



**High
Luminosity
LHC**

Cold Magnetic Shielding and a Proposal for Dressed Cavity Assembly

**Niklas Templeton STFC
10/11/2015**

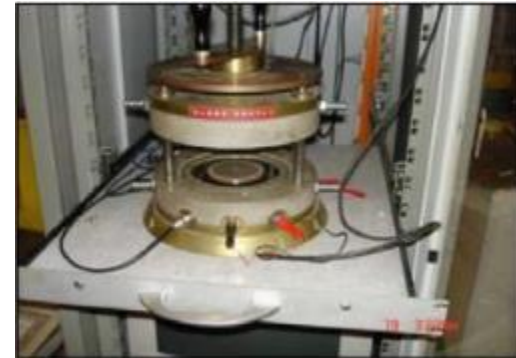
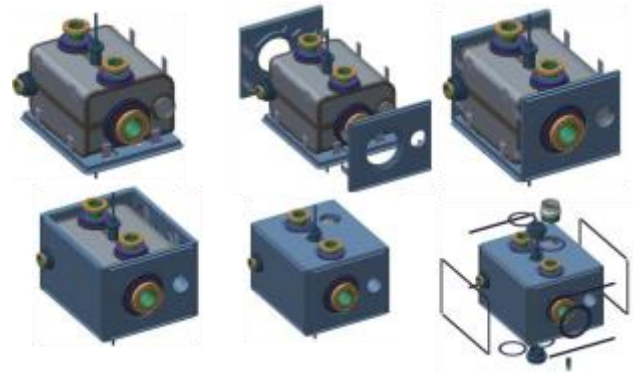


The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

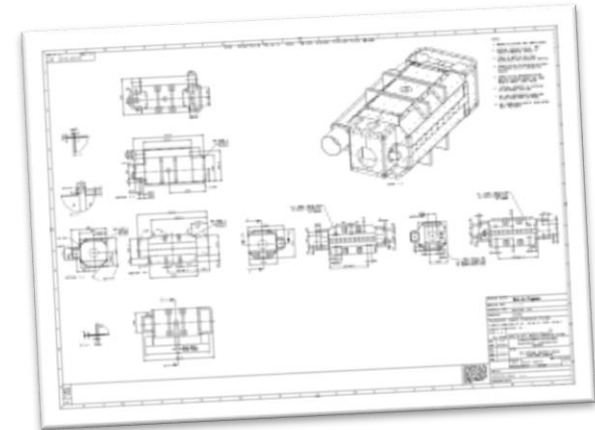
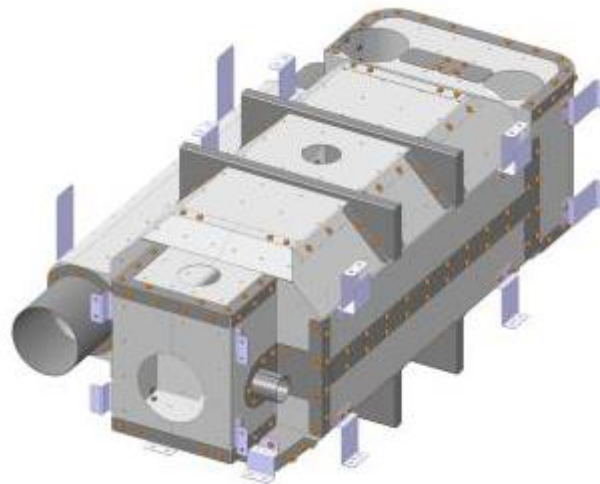
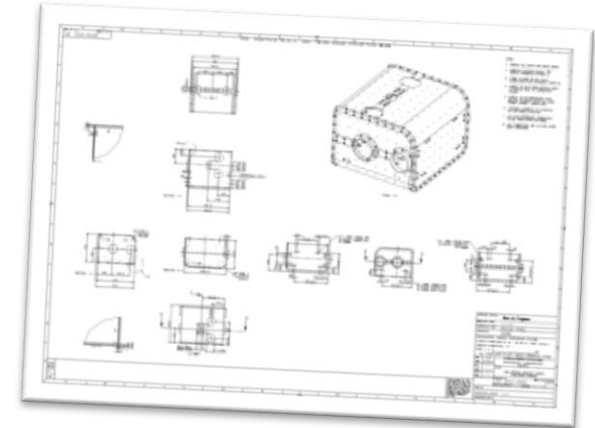
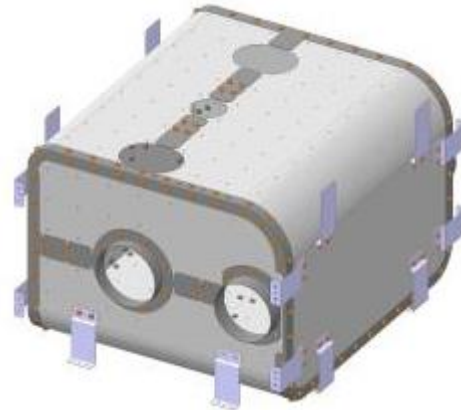
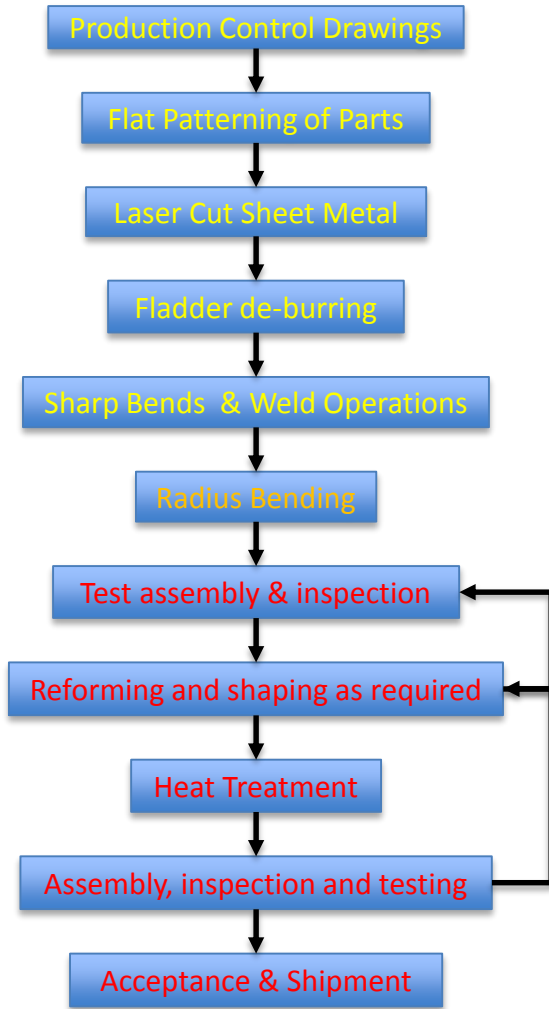


Content

- Manufacture
- Assembly Procedure
- Test Plans



Manufacture by Magnetic Shields LTD



Manufacture by Magnetic Shields LTD

Production Control Drawings

Flat Patterning of Parts

Laser Cut Sheet Metal

Fladder de-burring

Sharp Bends & Weld Operations

Radius Bending

Test assembly & inspection

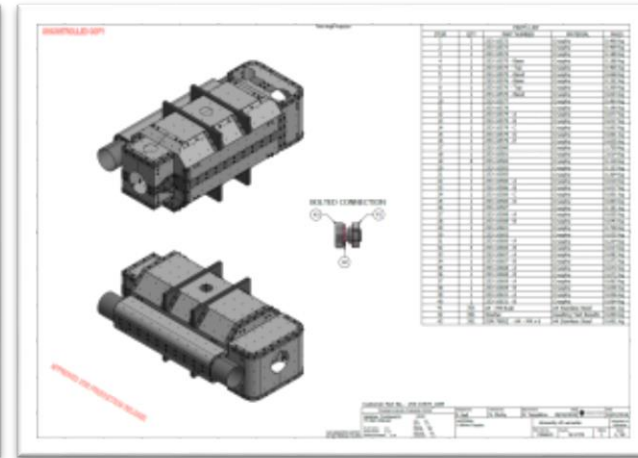
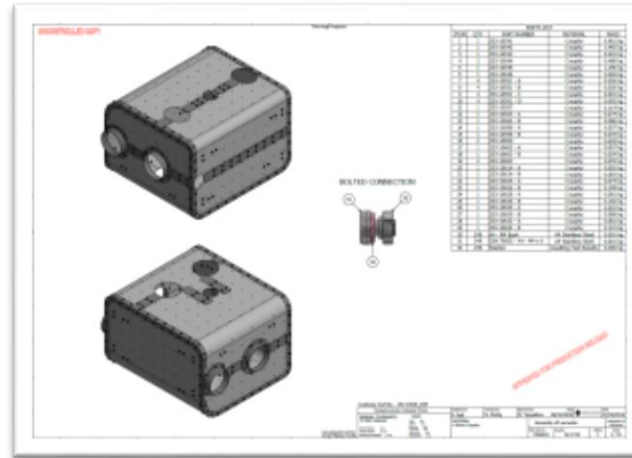
Reforming and shaping as required

Heat Treatment

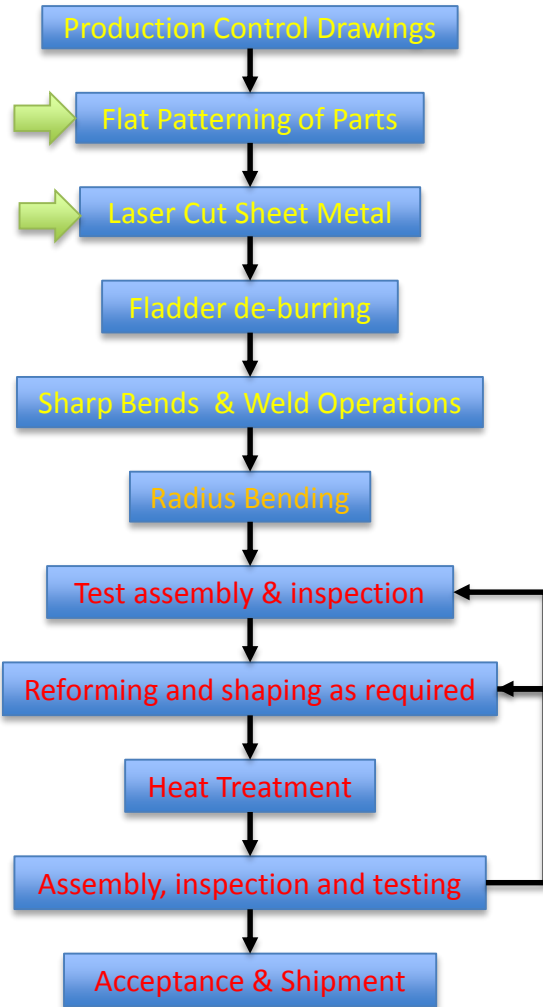
Assembly, inspection and testing

Acceptance & Shipment

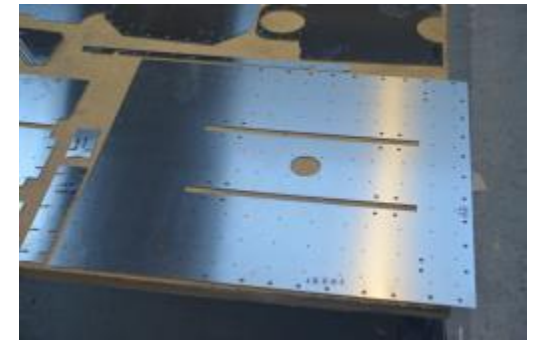
- A full set of production drawings have been completed by MSL's experienced design engineers.
- Drawings were based on the STEP file and functional drawings provided.
- Included information on tolerances, weld locations, fixtures and a fully detailed bill of materials.
- STFC reviewed and approved the final drawings prior to the parts being manufactured



Manufacture by Magnetic Shields LTD



- Following production drawing approval by the STFC, the CAD design engineers developed a flat patterned drawing and loaded all parts to the CNC laser.
- The plots were checked to ensure that the flat patterned drawings were consistent with the approved production drawings.
- Parts were laser cut as per the CNC program.
- All first off parts from the laser were checked against the flat pattern plots.



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Production Control Drawings

The parts were de-burred according to the spec. 'MSLEDG-FL400'

Flat Patterning of Parts

Laser Cut Sheet Metal

Fladder de-burring

Sharp Bends & Weld Operations

Radius Bending

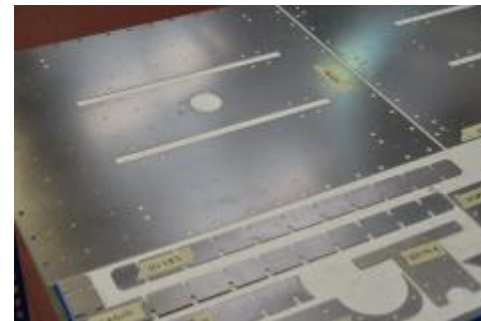
Test assembly & inspection

Reforming and shaping as required

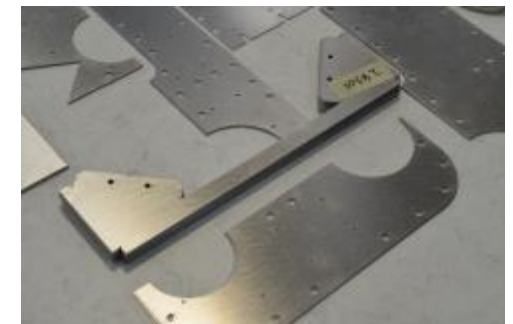
Heat Treatment

Assembly, inspection and testing

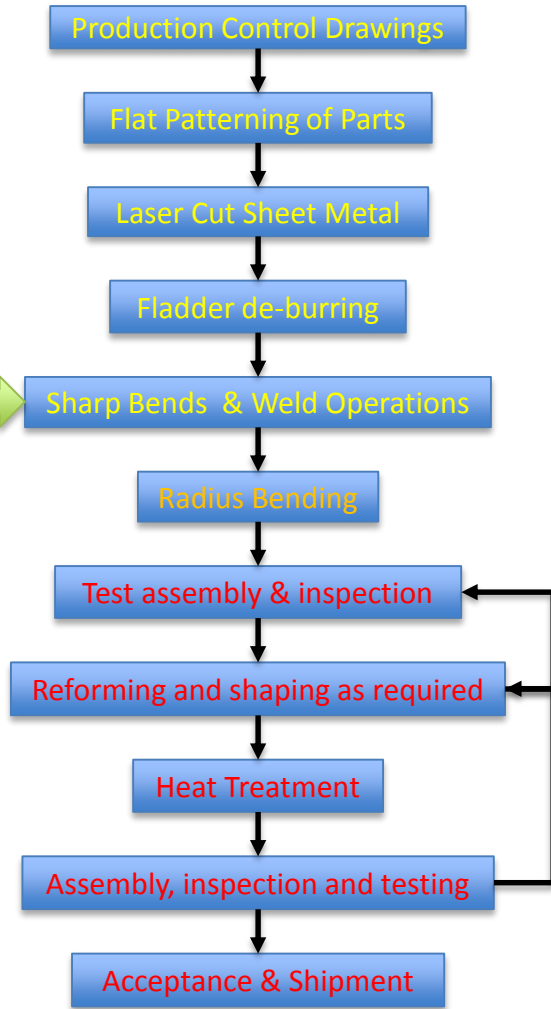
Acceptance & Shipment



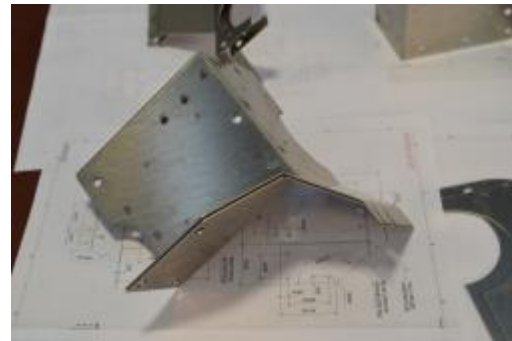
Brush Deburring Machine



Manufacture by Magnetic Shields LTD

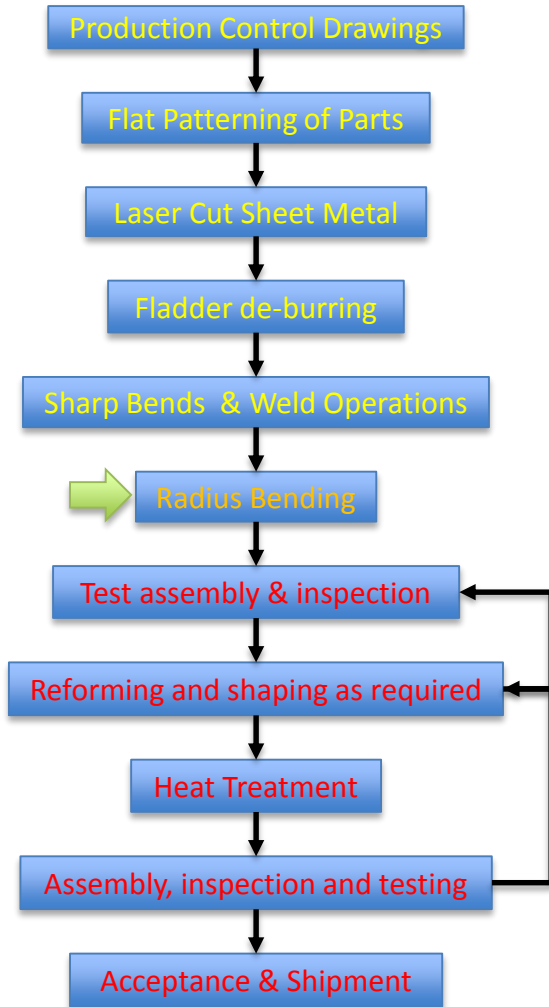


Bending: LVD 3m 110 metric ton CNC Press break with laser bend
Welding: Kemppi micro pulse TIG
Welds to be completed with material from the same batch as the original parent material

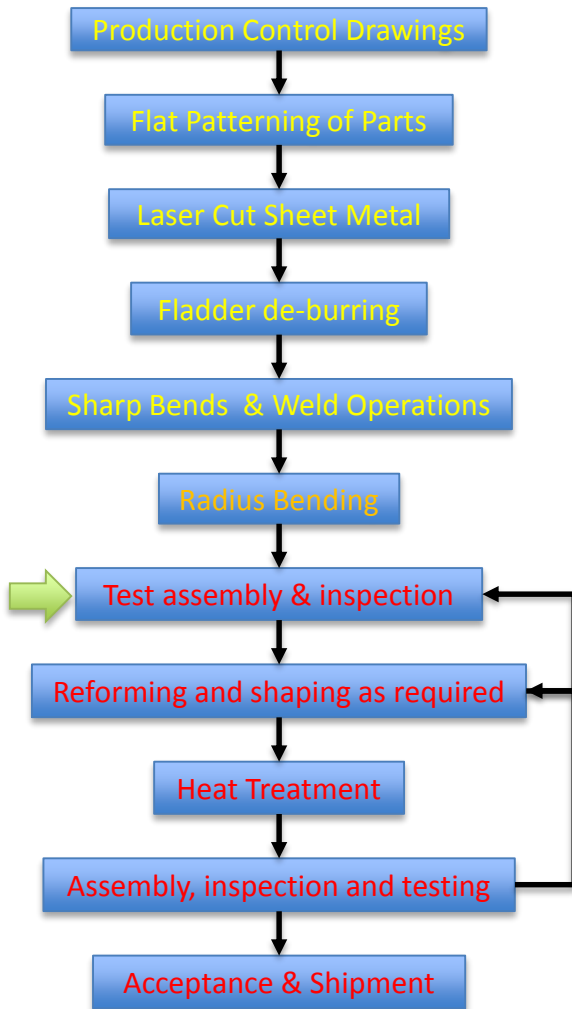


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Morgan Rushworth power and manual rollers

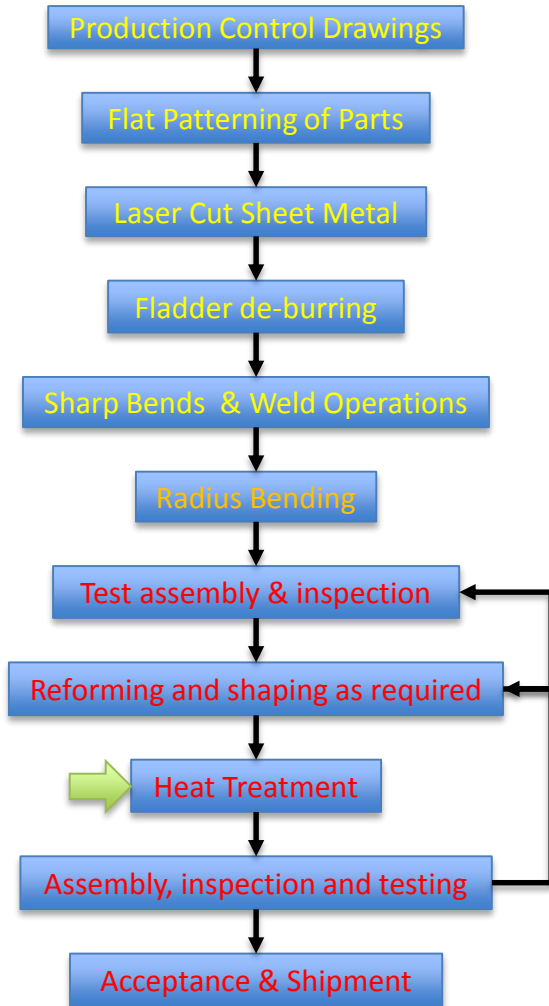


Manufacture by Magnetic Shields LTD



- *STFC CERN Inspection visit 12/11/15*
- Prior to heat treatment, all parts are inspected to check conformance to the agreed production drawing and to identify any required changes prior to heat treatment.
- All parts are cleaned and degreased to remove excess particles and grease prior to the heat treatment process.

Manufacture by Magnetic Shields LTD



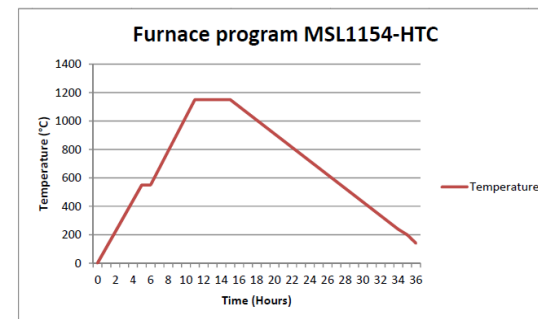
Cryophy material is heat treated in a pure dry hydrogen atmosphere according to the MSL1154-HTC specification:



Furnace program

MSL1154-HTC

Stage	Action	Tolerances
1	Ramp 2°C/min to 550°C	+/- 5°C
2	Dwell for 1 hour min	Exact to min time
3	Ramp 2°C/min to 1150°C	+/- 5°C
4	Dwell for 4 hours min	Exact to min time
5	Ramp 0.8°C/min to 200°C	+/- 5°C
6	Step to ambient	N/A



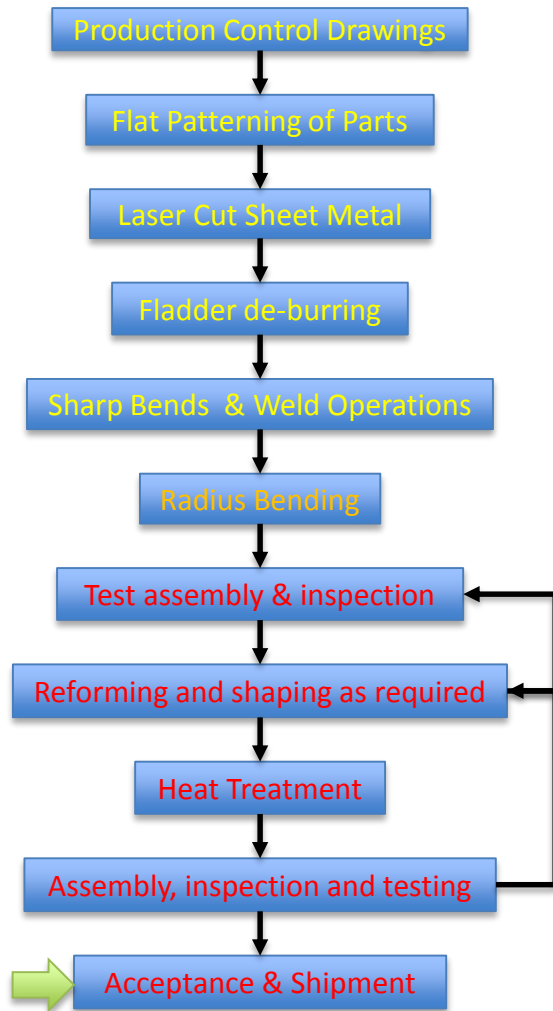
The data enclosed in this document are only given as indicative values and correspond to our standard product. Different specific requirements are subject to discussion and formal approval by Magnetic Shields Limited. For further information or special request, please contact us.

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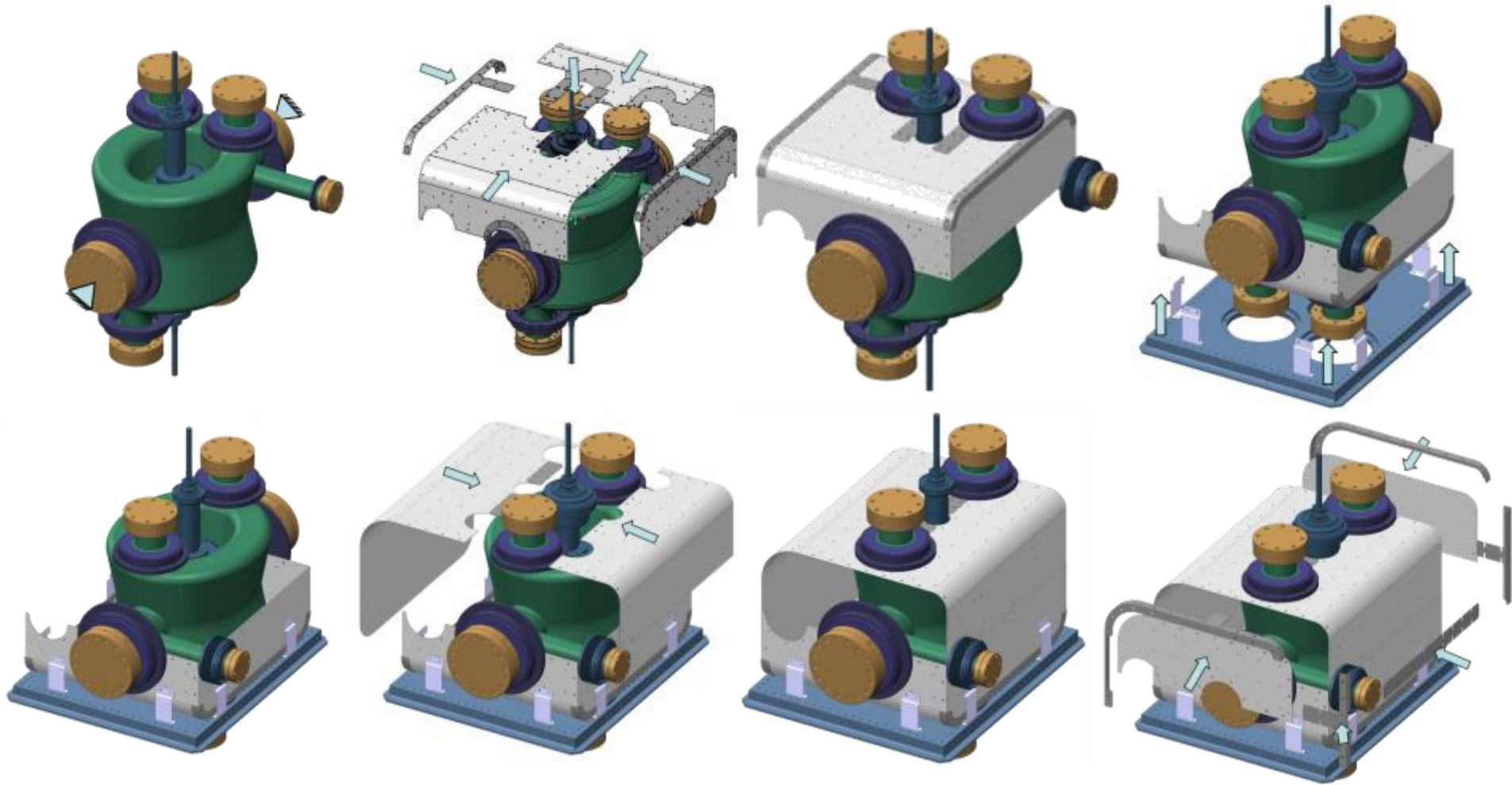
Heat treatment at 1150°C can lead to some slight deformation in parts which can require light adjustment following heat treatment. Any adjustment required is performed by hand and/or with very light soft nylon tools.

Manufacture by Magnetic Shields LTD

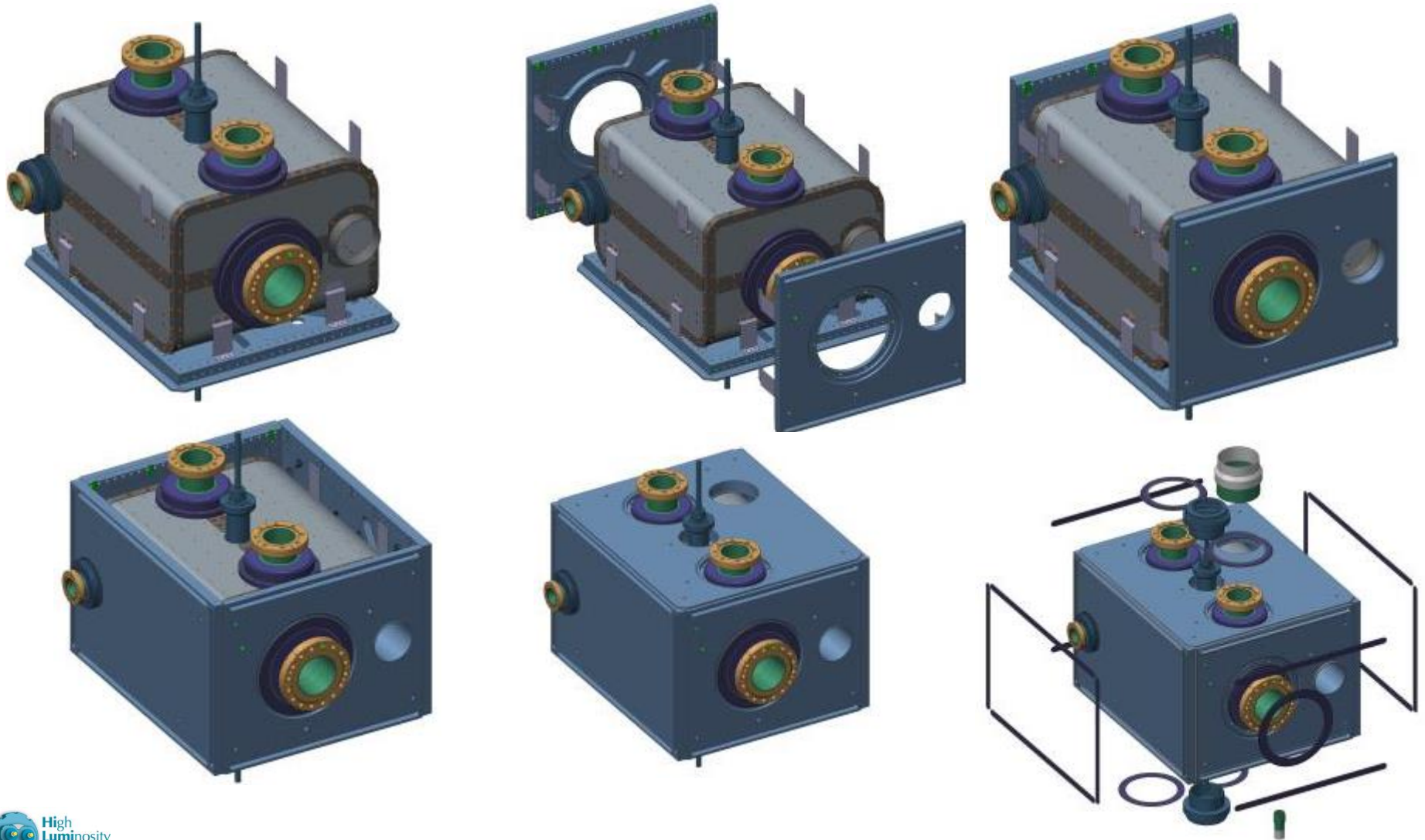


- Full inspection of the parts using a Faro Arm CMM machine.
- Full magnetic testing at room temperature using a Bartington mag 03 probe to verify that the attenuation is within the required parameters at room temperature.
- Detailed CMM and magnetic test report (at room temperature) to be provided as a deliverable with the parts.
- Parts to be cleaned in accordance with BS EN 12300
- All parts to be individually wrapped in anti-static bags. Parts to be loaded in a custom built shipment box. Boxes to include shock sensors to identify any impacts during shipping.

DQW Shield-Vessel Assembly

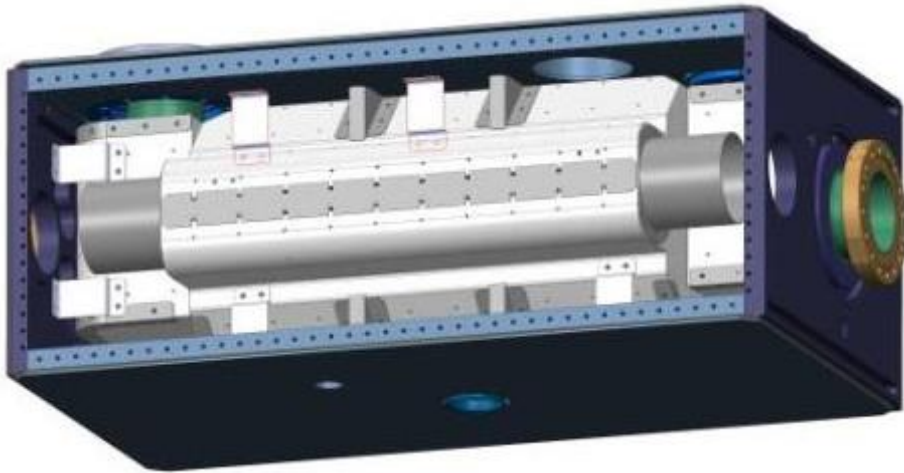


DQW Shield-Vessel Assembly

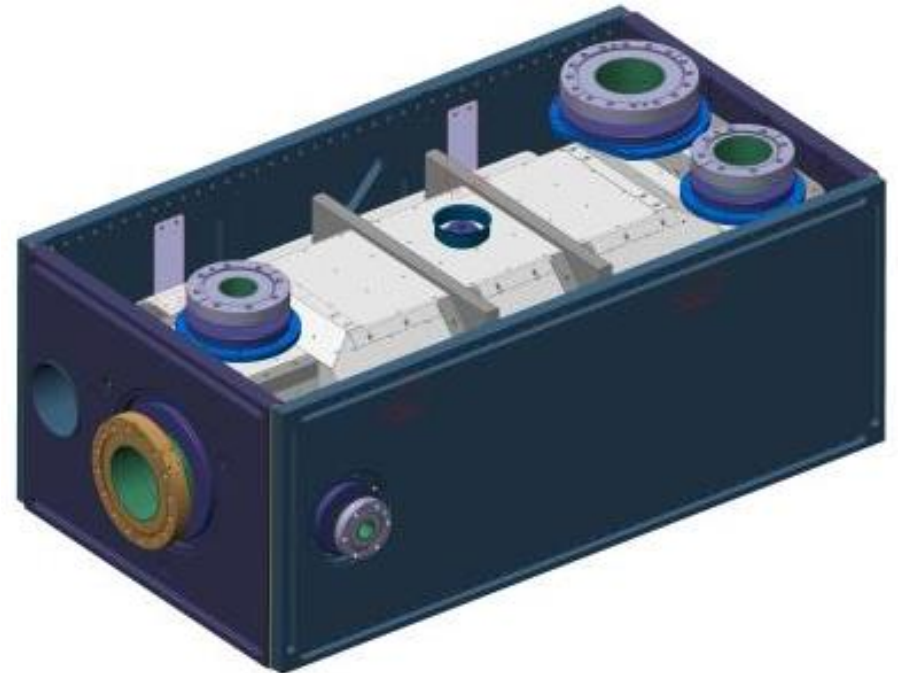


RFD Weld Sequence TBD

- Design has provision for both sequences
- Brackets to be fabricated once welding is decided



Side plates assembled last



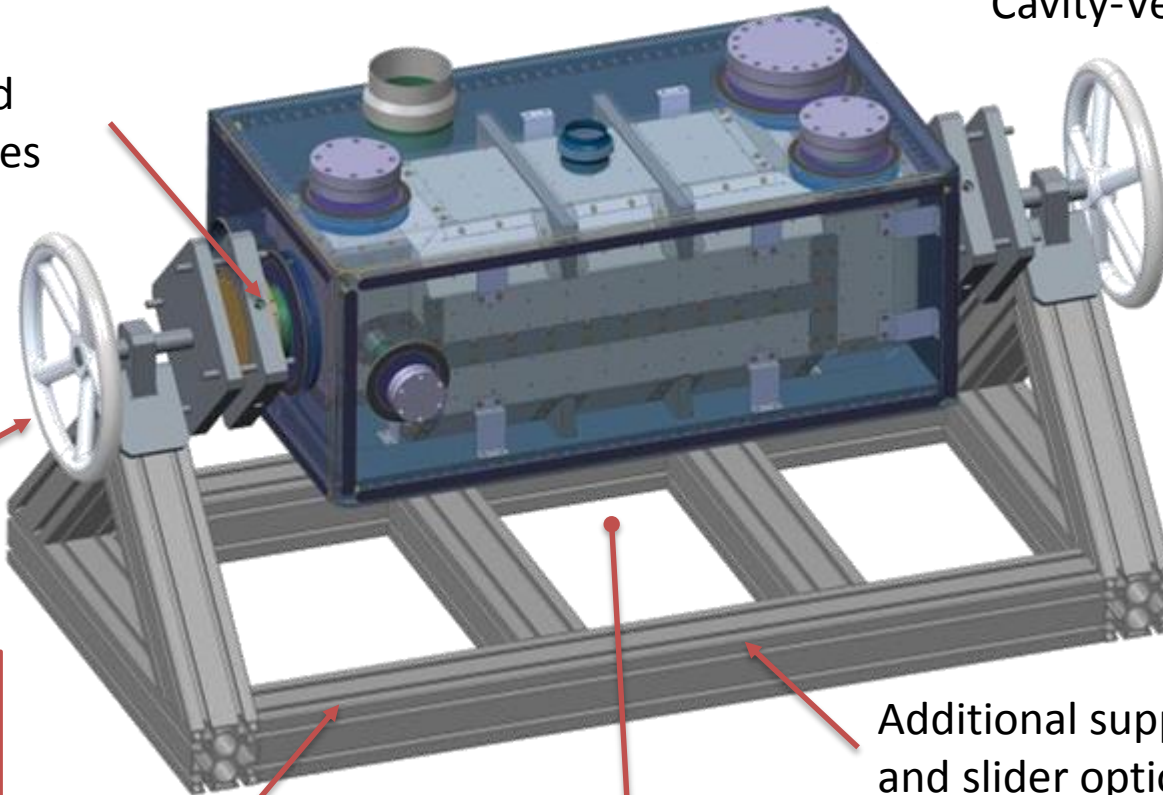
Top plate assembled last

Assembly Tooling Concept

Lock in 4 orientations

Adaptable for both
Cavity-Vessels

Fastens to 4 tapped
holes in blank flanges

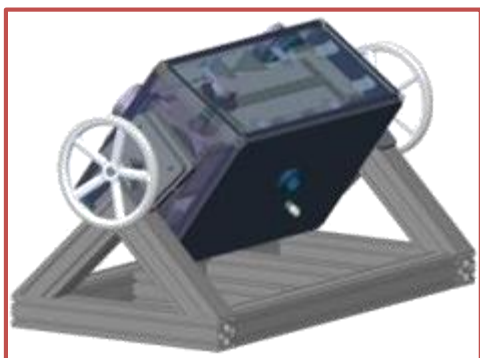


360° manual rotation

Versatile aluminium
extrusion

Additional support, tooling
and slider options

Maximum access -
ease of assembly



General Assembly Points

Cryophy is sensitive to the Villari effect meaning that the magnetic properties can be severely impacted by work post heat treatment, especially if the material is taken beyond the plastic deformation point.

Handling and Cleanliness after Final Heat Treatment:

- Magnetically annealed components should be **handled with care**.
- **No further work that involves jarring or vibration may be carried out**, as this may degrade the permeability characteristics achieved during the final heat treatment process.
- Protective gloves must be worn all times during assembly process in order to eliminate contamination from fingerprints.
- Cleanliness must be upheld in accordance with BS EN 12300

Material Testing Plan

Objective: To understand shielding behaviour during assembly and operation and to obtain accurate data for simulations.

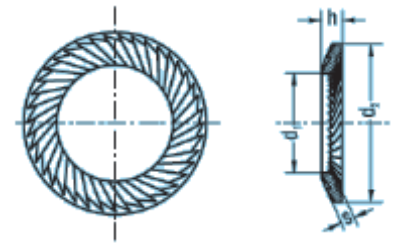
Tests:

- Cryogenic Fastener Investigation¹
- Permeability - Ring Measurements²
- Tensile Testing²
- Villari effect – Epstein Frame²
- Permeameter Tests³
- Needle Tests³

Cryogenic Fastener Investigation

Objective: To determine optimal torque and washer type for Cryophy connections:

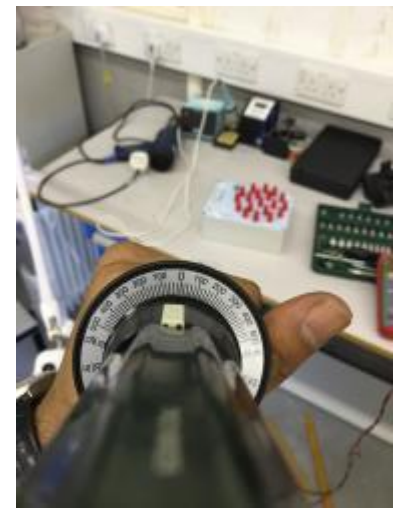
- Screw only (control)
- Cryophy Flat Washer
- A4 SS Flat Washer
- A4 SS External Tooth Washer
- A4 SS Conical Washer (Belleville)
- *A2 & CuSn8 Serrated Safety Washer*



Cryogenic Fastener Investigation

Test:

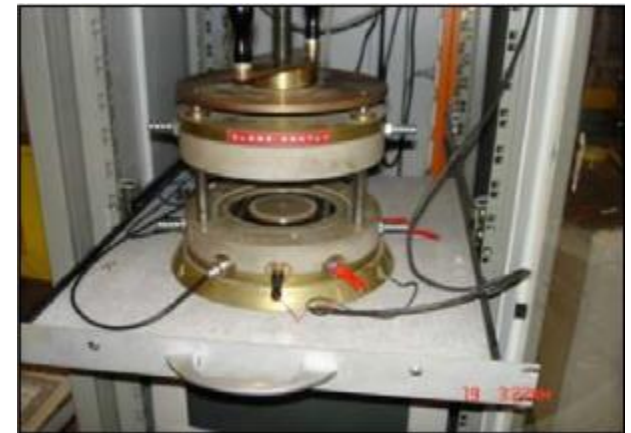
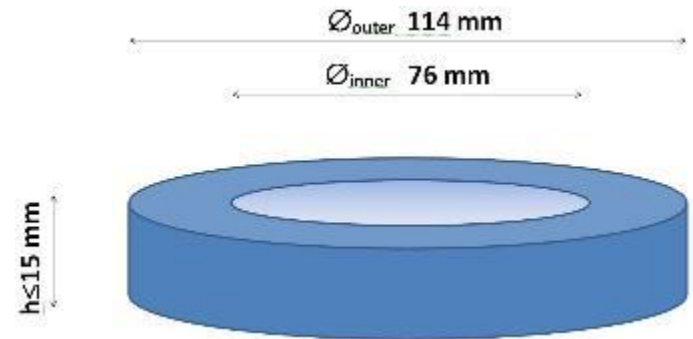
- Fast and slow thermal cycling of bolted Cryophy panels from 300-77K using LNi
- Screw Torque set using Digital Torque Wrench and measured using Precision Torque Screwdriver - reduction measured at 10 & 20 cycle intervals.



Ninad Pattalwar, STFC Daresbury Laboratory

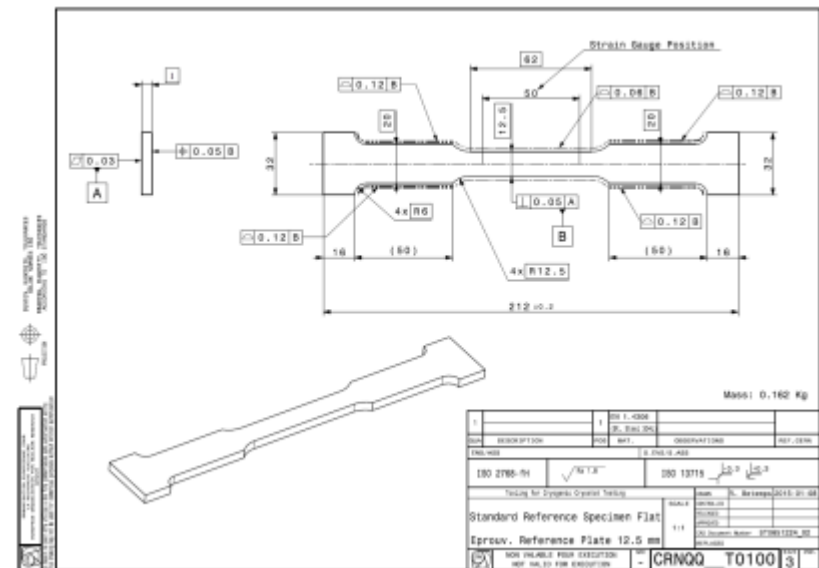
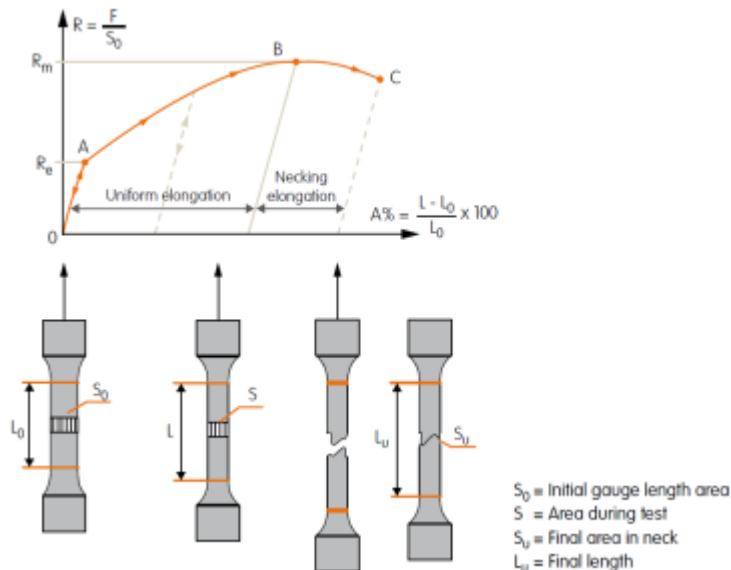
Permeability – Ring measurement

- In-plane permeability
- B-H curve
- Ring samples stacked up
- Elimination of distortions due to continuous magnetic path -> high accuracy
- Feasibility of measurements at 4 K to be determined



Tensile Tests

- To determine the mechanical properties of Cryophy at room Temperature
- Obtain Stress-Strain curves to define R_e & R_m for Strain-Permeability Tests

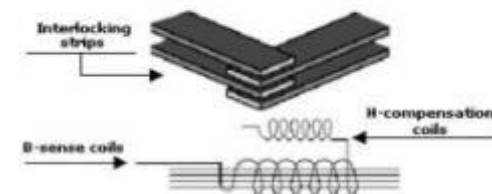
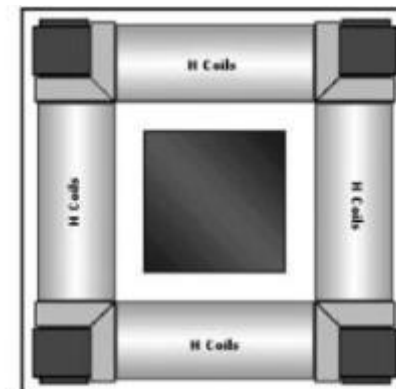


Permeability – Epstein Frame

- Standardised (IEC 404-2)
- 8 sheets arranged in a square
- Permeability in one direction
- Influence of strain on permeability
- 4 different strain states:
 - $\varepsilon=0$
 - 3 states between R_e and R_m

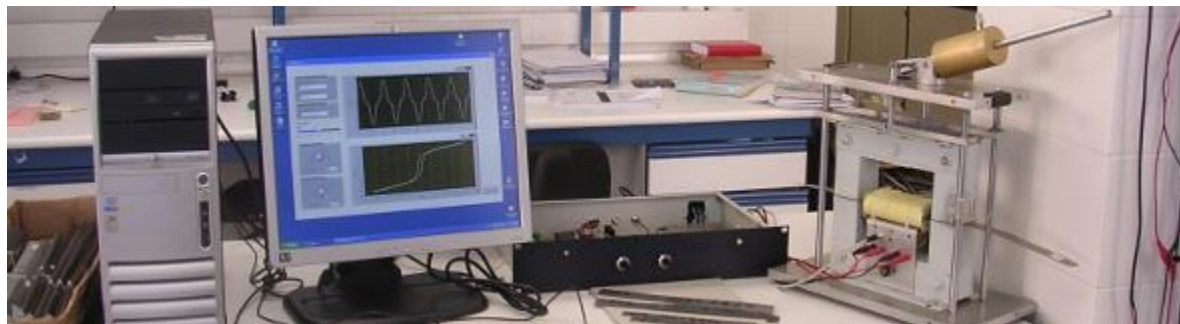


Epstein Frame



Permeameter Tests

- AC closed magnetic flux permeameter at Room Temperature
- Designed for the measurement of amplitude permeability, hysteresis loop and magnetic losses in W/kg
- Frequencies: 1 – 400 Hz .
Magnetic field: $\approx 30\text{A/m}$ – 10000 A/m .
- MuMetal & Cryophy Strips: Length $\geq 17\text{cm}$,
Width $\leq 5\text{cm}$, Thickness $\leq 0.25\text{cm}$



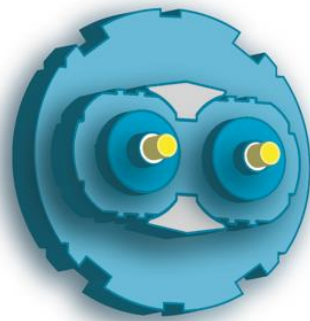
Stephanie Langeslag, CERN/SAI Zaragoza

Needle Tests

- MuMetal & Cryophy Permeability tests at 4 K
- Unstressed & Pre-stressed samples
- Specimens produced from 200 x 300 x 1mm heat treated sheet
- CERN to fabricate samples by spark erosion as not to effect the material magnetic properties
- Needle Samples: Length 15 x 1 x <1 mm
- Temperature Range: 1.9 K – 350 K
- AC & DC Measurements
- Magnetic Field Range: 0 to ± 9 T, ± 14 T



ACMS (Extraction magnetometer)



High Luminosity LHC



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Extra material

