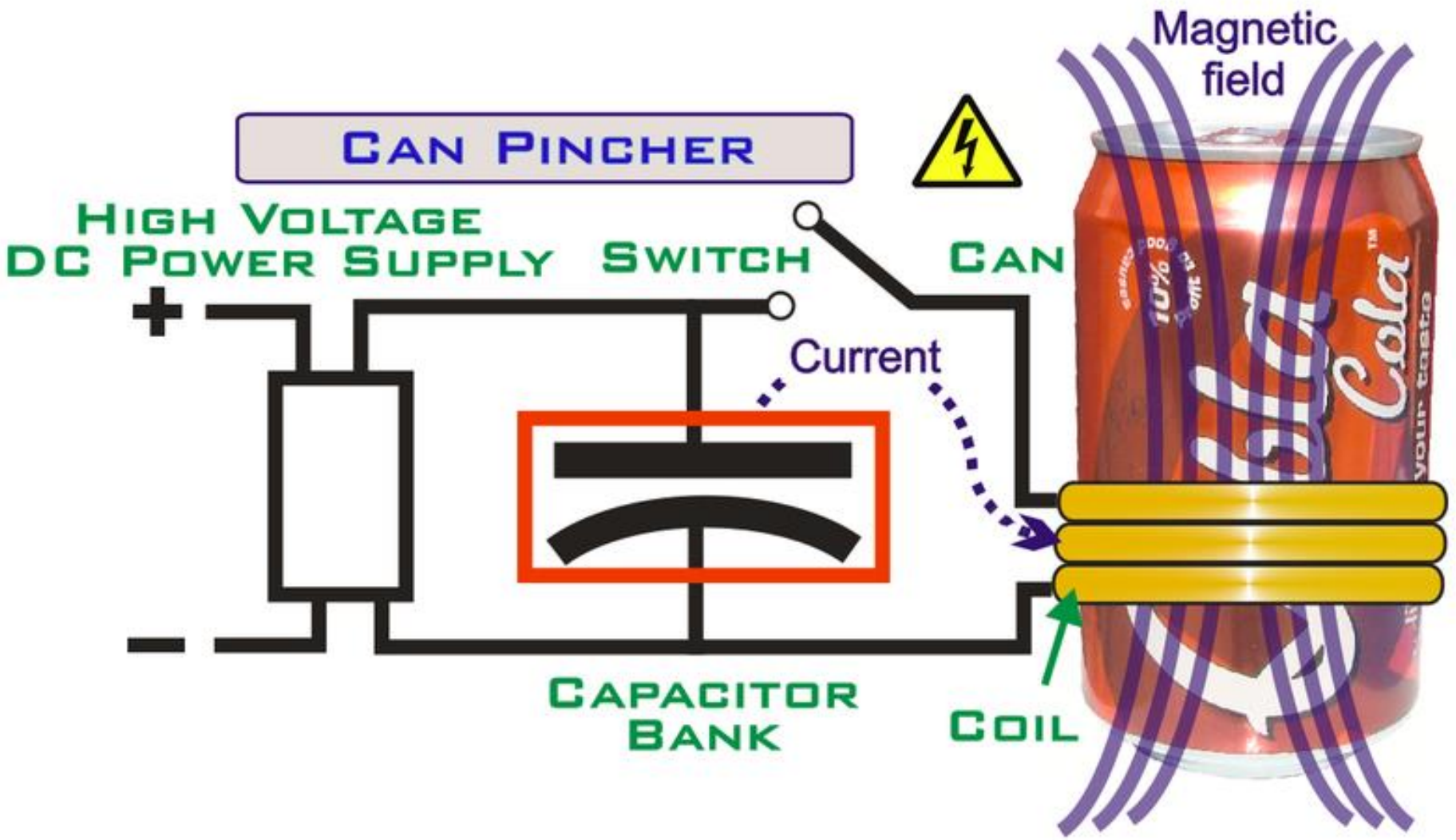
Seamless technology

- **Electro-magnetic forming**
- **Explosive forming**
- **Hydroforming**

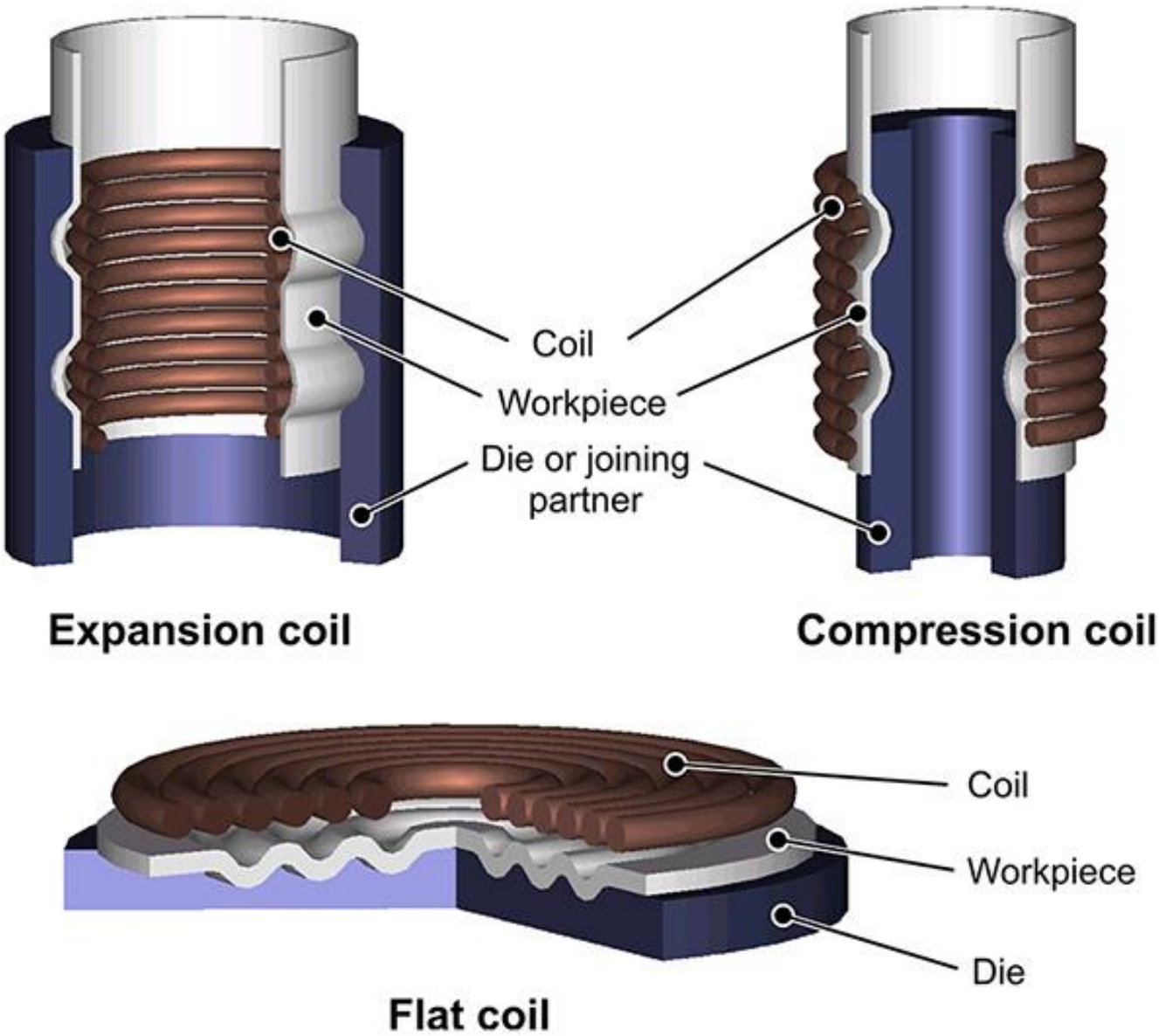
Electromagnetic forming



Electromagnetic forming



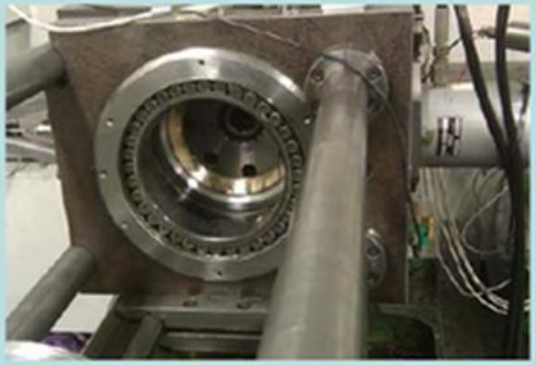
Electromagnetic forming



Hydroforming (W. Singer –DESY)

Hydroforming (W. Singer –DESY)

Spinning



Spinning of irises

Hydroforming

First Stage

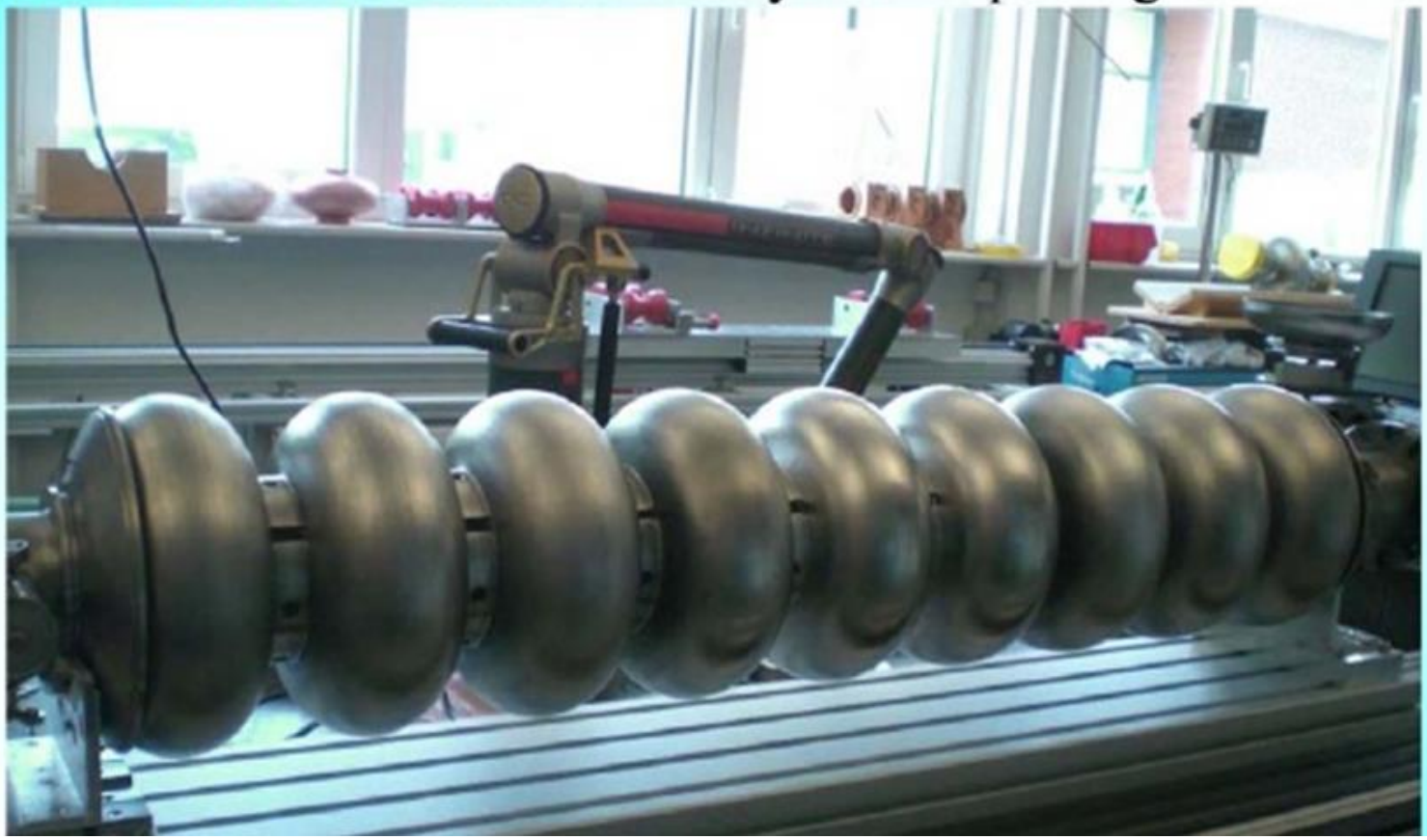
Final Hydroforming Stage

Second Stage

Hydroforming (W. Singer –DESY)

Z145: 9-cell as 3x3 cell cavity hydroformed at DESY, completed at E.ZANON (reached ca. 30 MV/m).

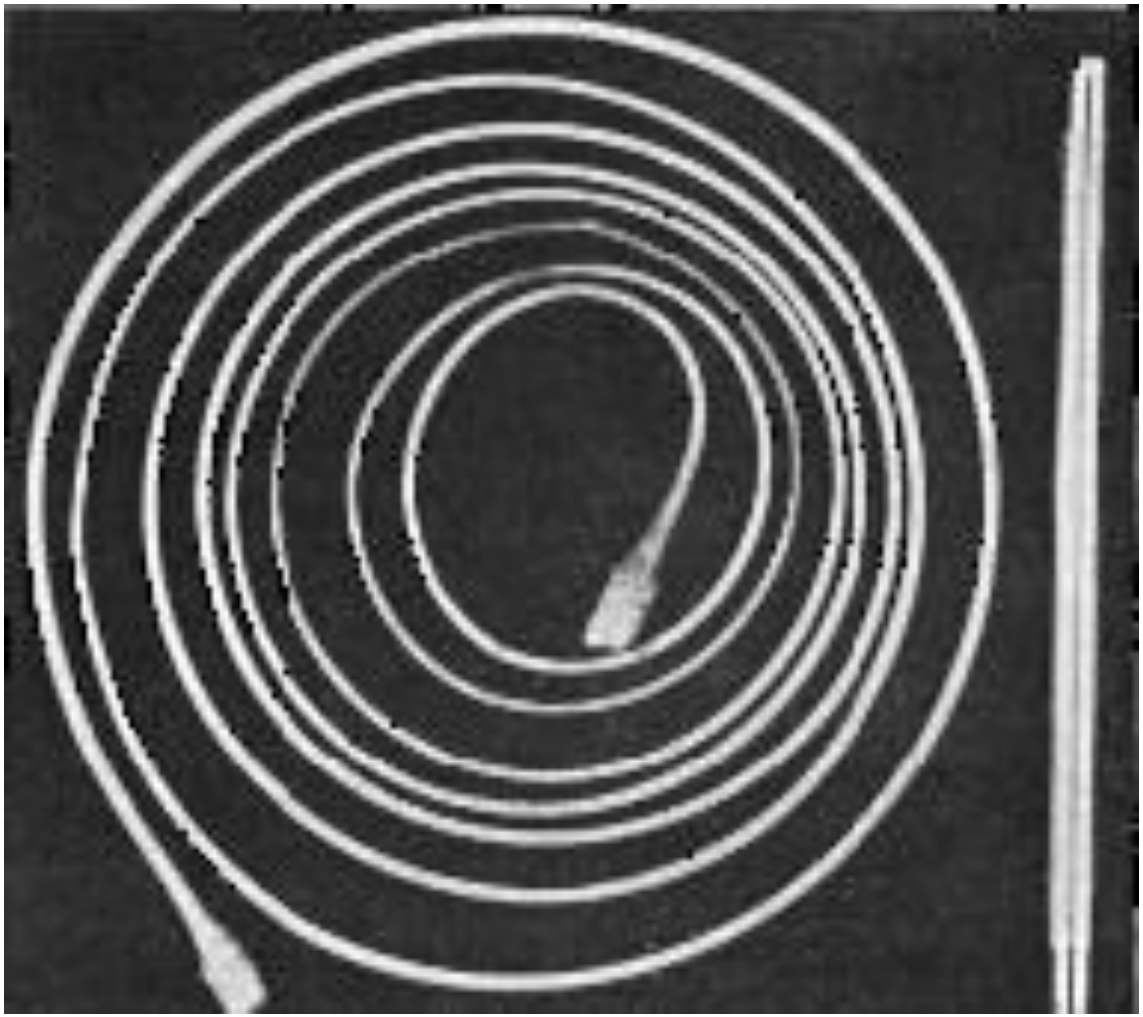
Two new 9-cell cavities are currently in completing at E.ZANON



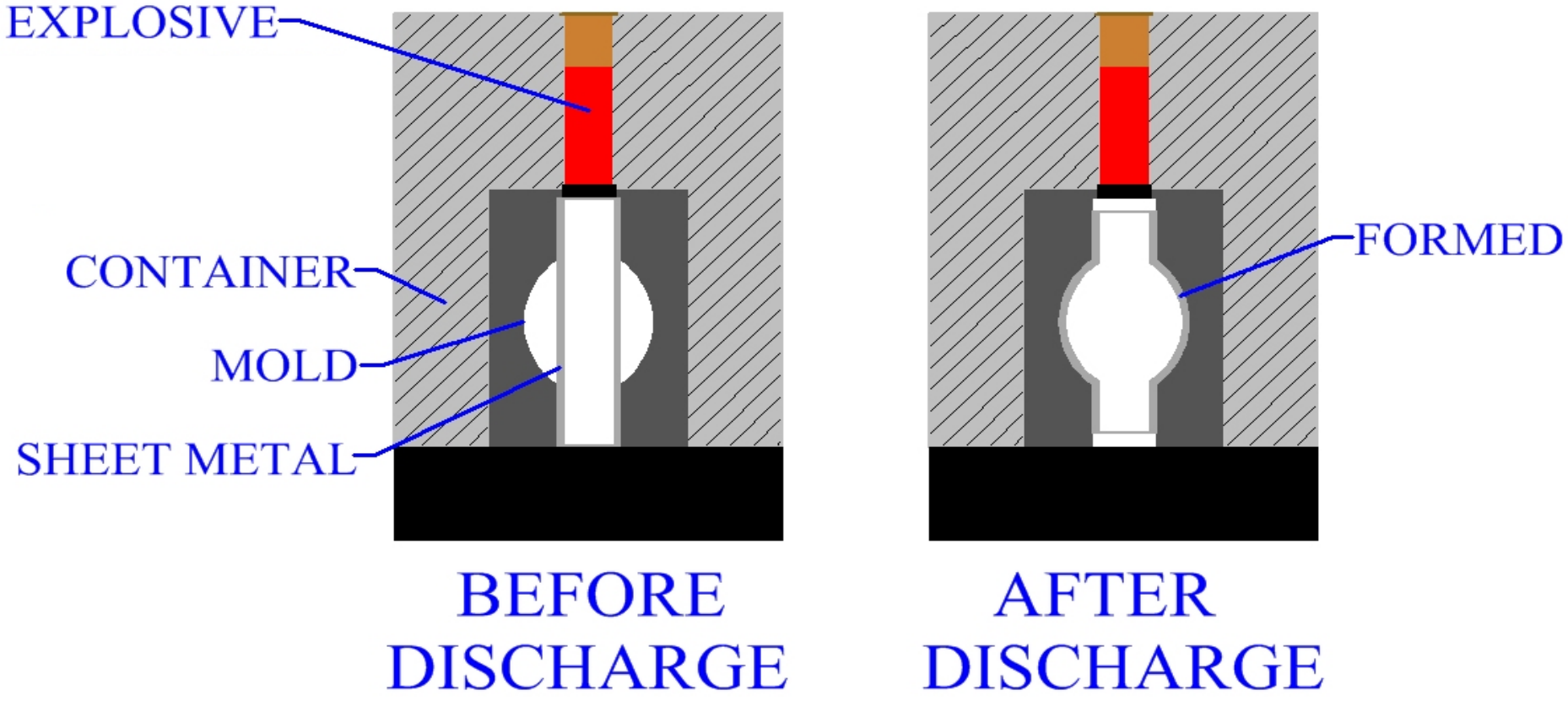
Hydroforming in Japan

Courtesy K. Ueno Sensei

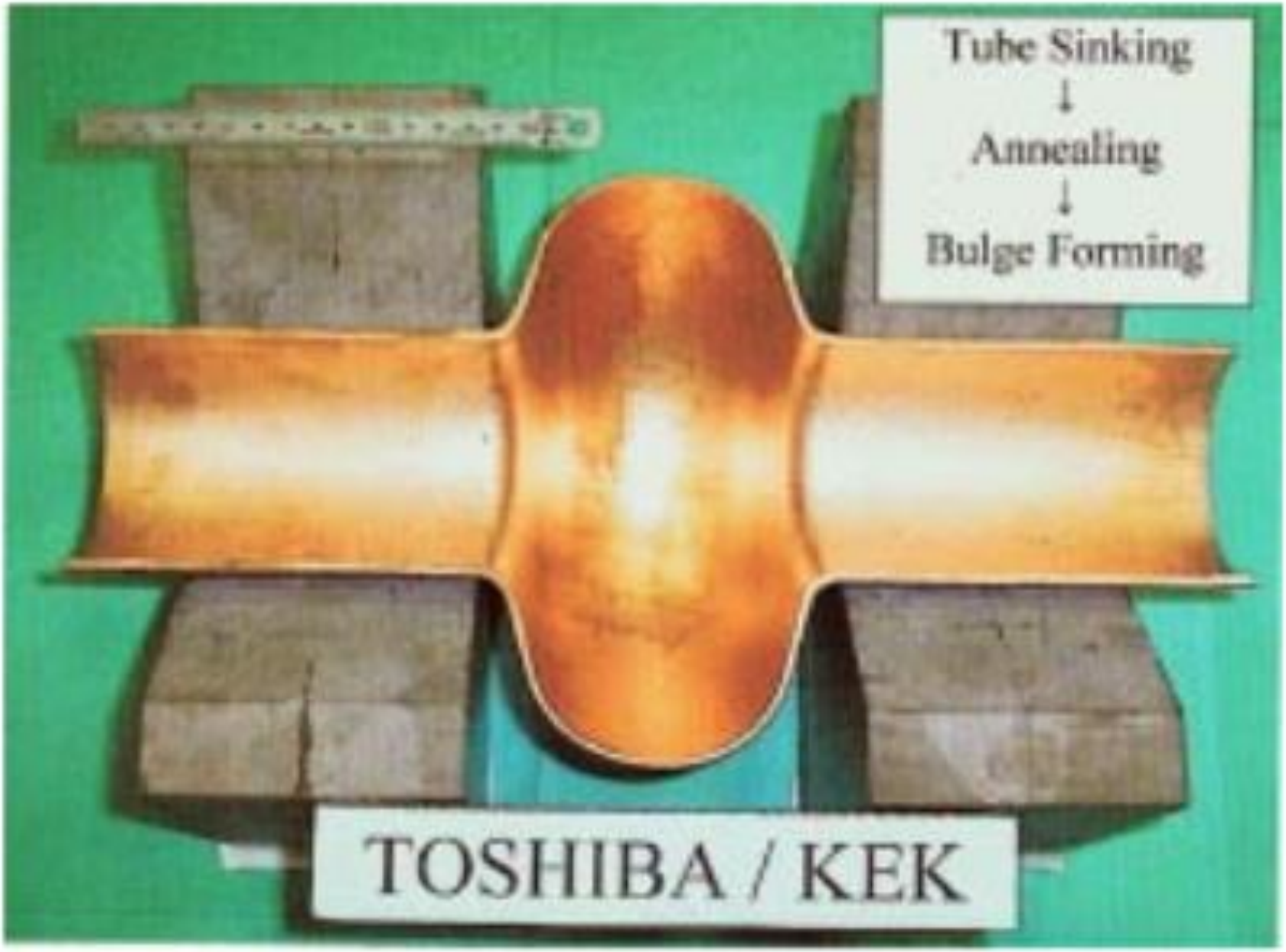
Superplasticity



Confined Explosive forming



Explosive Forming



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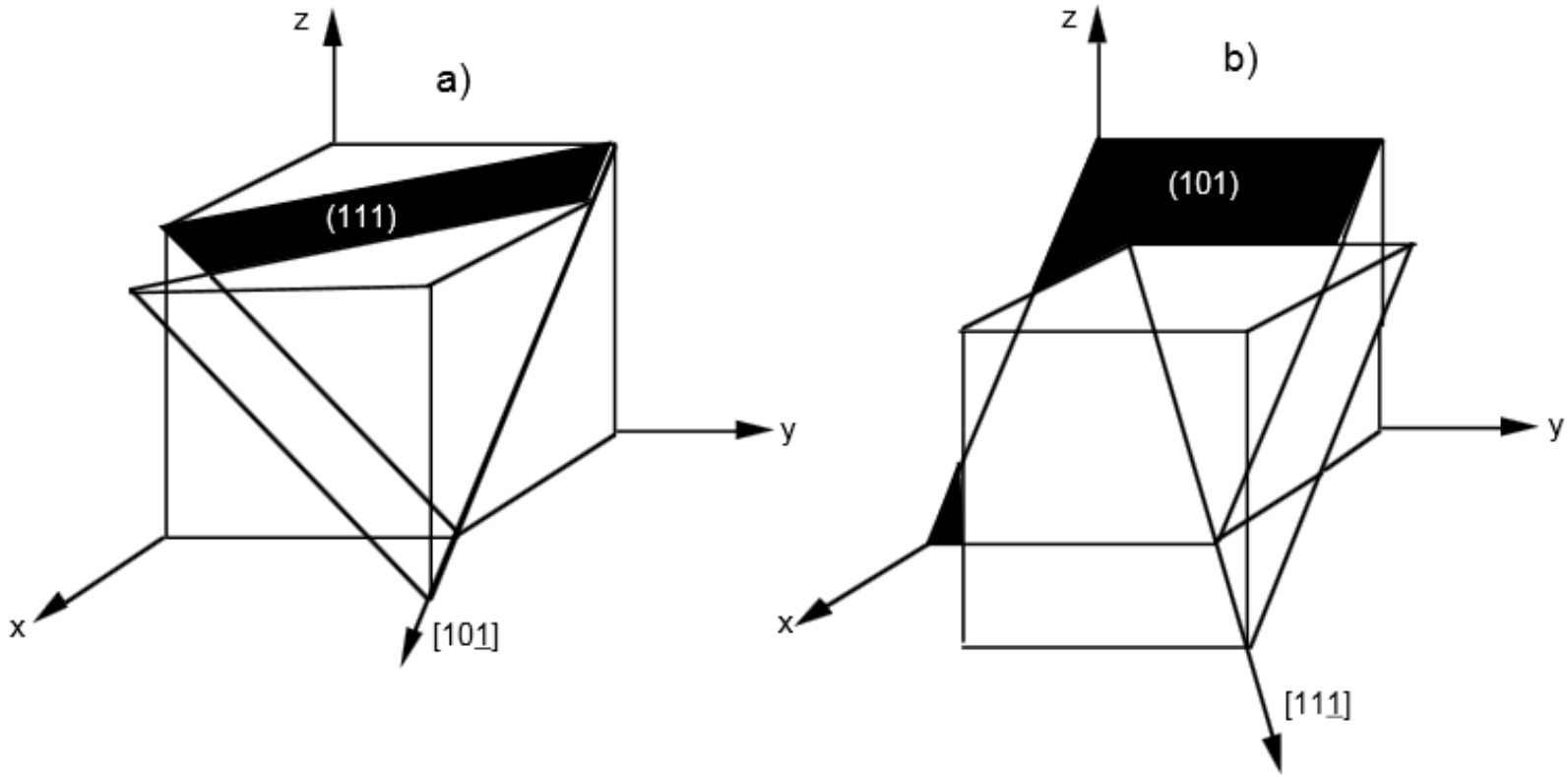
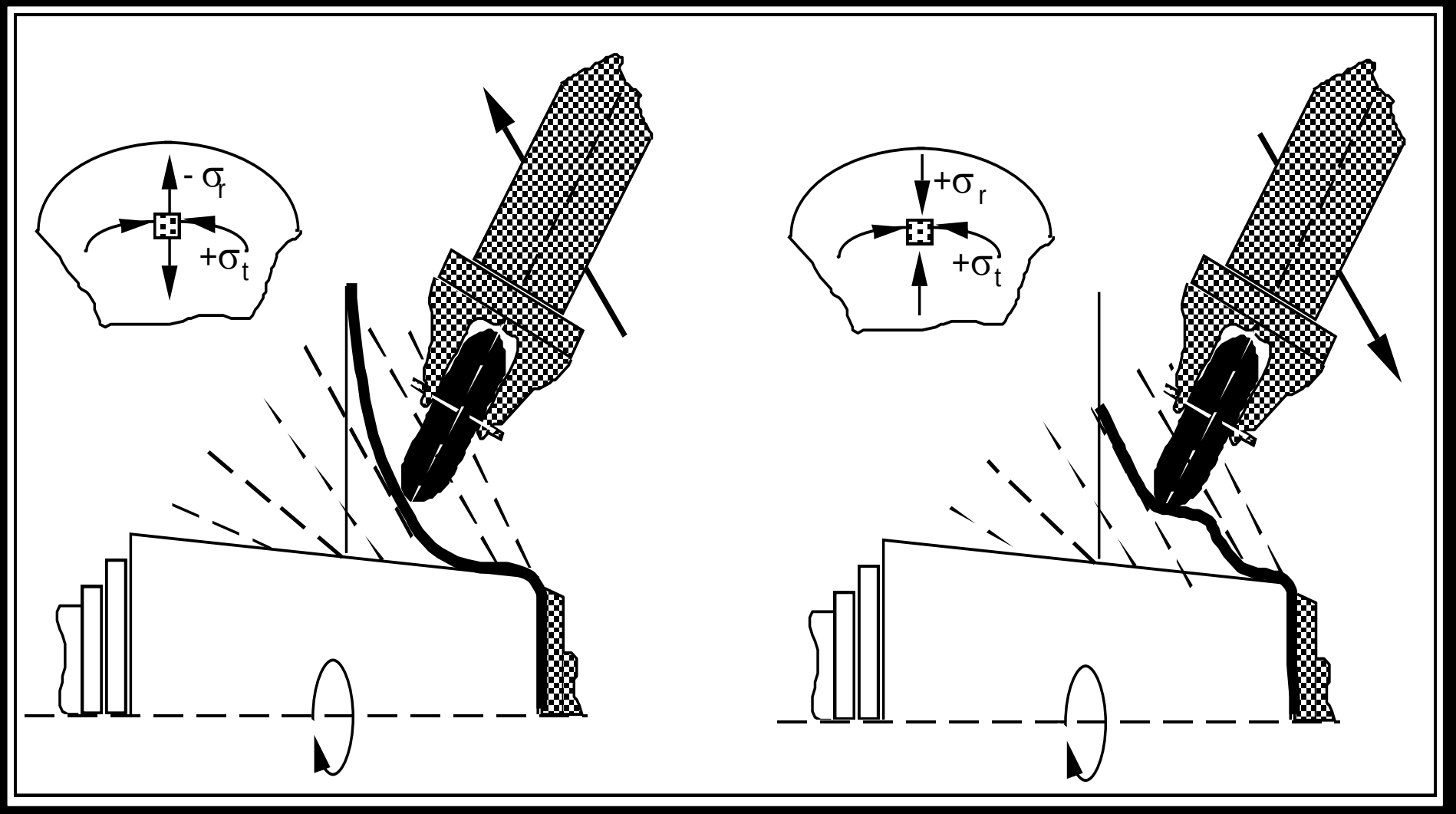
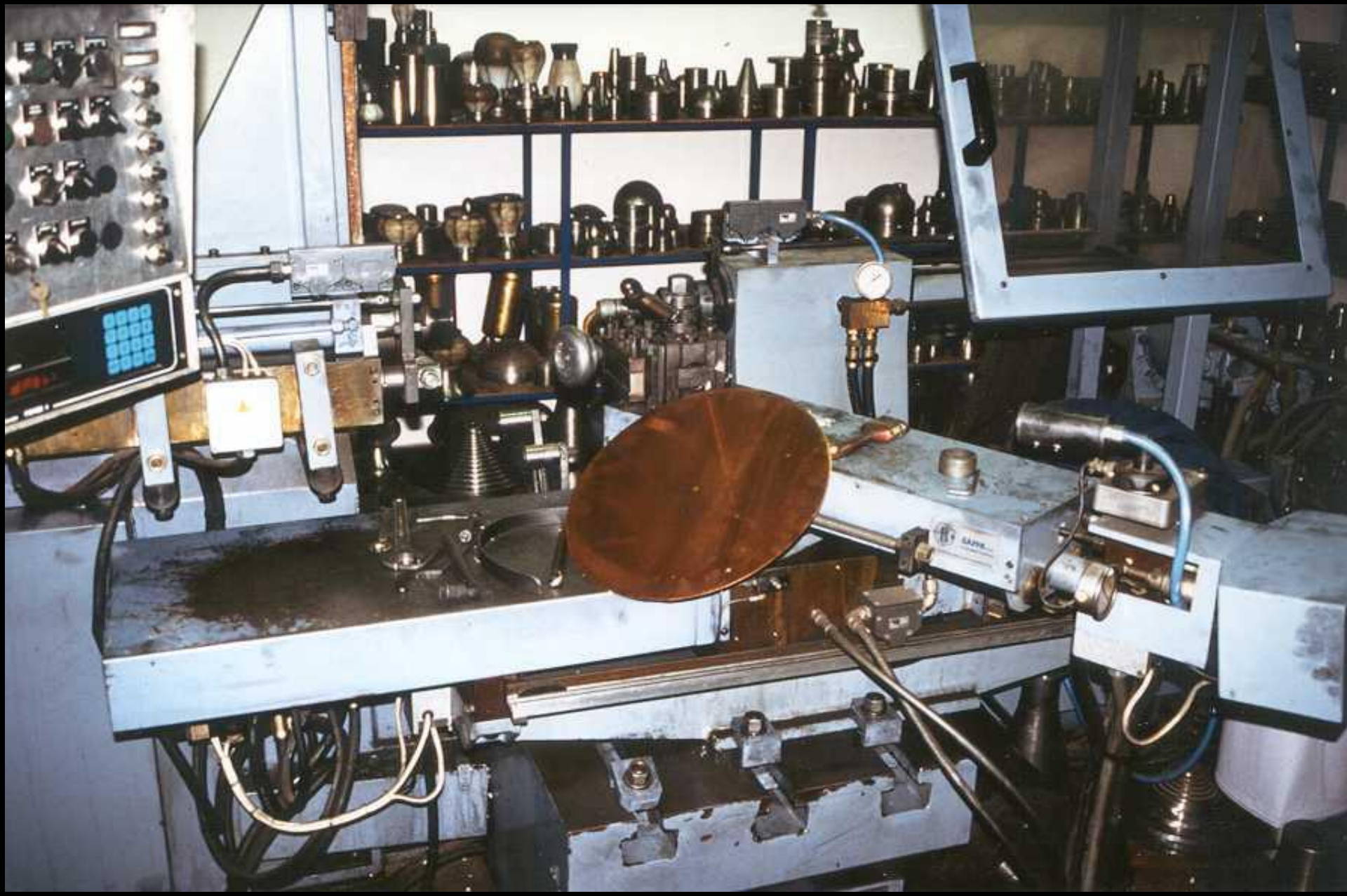
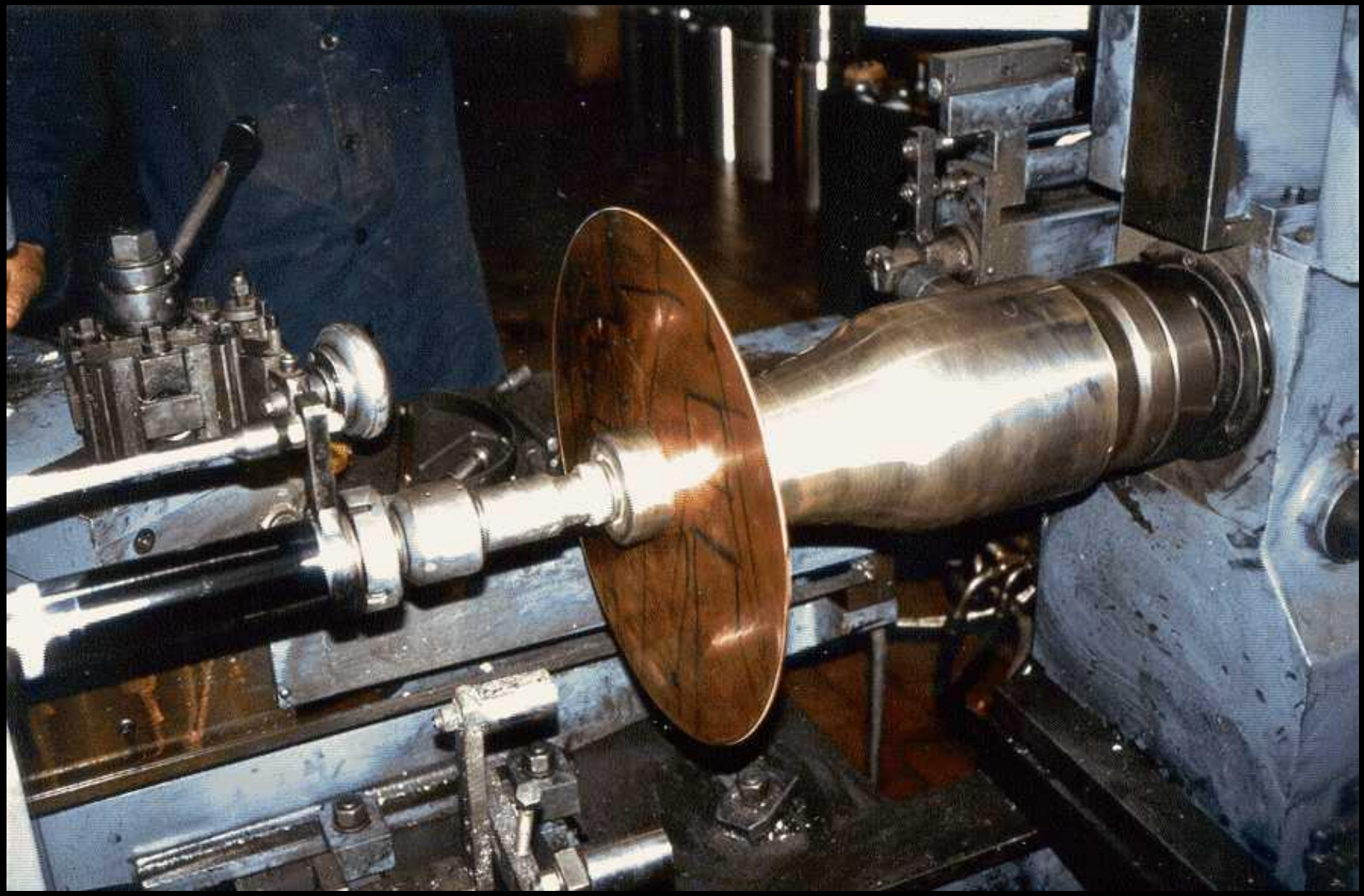
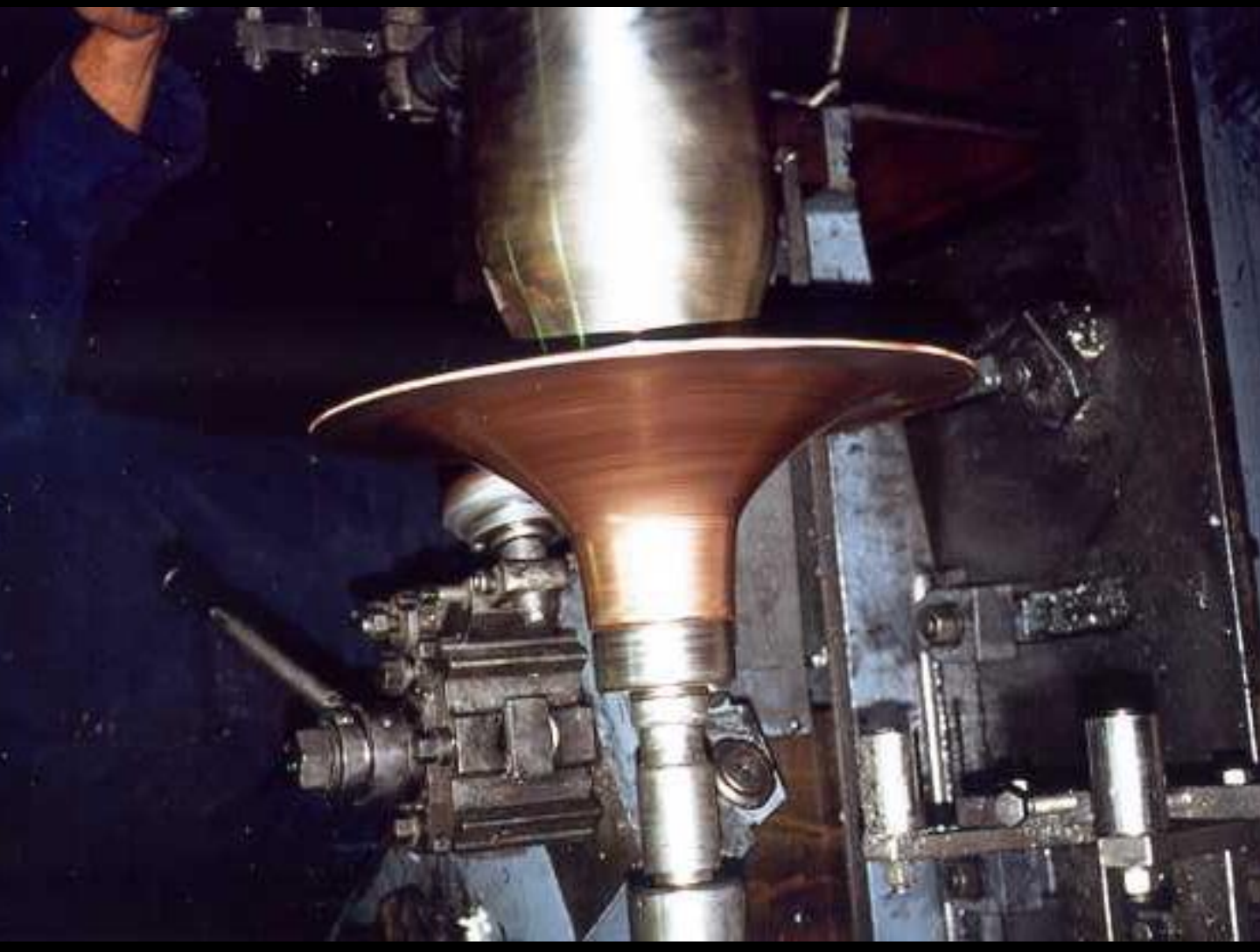


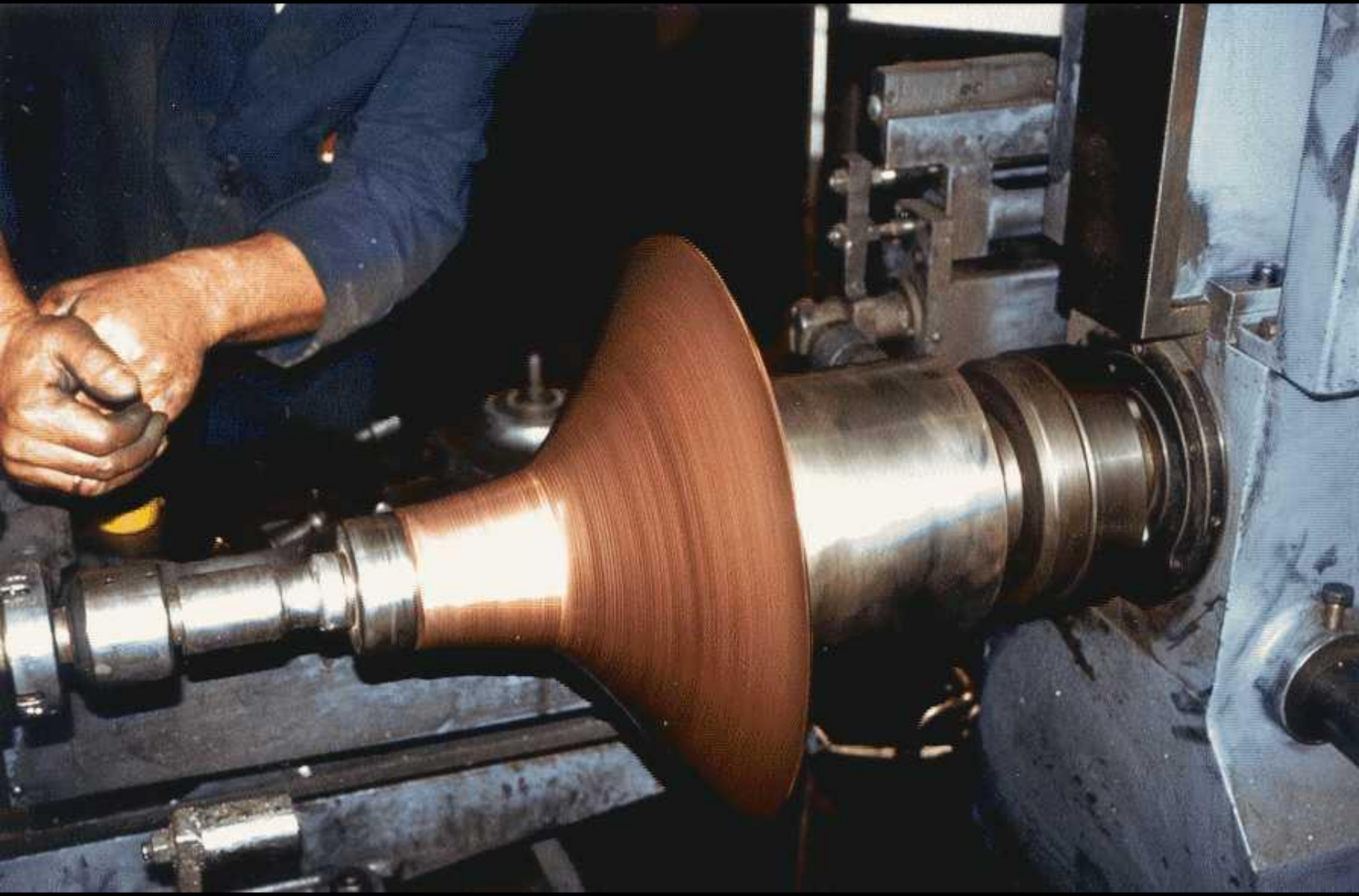
Fig. 3 a) Slipping system (111) [10$\bar{1}$] for FCC metals; b) slipping system (101) [11$\bar{1}$] for BCC metals. Among BCC metals, Niobium is a lucky exception since its anomalous slip direction [010] requires less energy for displacement if compared to the [11$\bar{1}$].

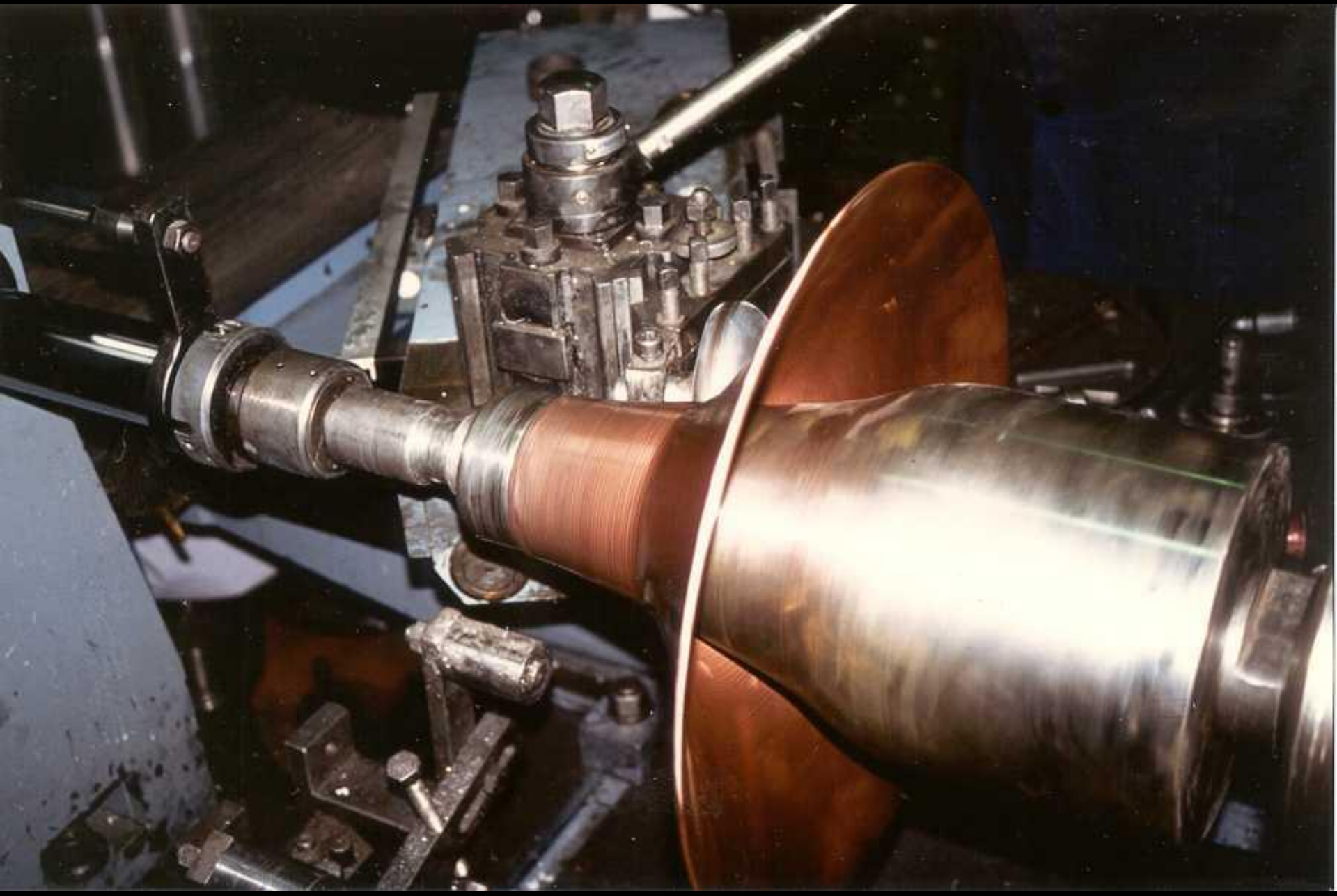

- σr
+σt
+σr
+σt

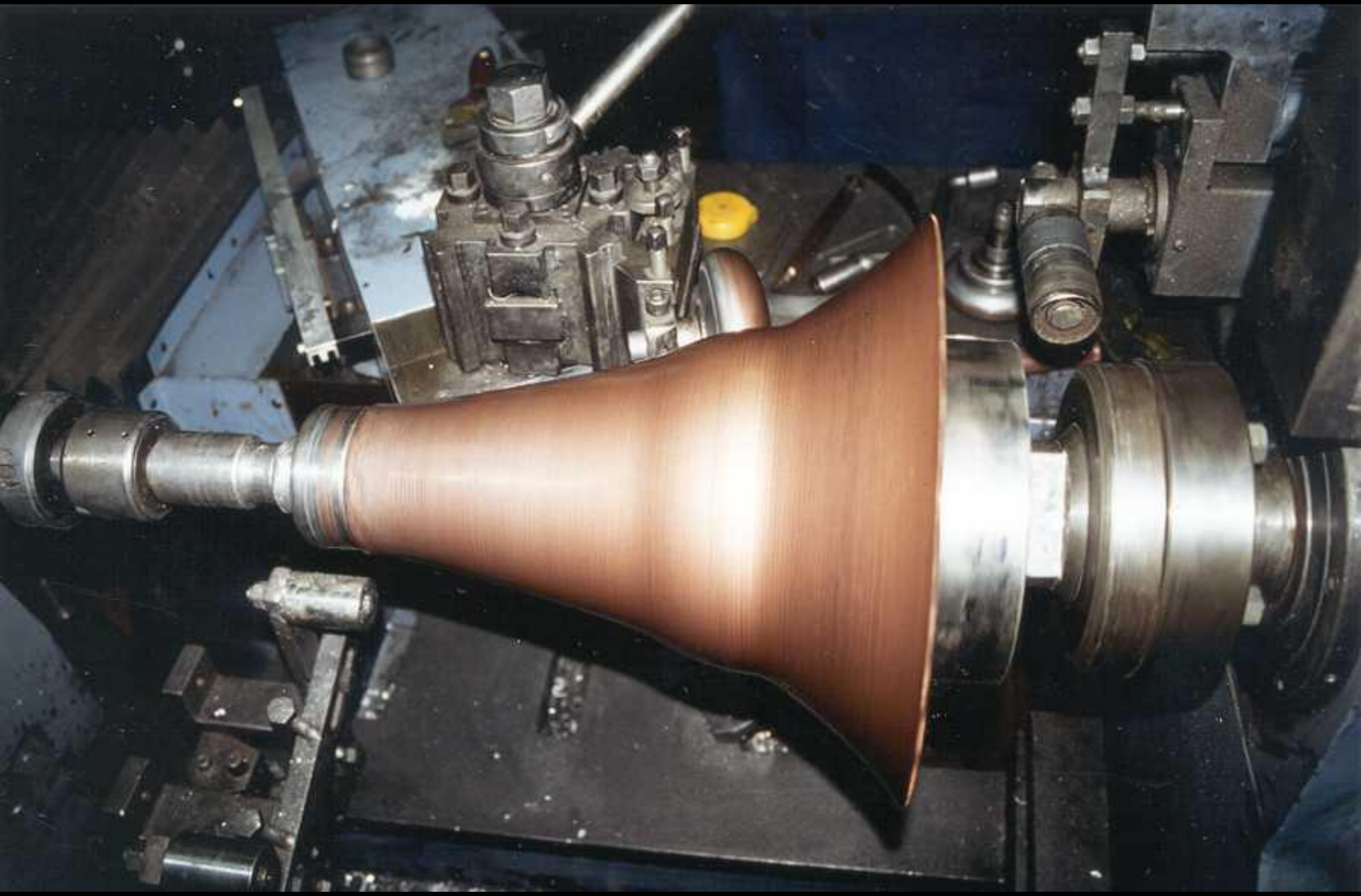


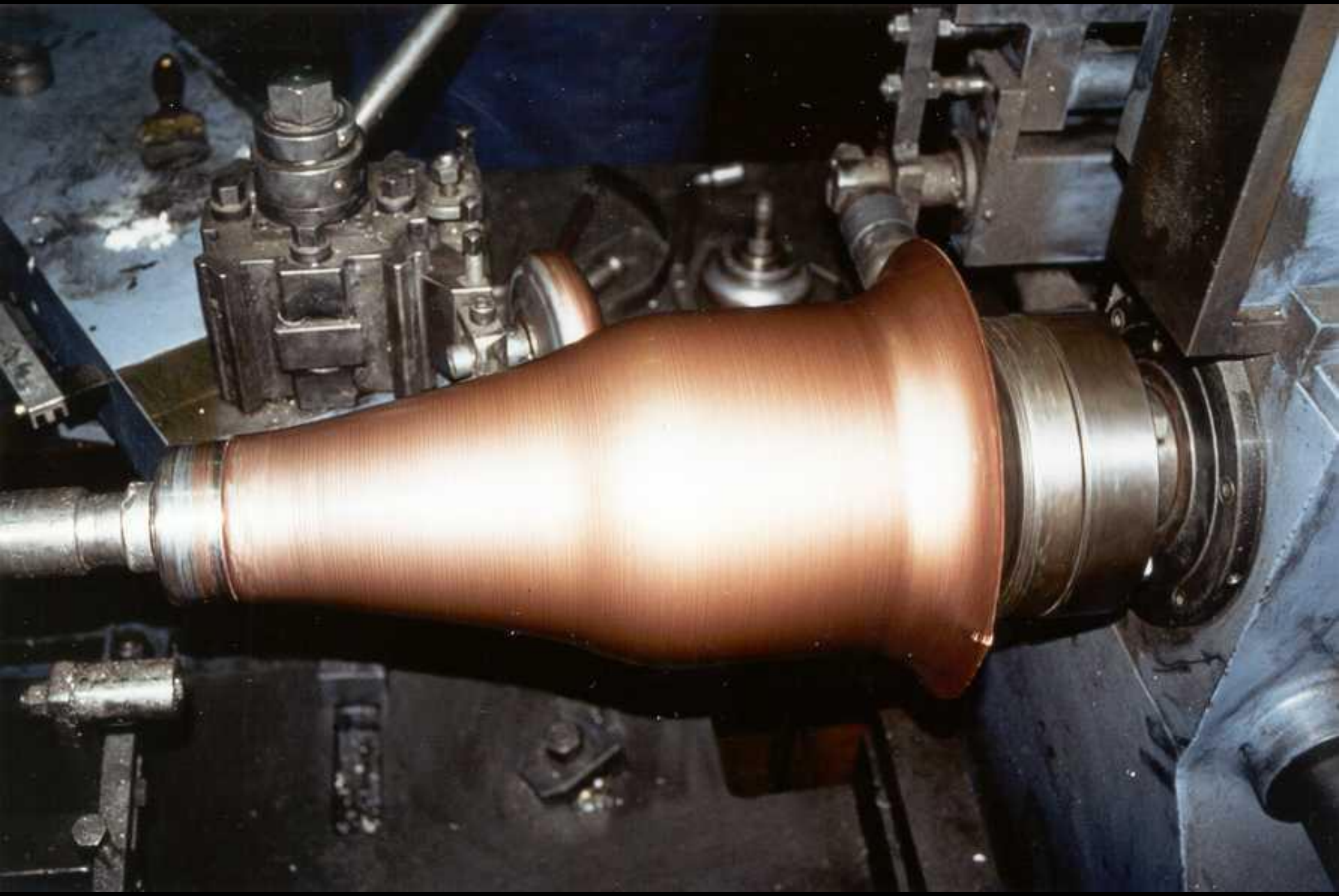


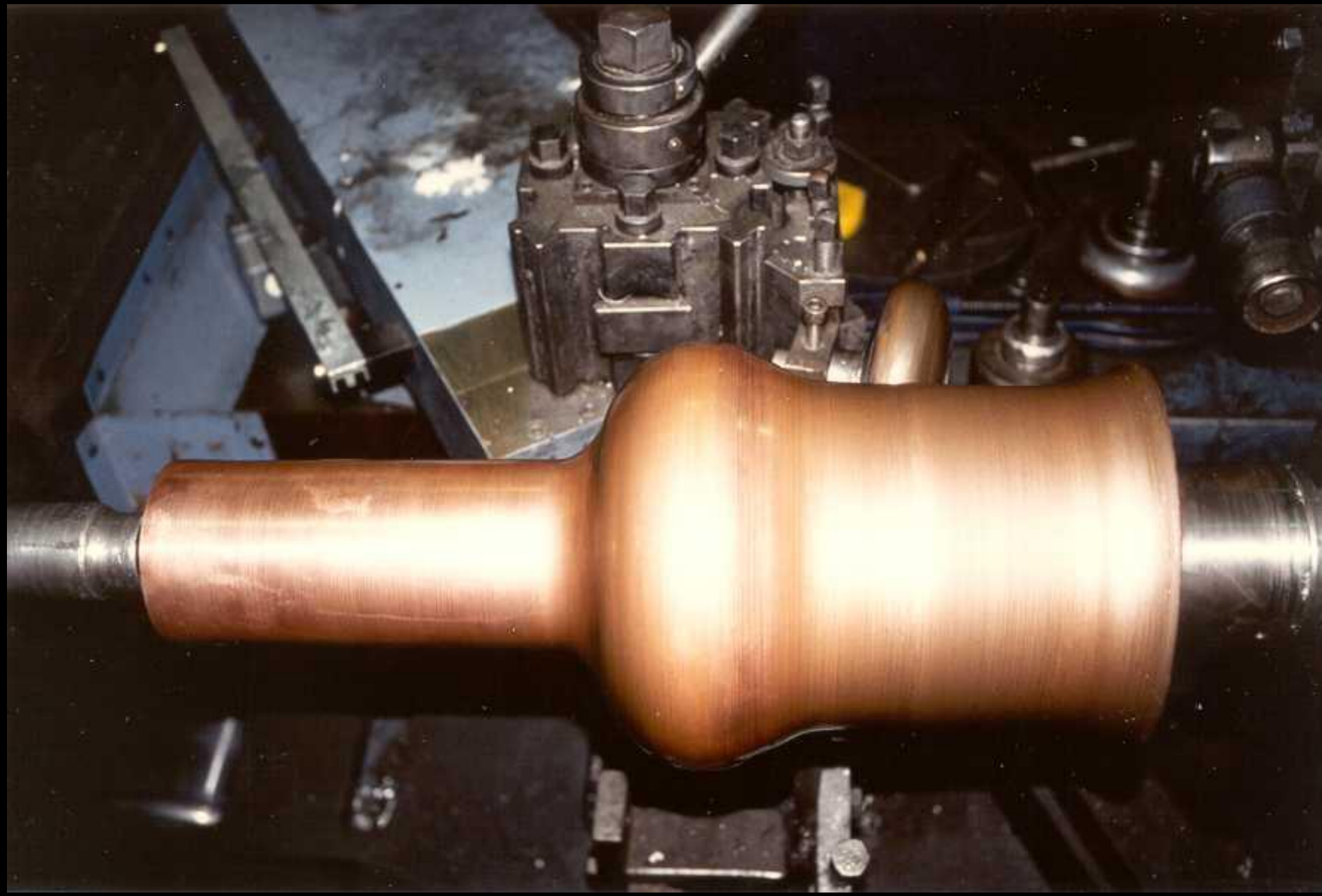


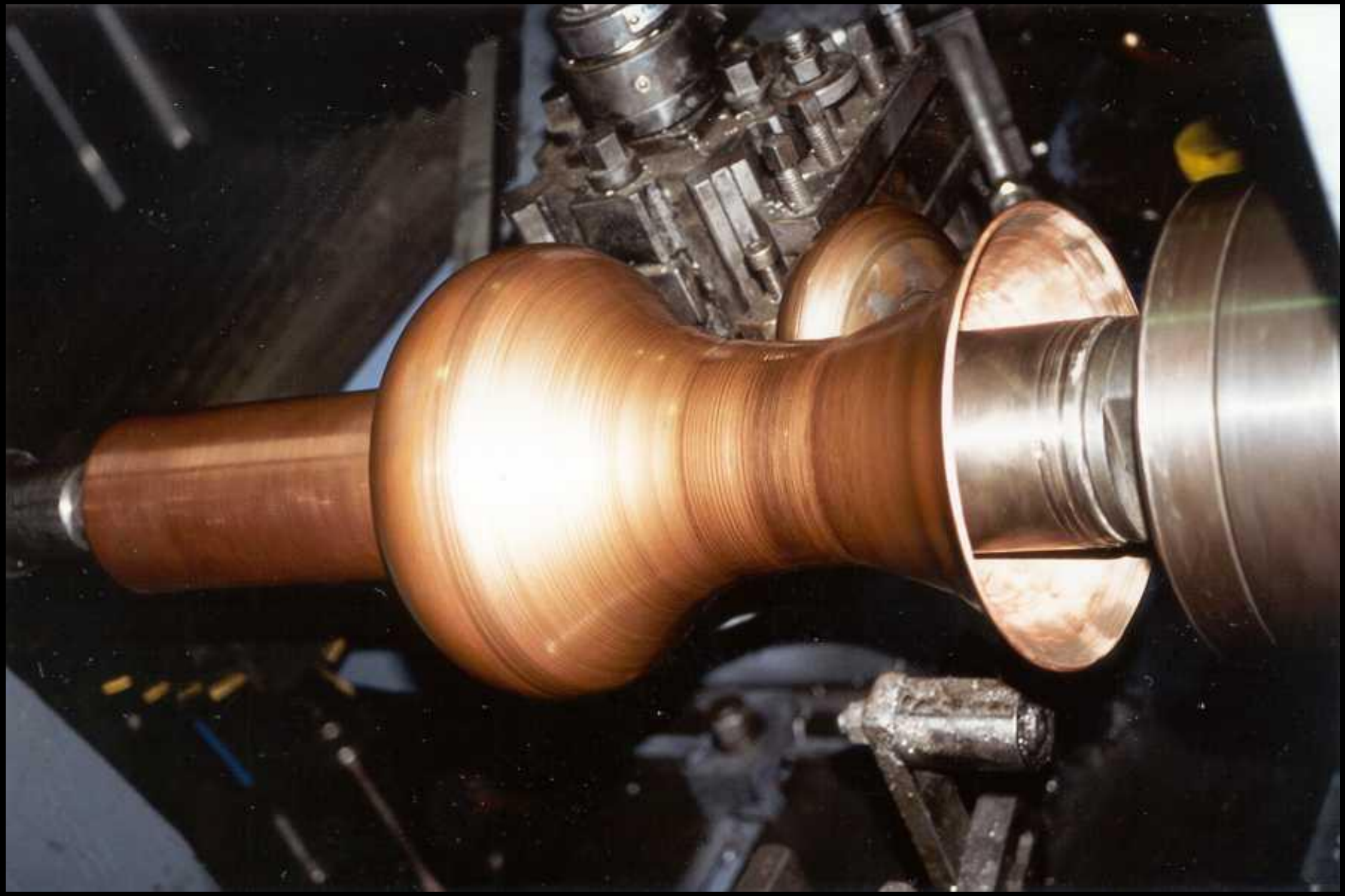


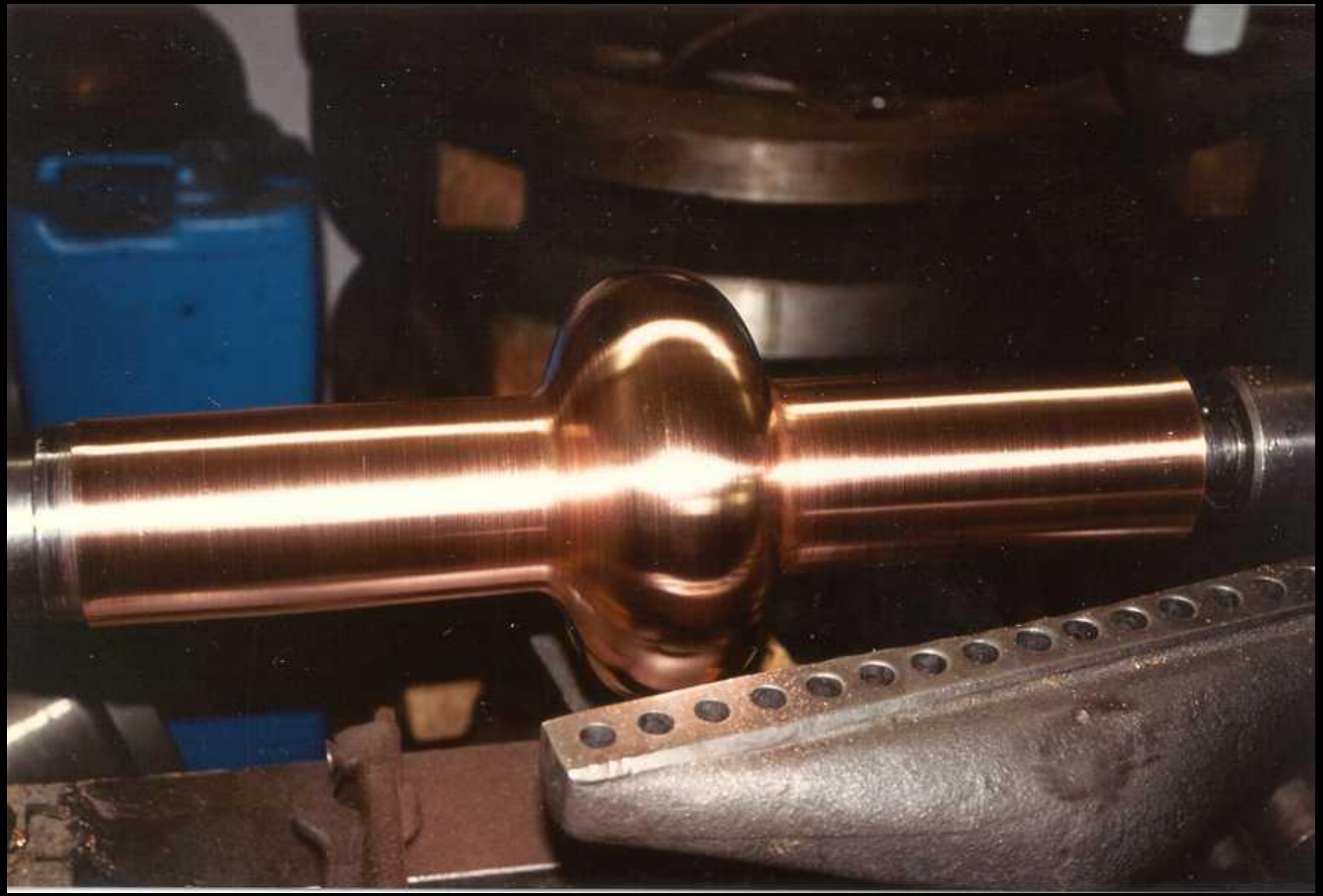


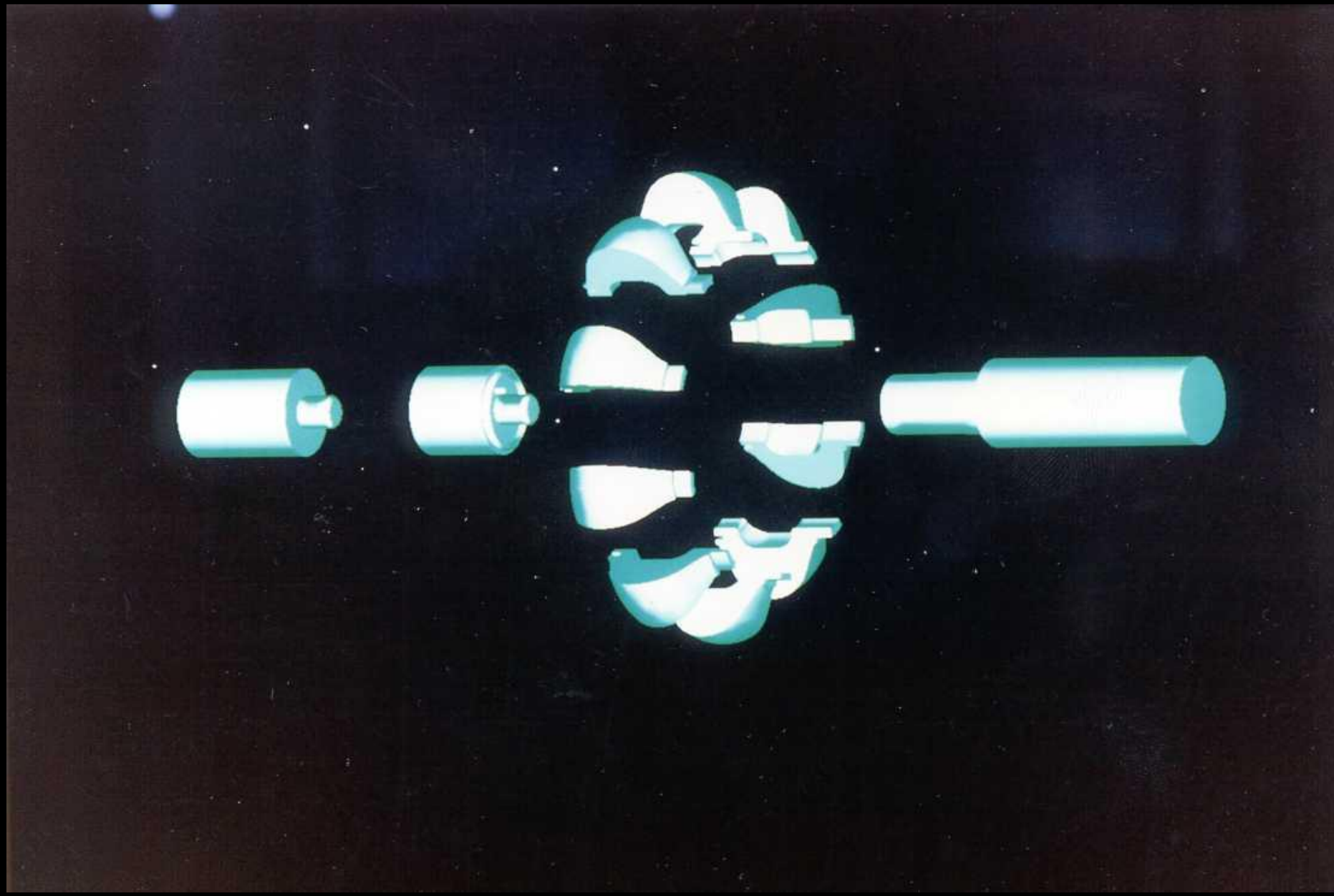












What are the advantages of Spinning?

Spinning

is a

3-D forming process

For standard 2-D forming processes,

material parameters, as:

- **young Modulus**
- **Ductility,**
- **Hardness**

are crucial parameters

For spinning

we don’t mind!

For a standard 2-D forming process

A 40% elongation is a limitation

For Spinning

10,000% elongations are

possible wihout annealing

For Hydroforming,

the tube thickness uniformity

is crucial

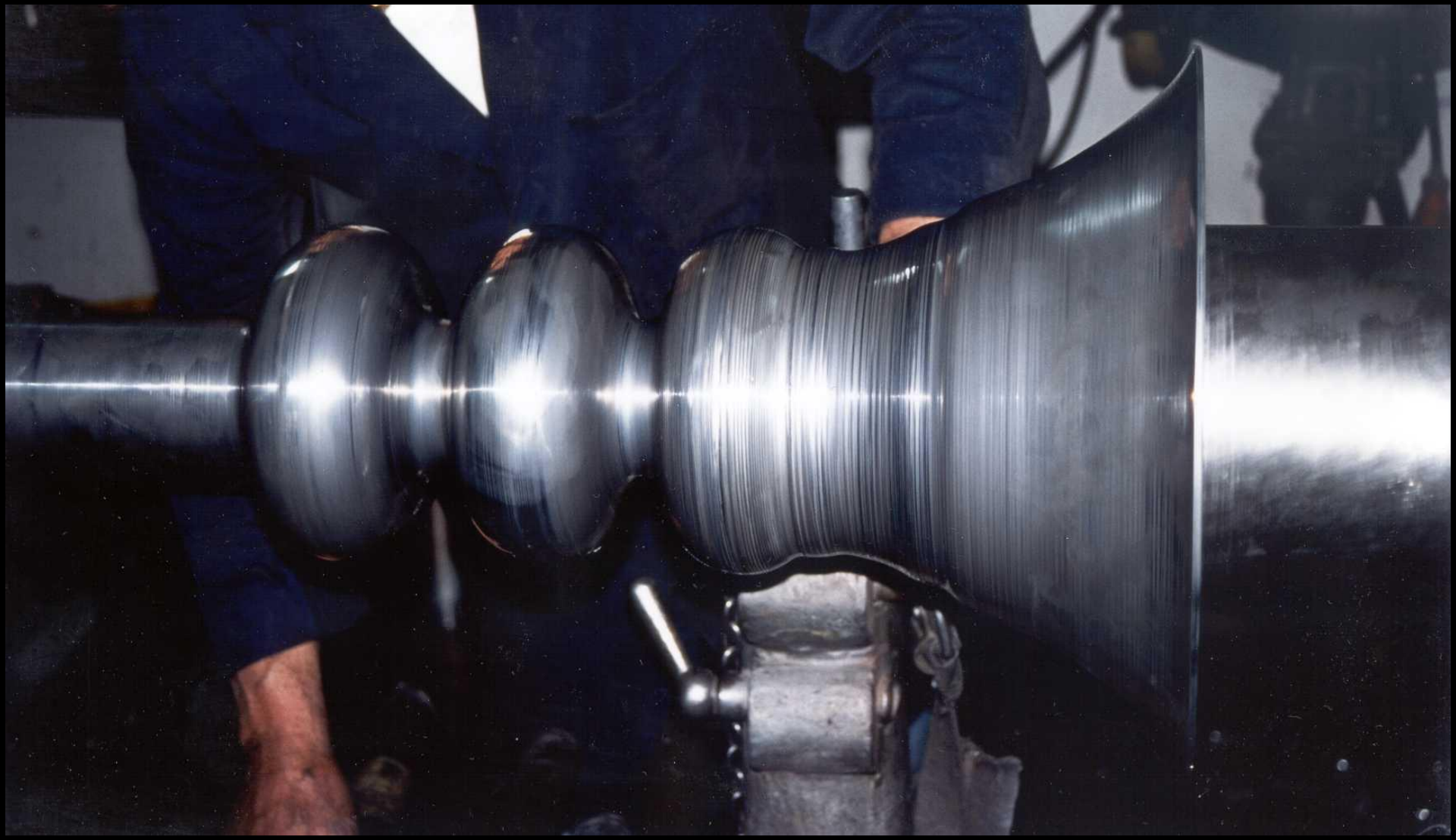
Otherwise ....

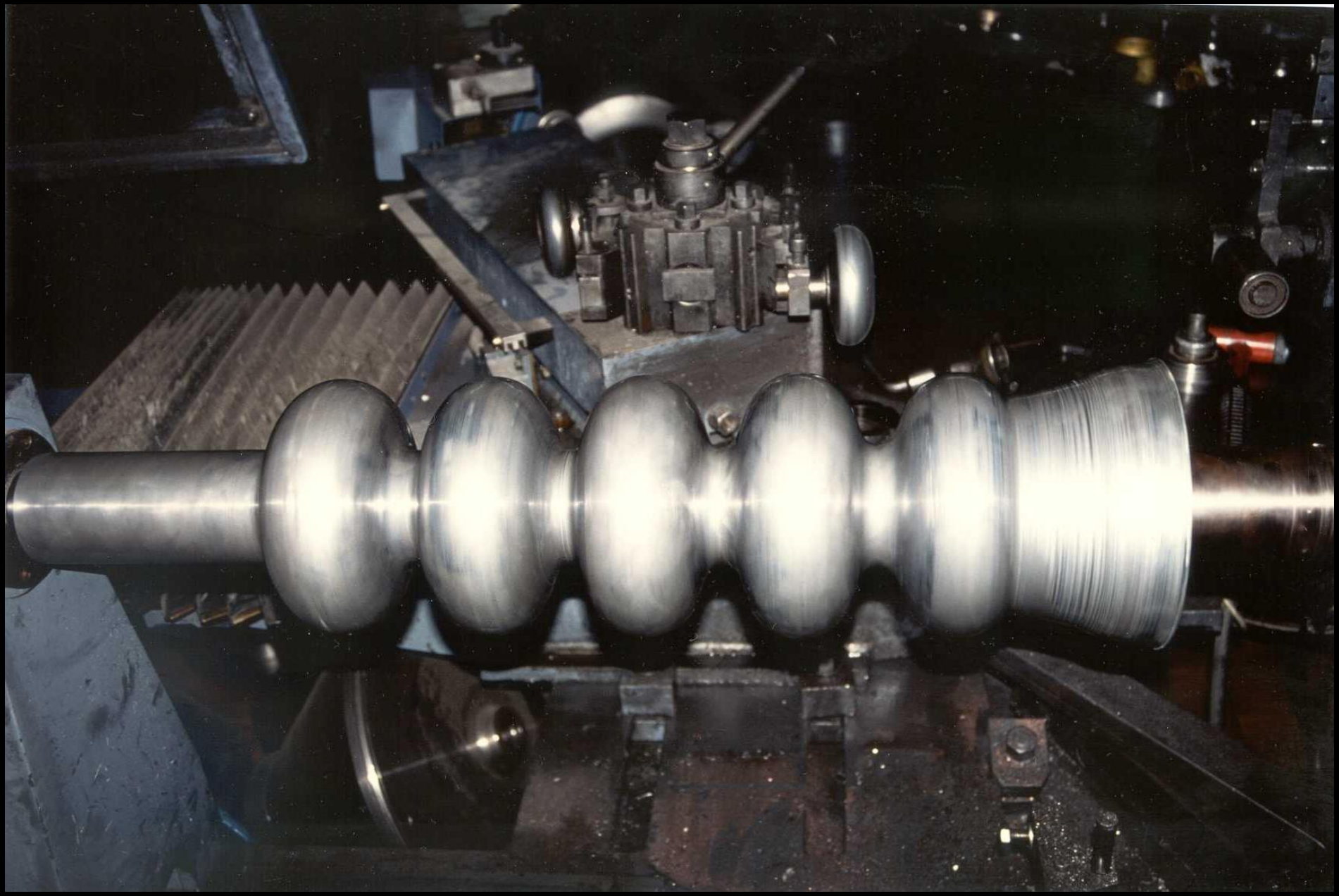
For spinning we do not mind!

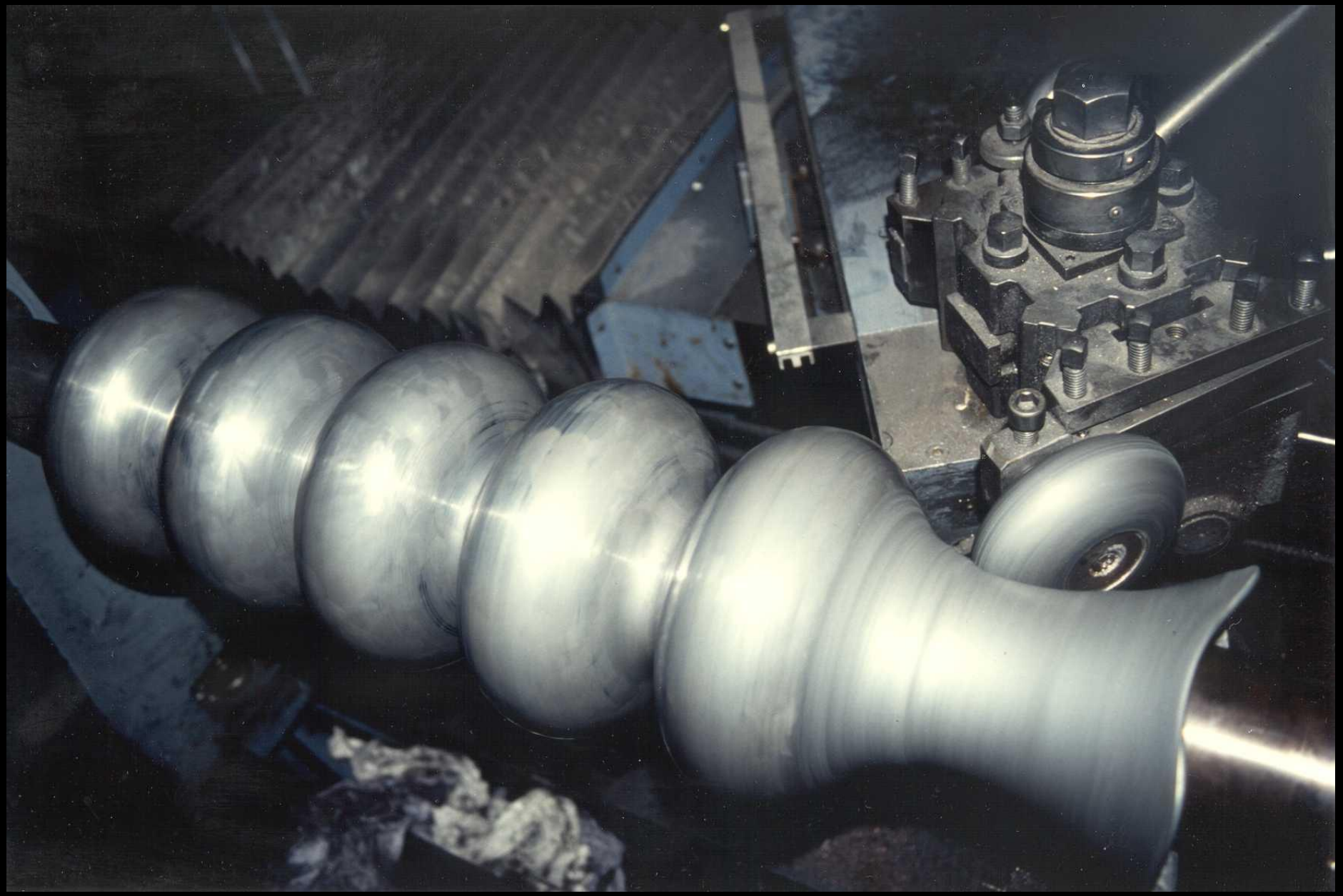
Tube with not uniform thickness will be re-rolled on the machine just before spinning the cavity

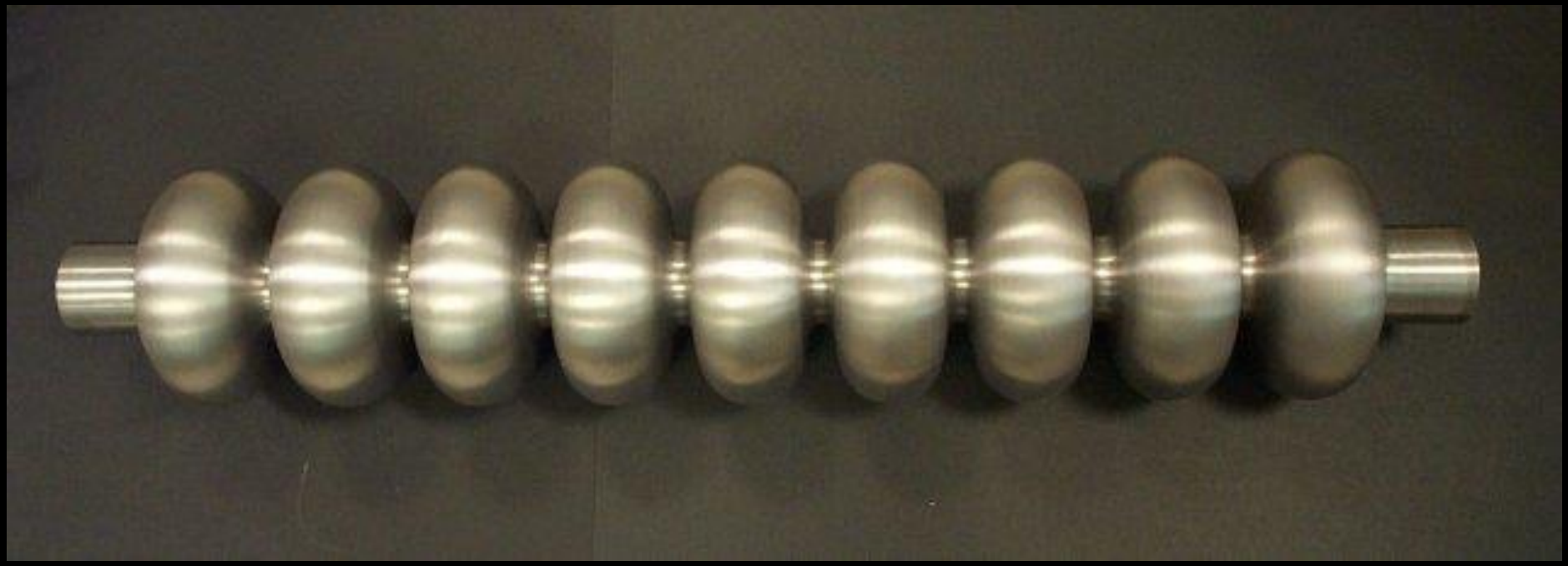
Drawbacks of the spin-forming process:

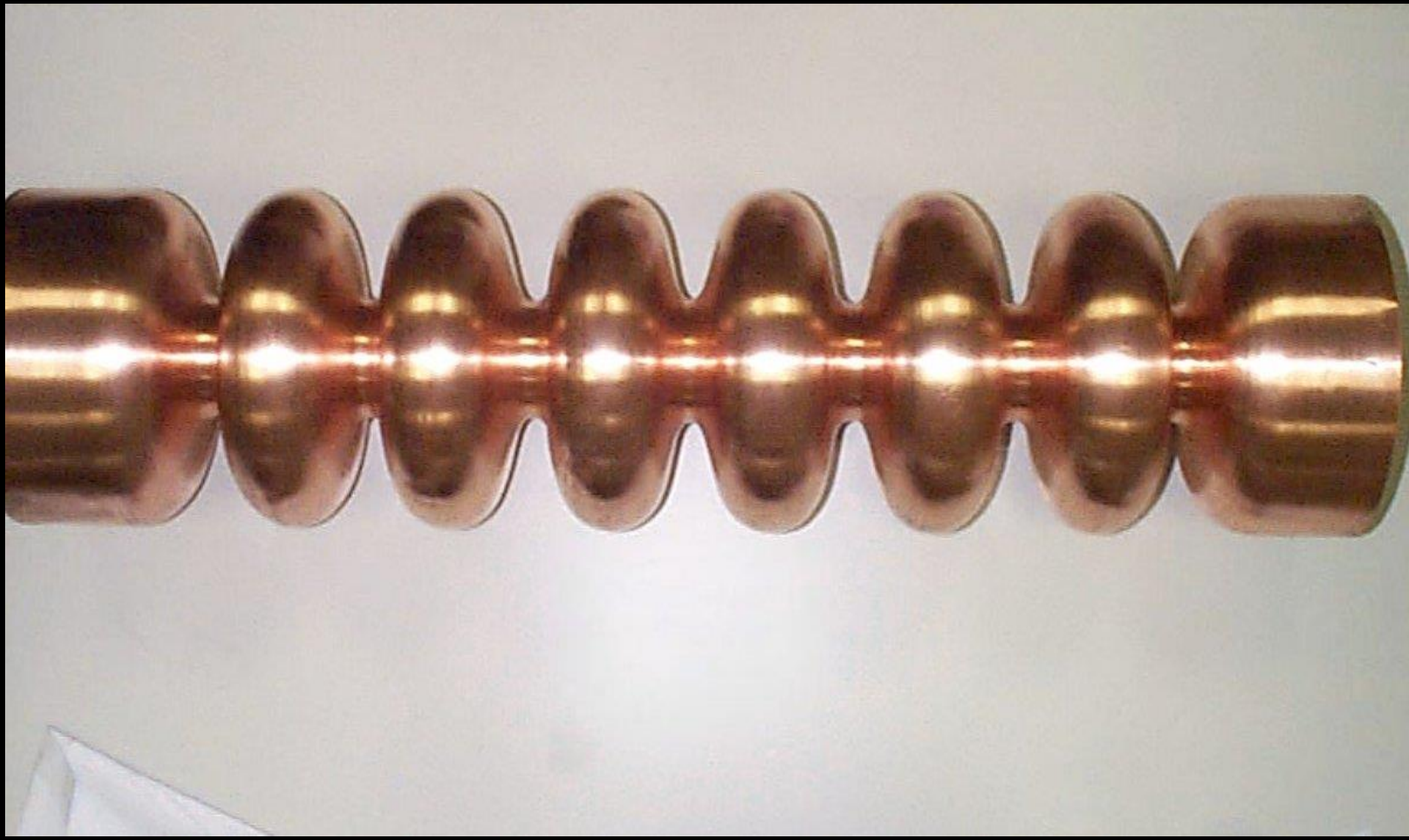
- Non-uniform wall thickness of the cavity
- Need of internal grinding or tumbling
- Still a manual process







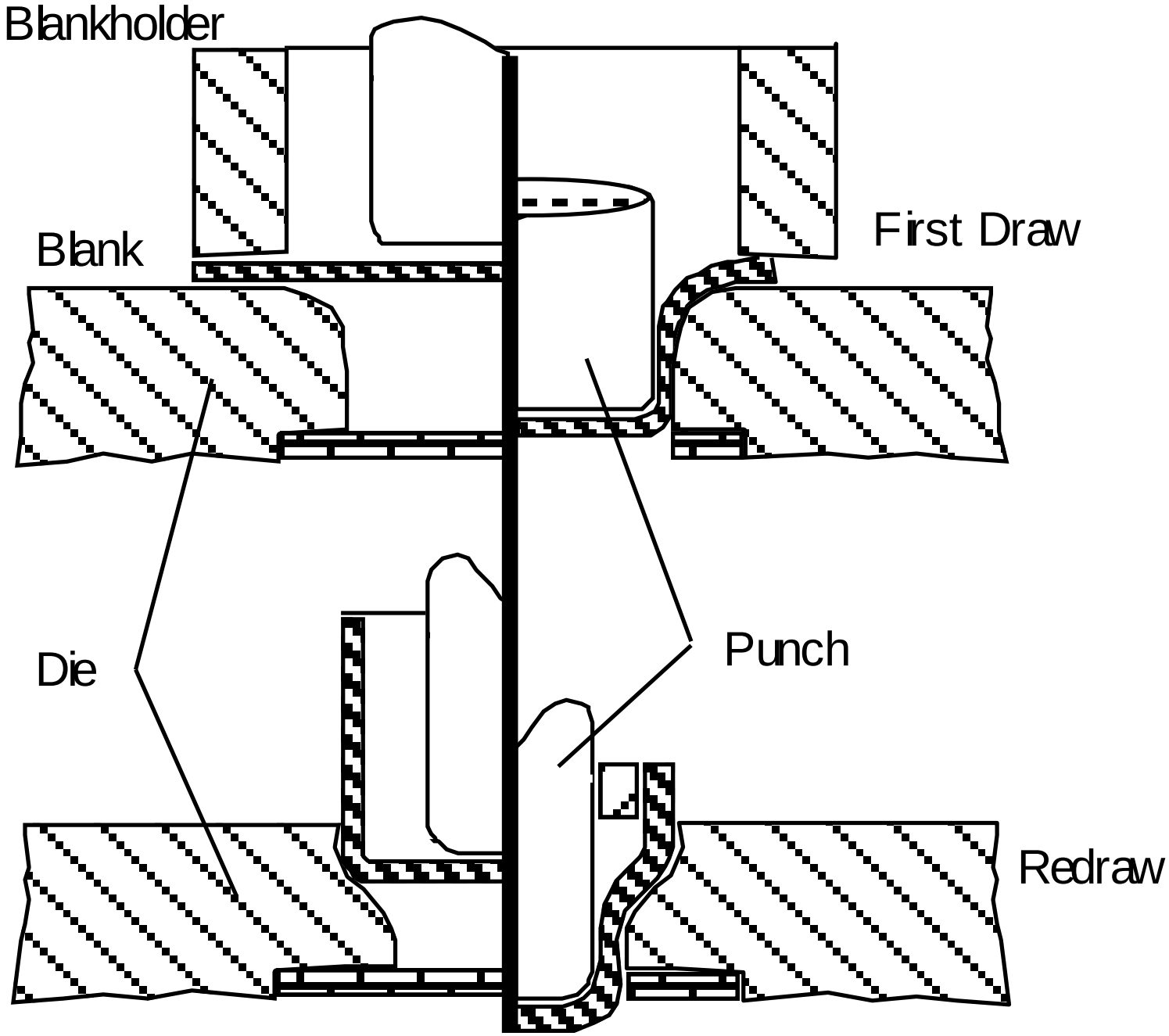




If we loook for a more engineerable process,

seamless tubes are mandatory

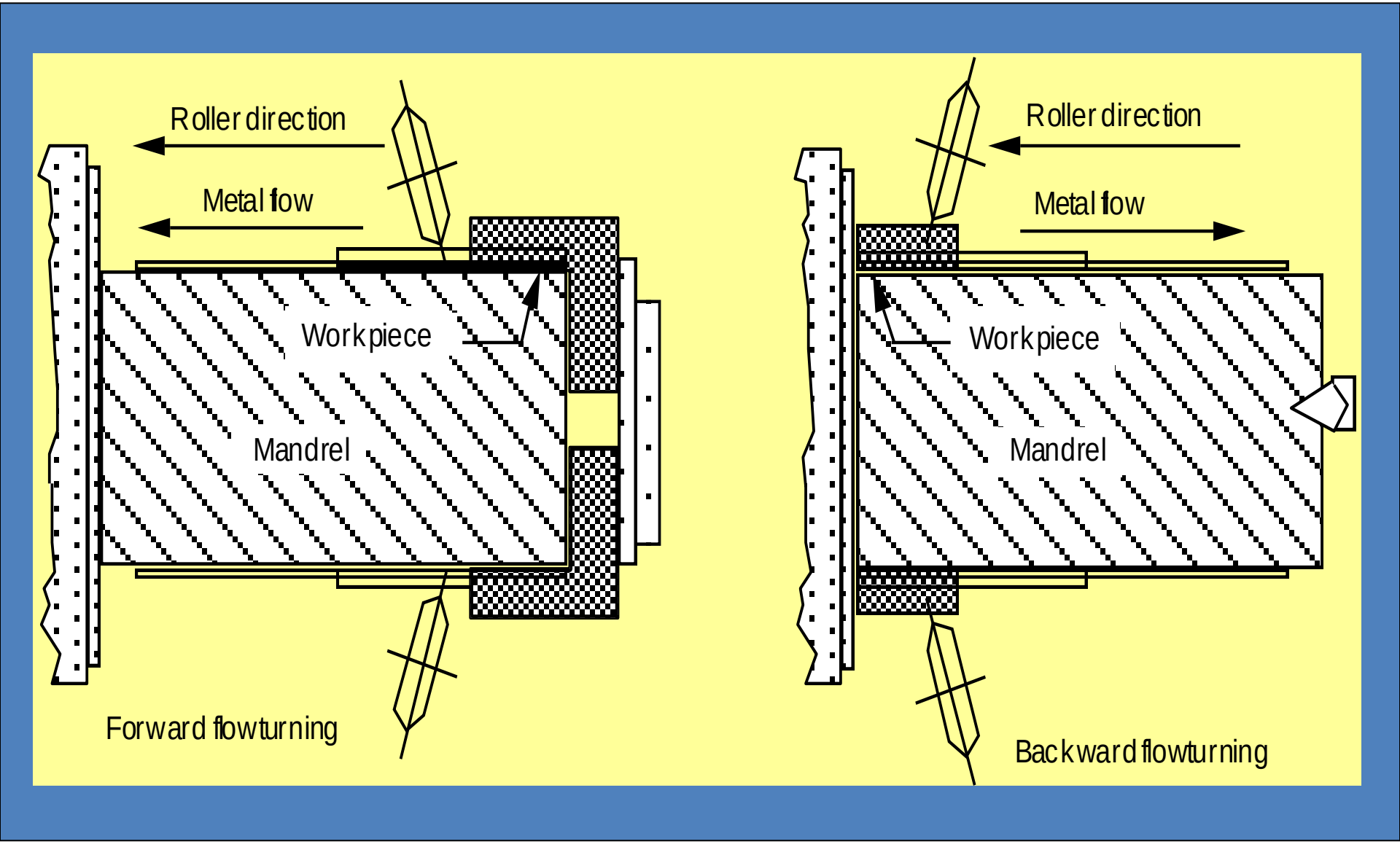
1. The Deepdrawing Process

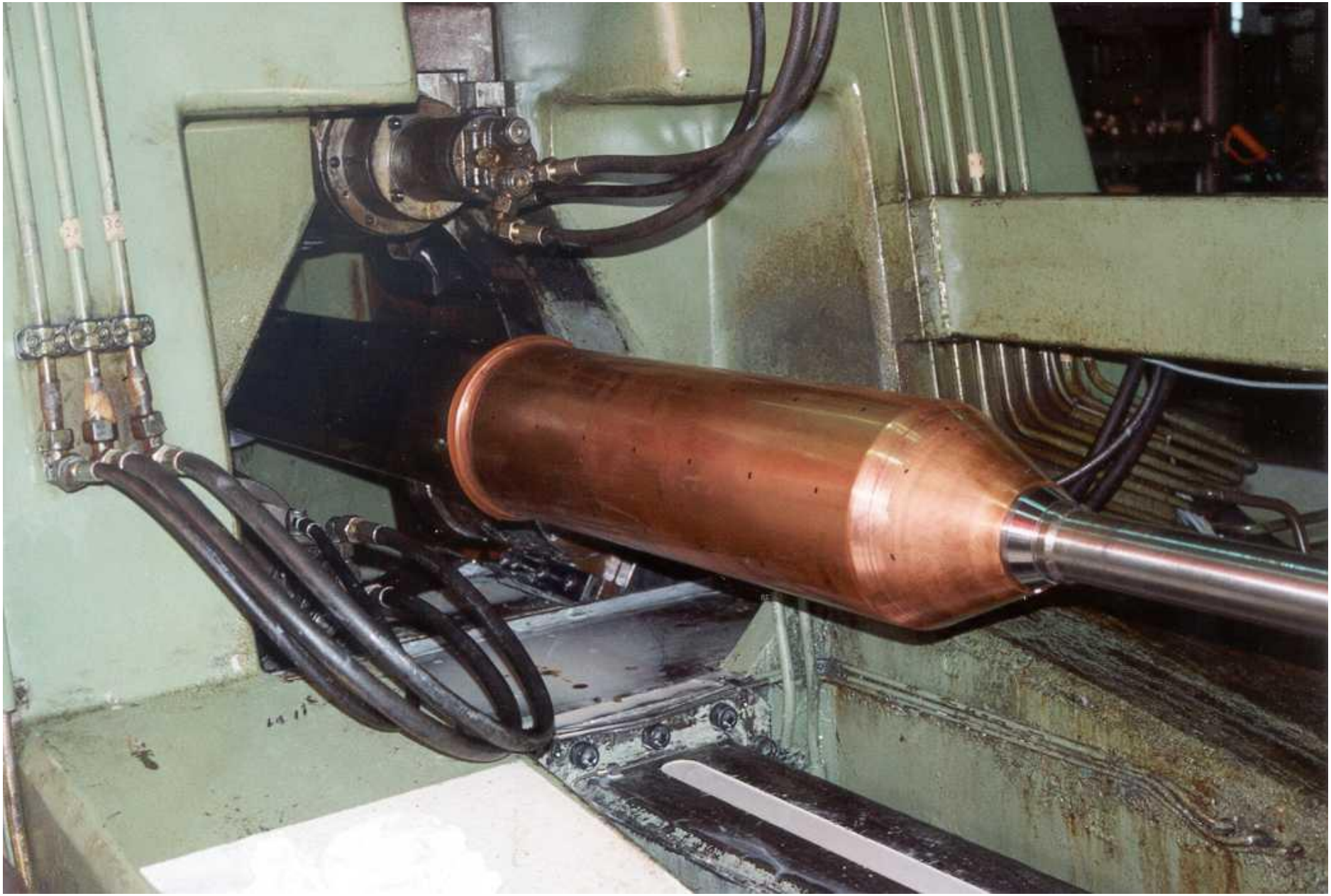

Blankholder
Blank
First Draw
Die
Punch
Redraw






2. The Flowturning Process


Roller direction
Metal flow
Workpiece
Mandrel
Forward flowturning
Roller direction
Metal flow
Workpiece
Mandrel
Backward flowturning



2 Nb ninecells

fabricated in 2001 for

being measured at KEK

(but broken meanwhile tumbling)

Two old 9-cells are going to be repaired

Three new 9-cells will be fabricated for the end of the year, for a total of 5 cavities

9- cell Cavity Unitary Cost
(both without end groups)

Standard EB-Welding	Spinning
In quantity of 20 (from B. Kephart)	in quantity of 3 (just bought)
• Niobium Material = 38K$	• Niobium Material =23 K€
• Forming, machining + • welding = 45K$	• Tube Preforming = 2 K€
	• Tube Flowturning = 2K€
	• Cavity Spinning = 3K€
Total cost = 83 K$	**Total cost = 30 K€**

Current Work:

Tube back-extrusion
directly from from billets

So maybe the cost can be lowered to < 20K€/nine-cell

A seamless flange

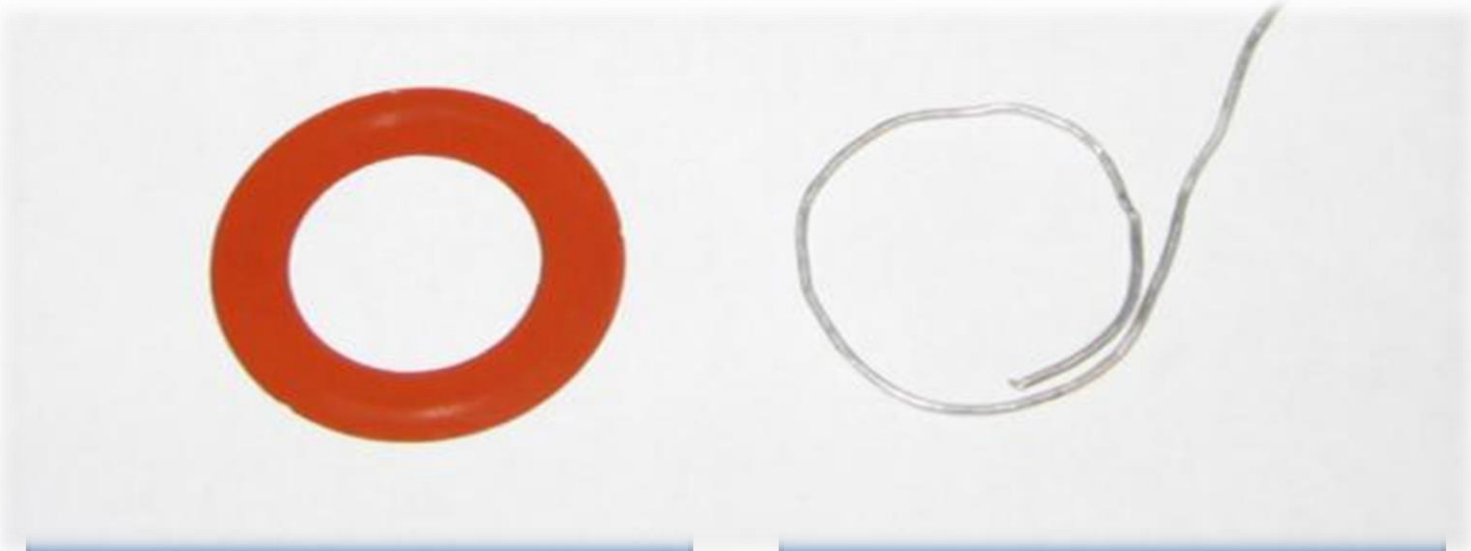
Cheap alternative to welded Nb-Ti

New flange design

Use **Kapton Joints** for sealing cavities

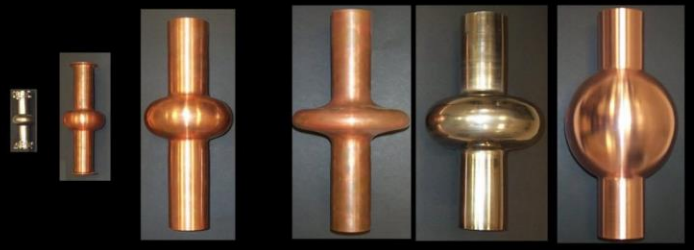
and ...

Life will never be the same!



Cavities of any shape and any size

Cavities Spun at LNL

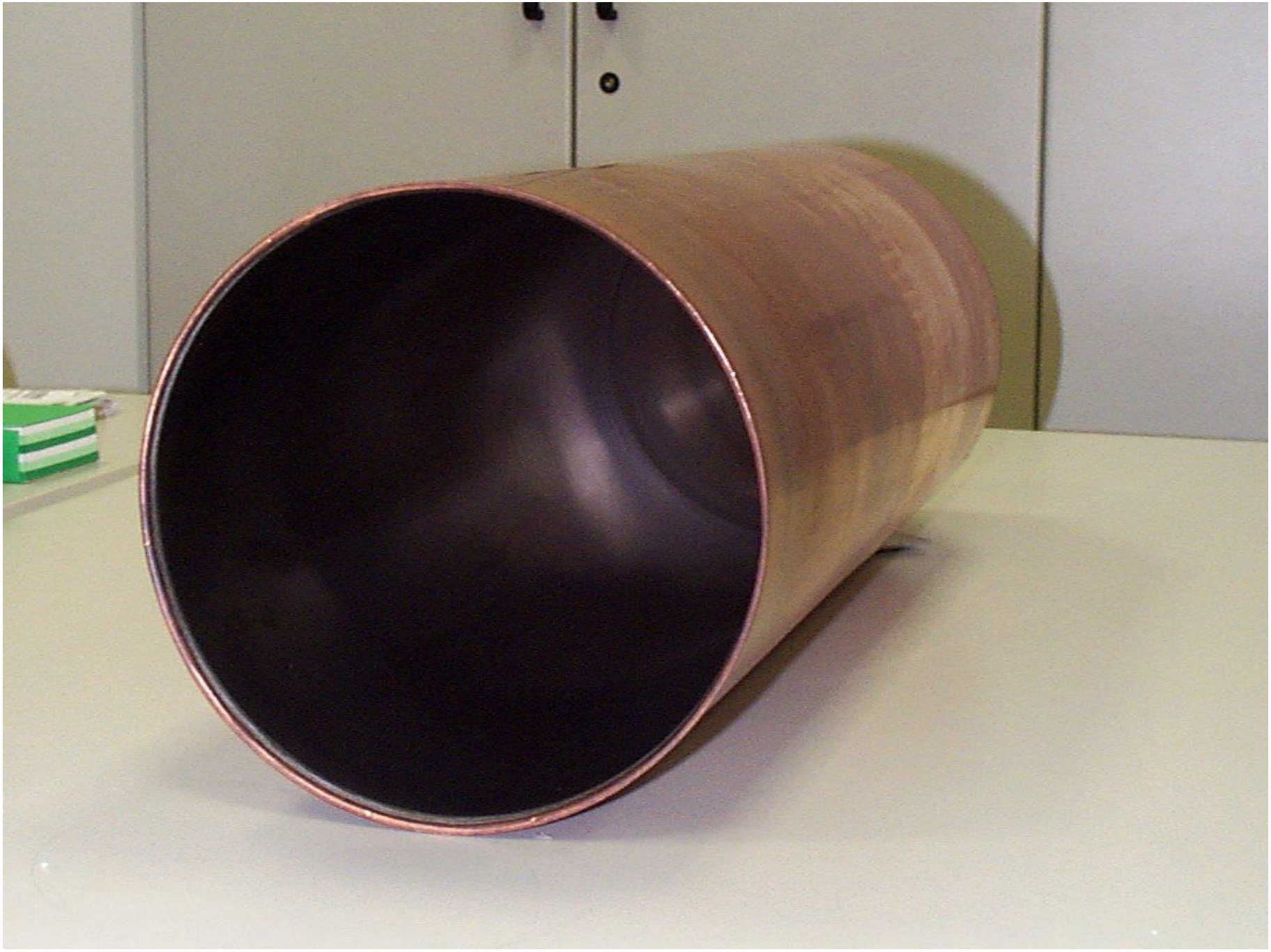


6 GHz

500 MHz

Nb Clad Cu?

No Problem!

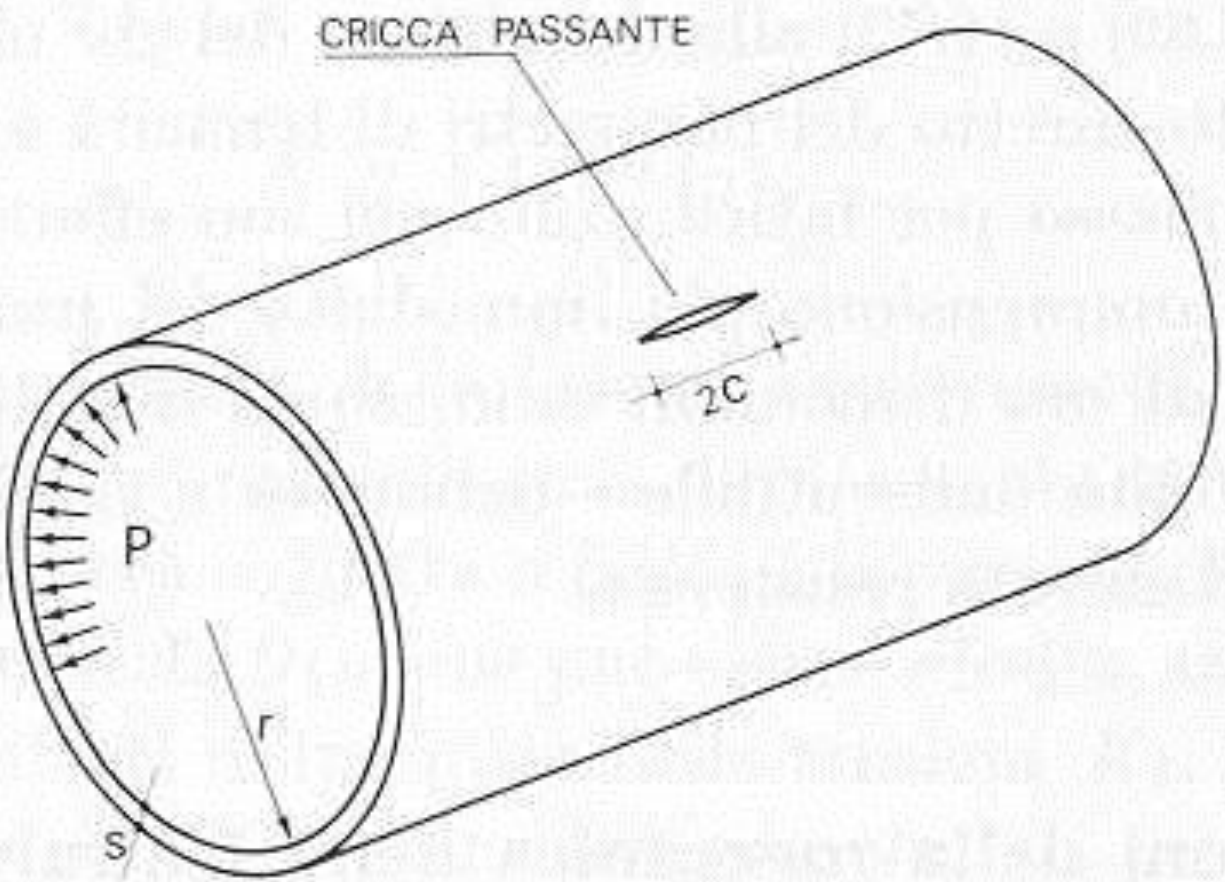


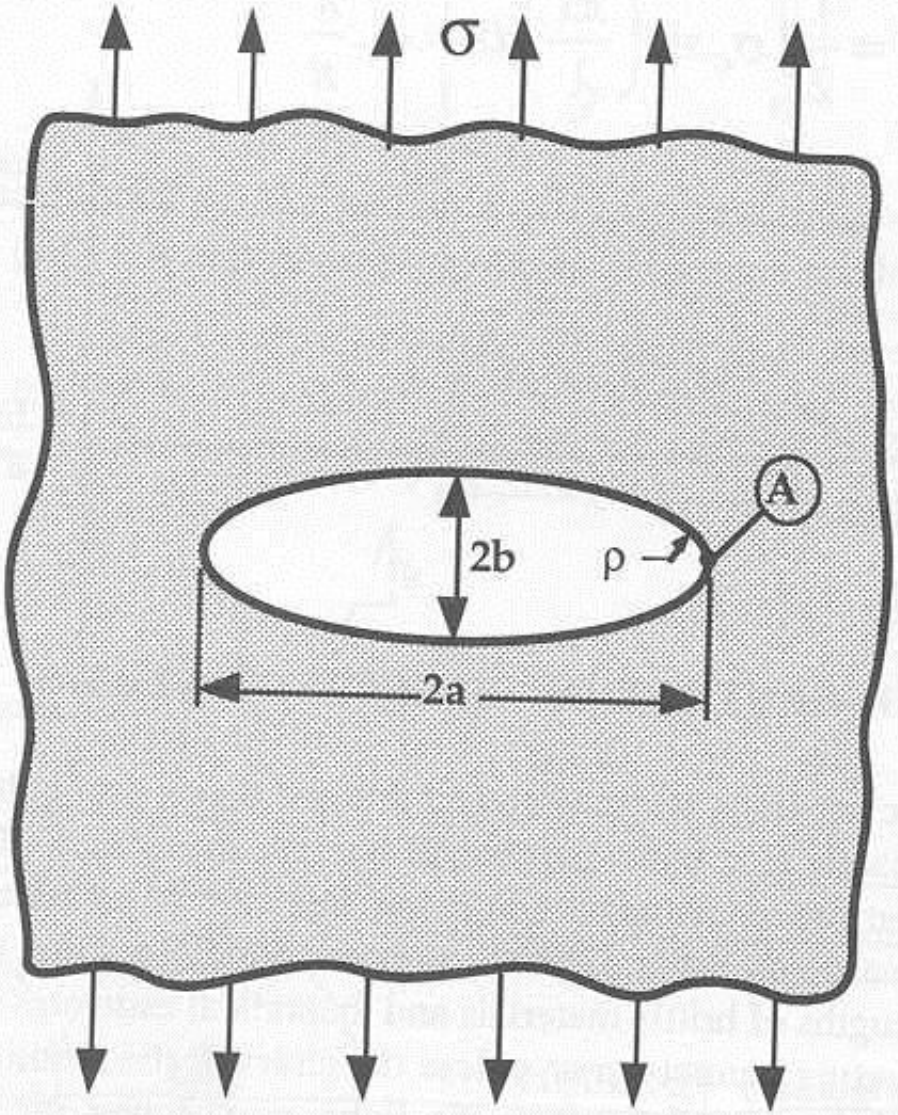

4.8.2000

The Spinning Proceedure

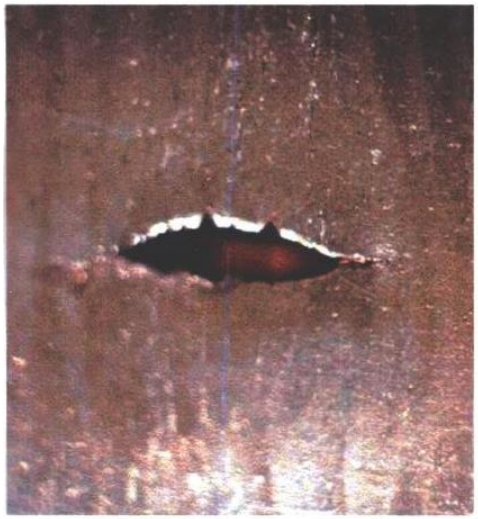
We produced calibrated holes in a Cu blank and

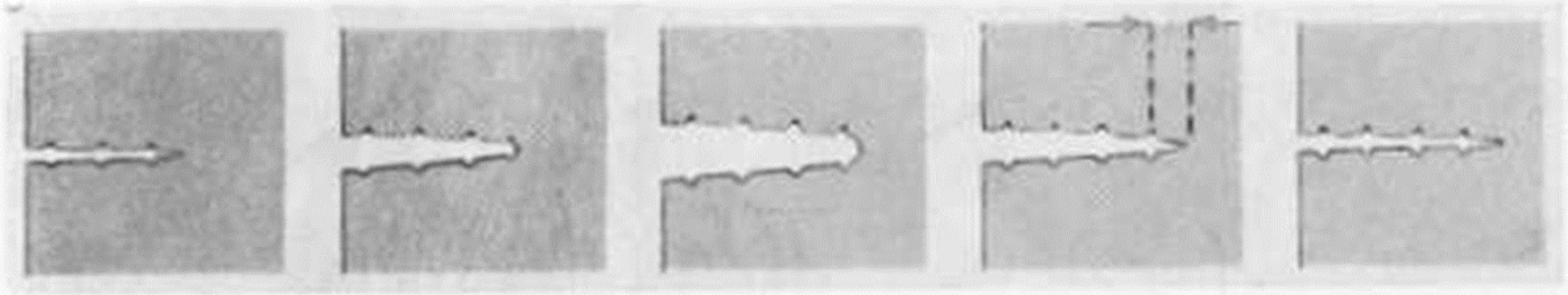
we used the crack propagation mechanism in order to find out how to spin


CRICCA PASSANTE
2C
P
r
s



Elliptical hole in a flat plate.





Finding the right parameters by the **Buckingham-PI Theorem** (dimensional analysis):

D = Blank Diameter

S= Blank thickness

v = roller feed velocity

ω = Angular velocity

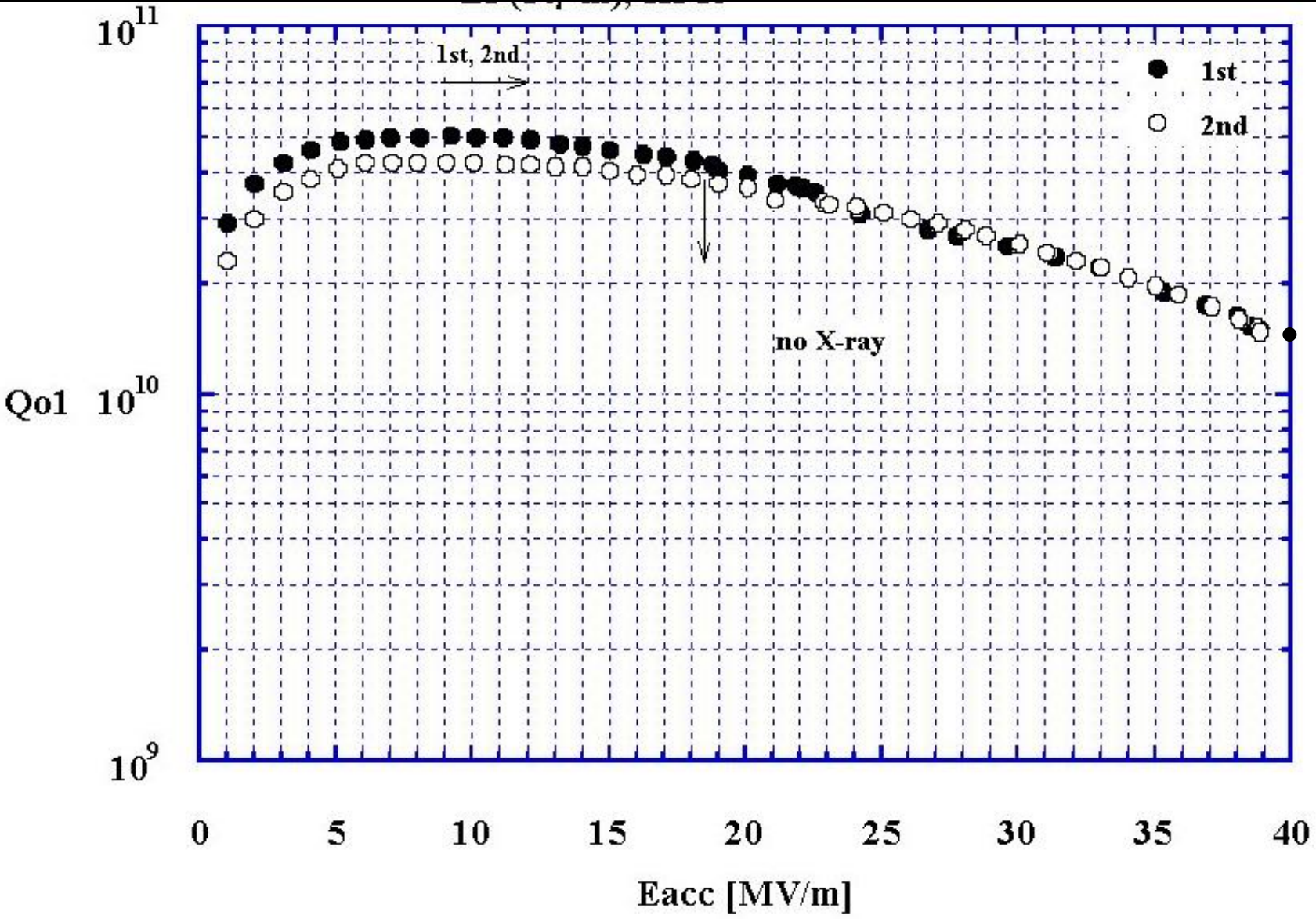
f = arc of the roller blank contact segment

Reduced parameters are: D/s; $\omega f / v$

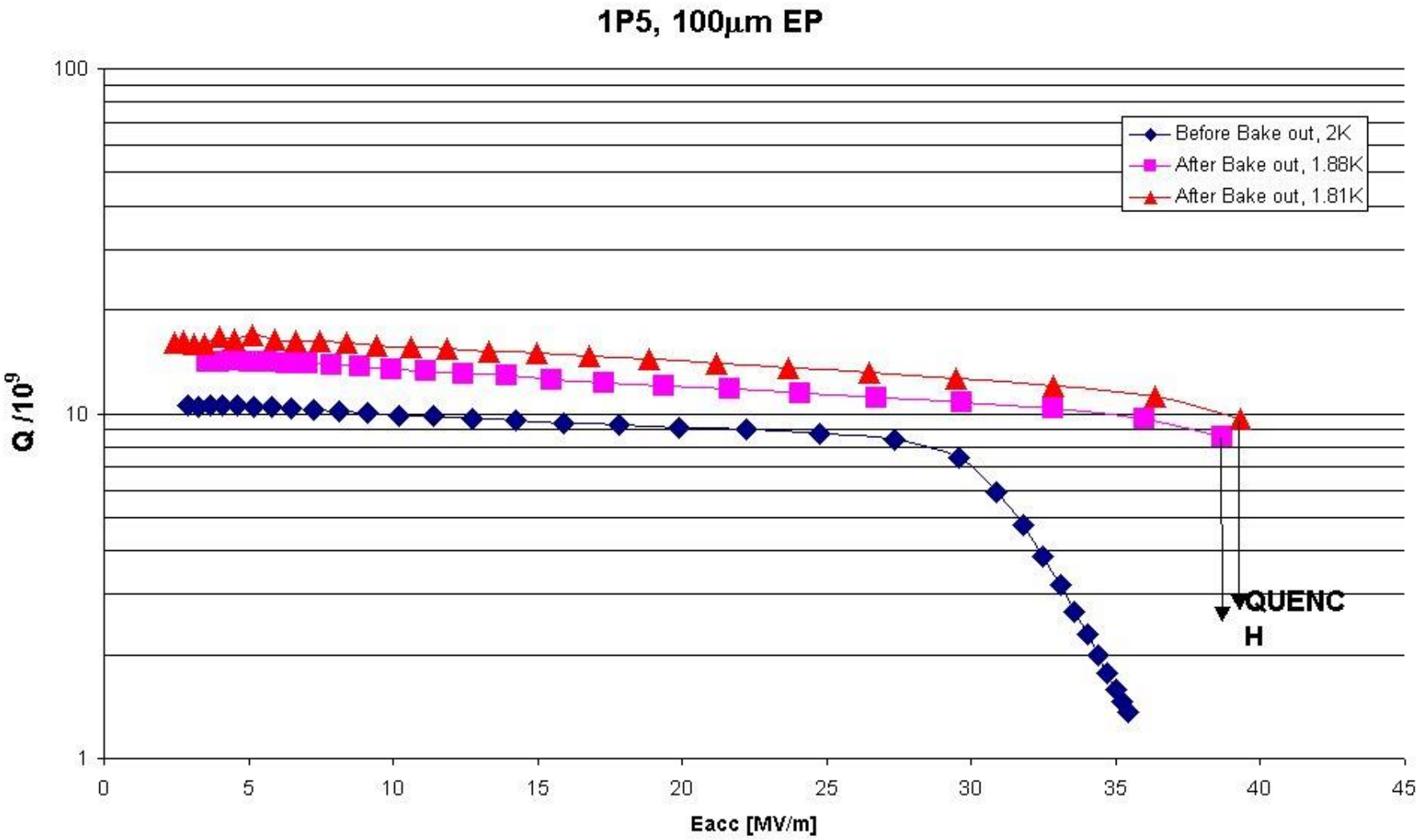
Q vs E_{acc} Results

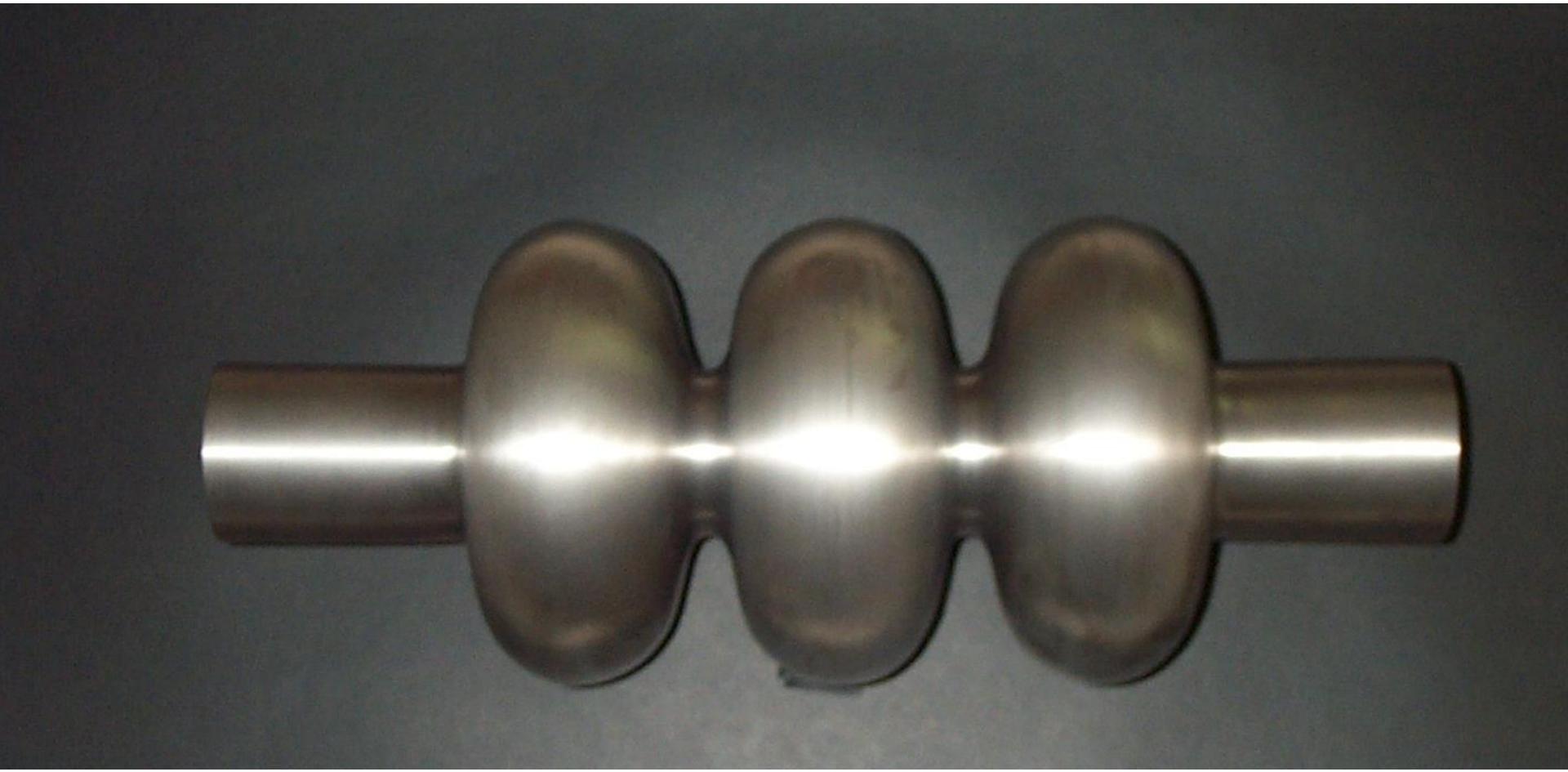
«But, ... Palmieri, who knows what it will happen to the Niobium when you willl stretch it as a crazy for spinning a cavity? .... will even it remain superconducting?»

The best result on a LNL spun monocell cavity, measured at KEK by Kenji SAITO



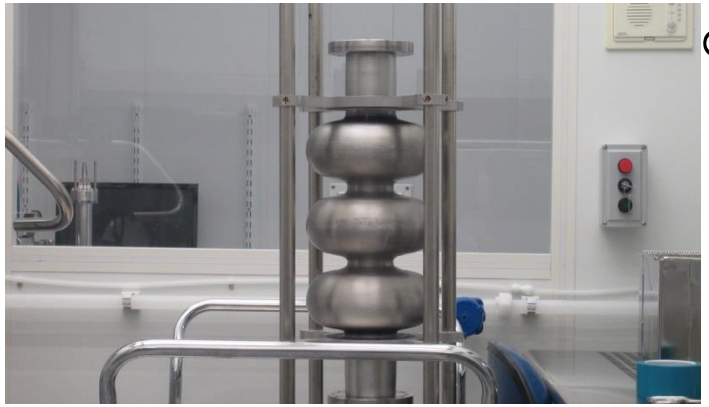
Seamless Nb Monocell, Sput at LNL, measured at CERN by R. Losito

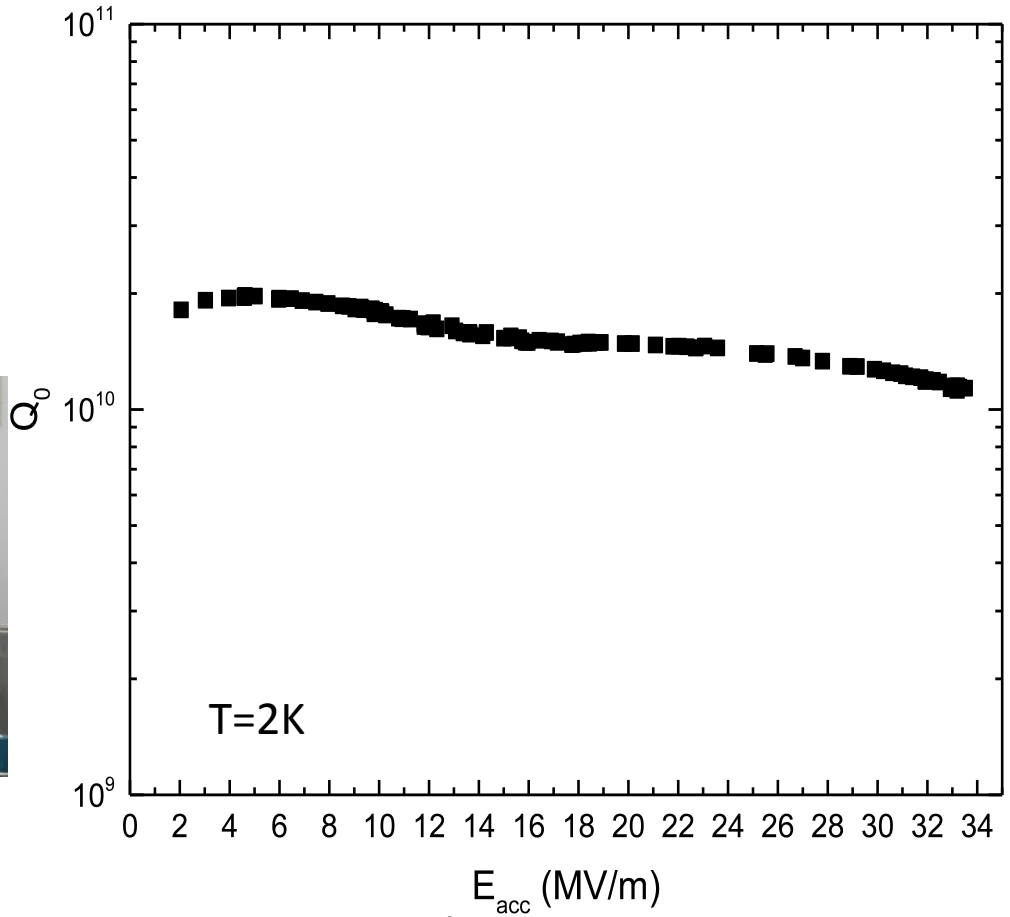




3-cell cavity made from Nb tube by spinning at INFN

Test at FNAL

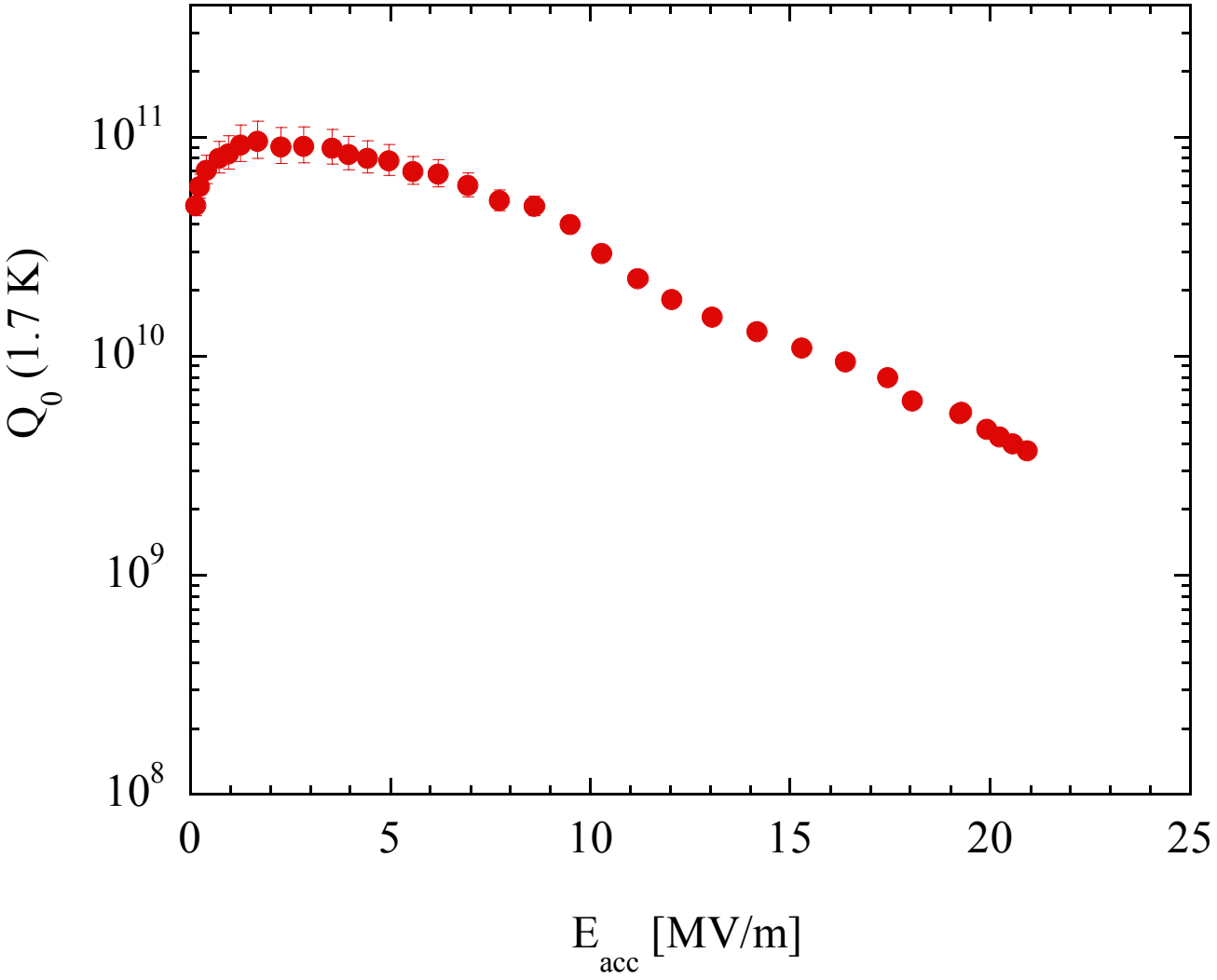




Spinning is mandatory for Nb/Cu Sputtered cavities

Nb film onto hydroformed cavities does not work!

Nb sputtered Cu spun cavity



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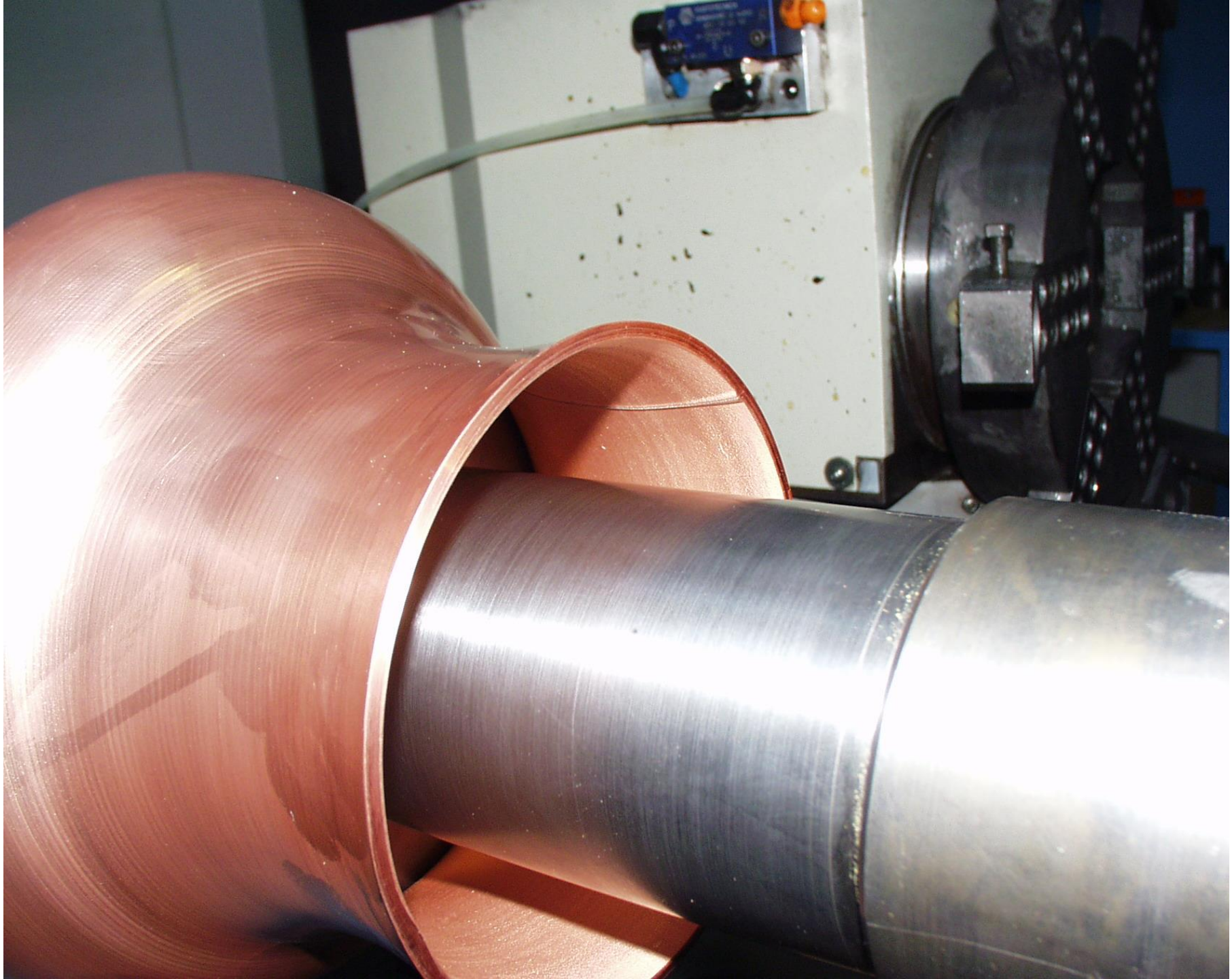
- What else the Technology offers;
- What kind of R&D INFN does;
- **What it could be needed for FCC**

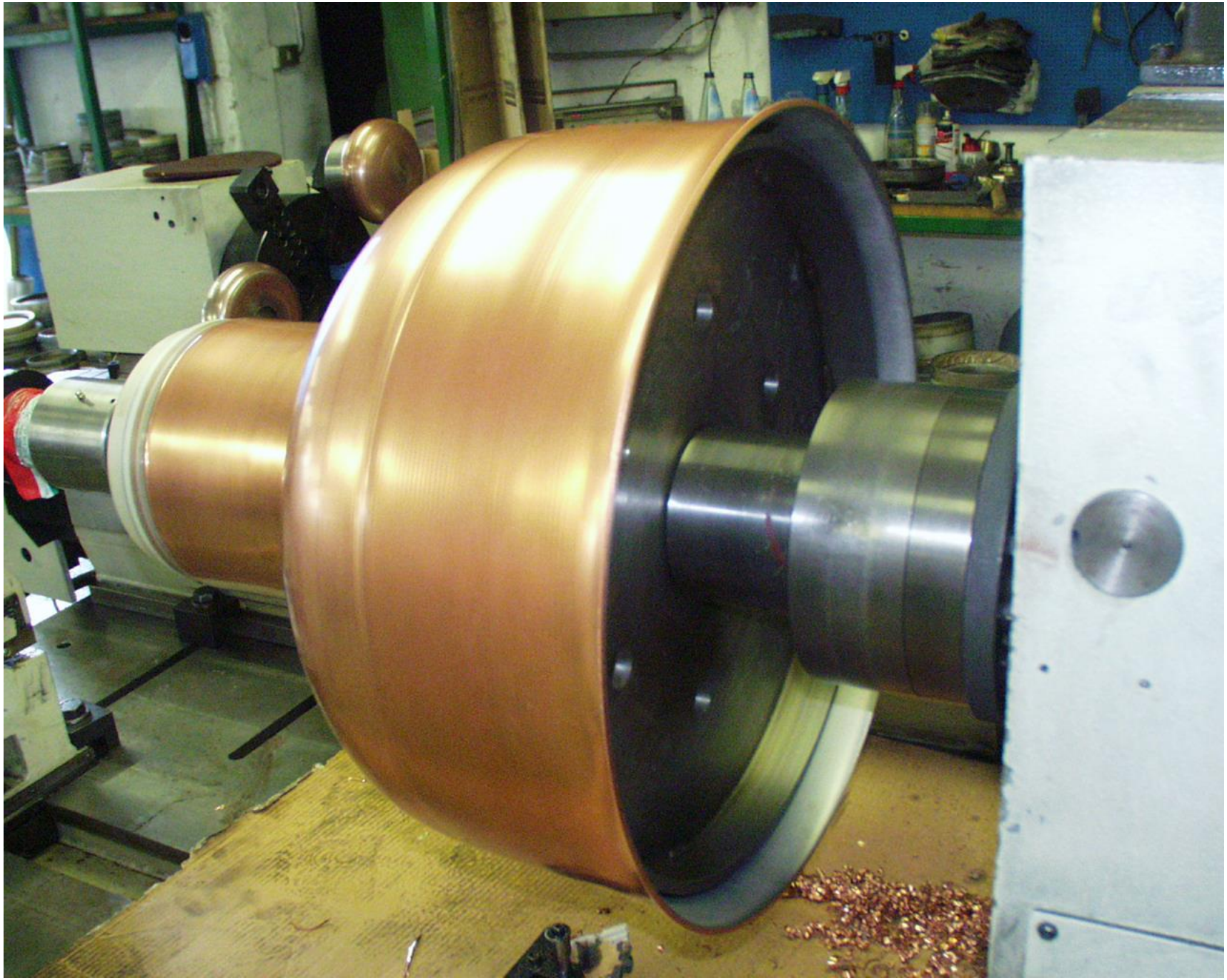
If we want to use spinning,

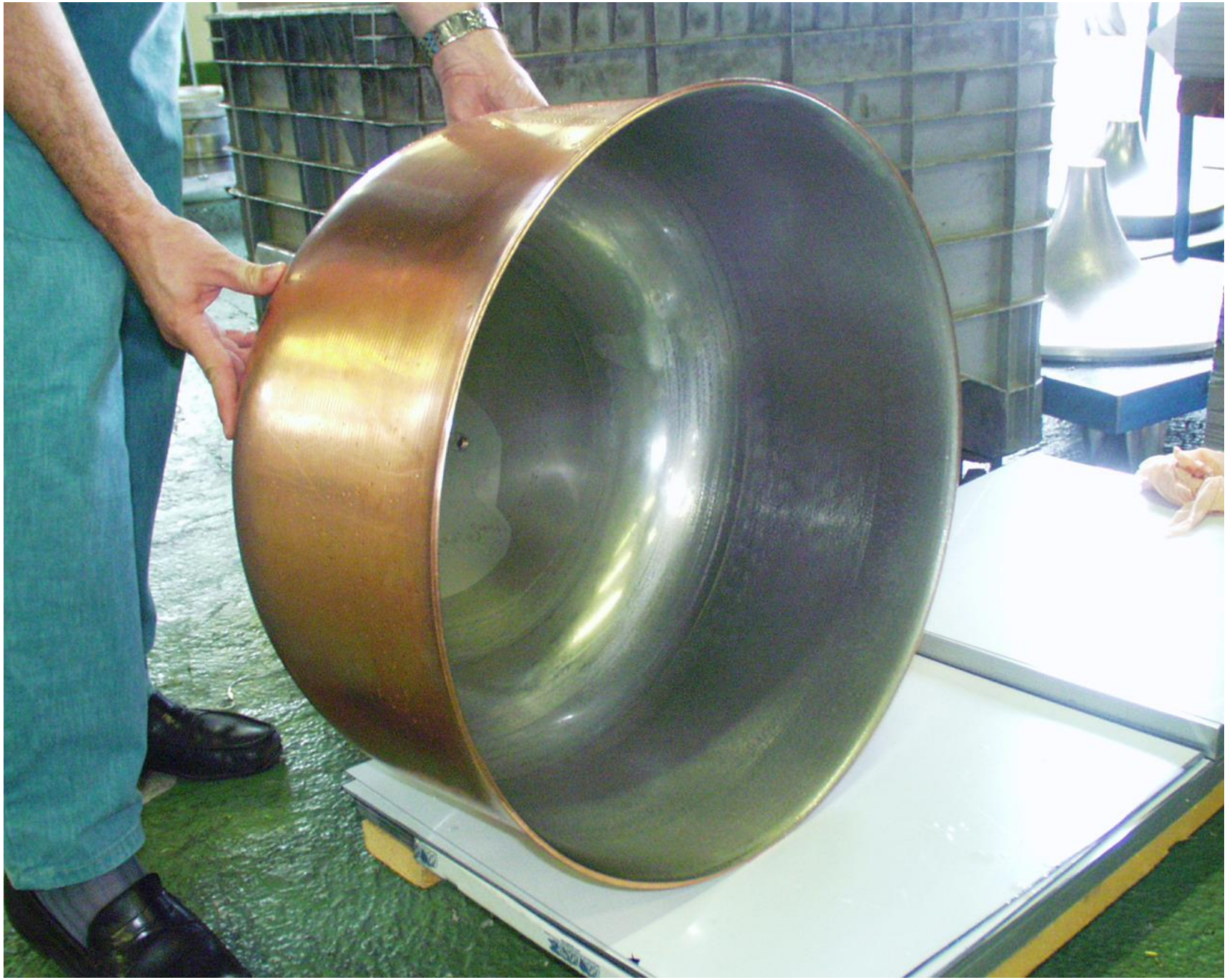
be aware that

The initial staus of the blank surfaace

must be defect and scratch free

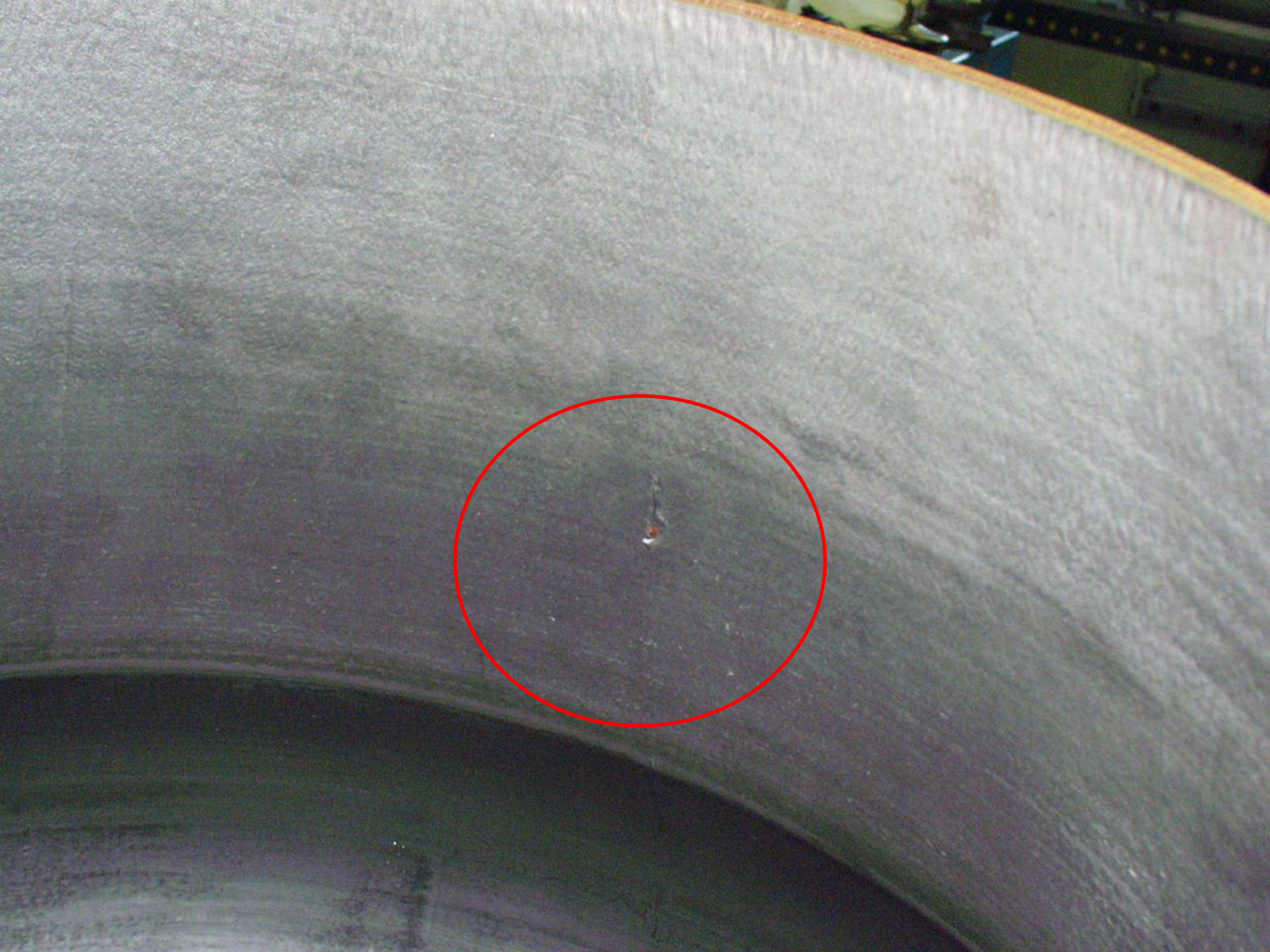






Nb Clad Cu is a well-established technology

Nb HIPPED Cu still needs to be optimized



What Other technology for 400 MHz 2 cells?

- **Rolling tube from sheets, EB welding and spinning the weld**
- **Spinning an extremely thin Nb cavity and then Electroforming Copper**
- **Idea C**
- **Idea D**
- **Idea E**

Let me before test if they are crazy ideas or not.
I will test them, then I will report at the next FCC conference

Now, seriously ...

THANK YOU FOR ATTENTION!