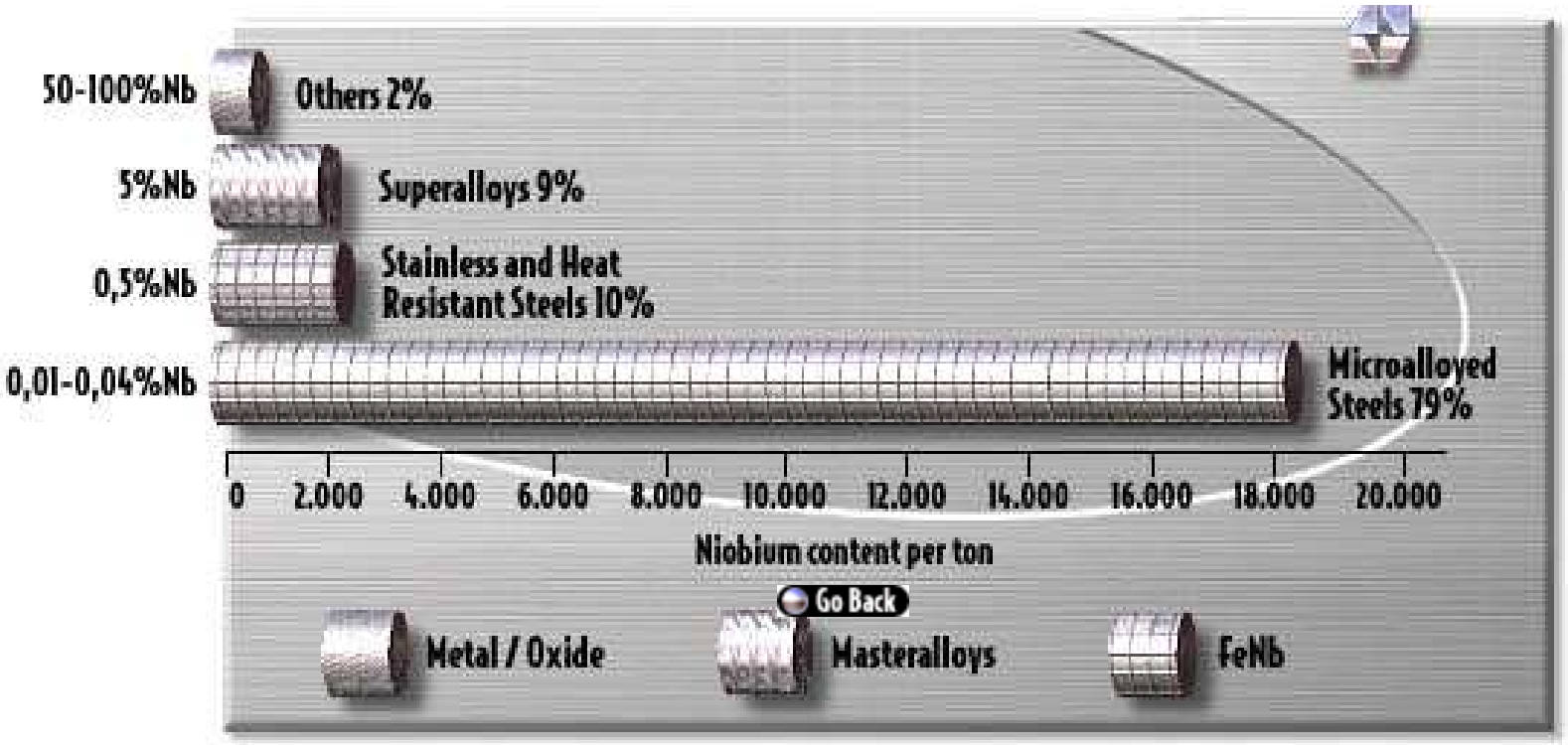
Niobium Production, Location of Ore Deposits

Niobium Users

Uses, Products and Consumption



Strip Mining Niobium Ore in Brazil
< 1% Nb

Transporting Ore to Refinery

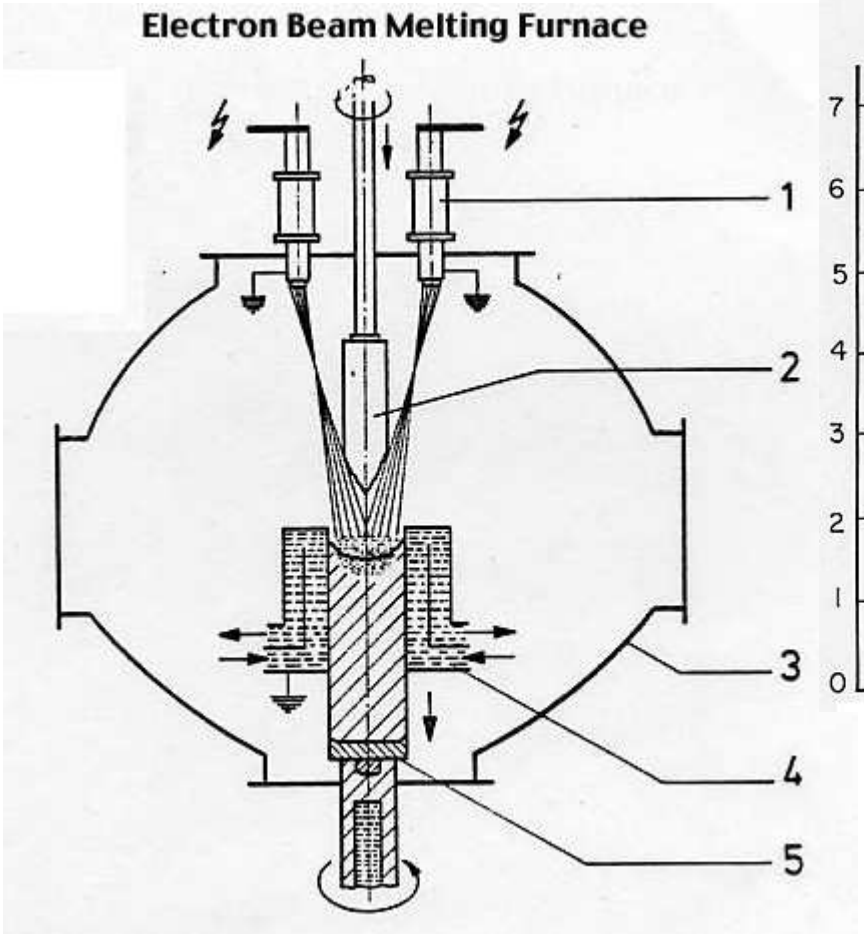
Increasing Niobium Content

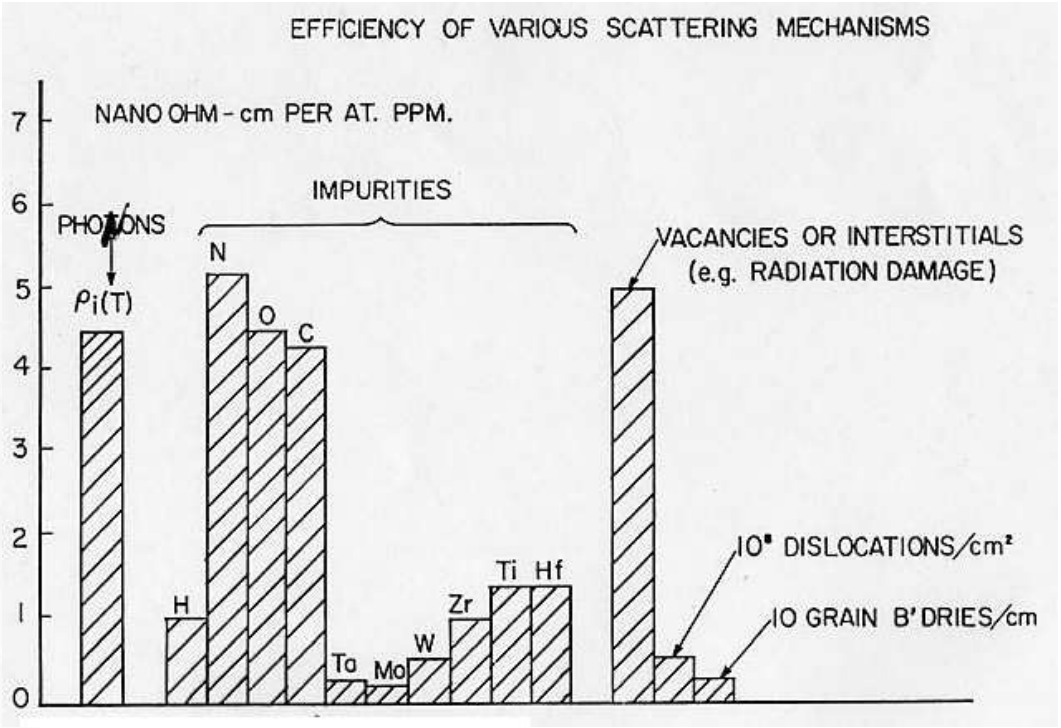
Reduction of Nb-oxide to Nb

Nb-oxide + Aluminum --> Nb metal + Al-oxide

Purification of Niobium

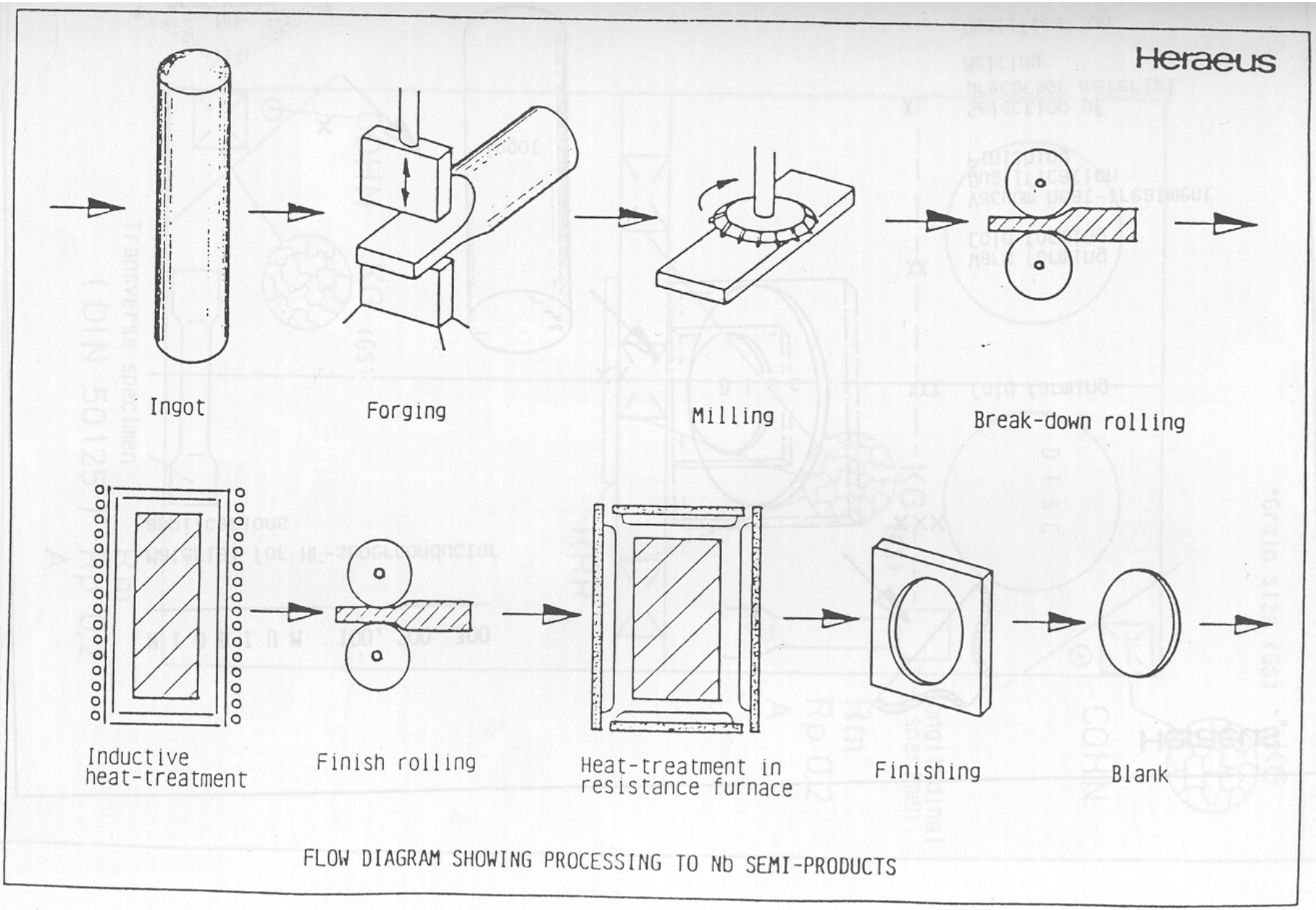
- Consolidation by arc melting
- Purification Melting in vacuum by electron beam (EB) to clean Nb from interstitials (C, N, H,...)
- Low grade: one or two melts (RRR50)
- High grade (RRR300): several additional melts under good vacuum
- Only 3 companies are qualified for cavity Nb
- Sequence of forging, rolling, etching, recrystallise heating (800°C)





Niobium Purification by Electron Beam Melting

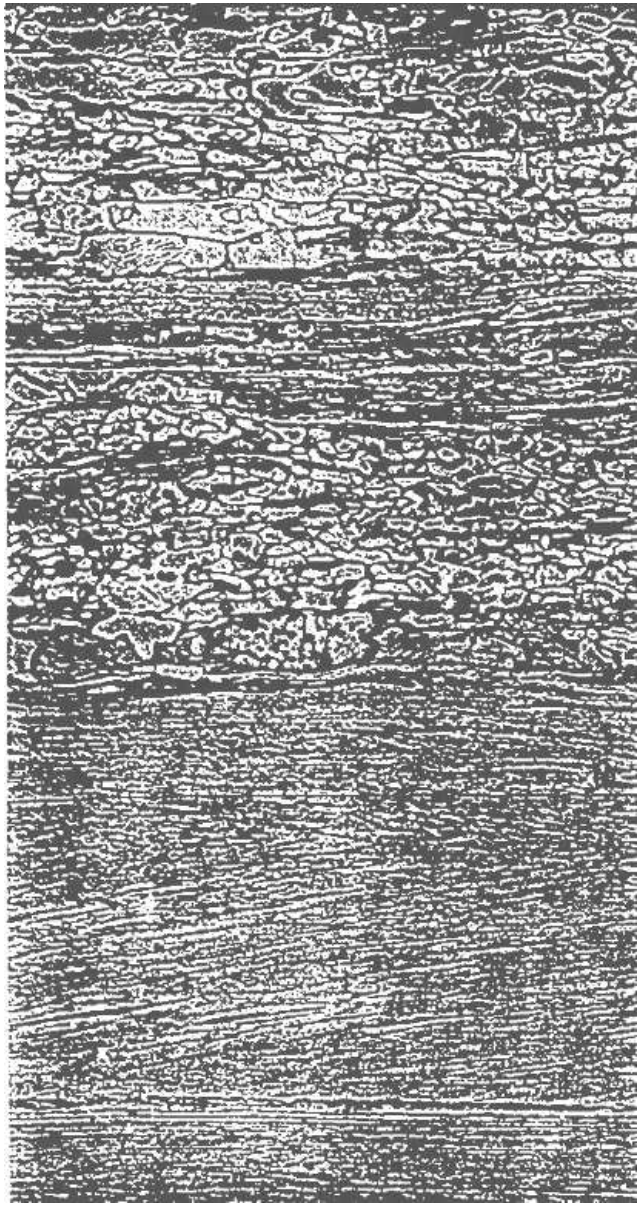
500KW electron beam cold hearth furnace



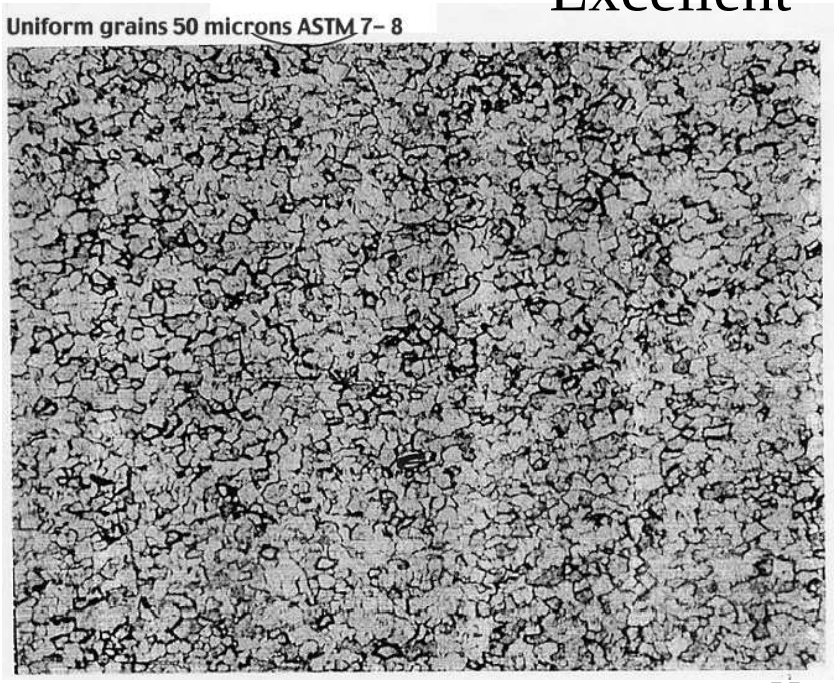
FLOW DIAGRAM SHOWING PROCESSING TO Nb SEMI-PRODUCTS

Nb Grain Size Control

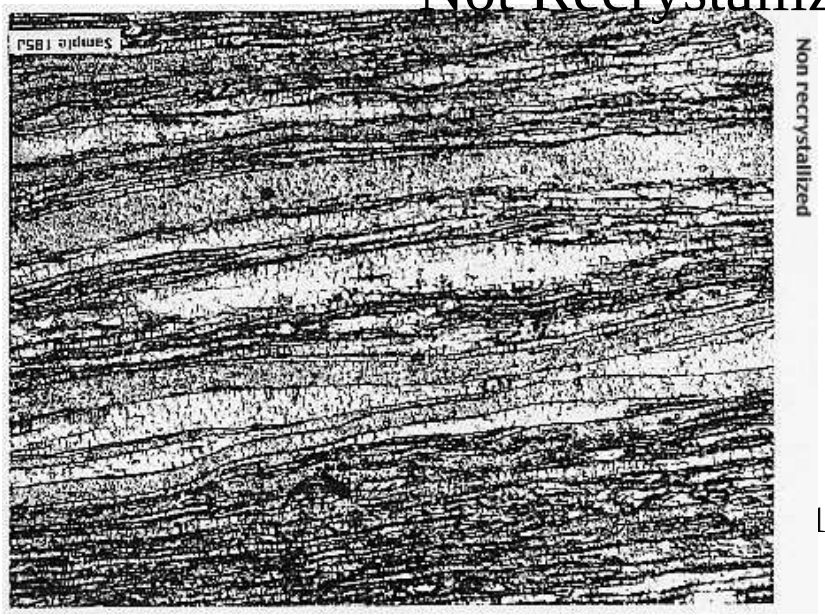
Partial Crystallized



Excellent

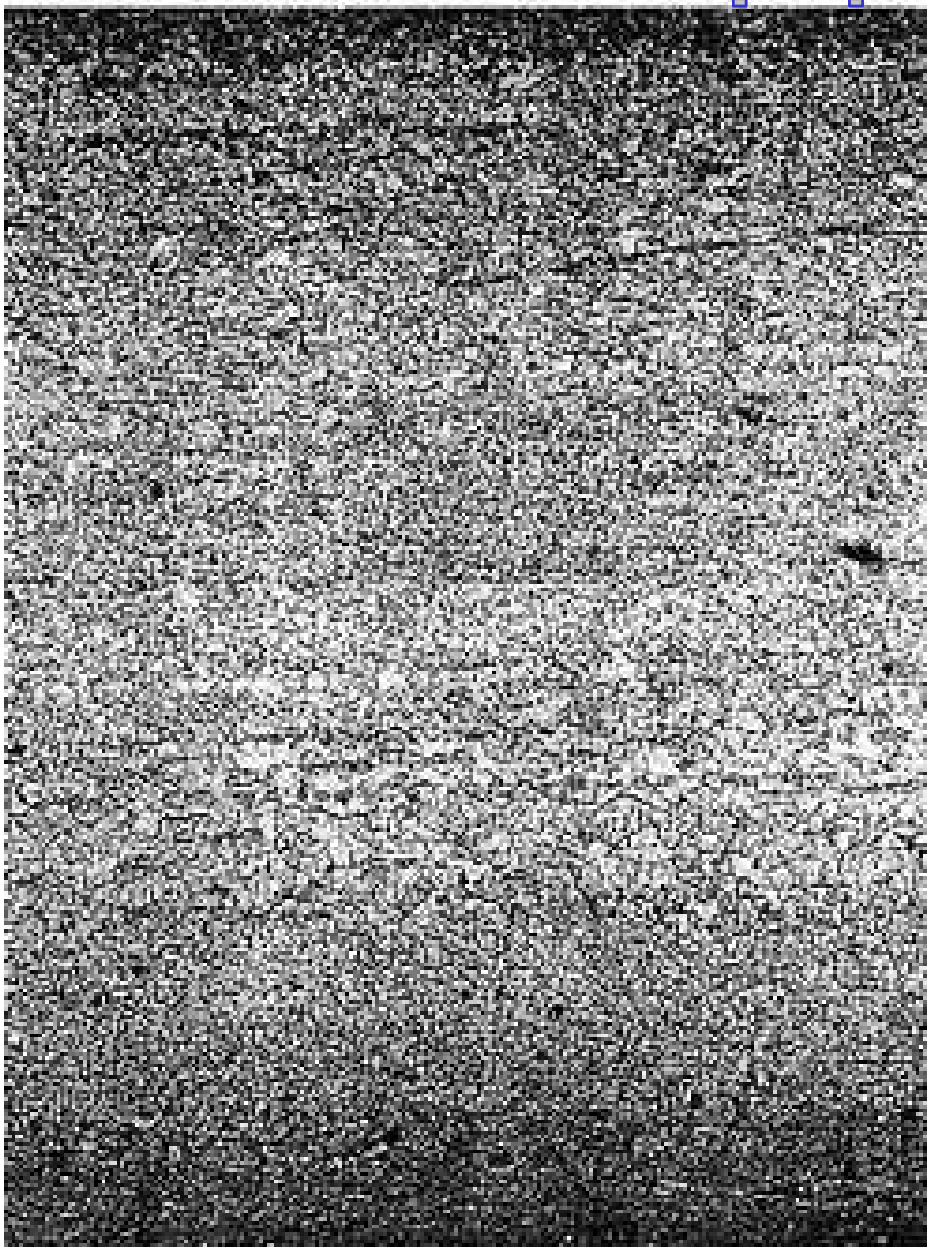


Not Recrystallized

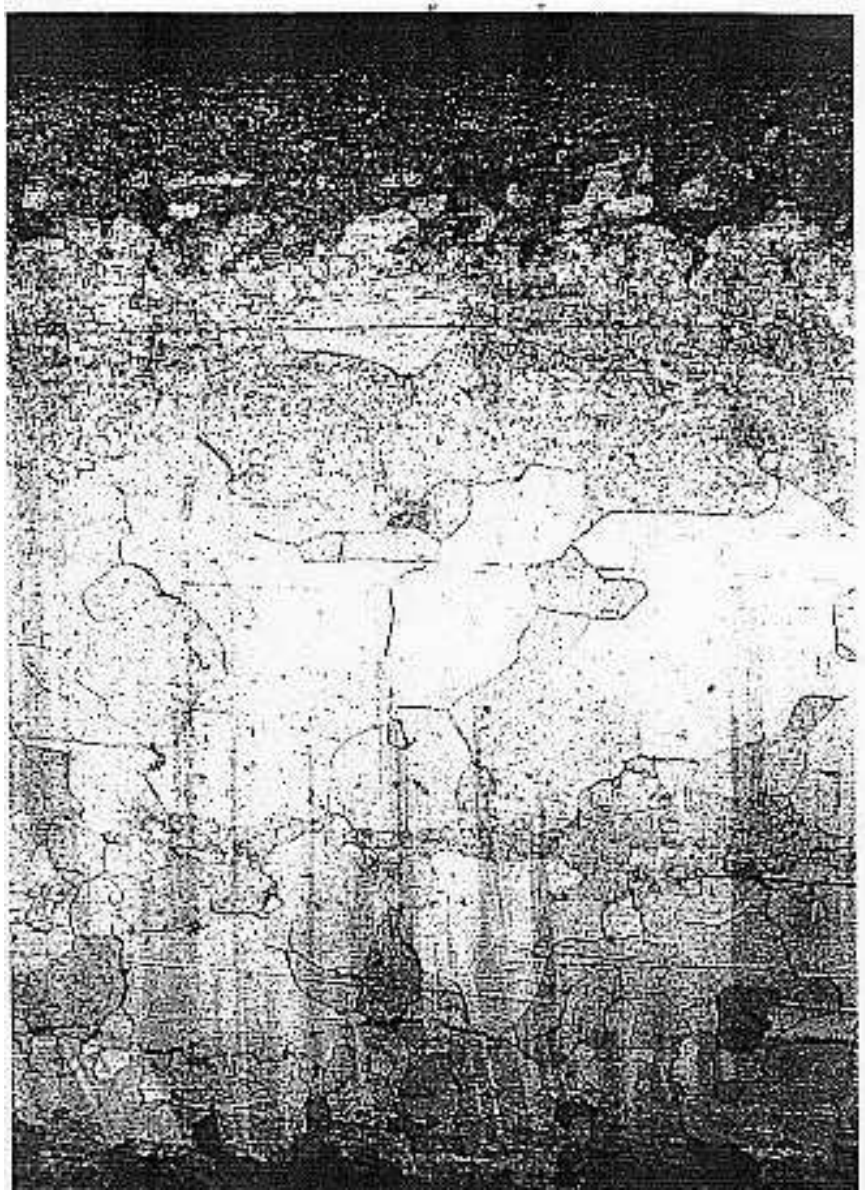


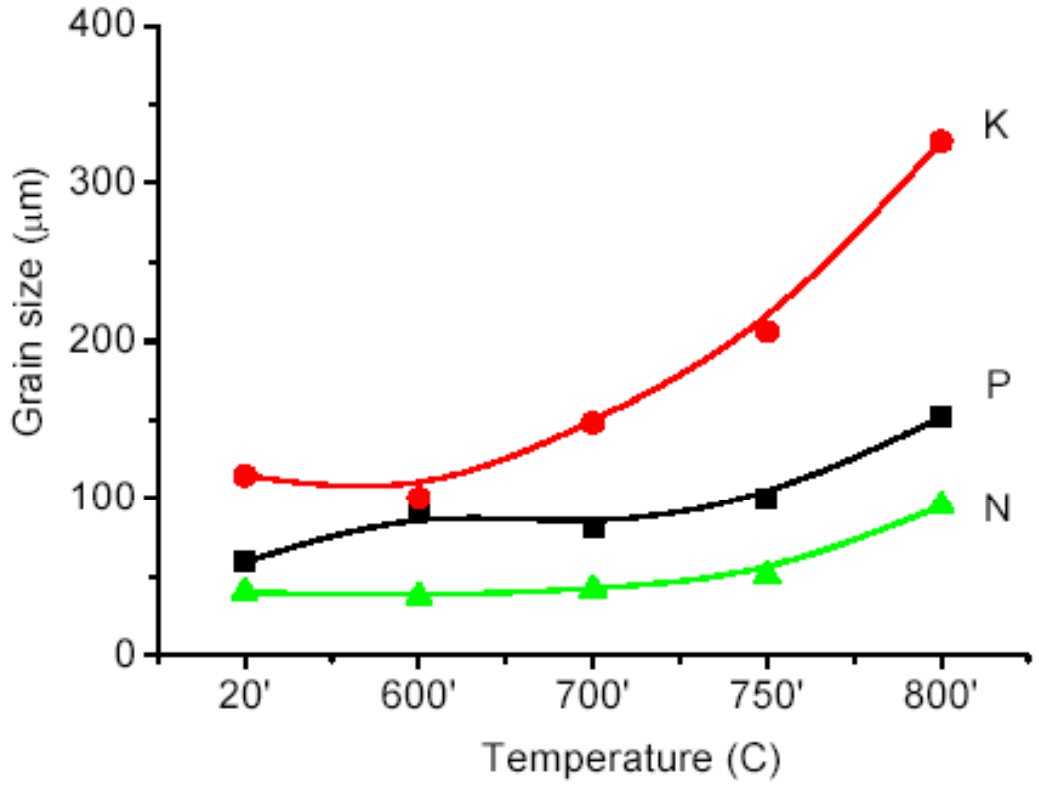
Improper Annealing

Non-uniform grain size

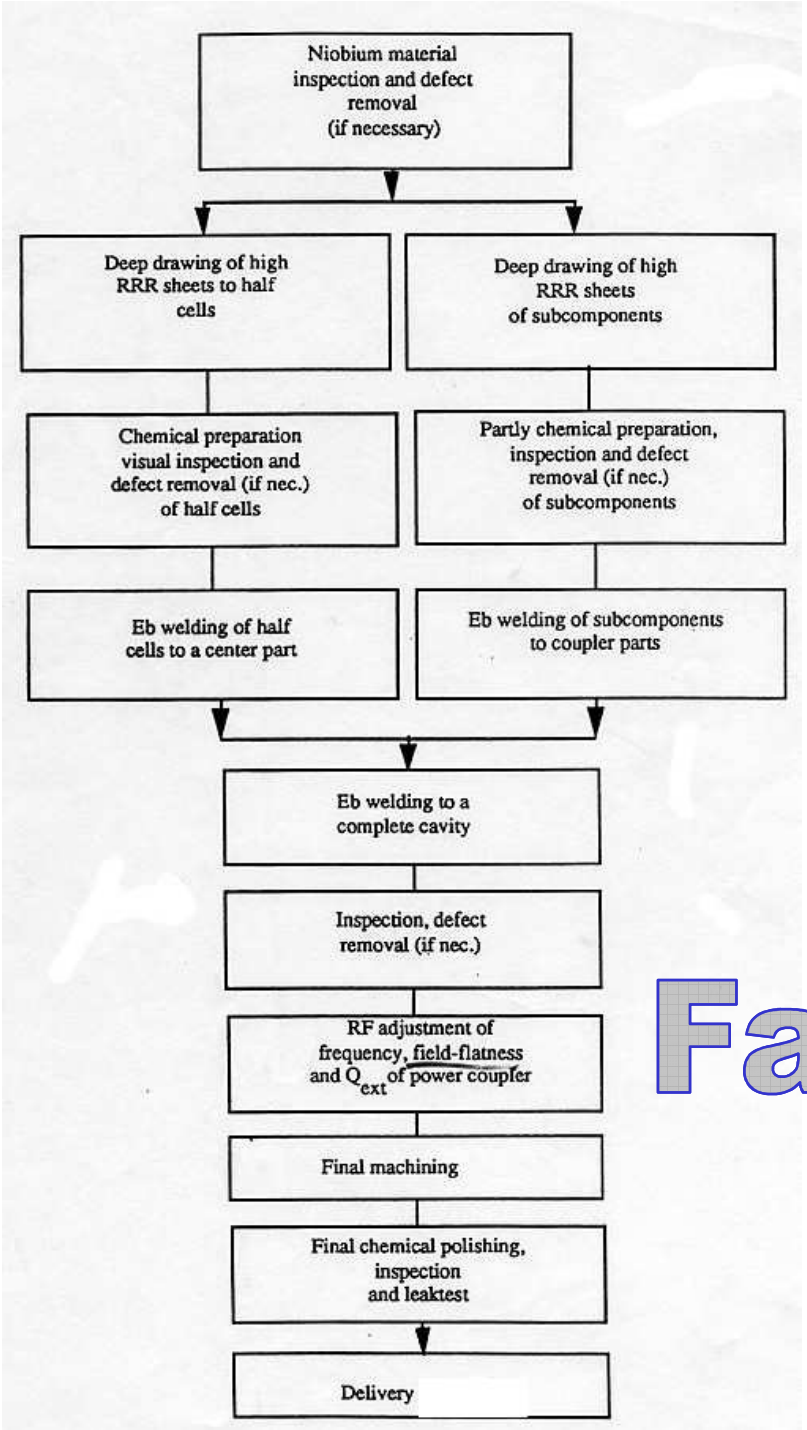


Annealed at 900 C – Too much grain growth



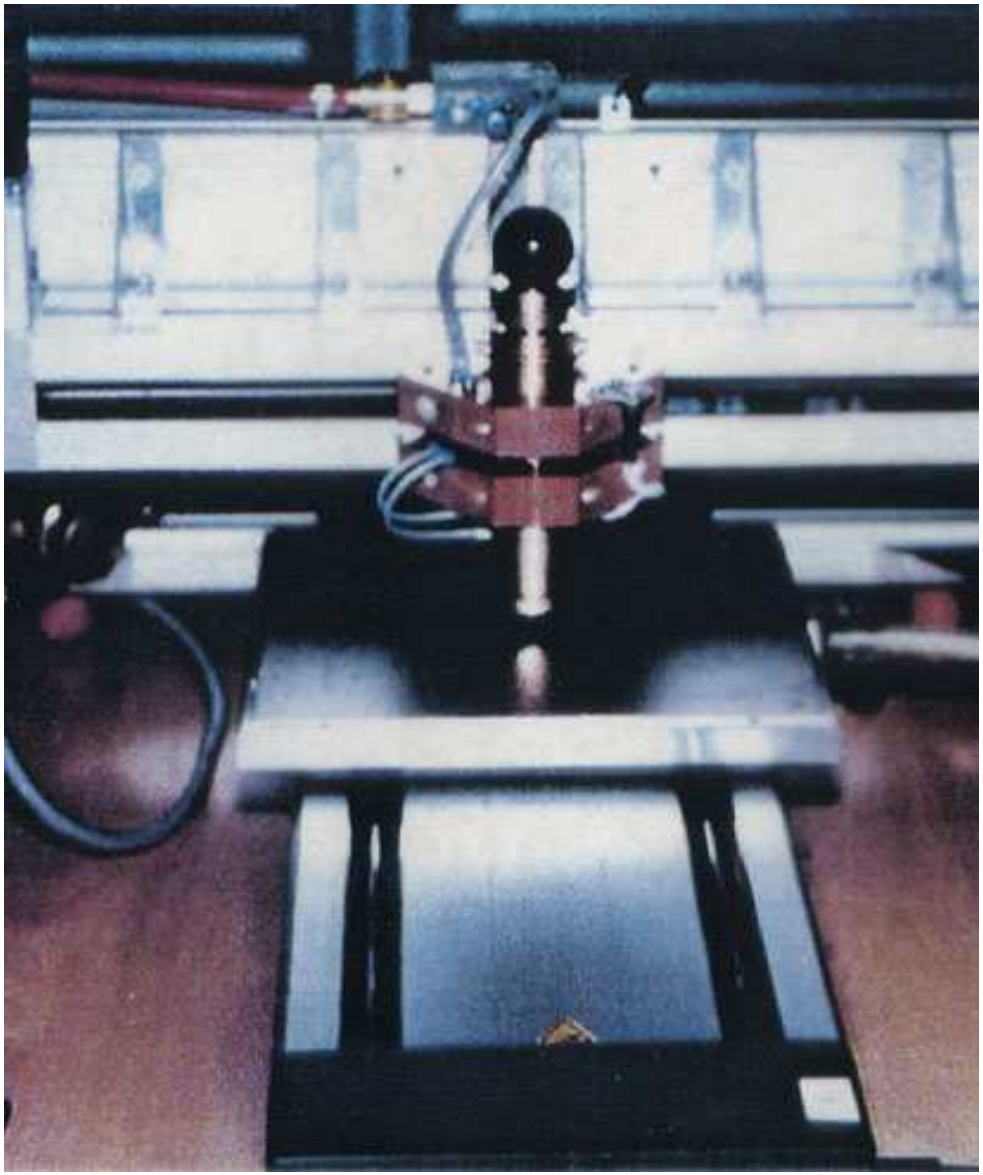


Lineal intercept grain size as a function of annealing temperature for the three lots of high-purity niobium



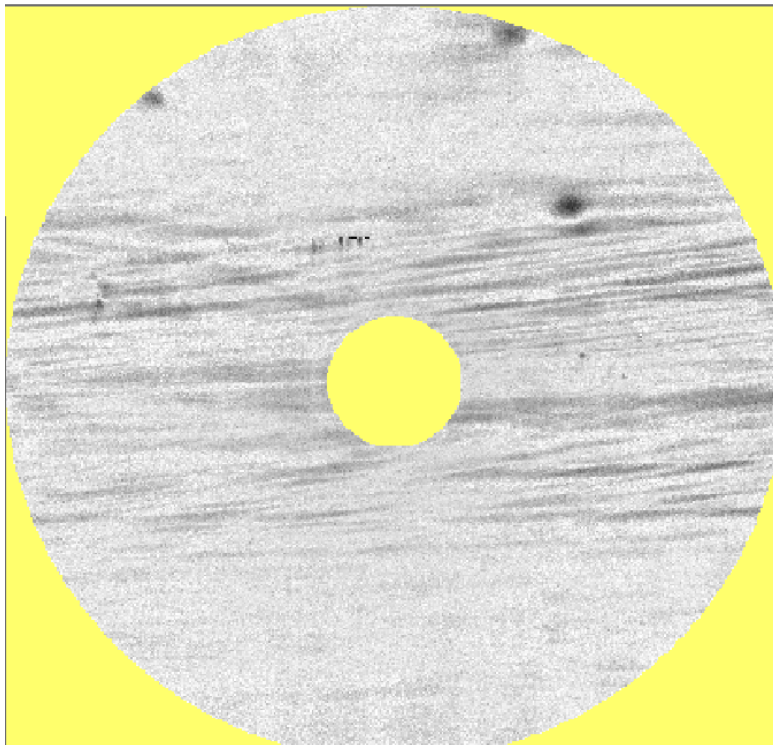
Cavity Fabrication

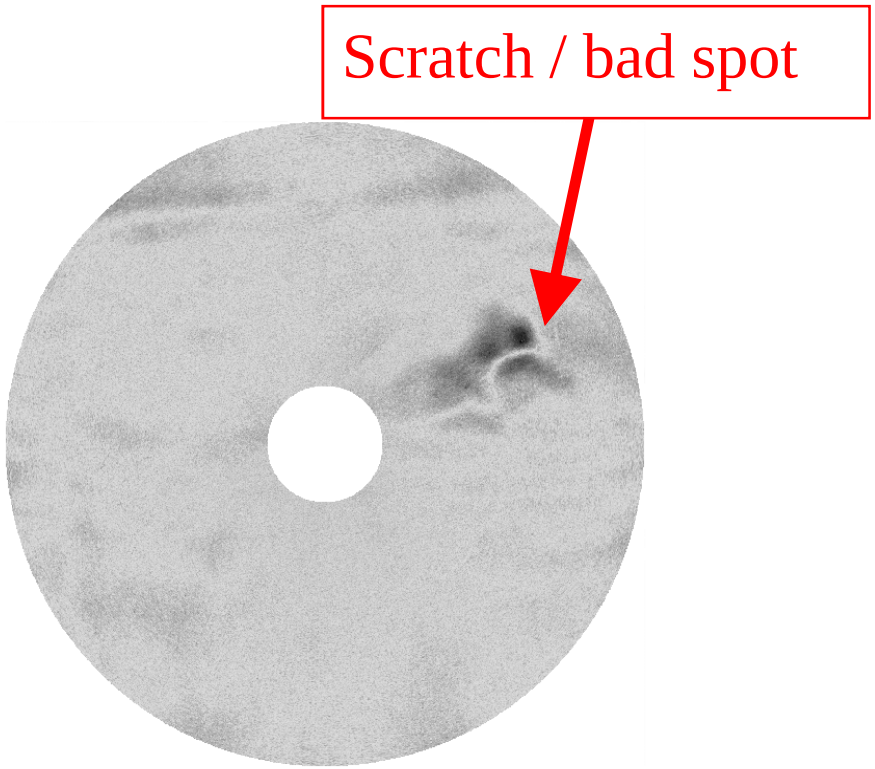
Eddy Current Scanning

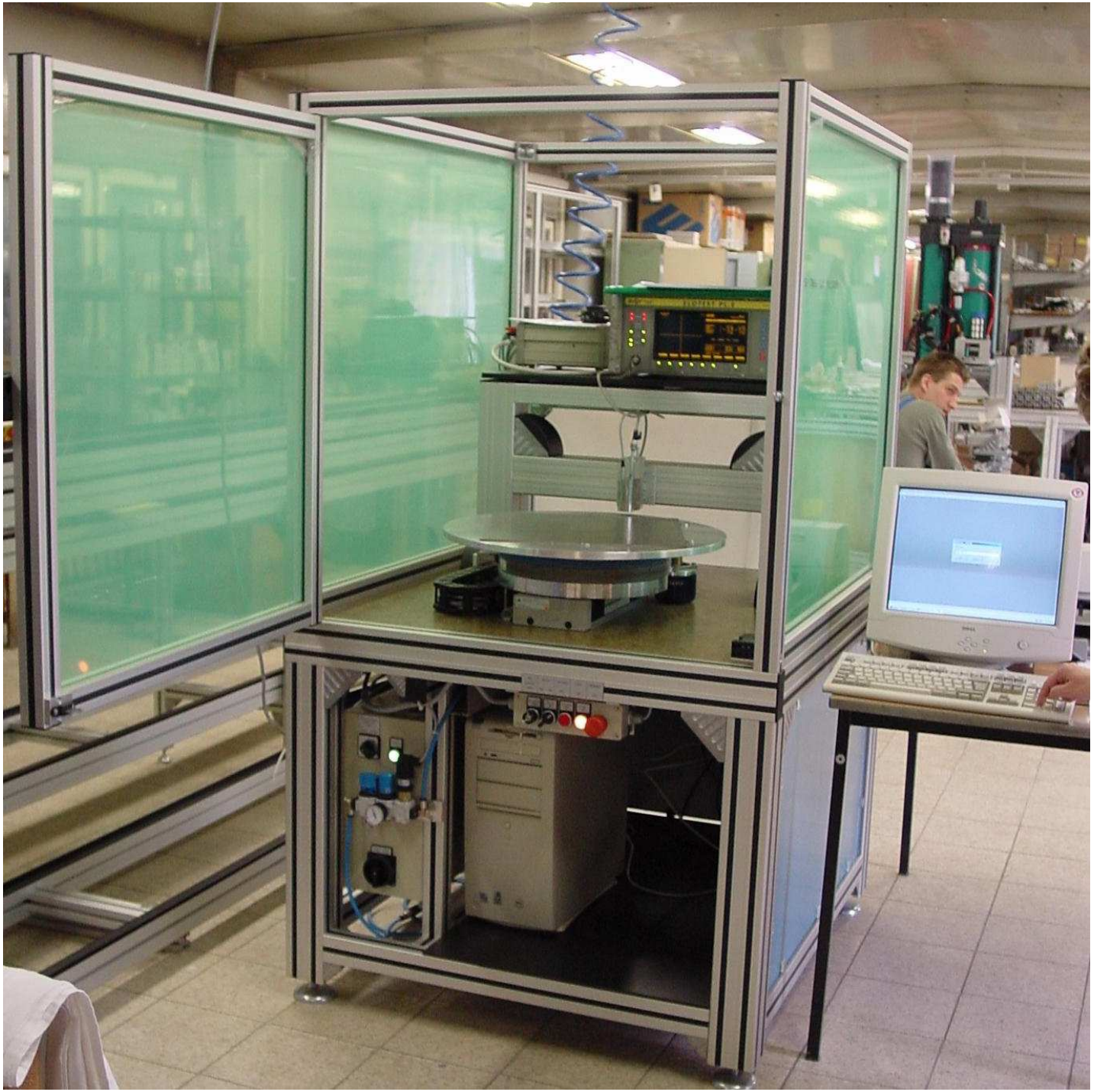


Eddy Currents to Check the Niobium

- Large inclusions of Tantalum as well as bad spots on the niobium surface can be found.





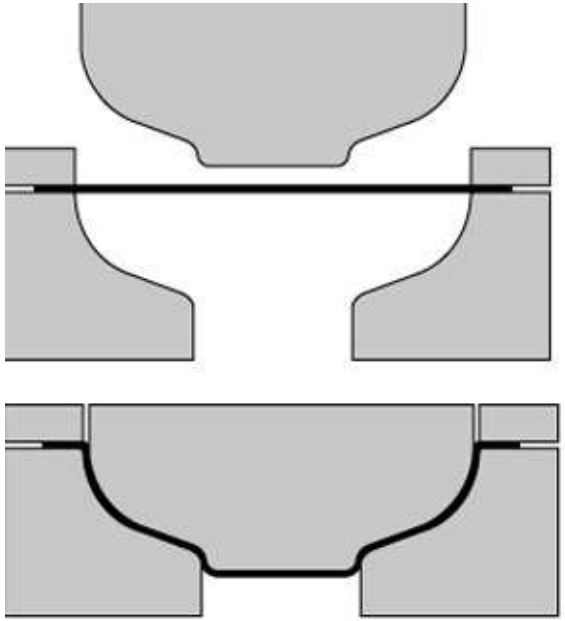


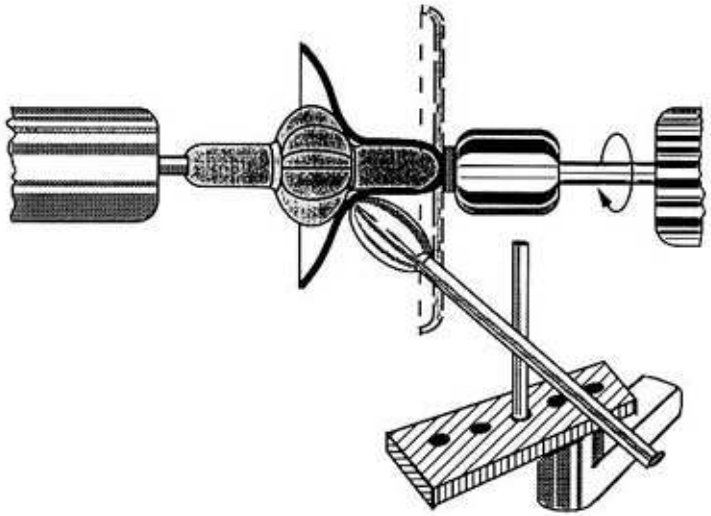
Eddy current scanner for Niobium sheets

Fabrication of cups

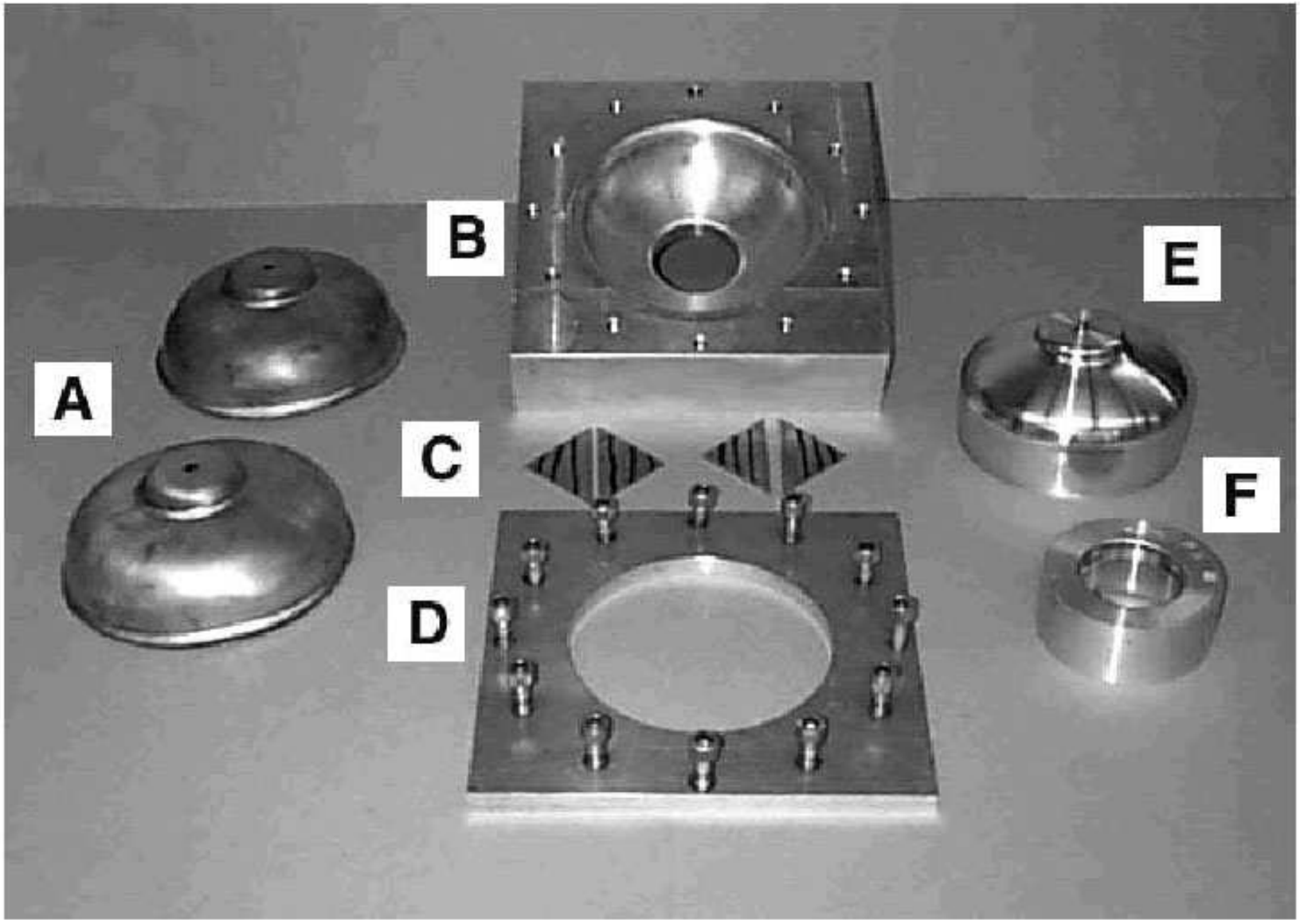
- Deep drawing or spinning
- Measurement of contour
- Better: measurement of frequency
- Trimming length at iris and equator plane
  - Consider welding shrinkage
- Slight chemical cleaning for welding

Deep Drawing and Spinning

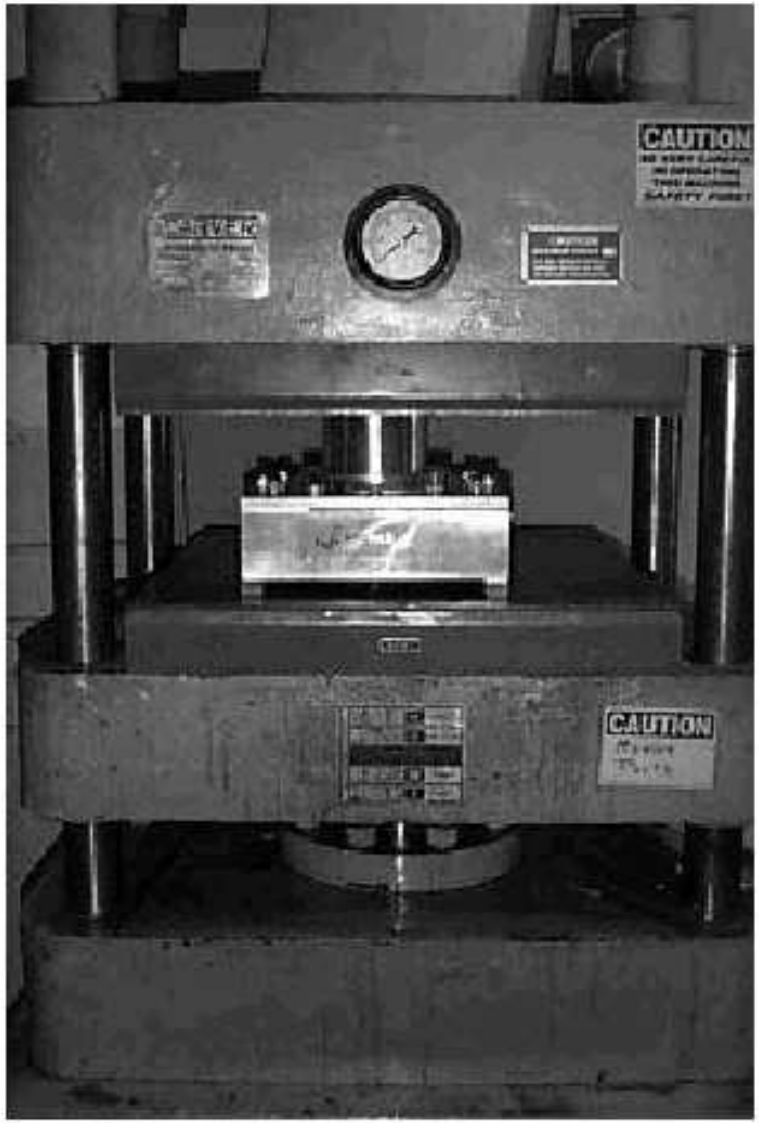




Deep Drawing Tools



100 Ton Hydraulic Press

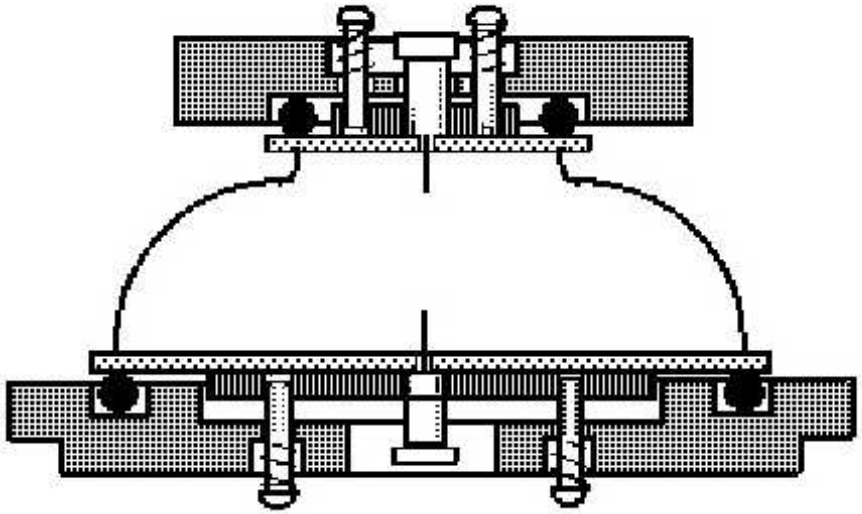


Trim Machining

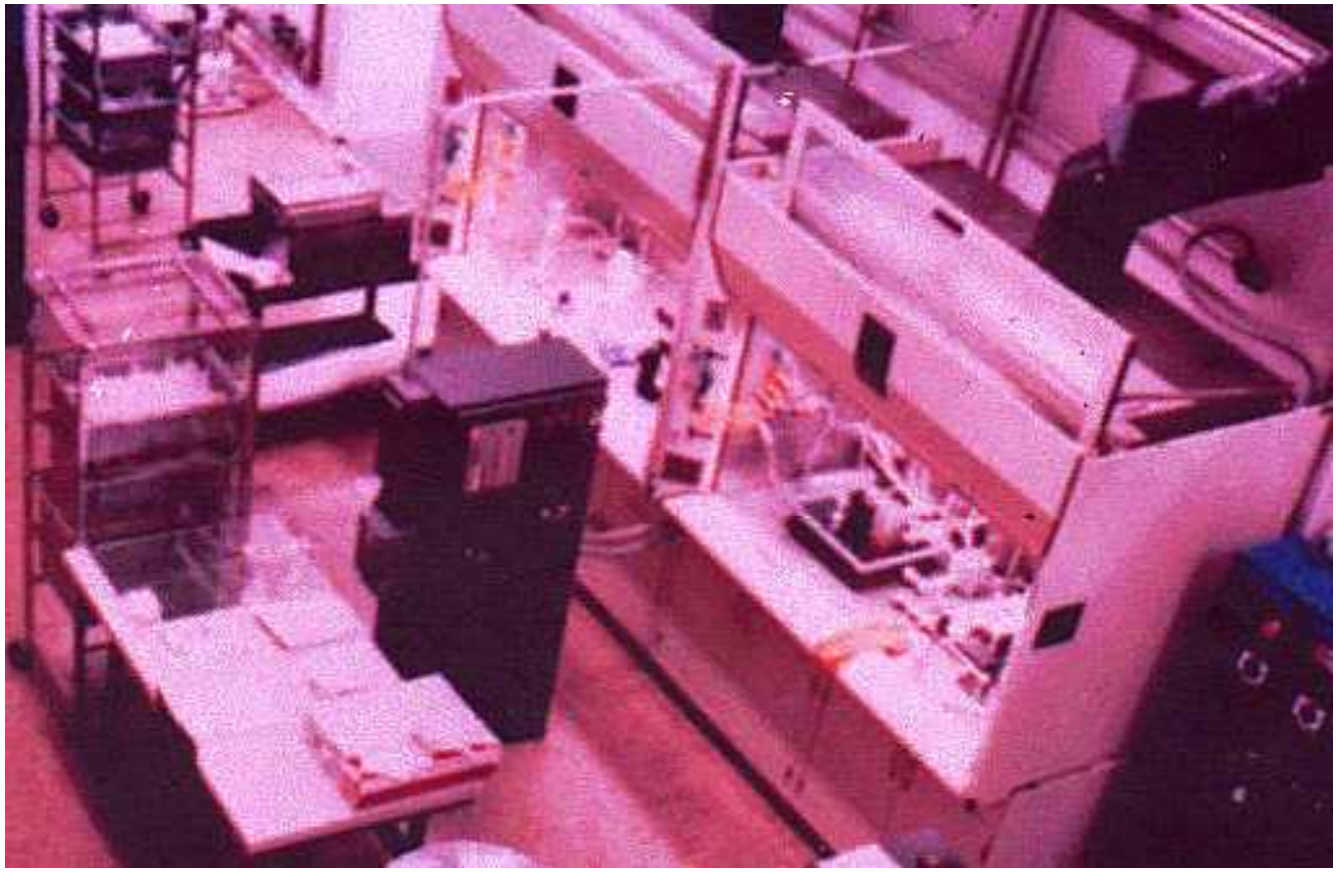
Dimension Control


'93 6 11

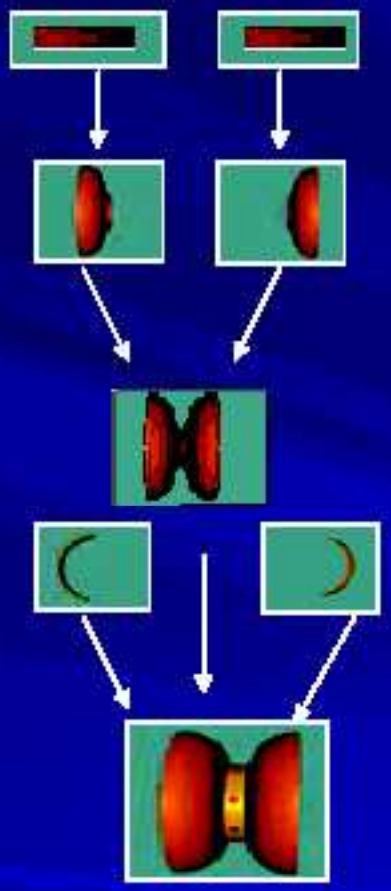
Frequency Check



Parts Chemistry



Cavity fabrication : Example dumb bell / Cavity



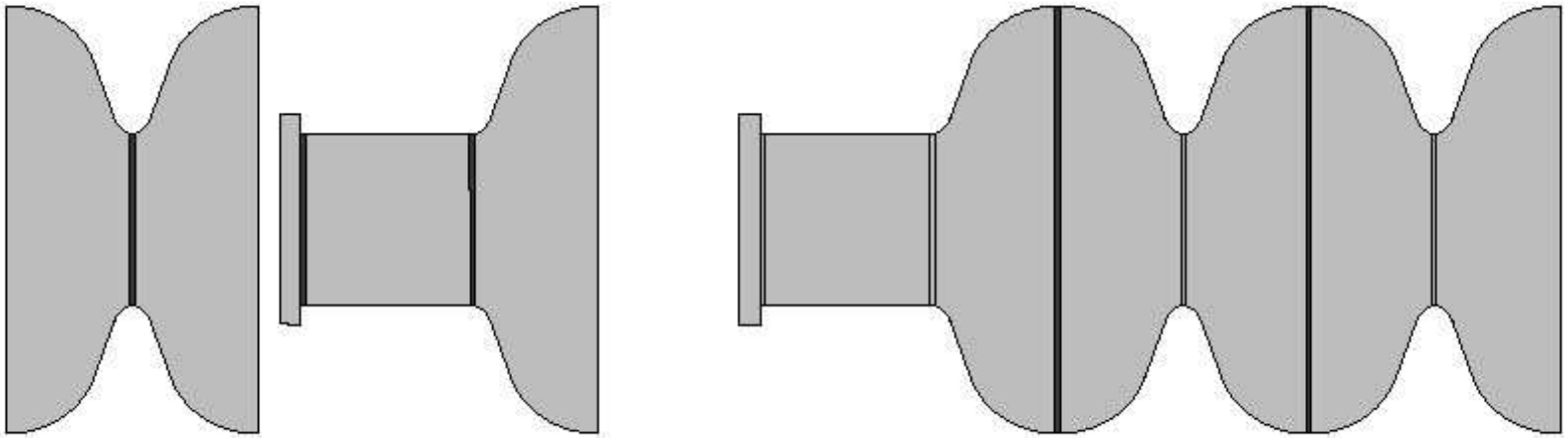
Dumb- bell

1. Mechanical measurement
2. Cleaning (by ultra sonic [us] cleaning +rinsing)
3. Trimming of iris region and reshaping of cups if needed
4. Cleaning
5. Rf measurement of cups
6. Buffered chemical polishing + Rinsing (for welding of Iris)
7. Welding of Iris
8. Welding of stiffening rings
9. Mechanical measurement of dumb-bells
10. Reshaping of dumb bell if needed
11. Cleaning
12. Rf measurement of dumb-bell
13. Trimming of dumb-bells (Equator regions)
14. Cleaning
15. Intermediate chemical etching (BCP /20- 40 µm)+ Rinsing
16. Visual Inspection of the inner surface of the dumb-bell

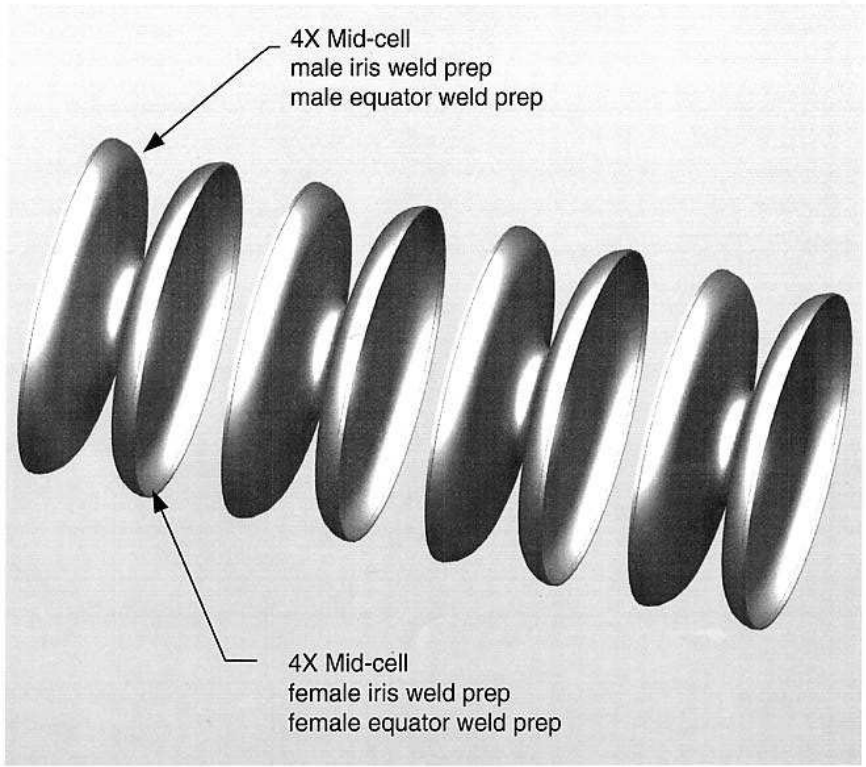
local grinding if needed + (second chemical treatment + inspection)

Dumb-bell ready for cavity

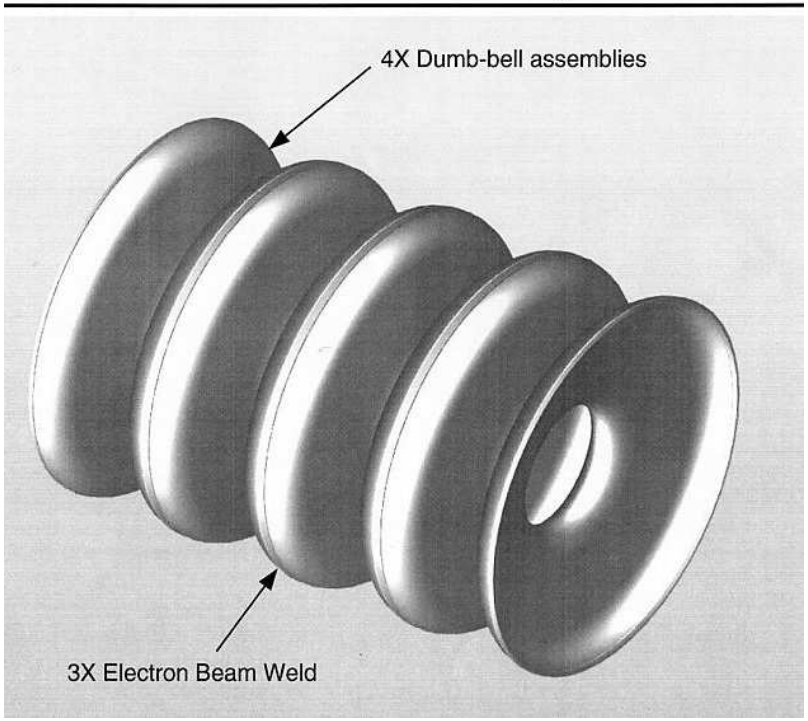
Welding Sequence

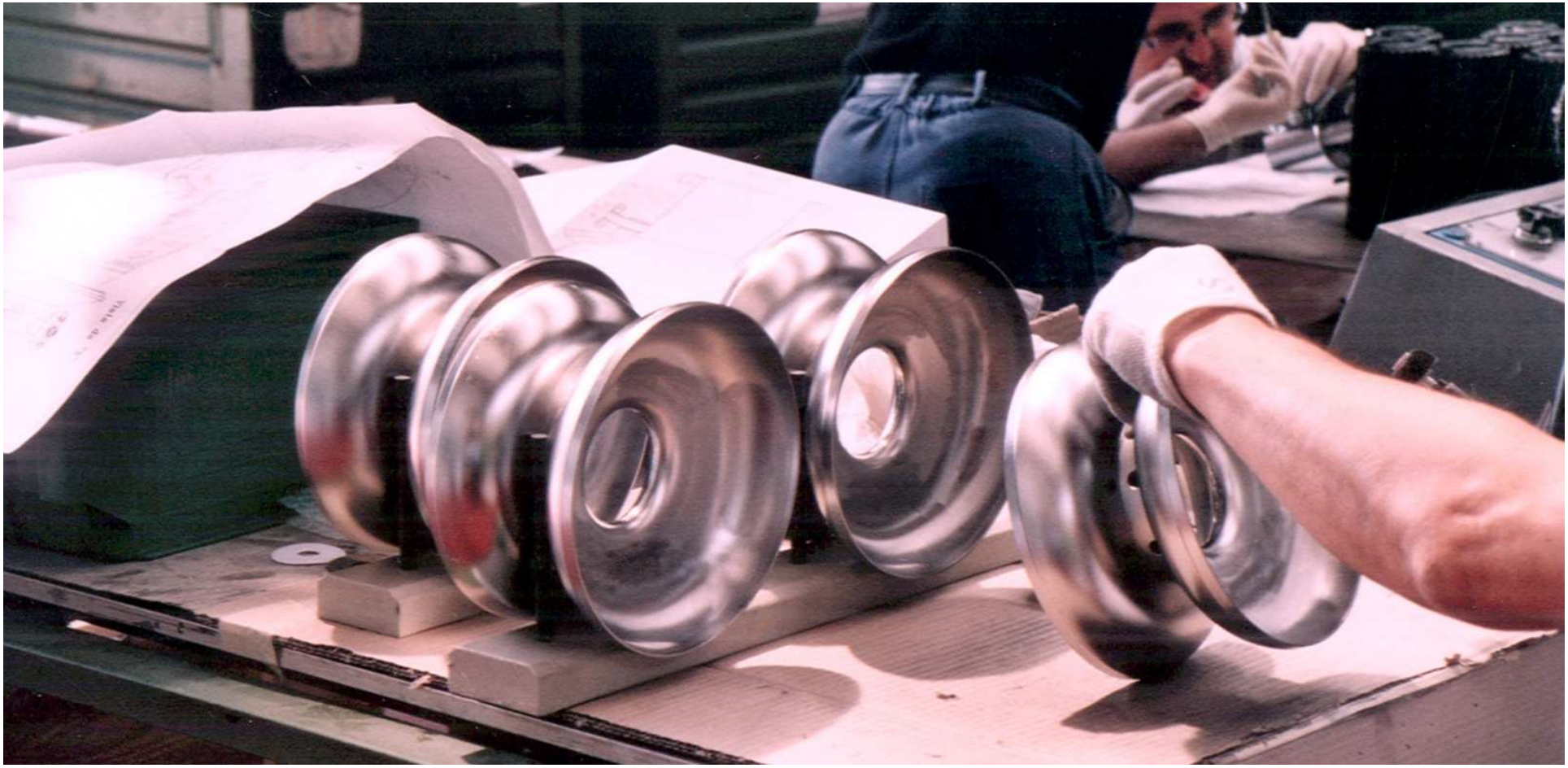


"Dumb-bell" Subassemblies



Mid-cell Assembly

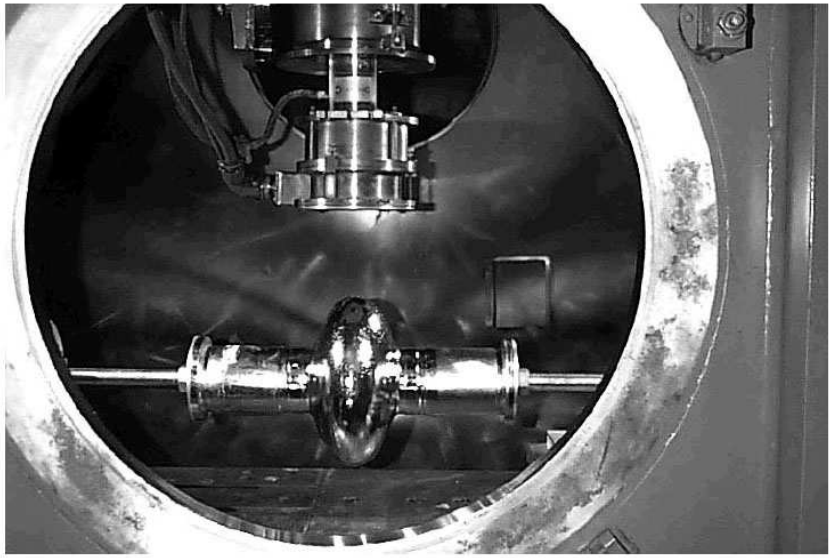


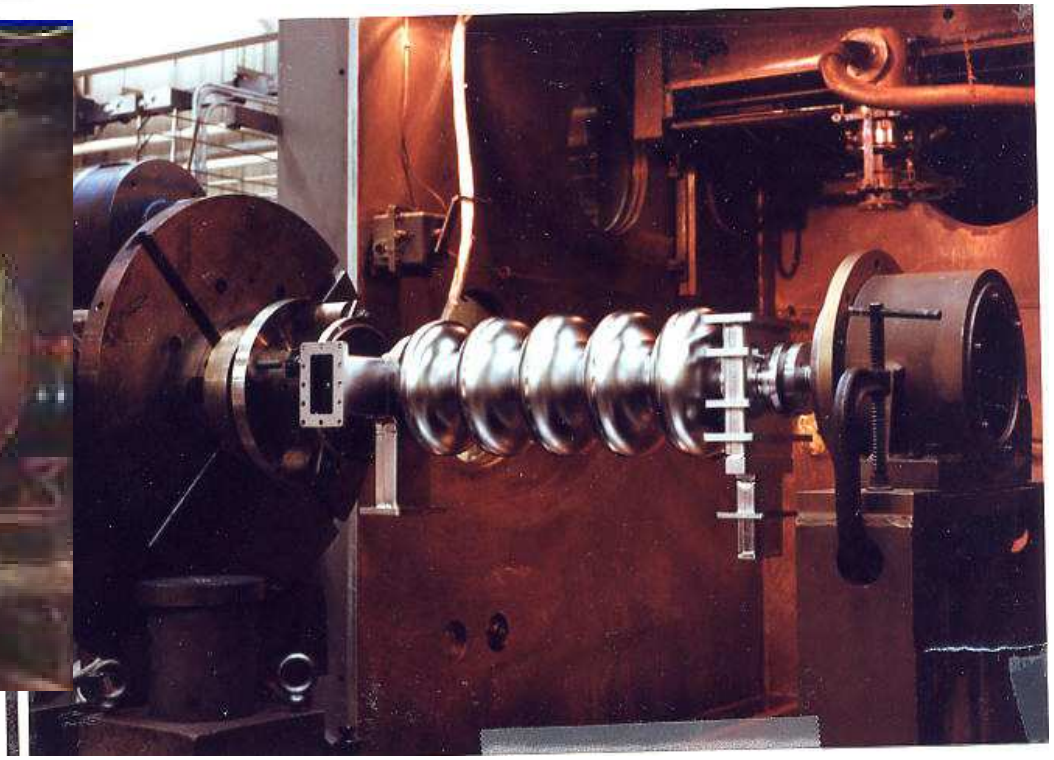


Welding sequence

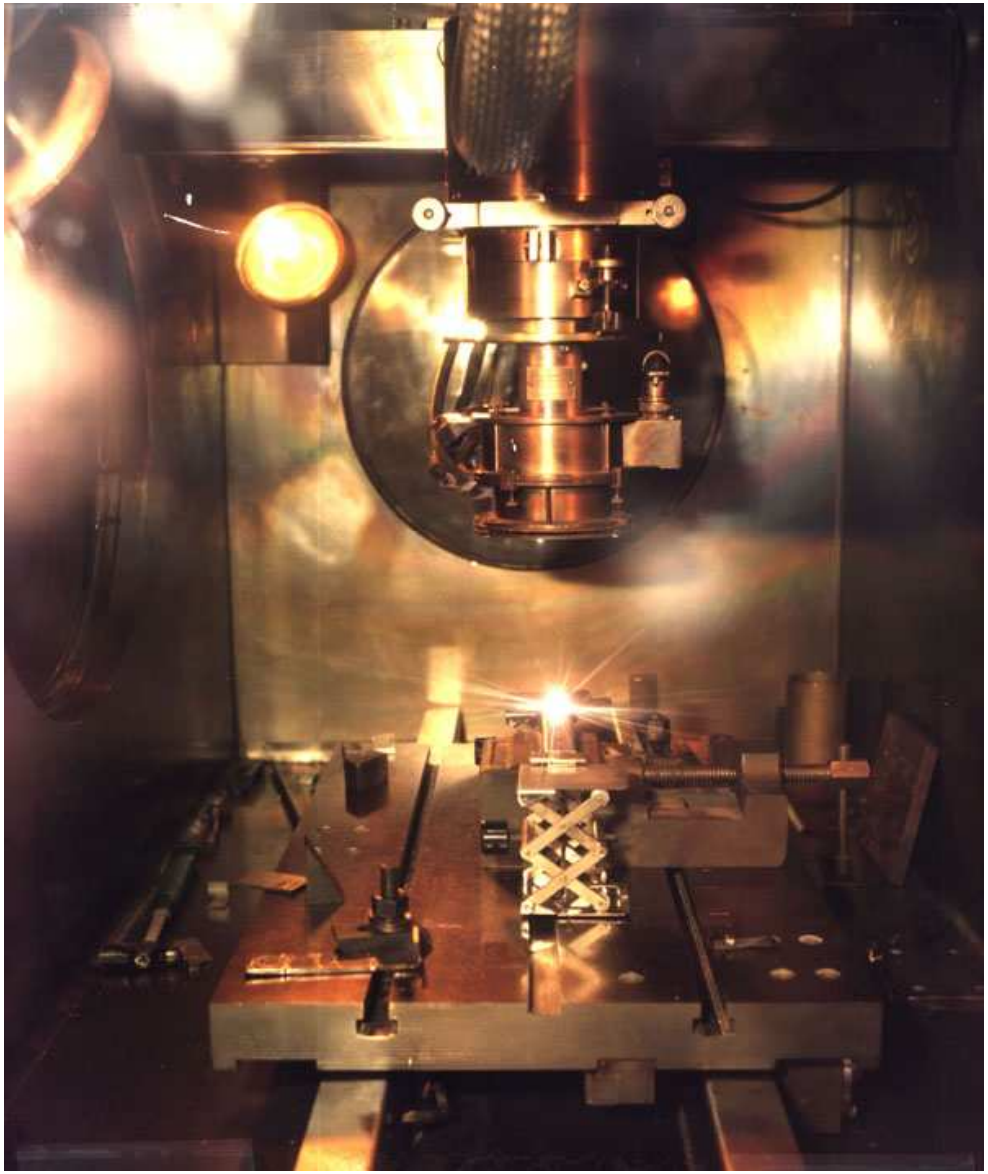
- Two cups form a dumb bell
- Stiffening ring at iris
  - frequency measurement of dumb bell, length trimming
- Welding together two dumb bells
- Add next dumb bell
- Add end group
- For mass production: weld all dumb bells at once

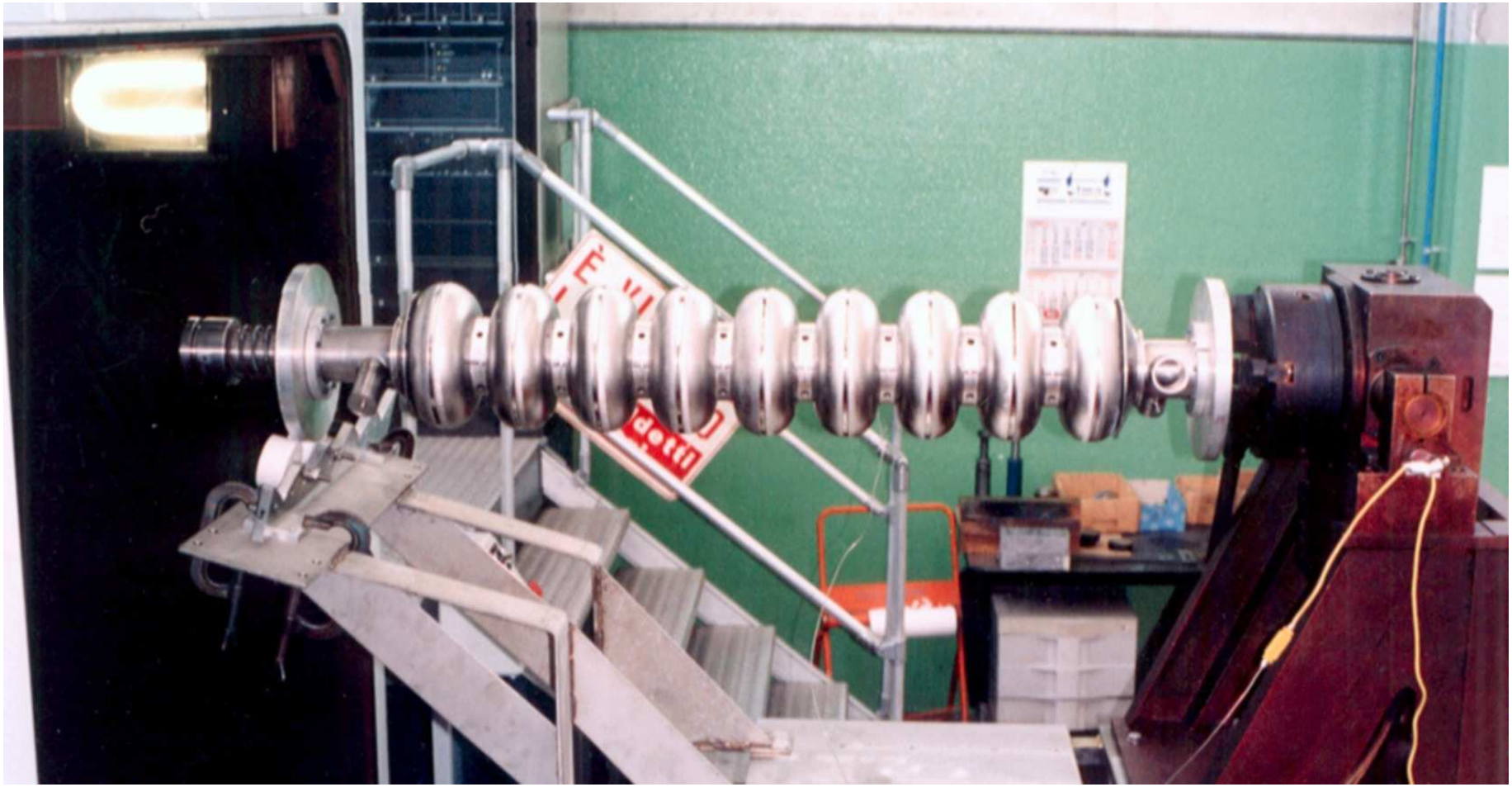
Welding





Ebeam Welding

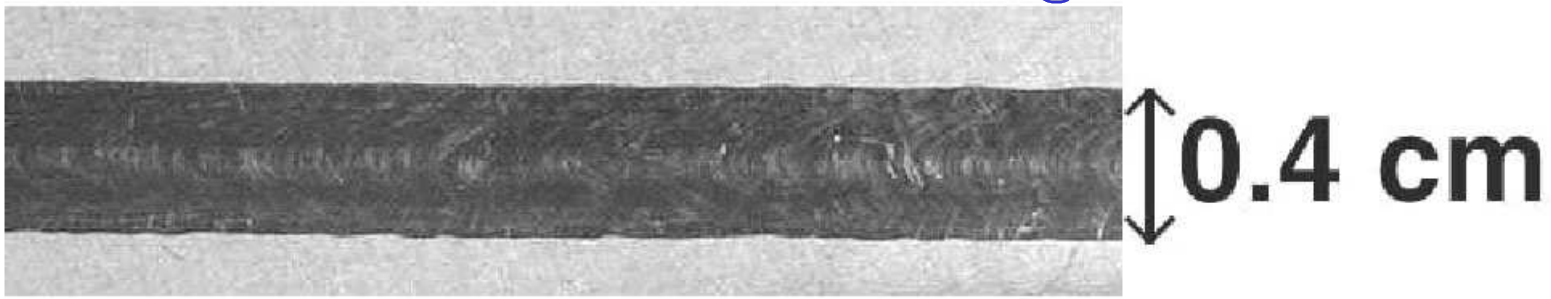


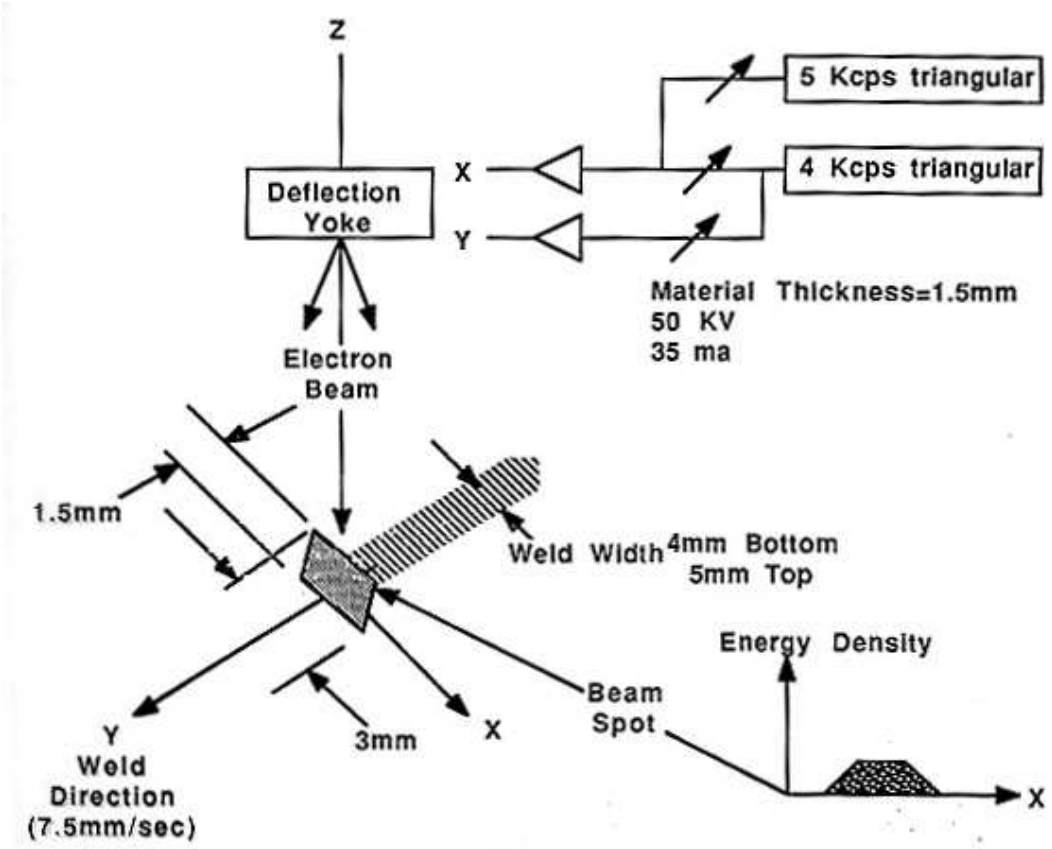


Electron beam welding

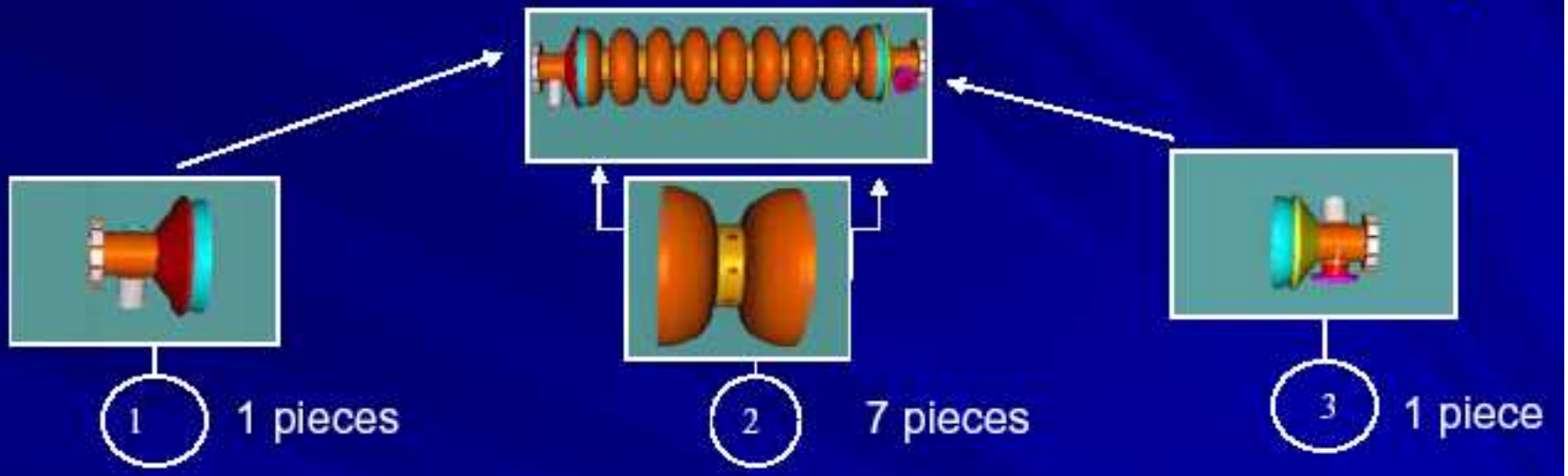
- Welding under good vacuum, 10^-5 range
- Broad welding seam
  - Operate with defocussed beam
  - Smooth underbead
- Overlap at end of welding to avoid accumulation of impurities
- Wait to cool down before opening chamber

Raster Welding



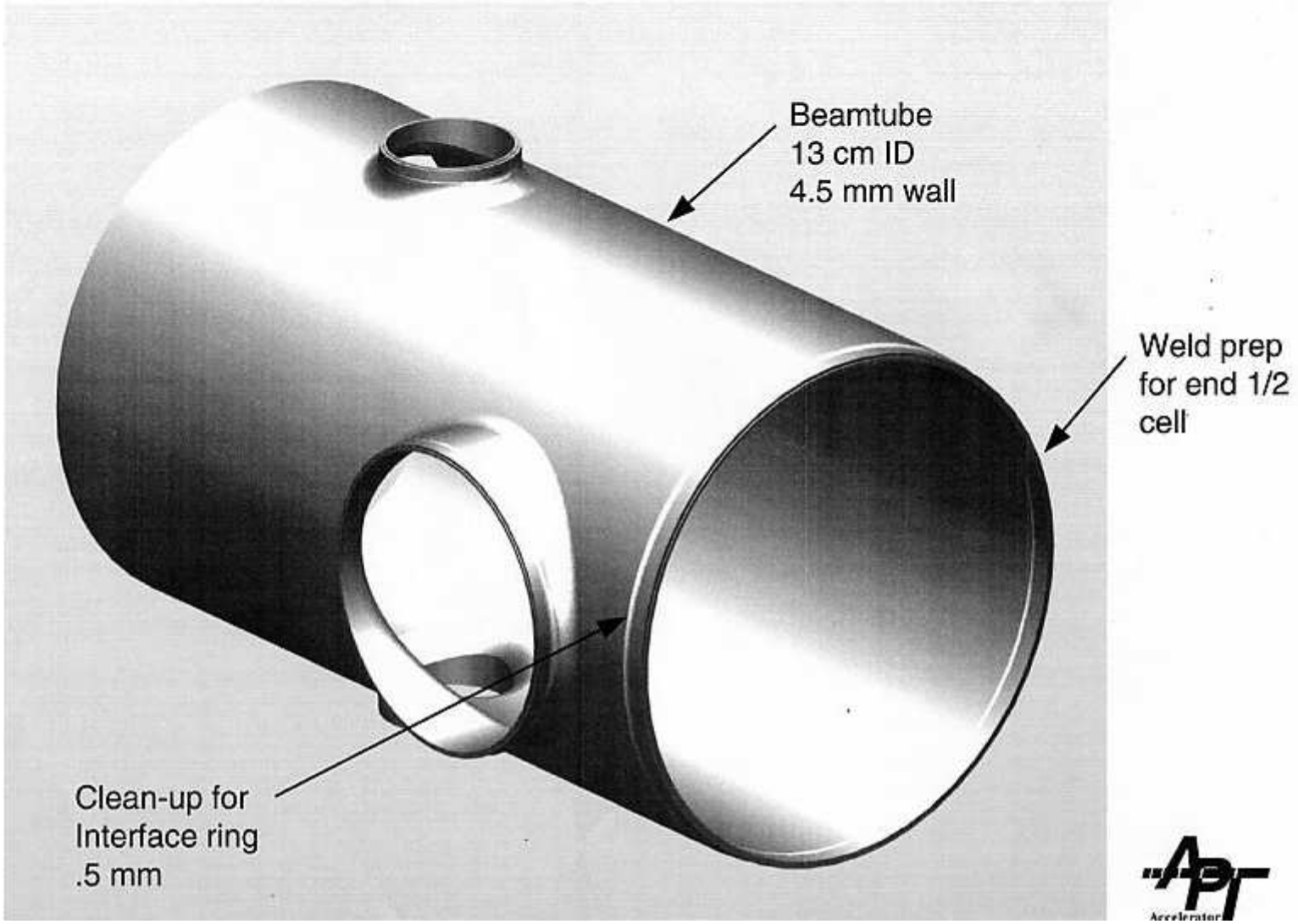


Cavity welding: the general way
There are differences of welding processes in industry

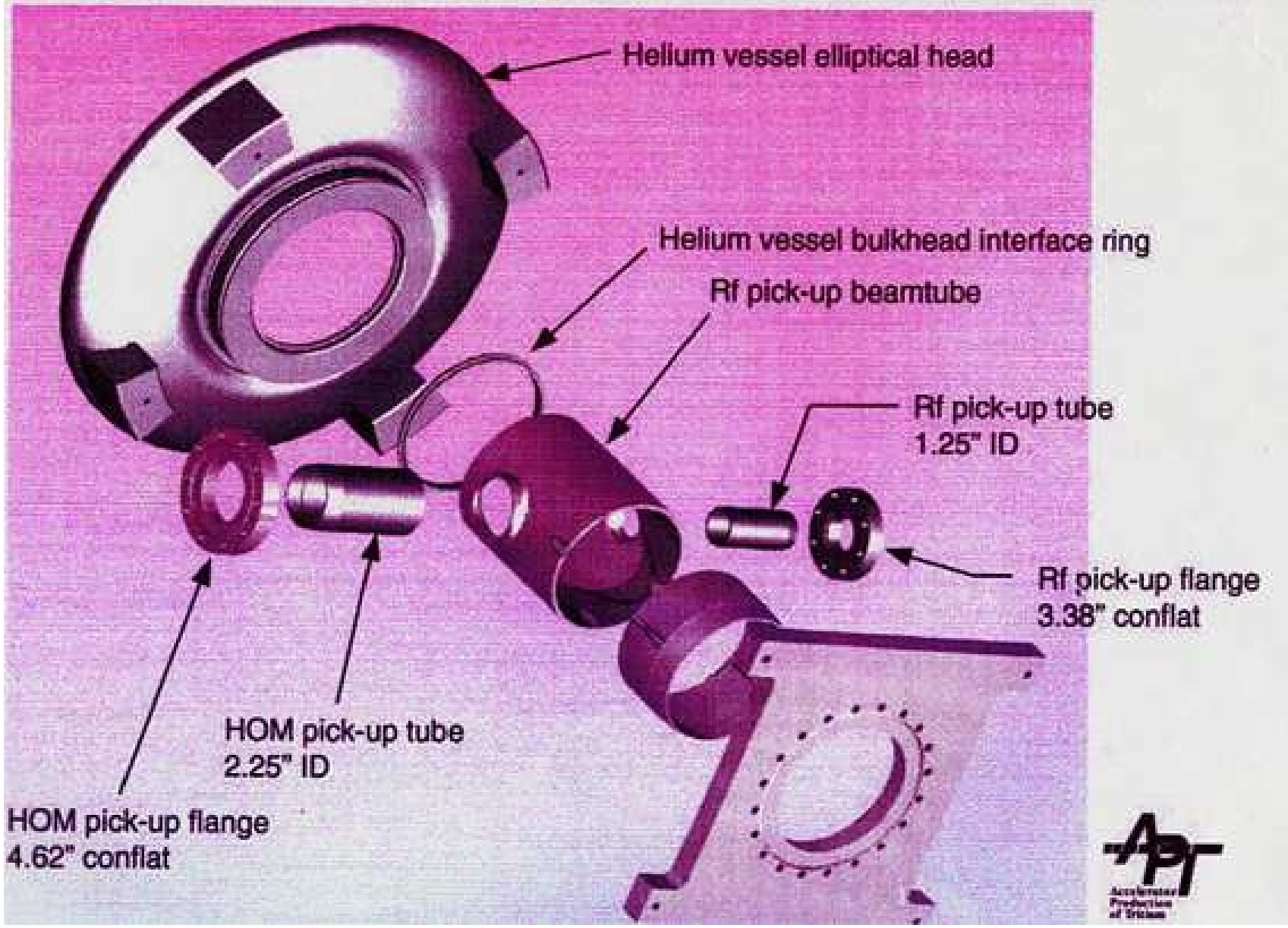


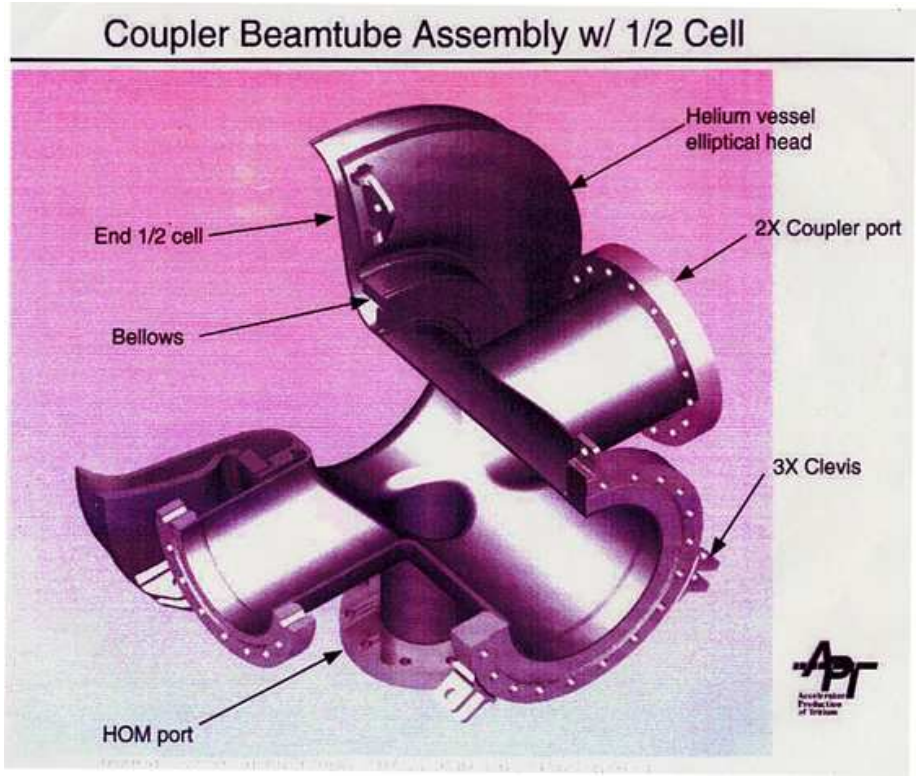
1. Degreasing and rinsing of parts
2. Drying under clean condition
3. Chemical etching at the welding area (Equator)
4. Careful and intensive rinsing with ultra pure water
5. Dry under clean conditions
6. Install parts to fixture under clean conditions
7. Install parts into electron beam (eb) welding chamber
   (no contamination on the weld area allowed)
8. Install vacuum in the eb welding chamber <= 1E-5 mbar
9. Welding and cool down of Nb to T< 60 C before venting
10. Leak check of weld

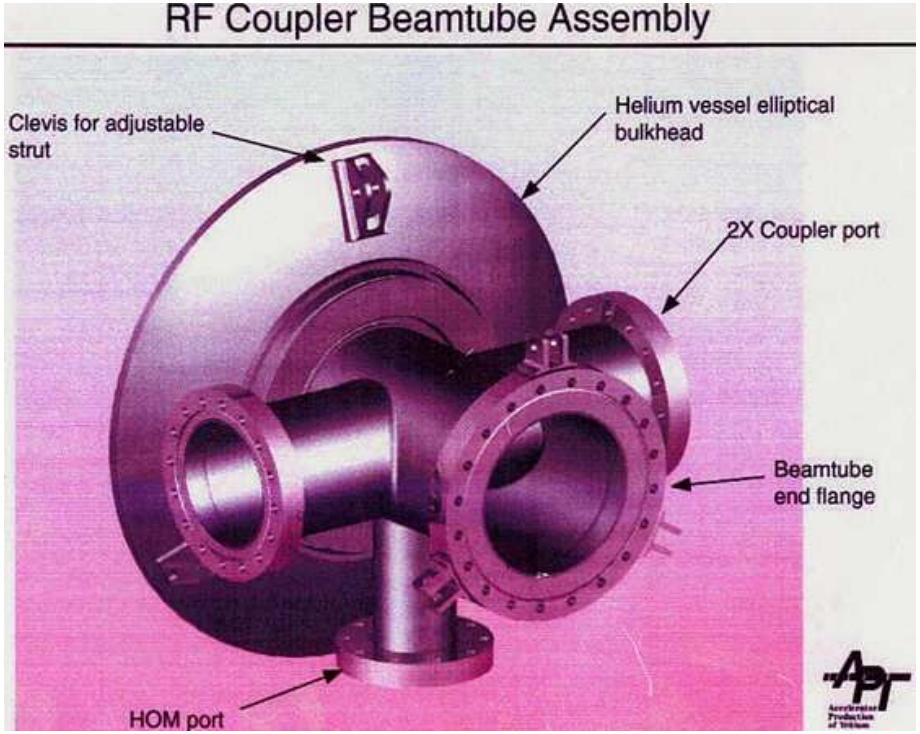
Beamtube with Weld Preps

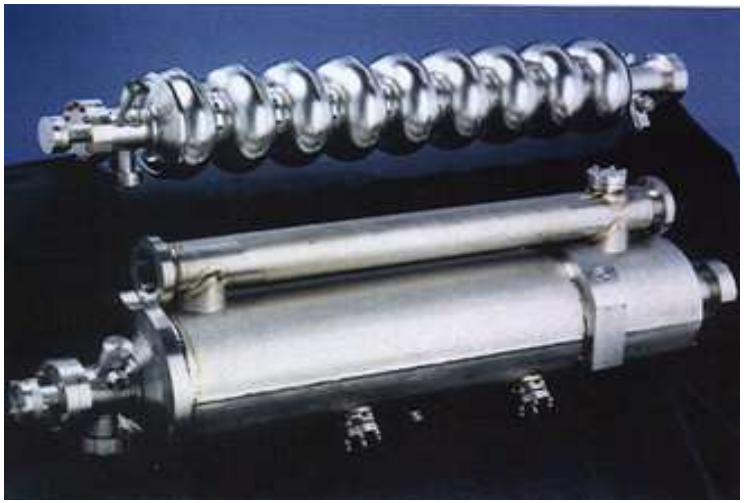


RF Pick-up Beamtube Assembly

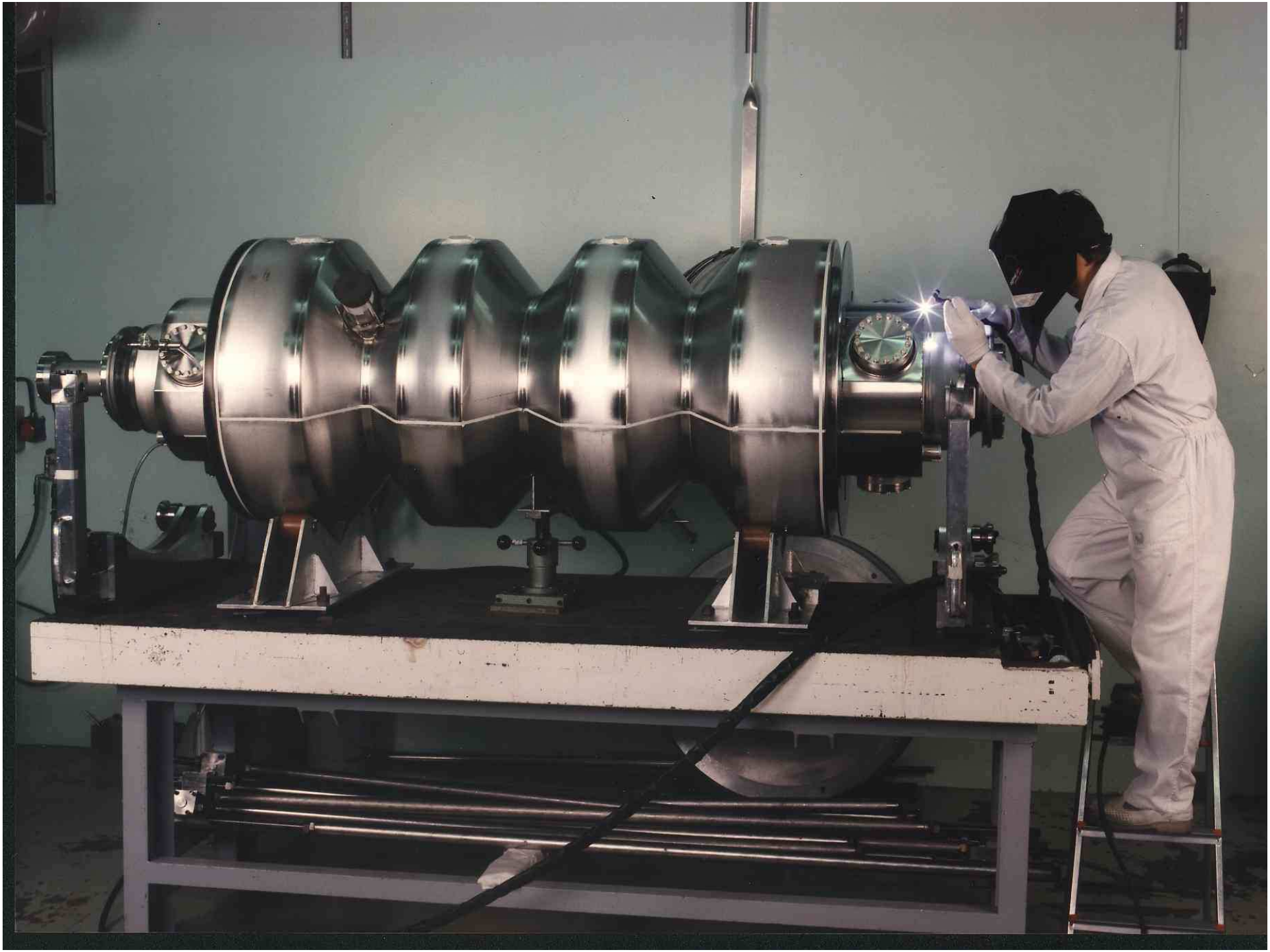




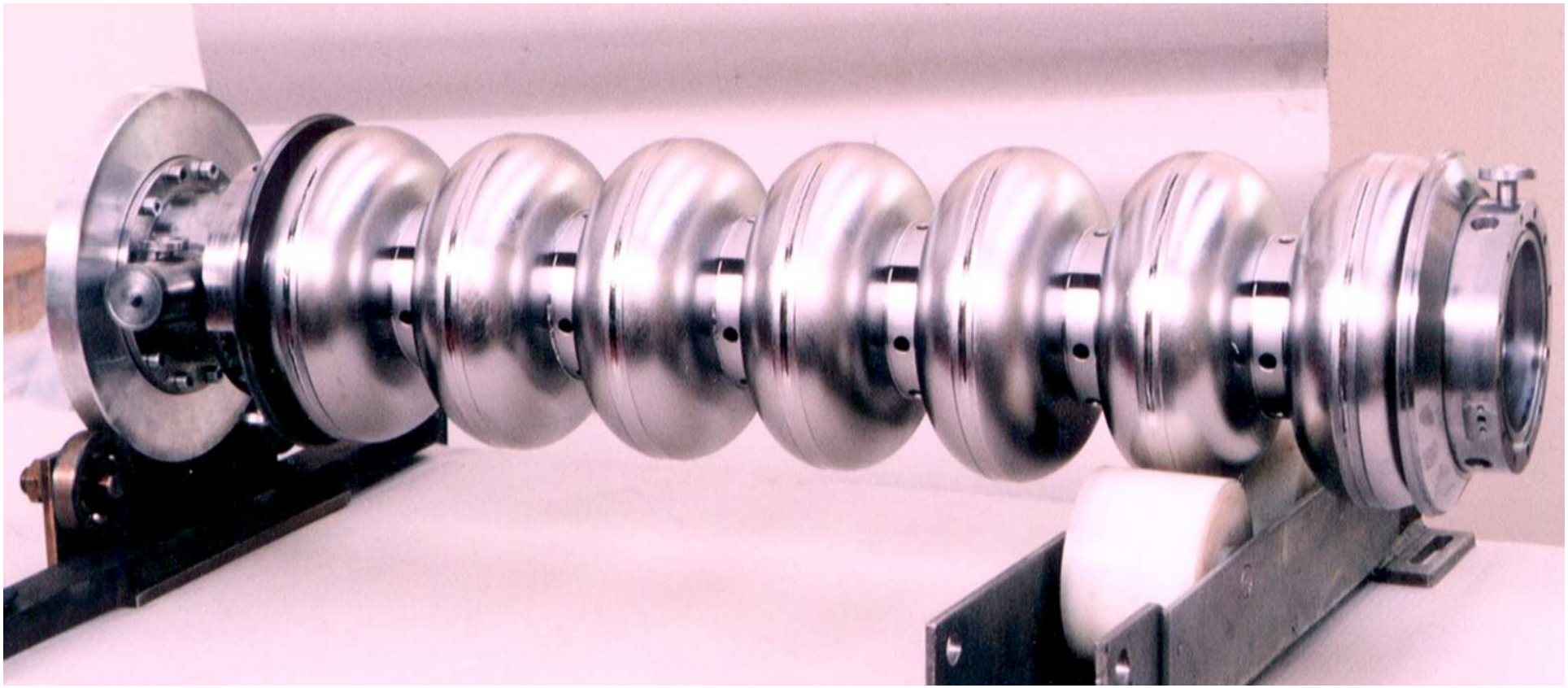




TESLA Cavity He Vessel



JLab Fabrication



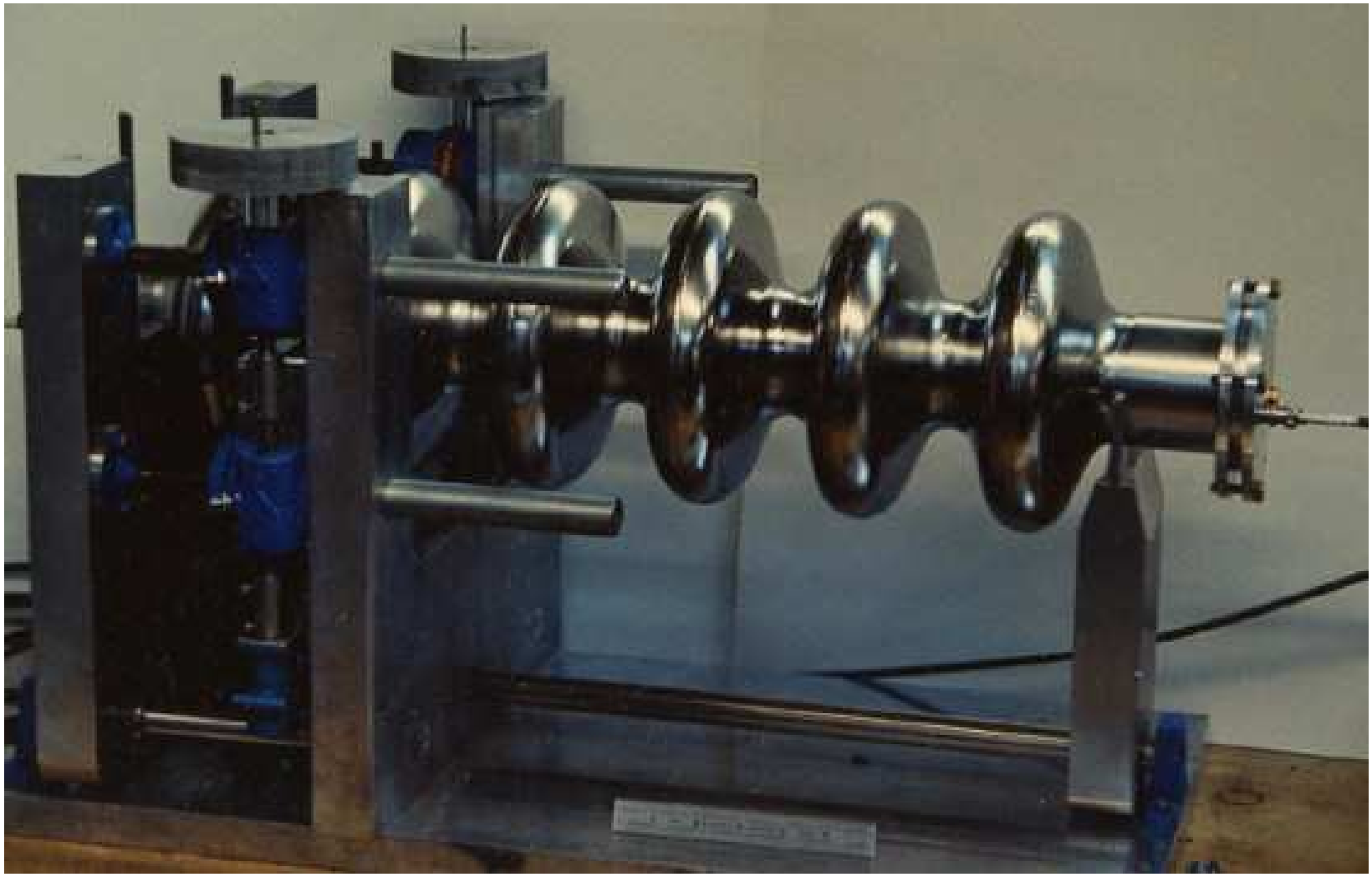
Cavity inspection

- Check of all mechanical tolerances
  - Take care with sealing surfaces
- Inspection of inner cavity surface
- Measure and adjust frequency and electrical field profile

Tuning of cavity frequency and field profile

- The cell length is adjusted
  - Tuning gate is „clamped“ to cavity at the stiffening ring (iris)
  - per cell: + 0.1 mm results in +300 KHz
  - Correct length can only be adjusted by proper trimming of the dumb bell
- Measure of field profile, frequency and tuning can be automised

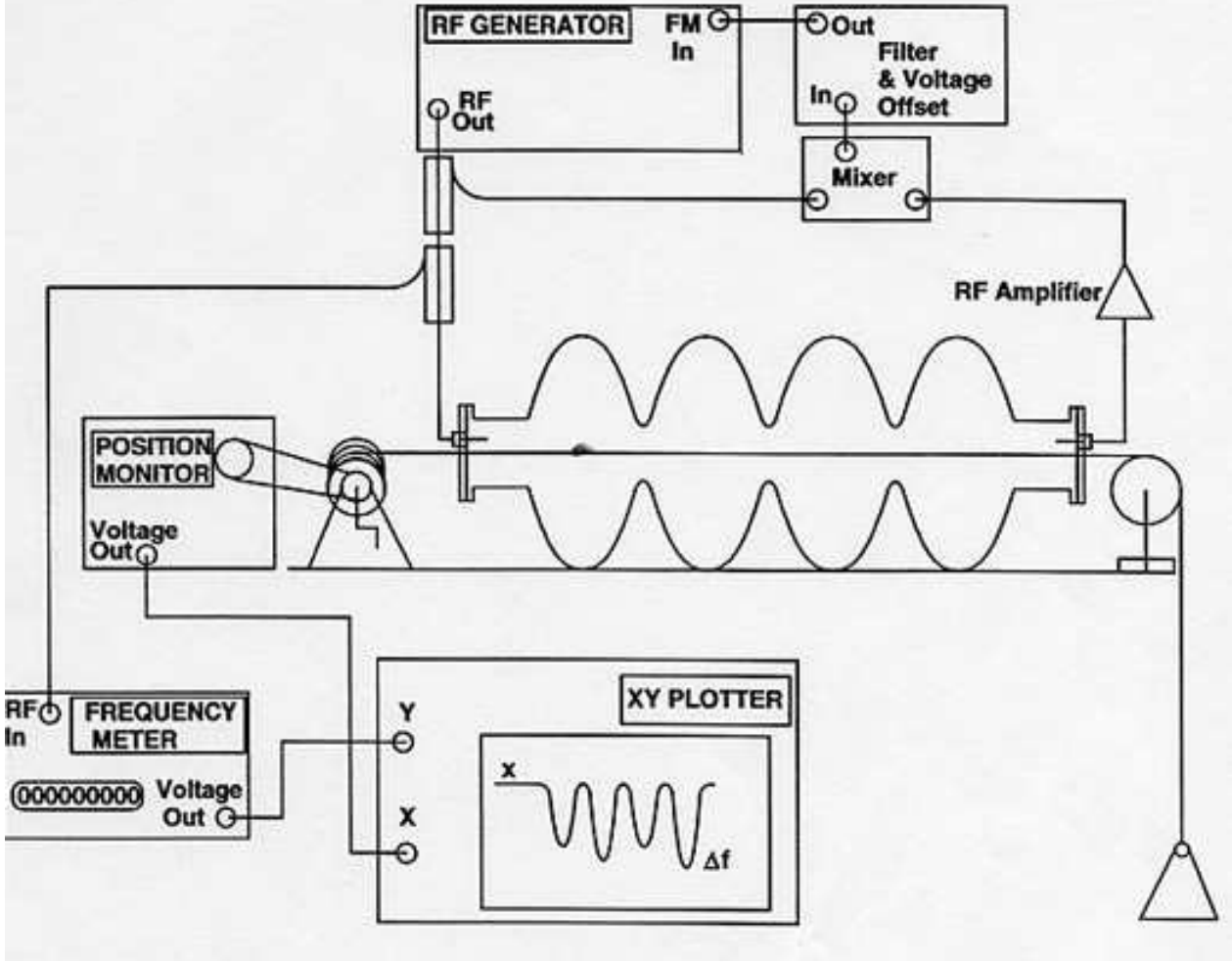
Tuning For Field Flatness



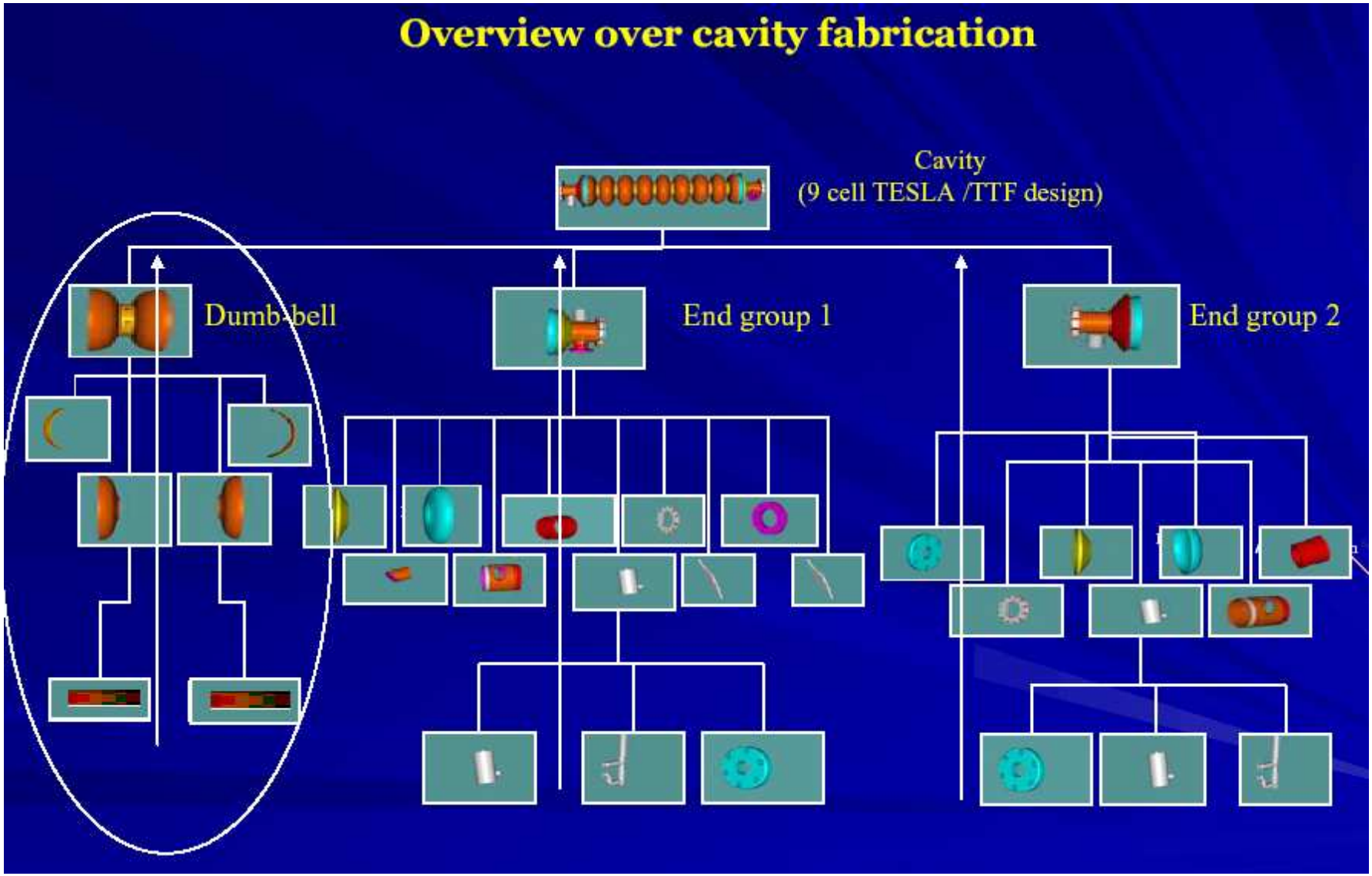
DESY Automatic Tuning

Diagram of tuning apparatus.

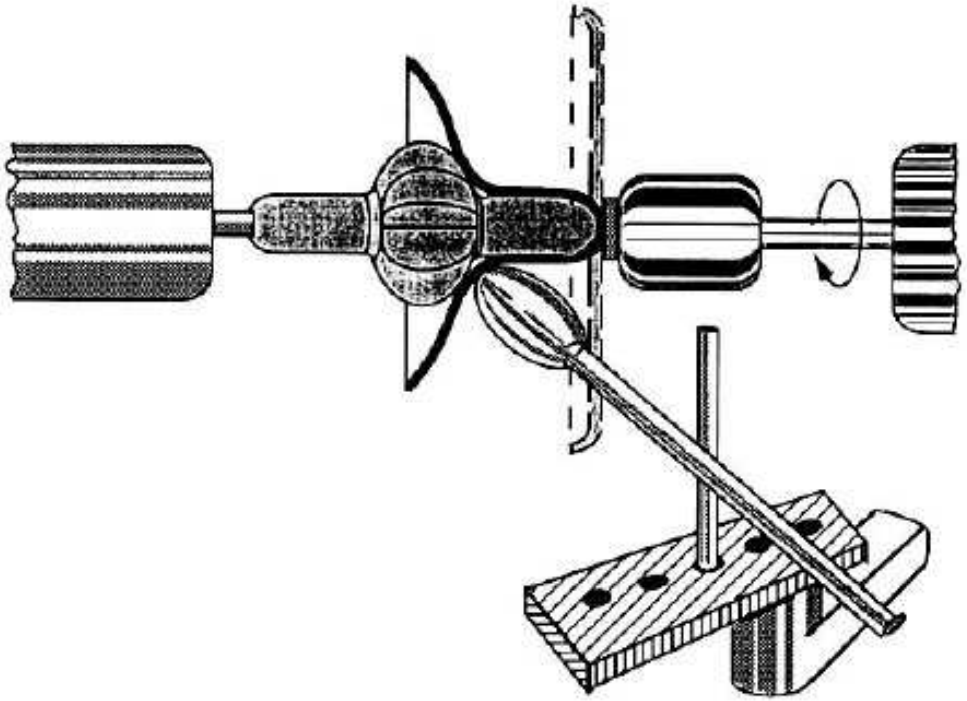
"Bead" is a tiny segment of metal tube on a fishing line.

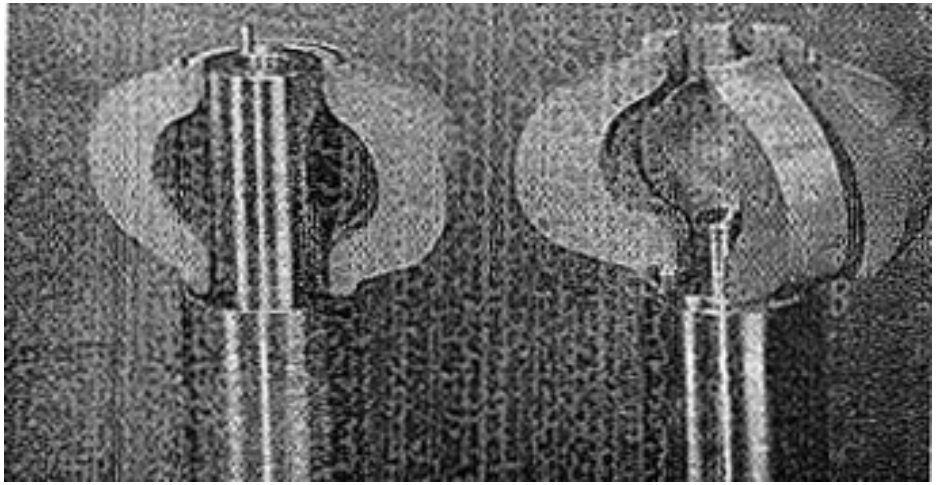


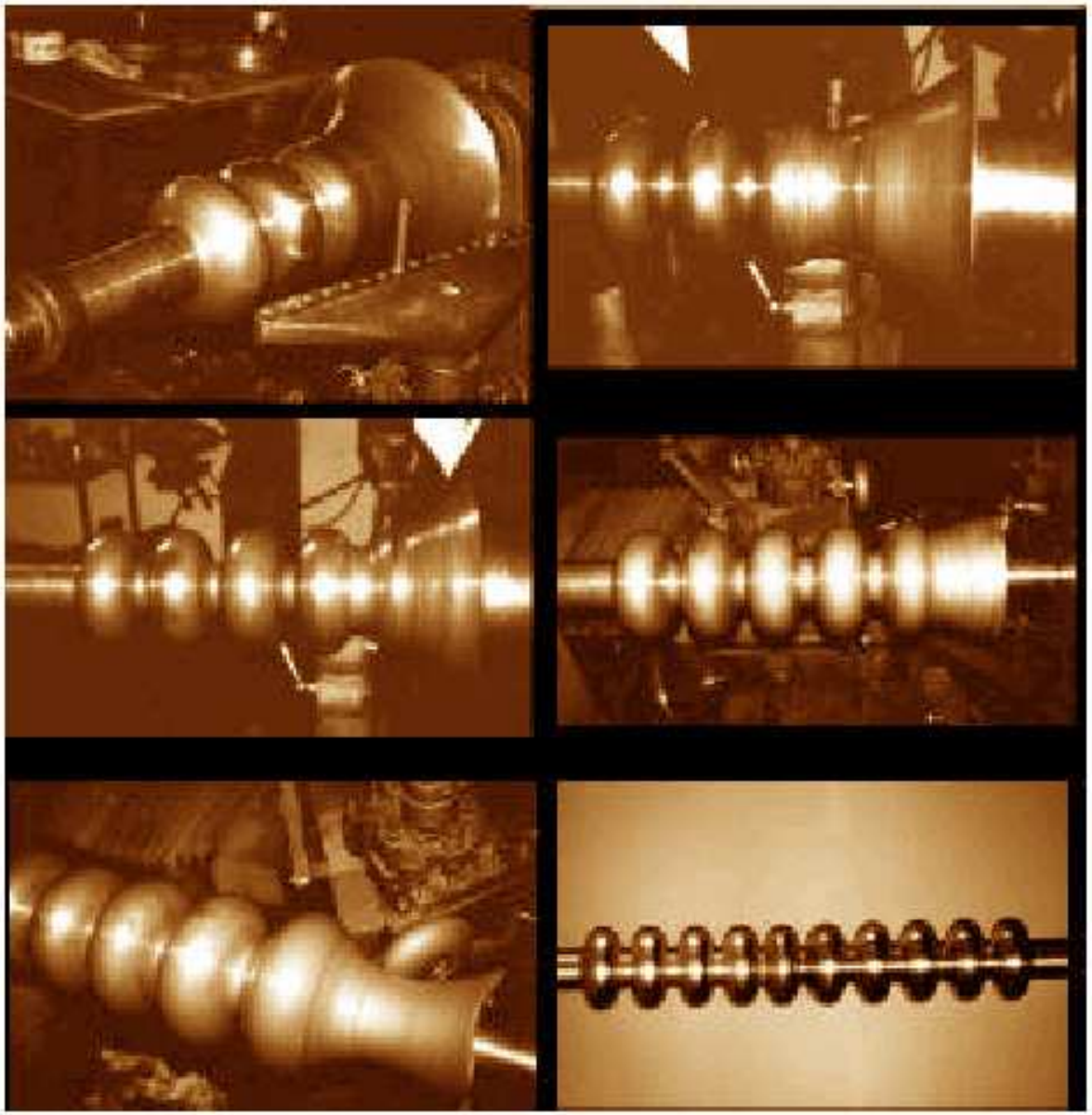
Alternate Fabrication Methods Under Development

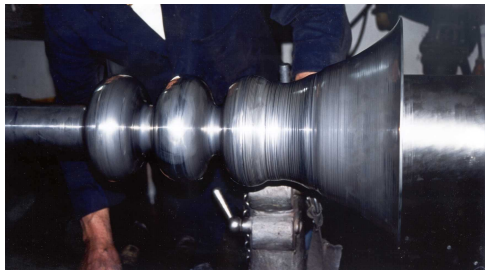

Overview over cavity fabrication
Cavity
(9 cell TESLA /TTF design)
Dumb-bell
End group 1
End group 2

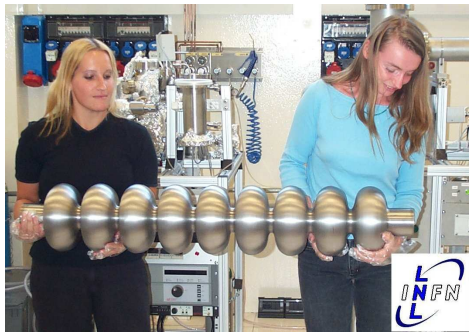
Monolithic Spinning

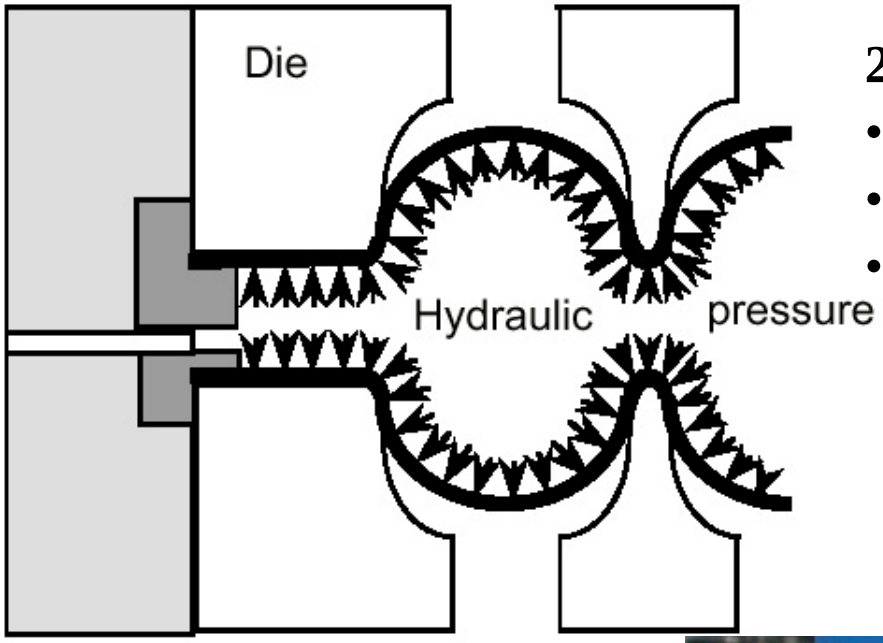








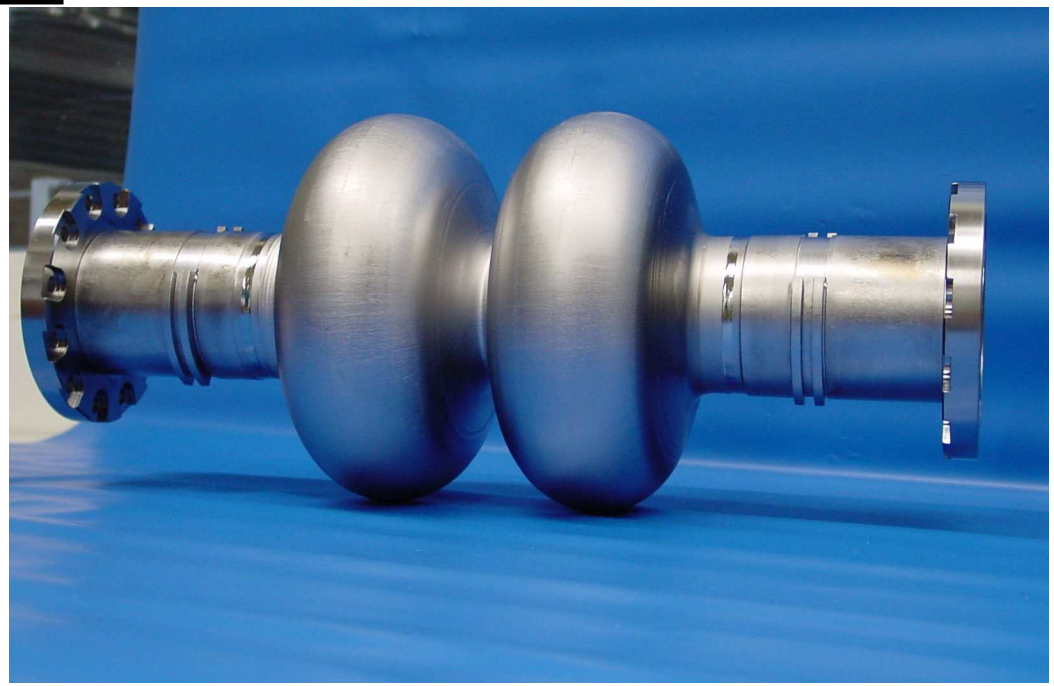

INFN
LNL

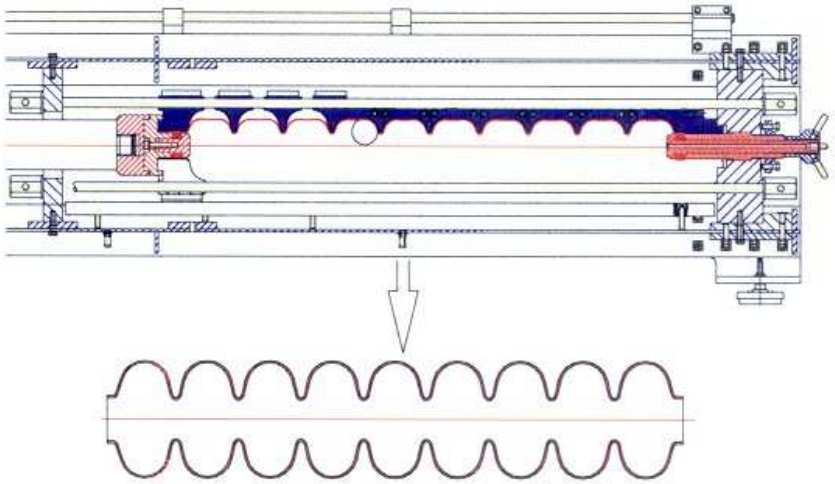


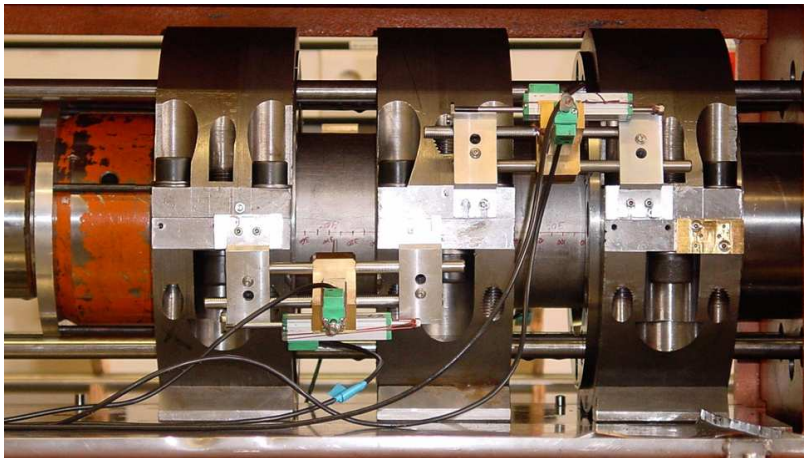
2 - cell Nb cavity hydroformed at DESY

- from Nb200 deep drawn tube
- no intermediate constraints
- no intermediate annealing

Hydroforming

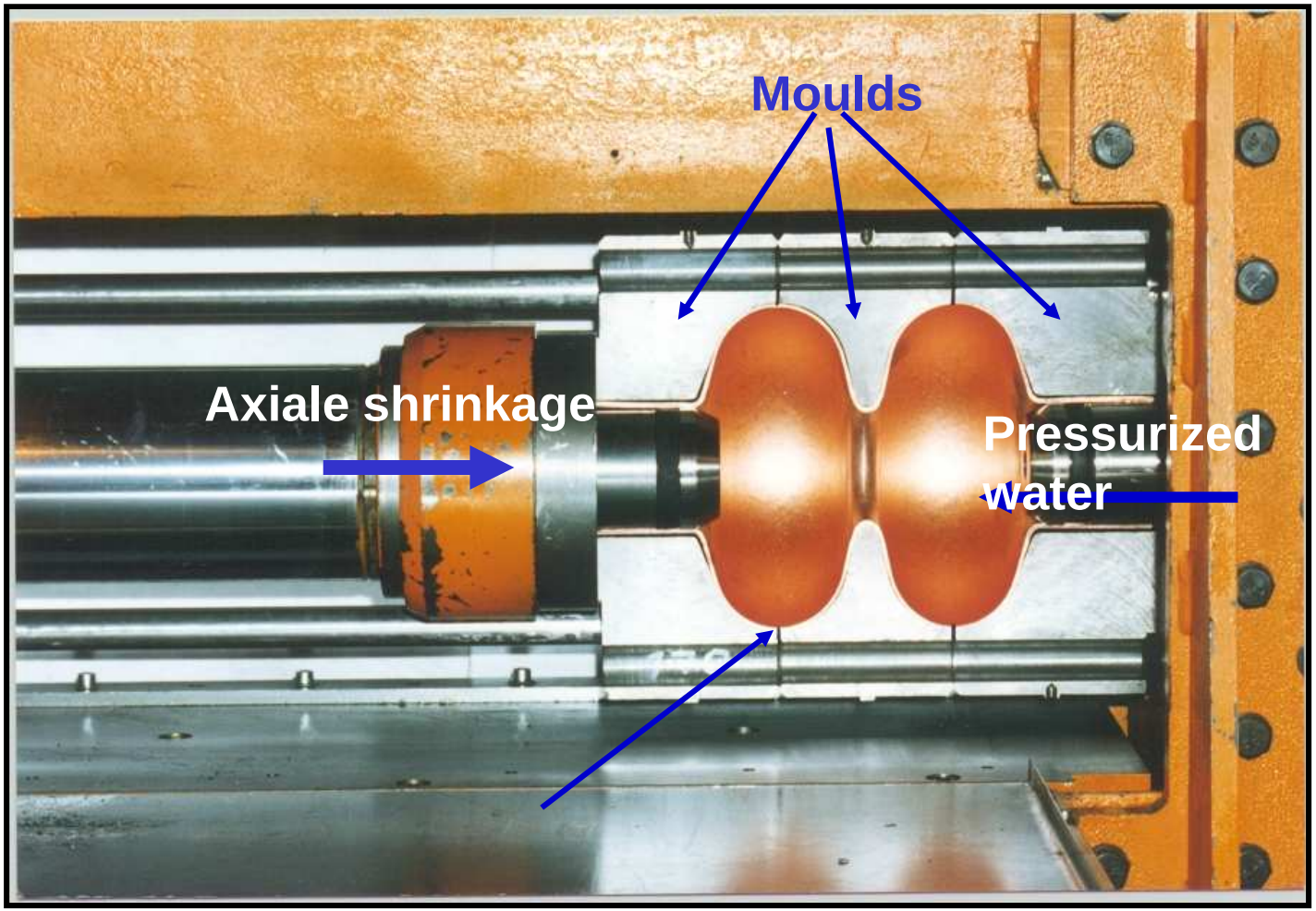




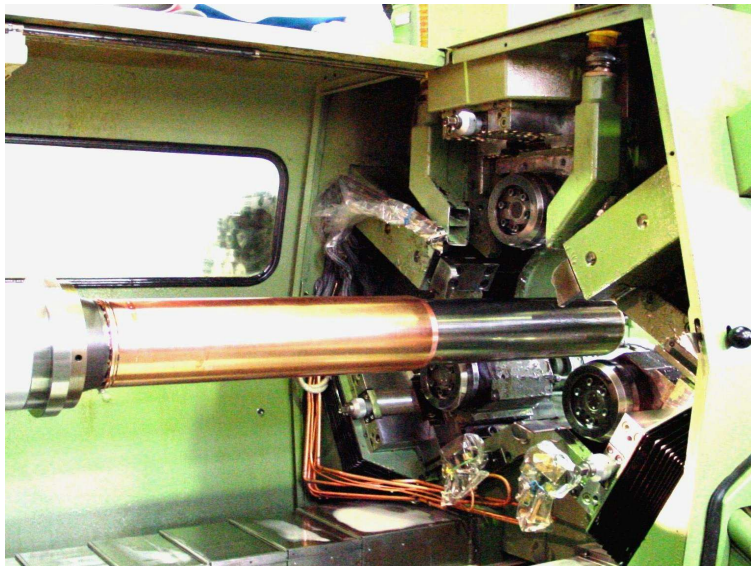


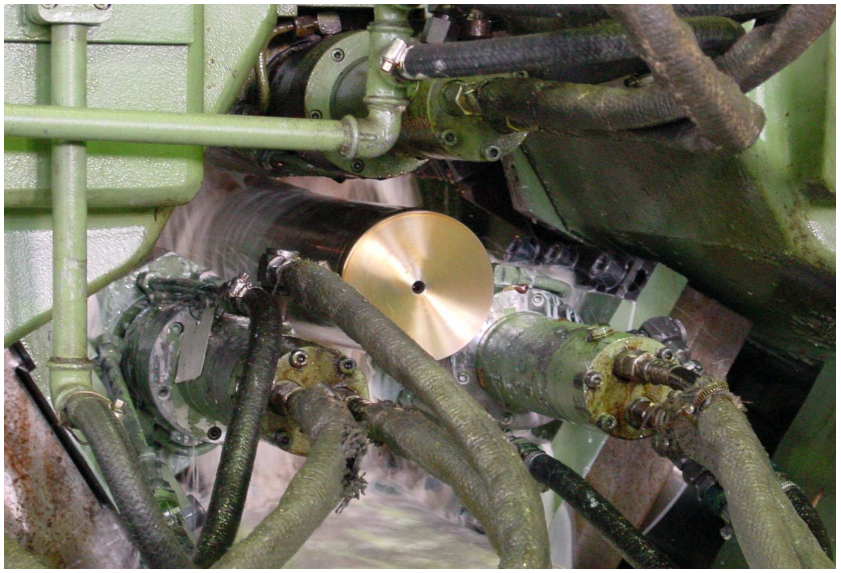
Hydroforming

H. Kaiser, W.Singer et al.

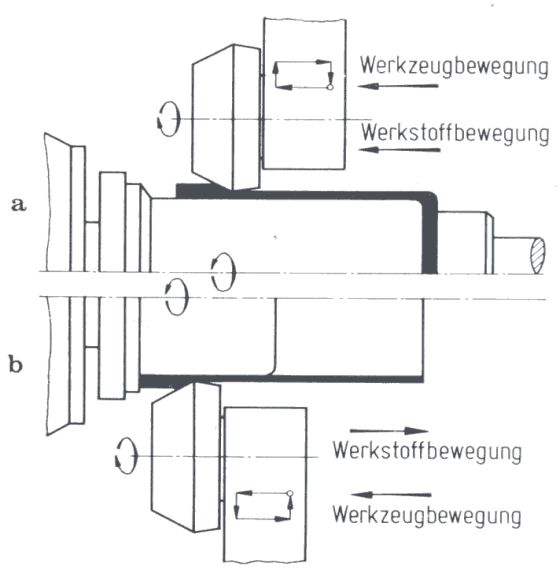


Hydroforming of a two-cell structure - H. Kaiser, W.Singer et al.





Flow forming over a cylindrical mandrel with three work rollers allows to produce long and very precise tubes from thick walled cylindrical part.
After optimization of several parameters shiny Nb surface and small wall thickness variations (less then +/-0,1 mm) have been achieved.



Tube Forming