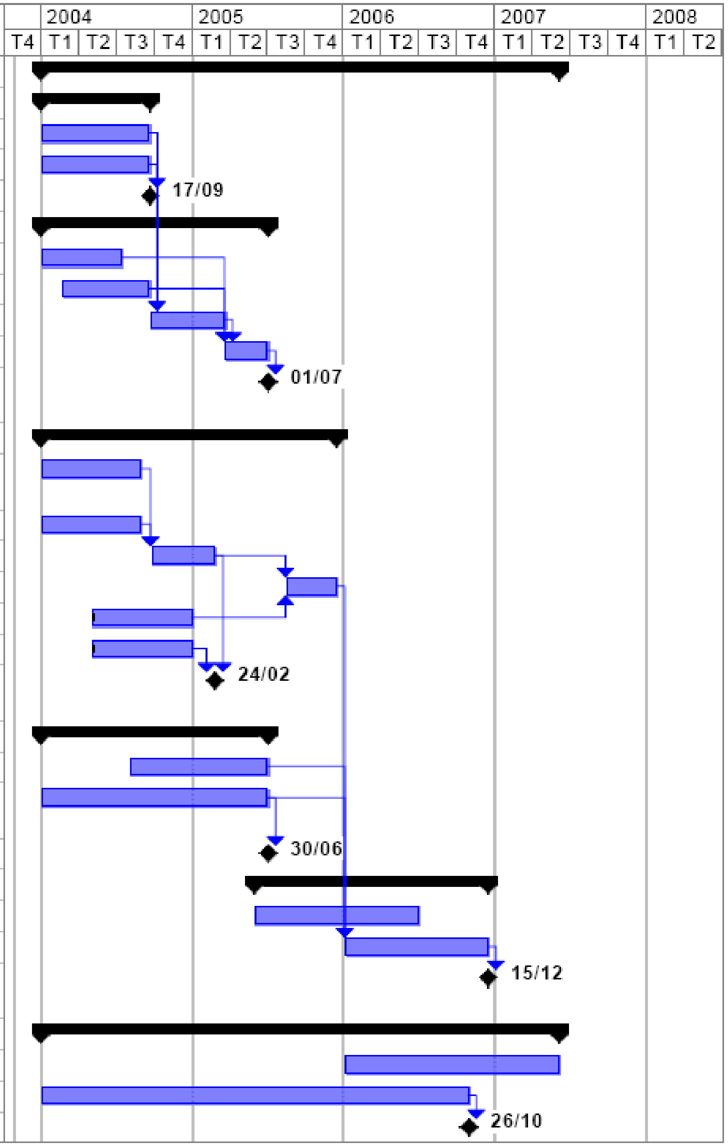
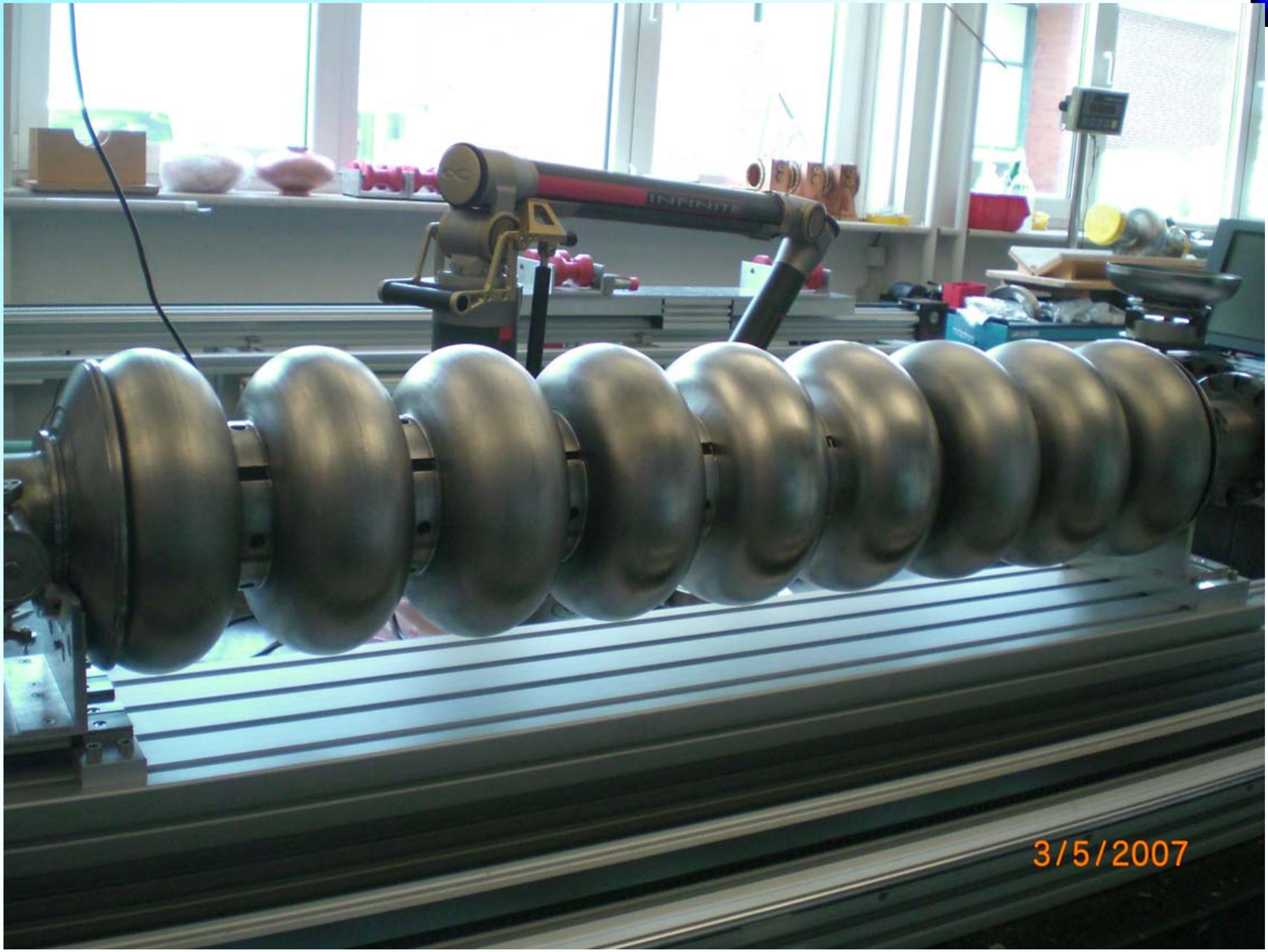
3.2 Seamless by Hydroforming

W. Singer

Task Name	Milestones, Deliverables
Seamless by hydro forming	
Design hydro forming machine	
Drawings of the matrices	
Drawings of the support system	
MS Drawings matrix & support finished	**Design Report**
Construction of hydro forming machine	
Hydraulic for machine	
Software for the machine	
Machine fabrication	
Commissioning of the machine	
MS hydro forming machine ready	**Hydro-forming machine**
Construction of tube necking machine	
Drawings of the support system and turning mechanism	
Drawings of the necking mechanism	
Fabrication of the tube necking machine	
Commissioning of the machine	
MS Necking machine ready	
Software for the tube necking machine	
MS Construction tube necking machine finished	**Necking machine**
Development of seamless tubes for 9-cell cavities	
Material and fabrication of bulk Nb test tubes	
Material and fabrication of bimetallic NbCu test tubes	
MS seamless tubes ready	
Development of tube necking	
Computer simulation of the necking	
Experiments on tube necking at iris	
MS Tube necking machine operational	**Necking Machine ready**
Hydro forming of seamless cavities	
Computer simulation of the hydro forming	
Hydro forming of bulk Nb 9-cell cavities	
MS Hydro formed 9-cell cavities ready	

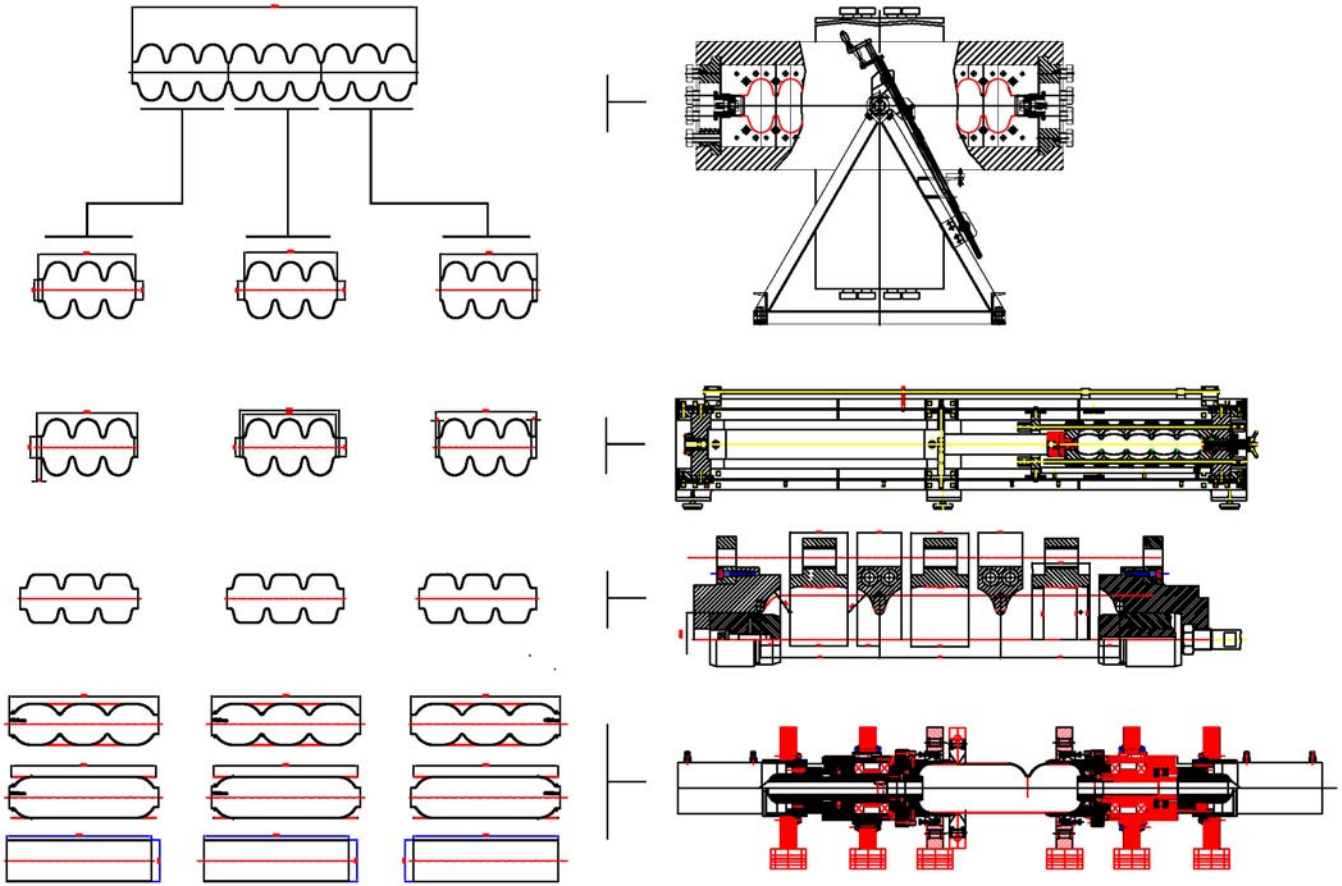


Z145: 9-cell as 3x3 cell cavity hydroformed at DESY

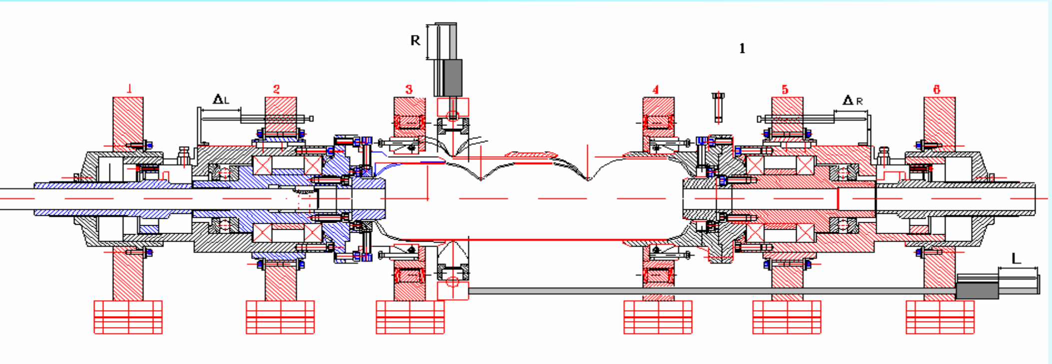


The cavity in in preparation for the RF test at DESY

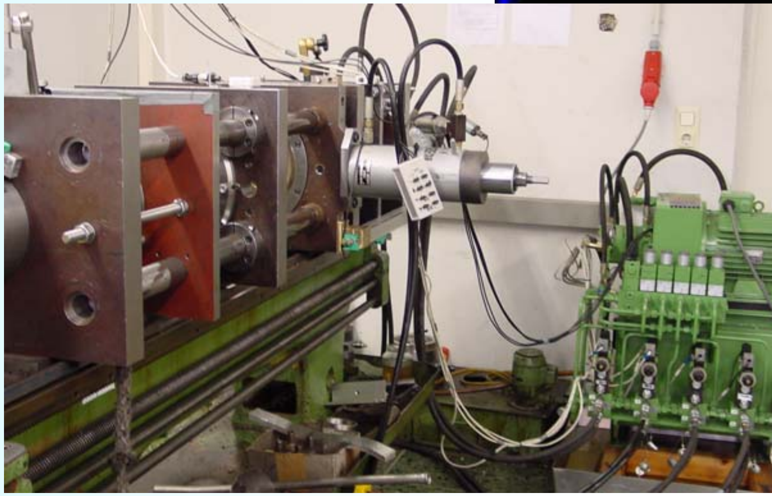
Fabrication steps of 9 cell cavity by hydroforming as an option 3x3



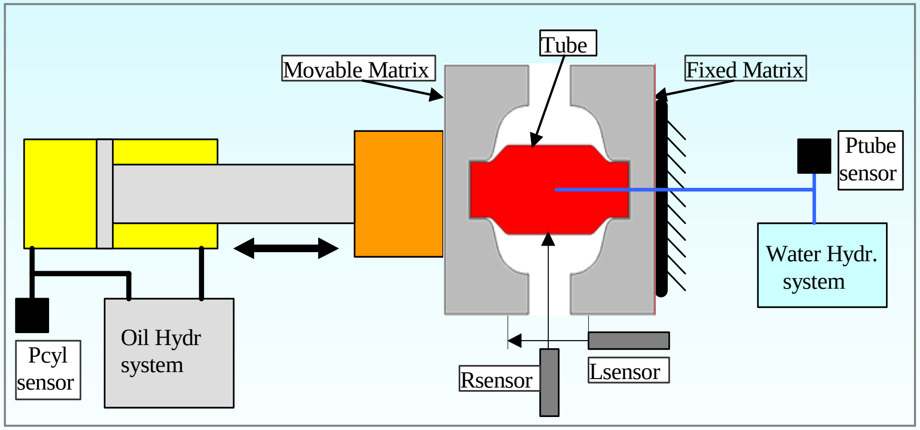
Hydroforming technique



Principle of tube diameter reduction in the iris area (necking)



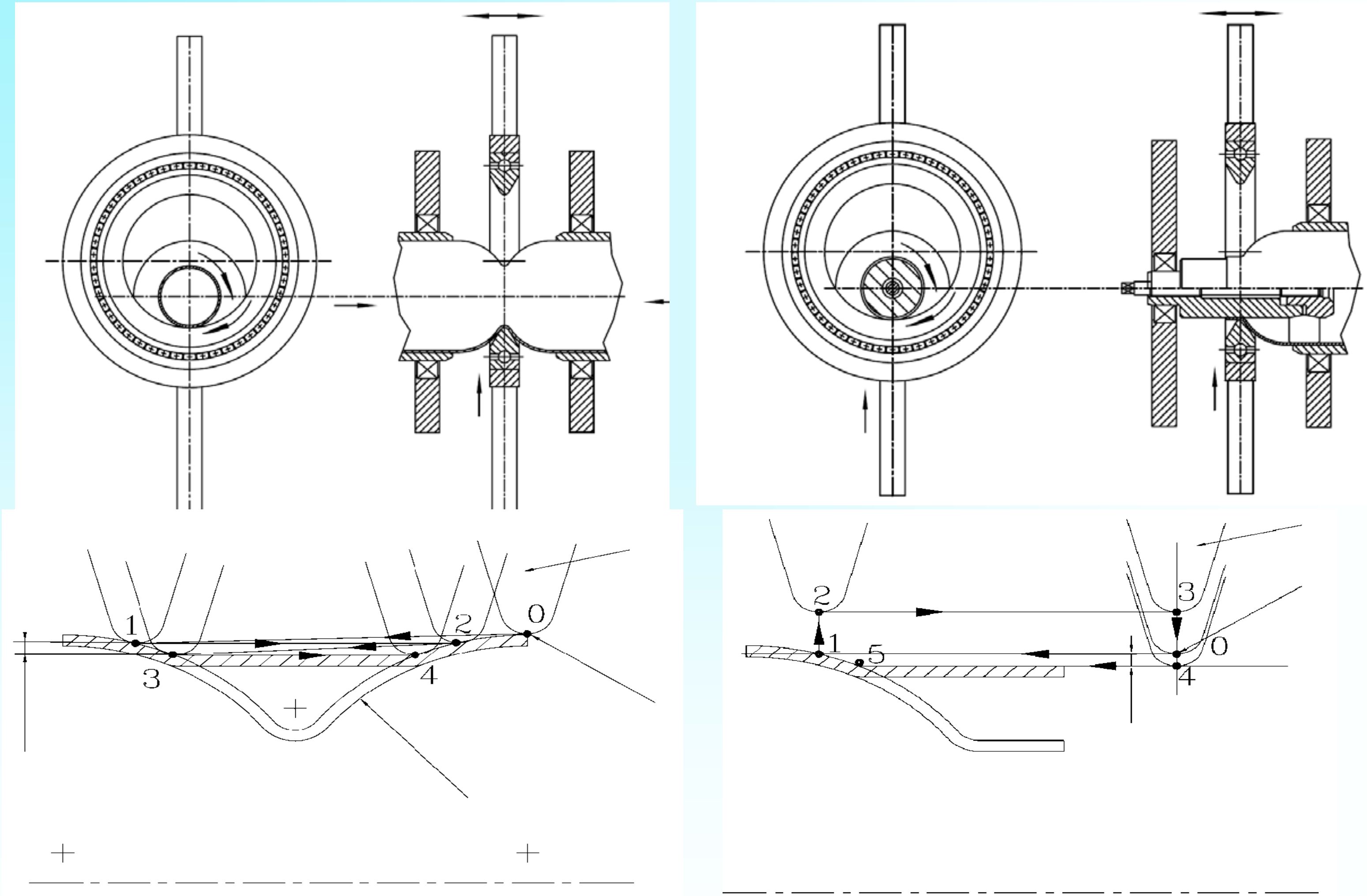
Necking equipment



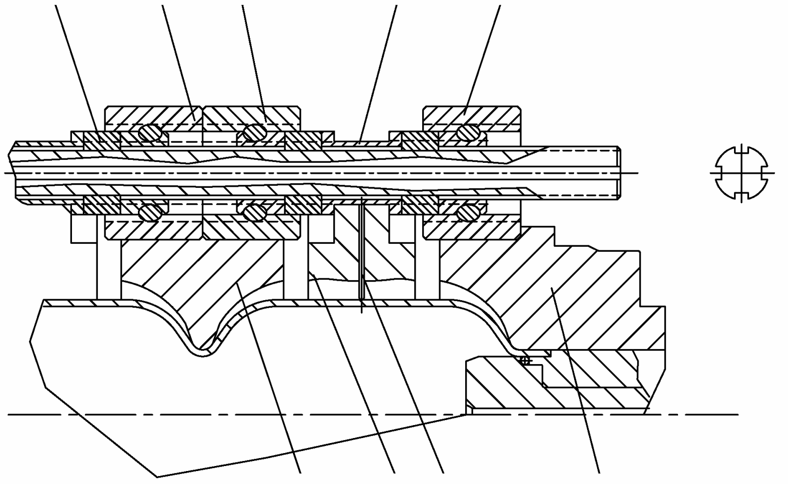
Principle of hydroforming

Hydroforming machine HYDROFORMA

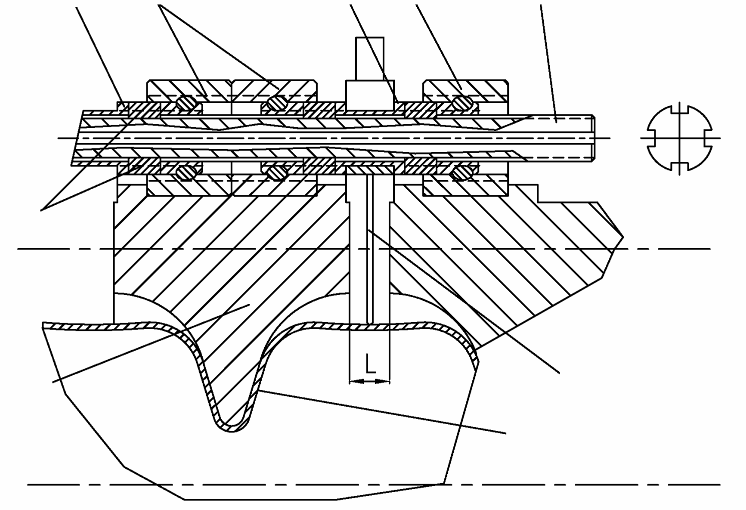
Some key ideas decisive for hydroforming success



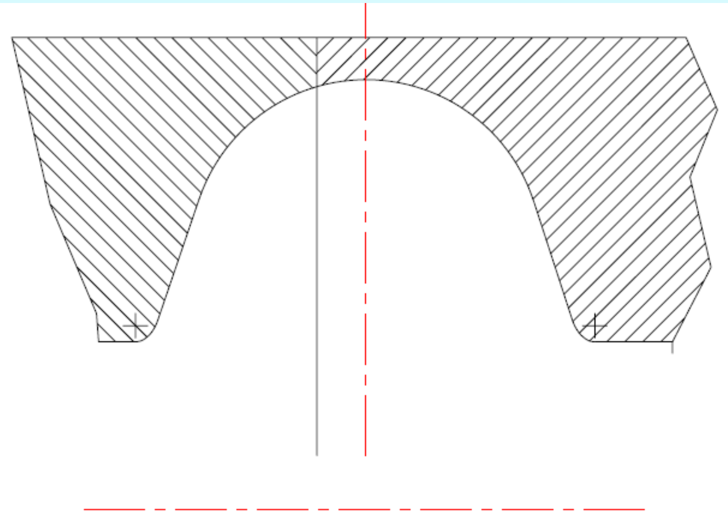
Diameter reduction at the tube end and in the tube middle



Synchronization mechanism for the intermediate step of hydroforming



Synchronization mechanism for the final step of hydroforming

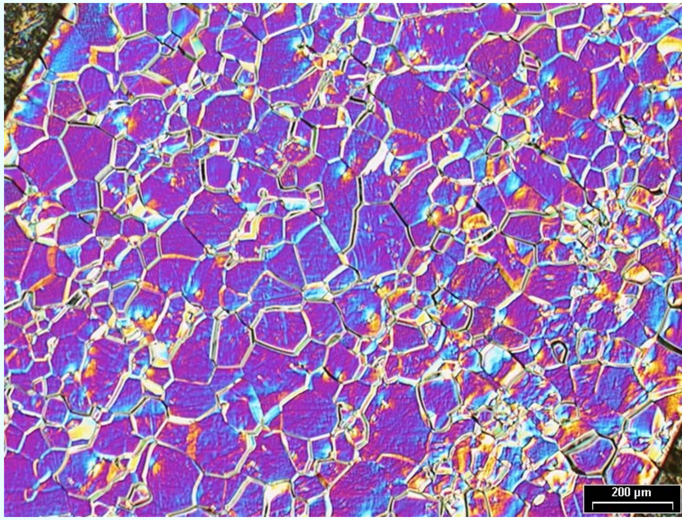


Nonsymmetrical mould for hydroforming

Developed ideas summarized in the submission for the patent.

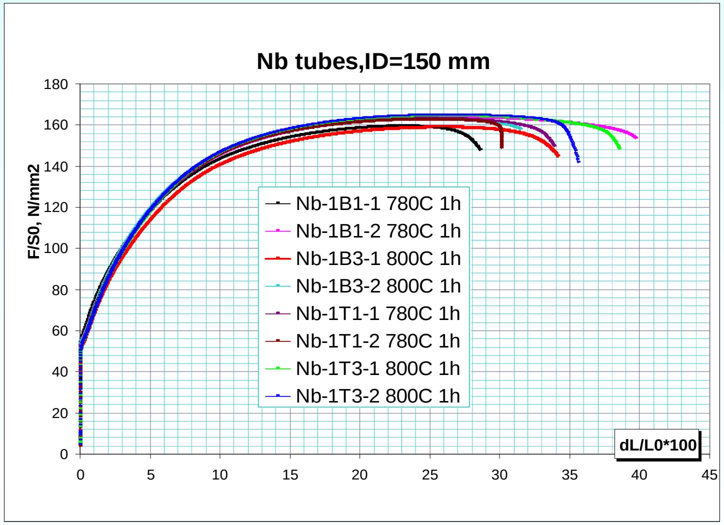
W.Singer, I.Jelezov; No. 10 2007 037 835.3; 10 August 2007

Seamless tubes build by combination of spinning with flow forming: appropriate microstructure of and rather high strain before onset of necking

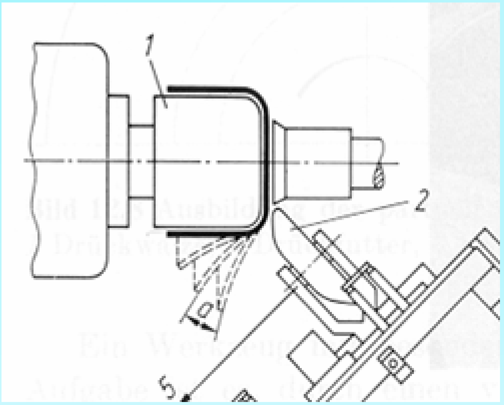


Microstructure of Nb tubes produced by combination of spinning and flow forming

Stress-strain curves and microstructure of Nb tubes produced by combination of spinning and flow forming. Tensile tests done in circumferential direction



Seamless bulk Nb tubes



Metalldrücken bei

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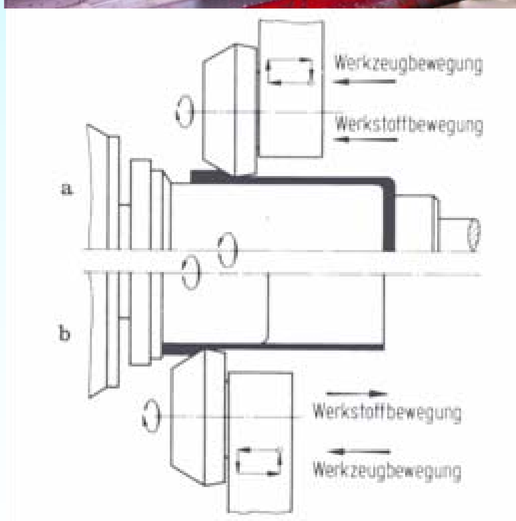
Pot with thick wall by spinning

The multi cell seamless bulk Nb cavities fabricated starting from the tube with inside diameter of ID=150 mm. The seamless tubes built starting from the thick sheet. Tubes are produced by combination of spinning and flow forming.

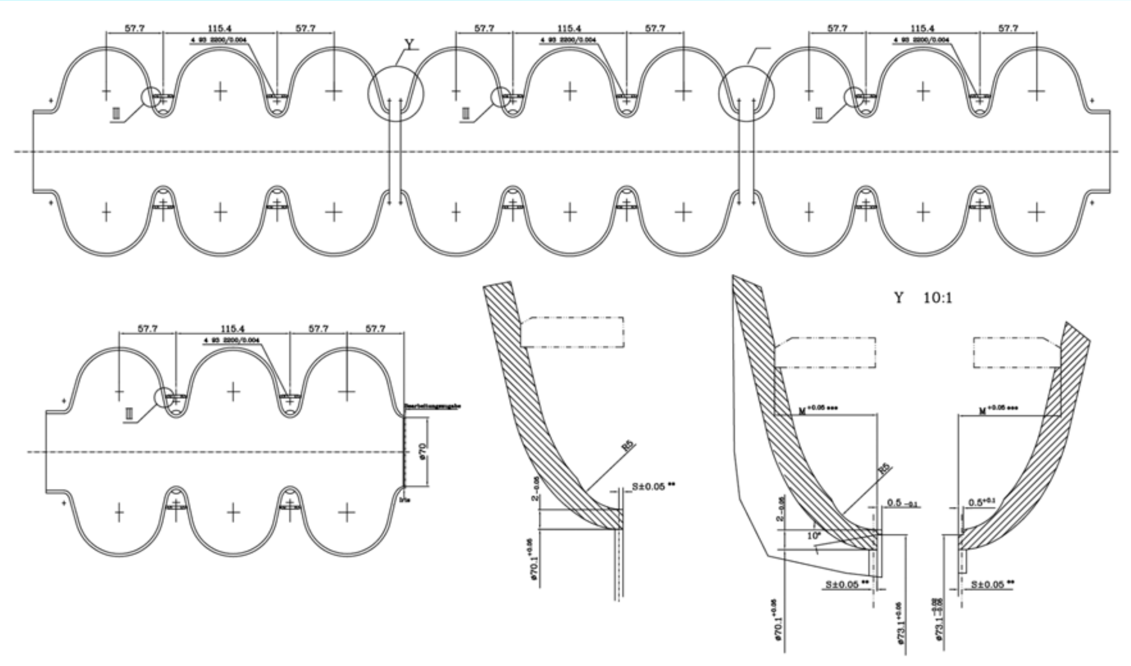


Flow forming

Fa.
MSR

Flow forming was done in forward direction. Length is ca. 800 mm. Wall thickness tolerances of the tubes: +/- 0.15 mm what should be sufficient for subsequent hydroforming.

The 9-cell hydroformed cavity was completed at E. ZANON

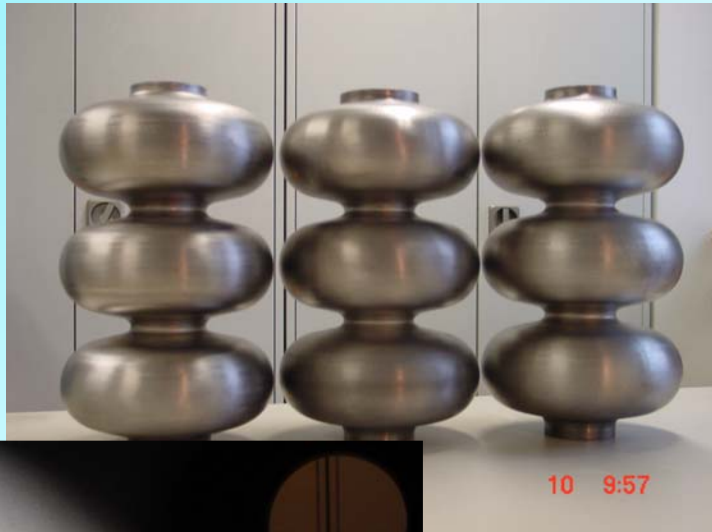


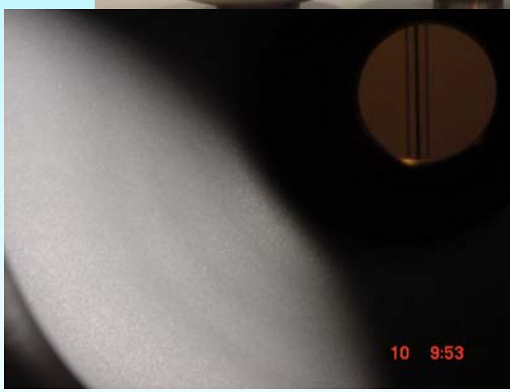
Fabrication included following steps:

- Fabrication of the long and short end groups connected with three cell units
- Machining, preparation and welding of three units together in a 9 cell cavity (two iris welds done from outside)
- Machining, preparation and weld on of the stiffening rings

The hydroformed cavity Z145 is currently in the preparation for RF test at DESY

Second hydroformed 9-cell cavity





Inside surface after CBP

Three cell units for second cavity are in work on Centrifugal Barrel Polishing CBP at DESY

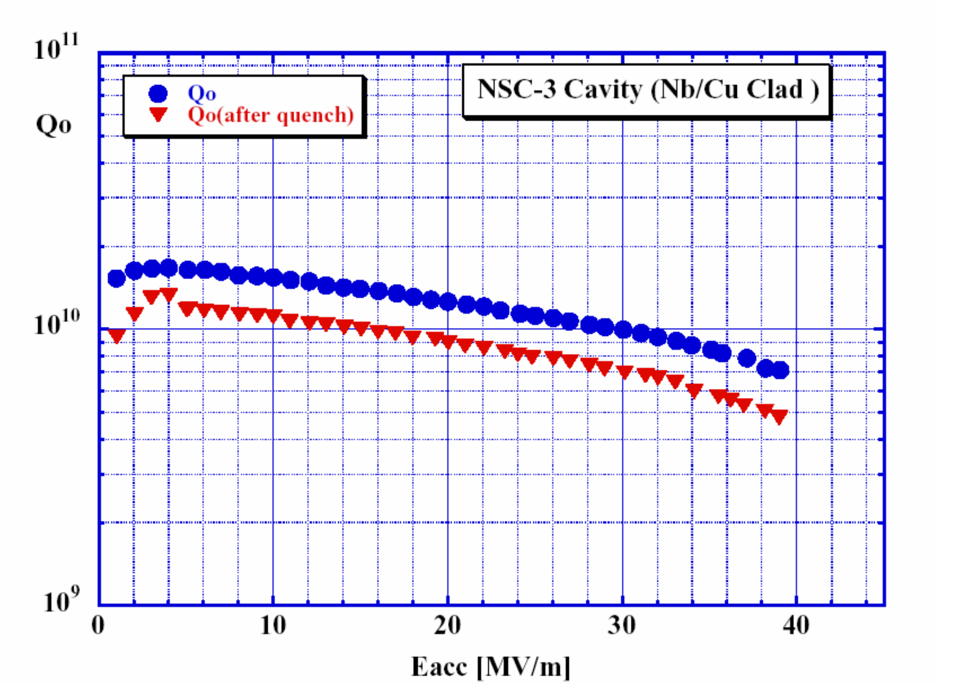
Barrel polishing, 800°C annealing, EP (KEK recipe) seams to be a most appropriate treatment for seamless cavities

Fabrication of NbCu clad cavities

Single cell NbCu cavities produced earlier at DESY by hydroforming from KEK sandwiched tube.

One NbCu sandwiched cavity was tested NSC-3.

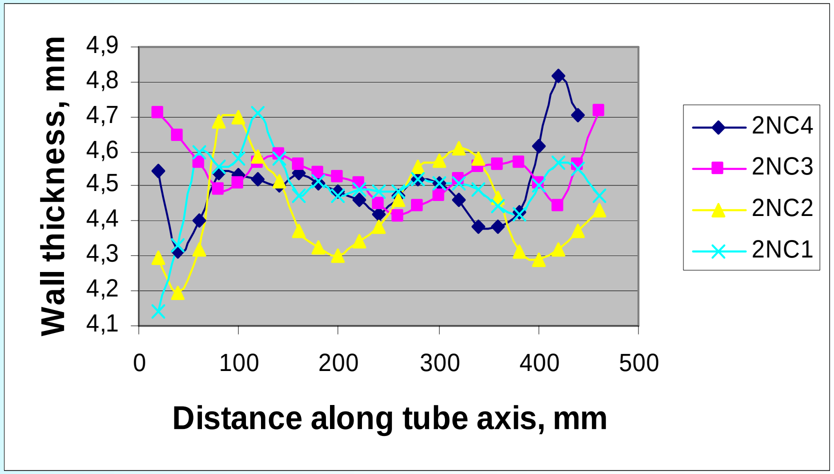
Hot roll bonded tube fabrication at Nippon Steel Co., hydroforming at DESY, Preparation and RF tests at KEK



NSC-3: Barrel polishing, CP(10 mμ), Annealing 750ºC x 3h, EP(70 μm) K.Saito

Multicell NbCu clad cavities, produced in frame of the CARE project

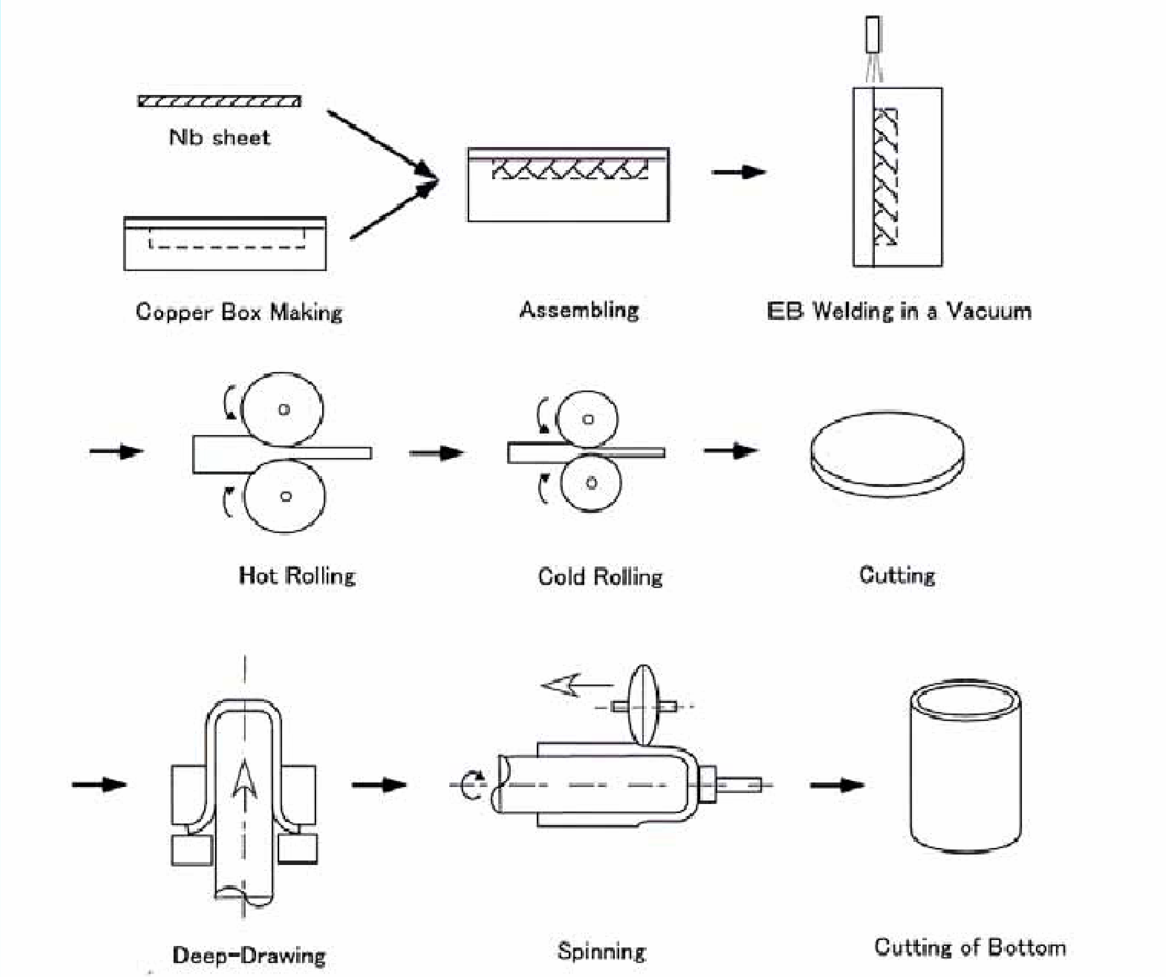
4 NbCu clad tube of KEK



Wall thickness distribution

Four 2 cell NbCu clad cavities produced at DESY from KEK tubes (inside surface OK). Cavities are in preparation and waiting for RF test at KEK

Hot bonded NbCu tubes are used



Fabrication principle of sandwiched hot rolled Cu-Nb-Cu tube (KEK and Nippon Steel Co.)

Hot roll bonded Cu-Nb-Cu tube produced at Nippon Steel Co.

Difficulties in NbCu technology

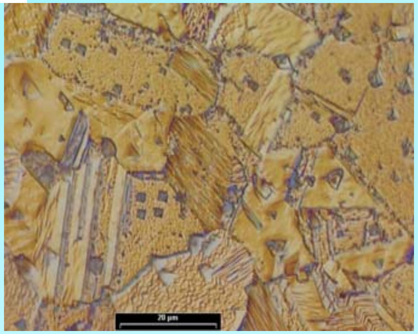
Dangerous of cracks appearance in iris area during fabrication (because of big difference in recrystallization temperature of Nb and Cu)

Microstructure of Cu and Nb after annealing at 560°C for 2 hours. Nb is not recrystallysed (hard).

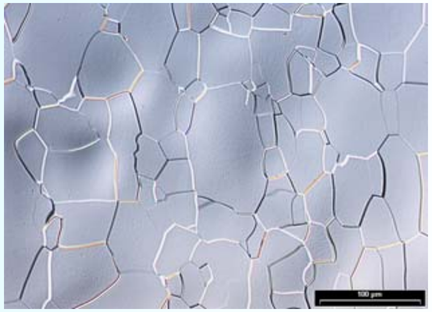
Two ways to defeat the cracks

a) Sandwiched tube (Nb is between two Cu layers. Cu layer on both sides prevent creating of cracks in Nb); removing of inside Cu layer on the cavity after forming (K.Saito). The option was checked, it works

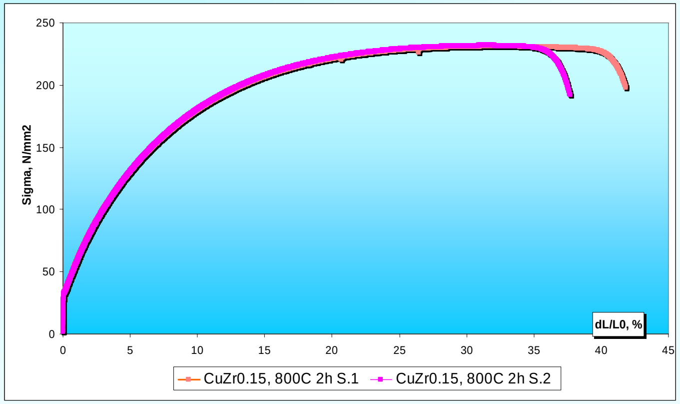
b) special Cu with high recrystallization temperature



Microstructure of Cu0.15%Zr (left) and Nb (right) after annealing at 800°C for 2 hours.



Stress –strain behavior and thermal conductivity of Cu0,15%Zr after annealing at 800°C for 2 hours compared with Cu and Nb.



The Cu0.15%Zr shows a high elongation after annealing at 800°C, small and rather uniform grain and can be a good candidate for replacing of pure Cu in NbCu clad tubes

Thermal conductivity can be recovered by aging at ca. 400°C/one hour. Zr leaved the solid solution and creates precipitates Cu_5Zr finely distributed in Cu matrix

Cu only outside: Cu0.15%Zr special Cu with high recrystallization temperature

Up to now hydroforming only of the sandwiched tube. Cu layer on both sides prevent creating of cracks in Nb; removing of inside Cu layer on the cavity after forming chemically (costly)

NbCu0.15%Zr tube

Single cell cavities produced from Nb/ Cu0.15%Zr clad tube

Conlusions

•The hydroforming technique is so far developed that fabrication of the 9-cell cavities become a reality

• Remaining tasks:

- Preparation and RF test of Z145
- Fabrication of the second 9-cell bulk Nb-cavity
- Completing and tests of single cell NbCuZr cavities