

Design Considerations for SE

Ali Mortazavi

ISSE 2026

20/01/2026

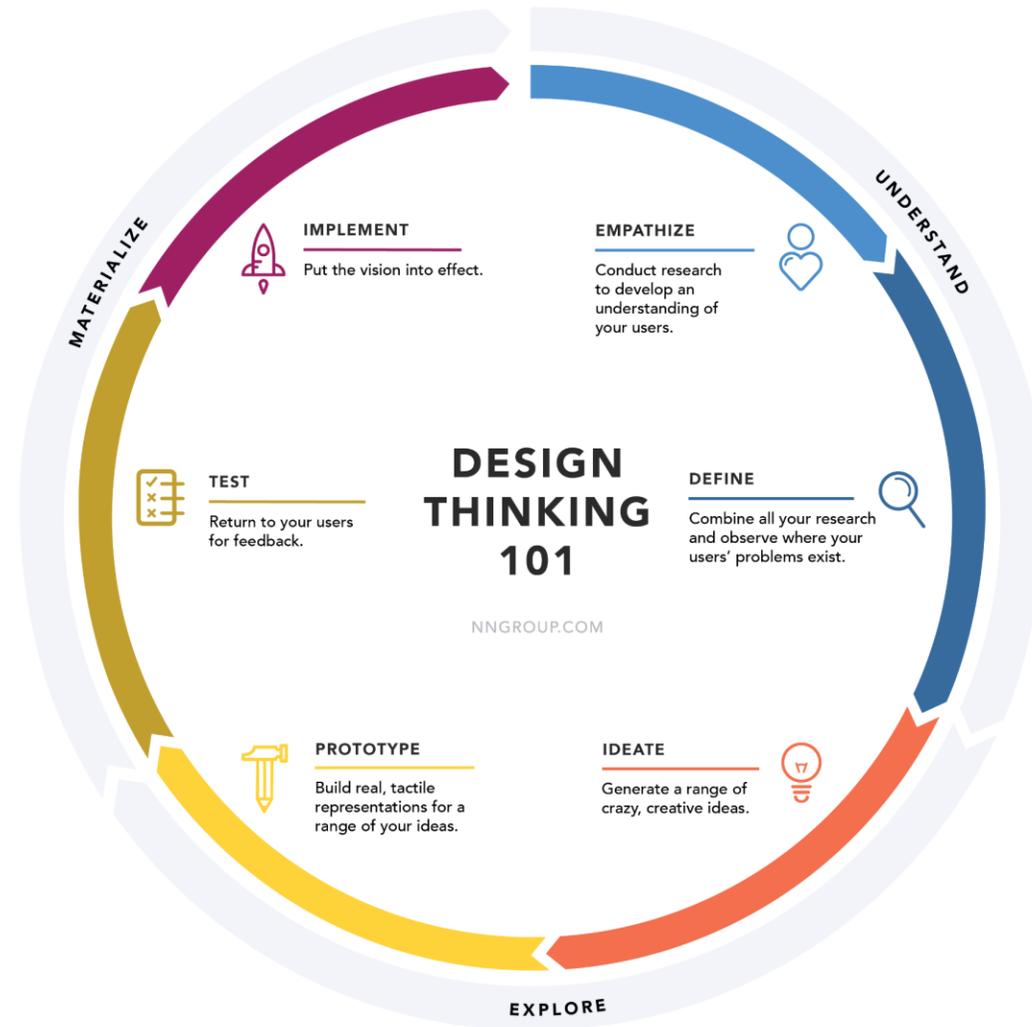
About Me

- Mechanical engineer
- 8 years in ISIS
- 8 years in automotive / measurement equipment
- Generalist mechanical engineer in a very specific job!

- Each slide could get a full presentation!

Design Process

- Specification / scope
- Design + reviews
 - Concept
 - Preliminary
 - Final
- Drawing
- Procurement
- Manufacture
- Assembly
- Testing / commissioning



Documentation!

- Specification
- Technical reports
 - Design
 - Test data
 - Closeout
- Drawings
 - Inspection reports
- Safety
 - Risk assessment
 - Stress analysis / FEA
 - Material certificates
- Project management
 - Budget
 - Quotes / invoices
 - Gantt chart

ISIS
ISP 966 Design Report

Project number	966
Project title	New Goniometer
Date created	12/05/2020
Project Engineer(s)	Ali Mortazavi (AM)
Project Sponsor(s)	Stephen Hull (SH)
Customers(s)	Silvia Capelli (SC), Matthias Gutmann (MG)
Project Size	Small (<£100k)
Beamline/area	SXD
Steering group	Neutron and muon instruments - Sample environment
Drawing number sequence	SI-4103-087
Cost Centre	STJA 01310 Task 01.02
Asset number	Add asset number (optional)
Project phase	Handover and close out

ISP 0966 - New CCR Mini-Goniometer For SXD

Private group ☆ Not following 9 members

Home + New Page details Preview Analytics Published 26/04/2024 Share Edit

Project Documentation

Technical Documentation

Teams

Meetings

966 Kanban Board

Site Admin

Recycle bin

Edit

Project documents See all

Technical documents See all

Customer

Sponsor

Project Manager

Meetings

View all meetings

Specification / Scoping

- Project Constraints
 - Deadlines
 - Budget
 - Milestones & Deliverables
- Technical Constraints
 - Science
 - Sample
 - Pressure
 - Temperature
 - Magnetic field
 - Chemical compatibility
 - Sustainability
- Physical Constraints
 - Interfacing instrument / equipment
 - Working envelope / restrictions
 - Beam / detectors
 - Lifting
 - Storage

General

- Stakeholders
- Scheduled dates
- Cost centre
- Available budget
- Quantity
- Similar equipment for comparison

Sample & Environment

- Instrument(s)
- Interfacing equipment (cryostats, furnaces, gas panels, etc)
- Sample (solid/liquid/gas, composition, reactivity, susceptibility to become radioactive, etc)
- External environment (vacuum, ambient air, etc)
- Internal environment (vacuum/solid/liquid/gas, inert/oxidising/reducing/toxic/flammable)
- Temperature range (minimum required, and desirable)
- Pressure range (minimum required, and desirable)
- Experiment duration
- Known hazards (CoSHH, datasheets, etc)

Design

- Shape (stick, flat cell, cylindrical cell, etc)
- Known size requirements (sample size, etc)
- Sealing (indium, o-ring, metal (copper, gold, platinum), etc)
- Orientation in beam
- Detector angles
- Preferable construction materials (including metric, e.g. cross section)
- Interfacing features (threads, location pins, etc)
- Magnetic requirements
- Integrated lifting (eyes, welded lugs, etc)
- Integrated heating (cartridge heaters, Julabo heat exchangers, etc)
- Integrated cooling (CCR, Peltier, Julabo heat exchangers, etc)
- Integrated sensing (Pt100, Cernox, thermocouple, etc)
- PRV requirements (integrated, gas panel, etc)
- Neutron shielding requirements

Packaging & Handling

- Space restrictions (bore diameter etc)
- Storage requirements (trolleys, stands, etc)
- Lifting provision (lifting frames, etc)

Interfaces

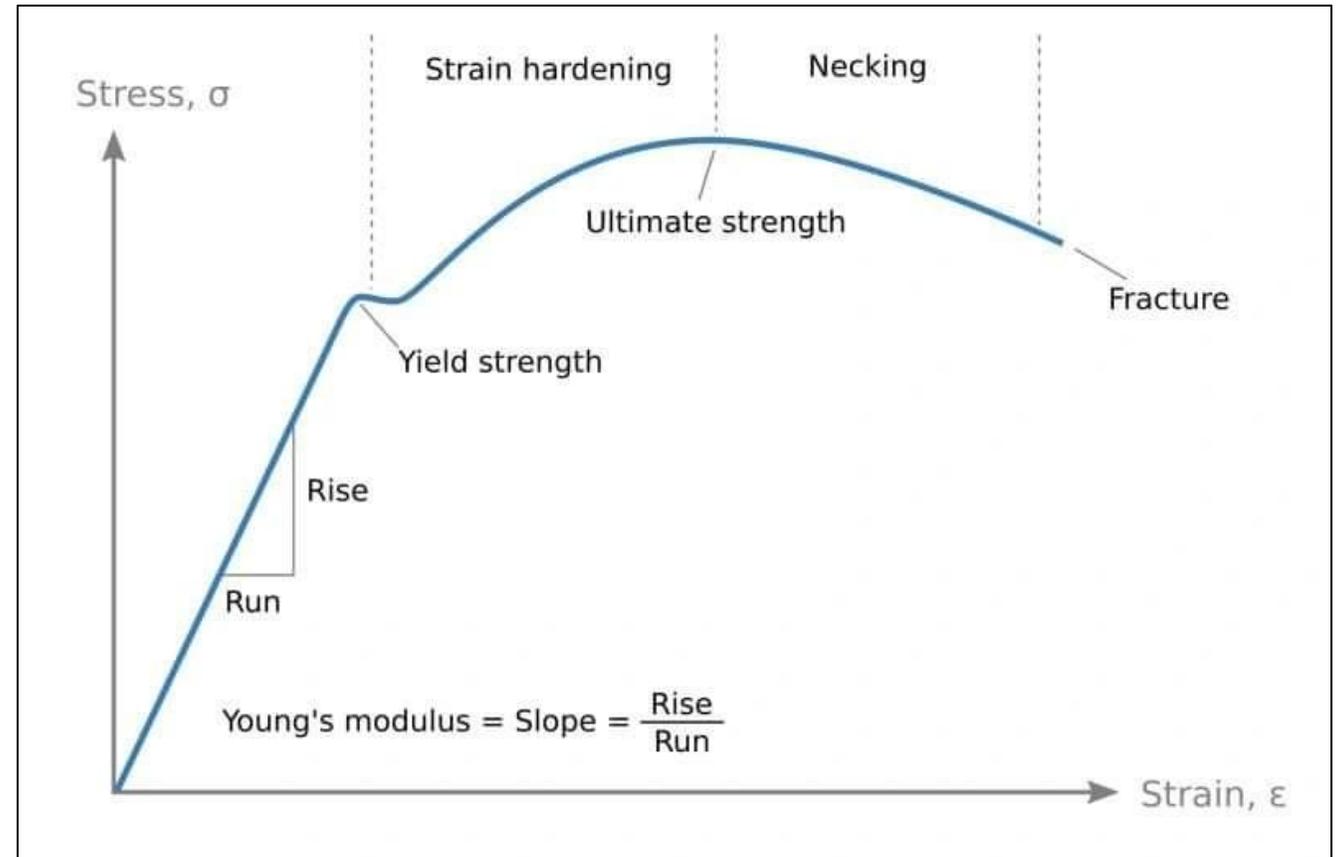
- Gas / vacuum fittings
- Electrical fittings
- Valves

Material Properties

- Strength (UTS & yield / proof strength)
- Stiffness (elastic / Young's modulus)
- Ductility
- Toughness
- Malleability
- Thermal expansion
- Thermal conductivity
- Density
- Cost / Availability
- Background

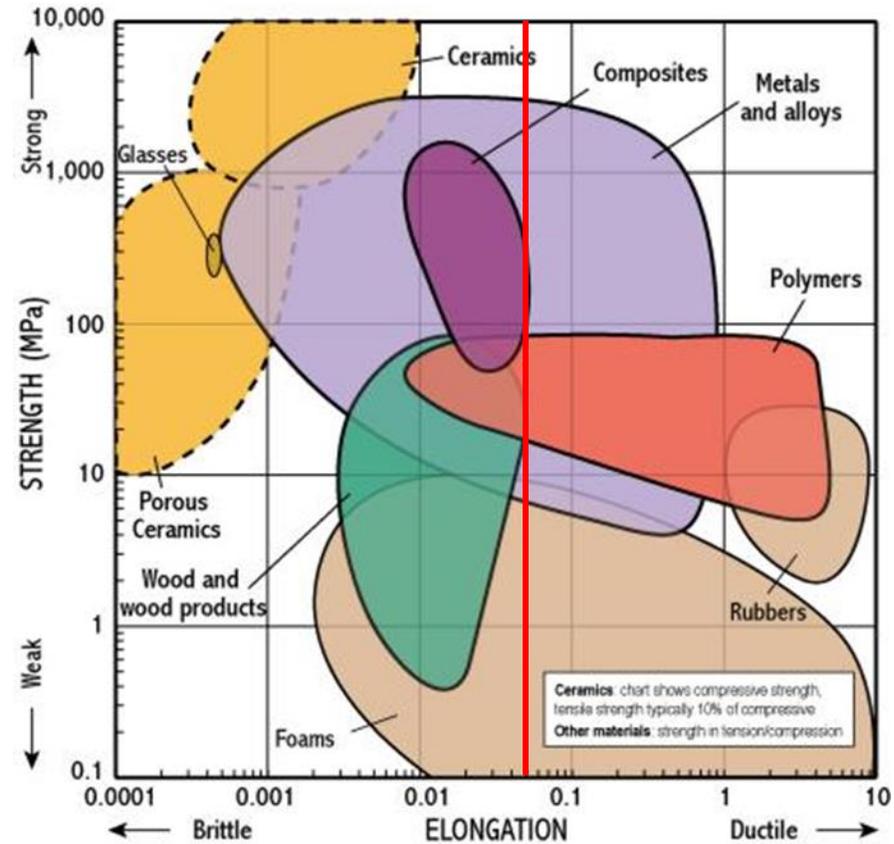
Material Properties

- Ultimate Tensile Strength, MPa
- Yield / proof strength, MPa
- Young's modulus, GPa
- Ductility, % elongation
- Toughness, Nm/m³ or J/ m³

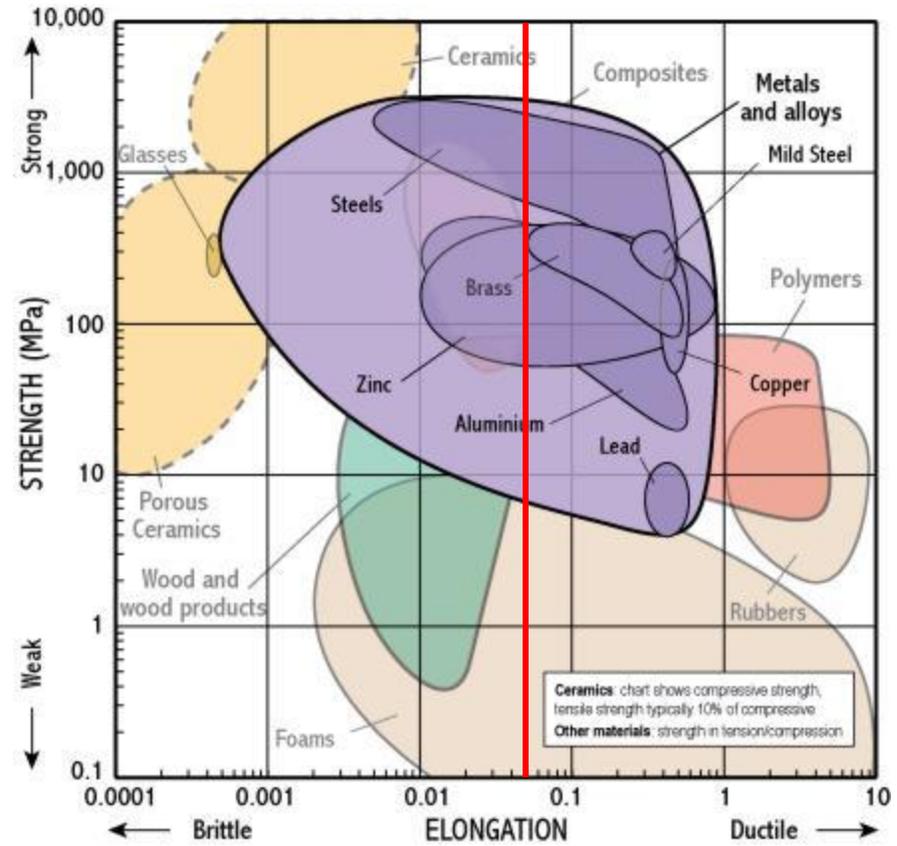
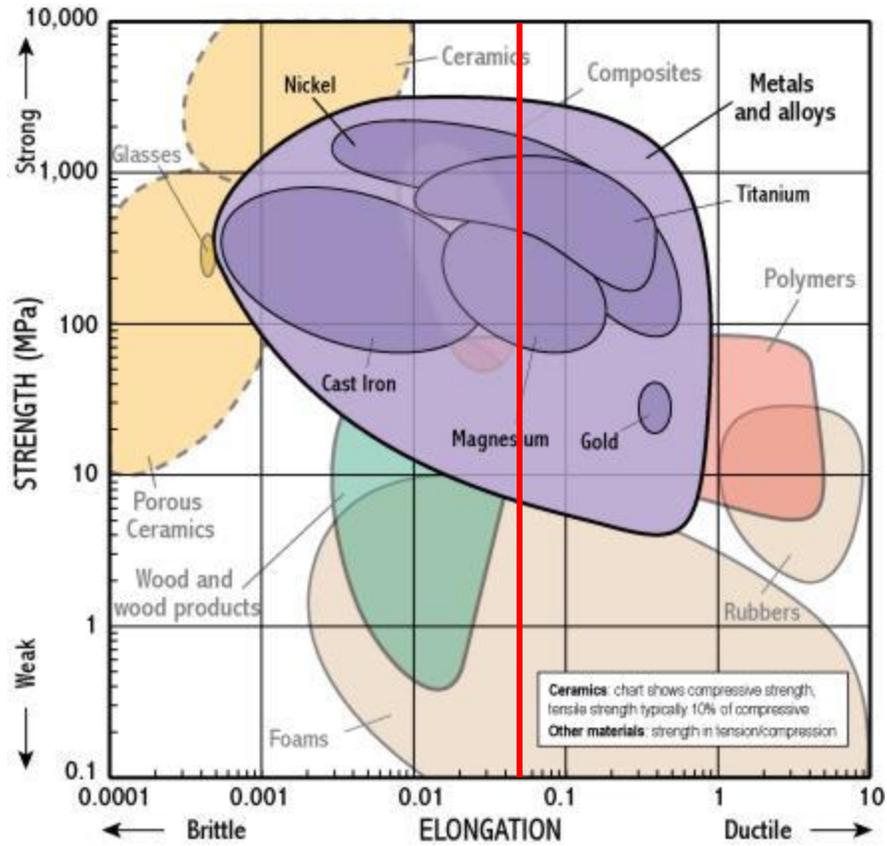


Material Properties - Ductility

- Brittle materials
 - <5% elongation = brittle
 - Also 10% can be brittle
- Pressure windows
 - Safety factor 4 minimum
 - Safety factor 7 recommended

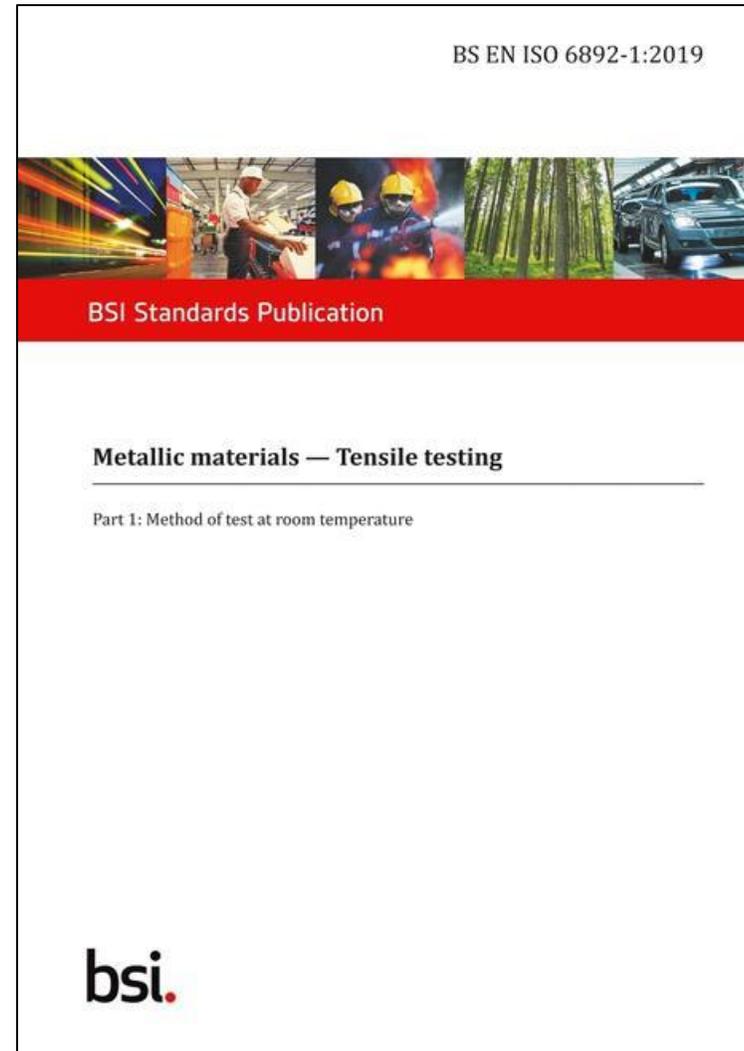


Material Properties



Caveat 1 – Tensile Test Process

- Sample variation
- Sample geometry
- Strain rate
- Standardisation

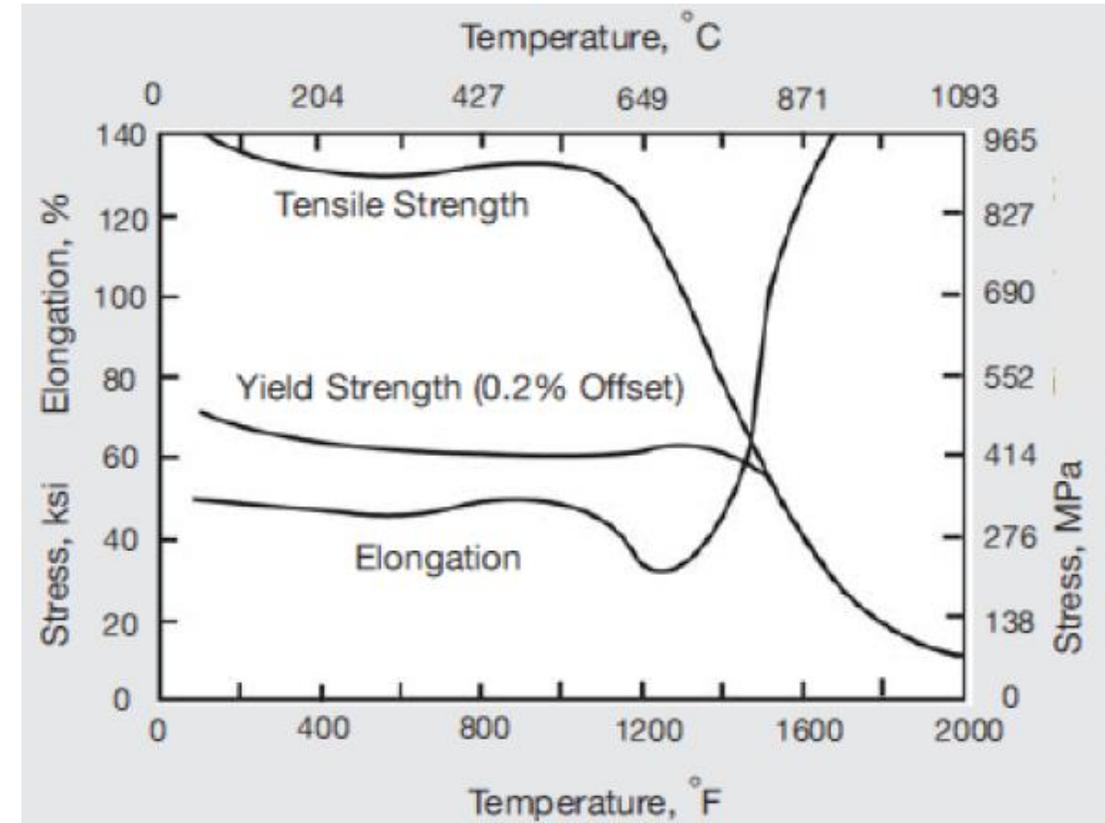
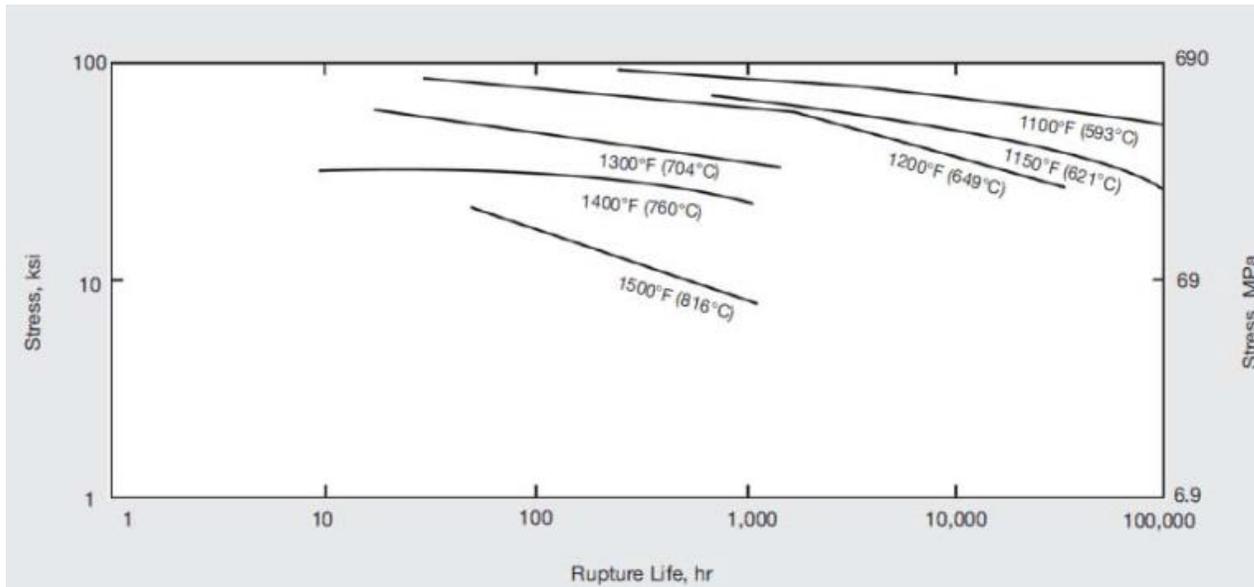


Caveat 2 – Directionality

- Isotropic materials
 - Properties (mostly) same in all directions
 - Most metals, depending on processing
- Anisotropic materials – tensile vs compressive
 - Stronger in tension; CF/GF composite materials, wood, ...
 - Stronger in compression; brittle materials, ceramics, fused quartz, sapphire, ...
- Anisotropic materials – directional (X,Y,Z)
 - CF/GF composite materials, wood – heavily dependant on fibre direction
 - Rolled metal sheets stronger in rolled direction
 - 3D printed parts weaker in Z (print direction)

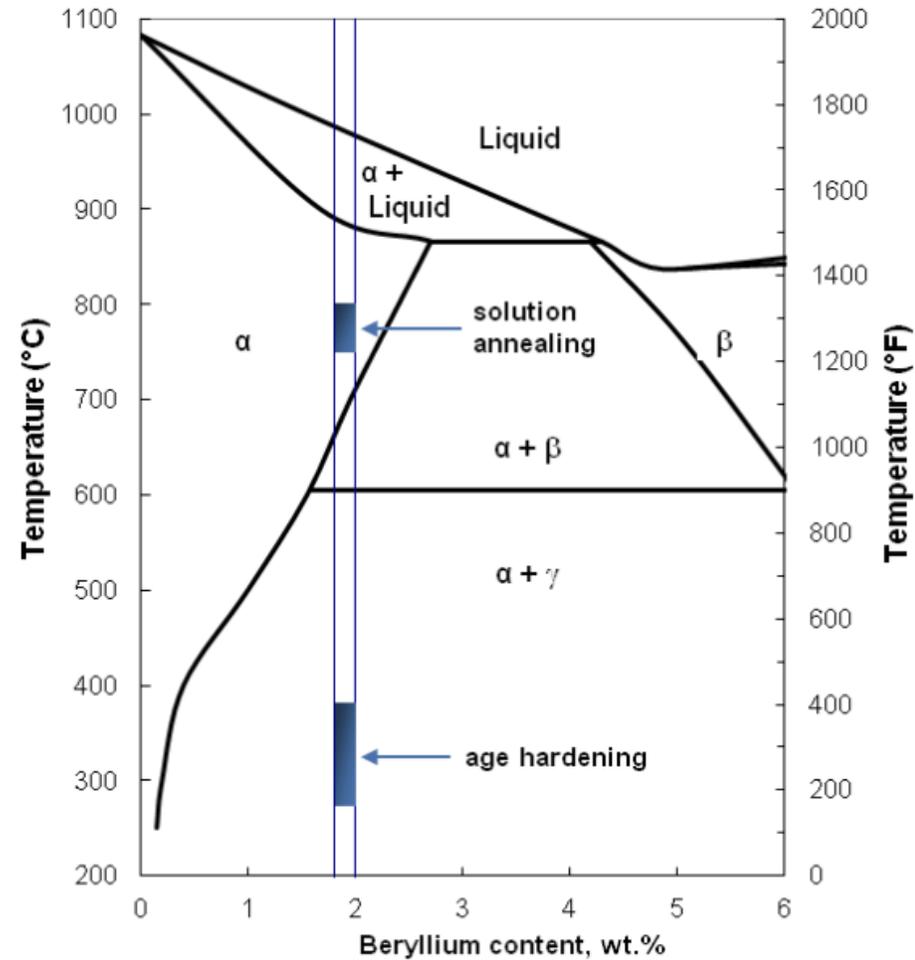
Caveat 3 – Temperature Dependence

- Hotter – weaker
- Charts: Inconel 625
- Reusability - creep! 649°C:
 - 827 MPa, instantaneous
 - 600 MPa, 10 hours
- Colder – stronger



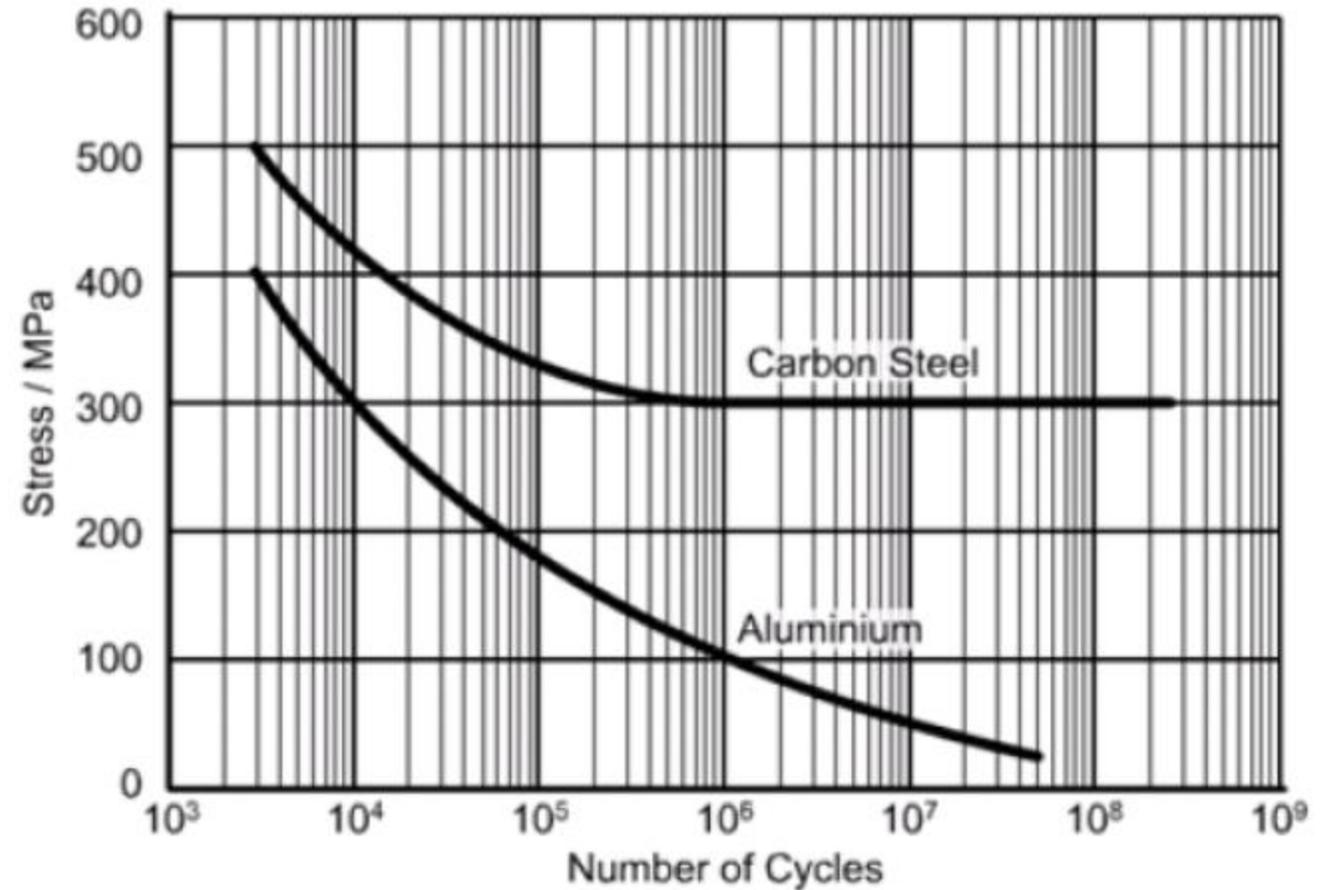
Caveat 4 – Watch your temper!

- Heat treatment matters
- Use annealed strength if unsure
- Welding = annealing!
- Hot experiments = annealing!



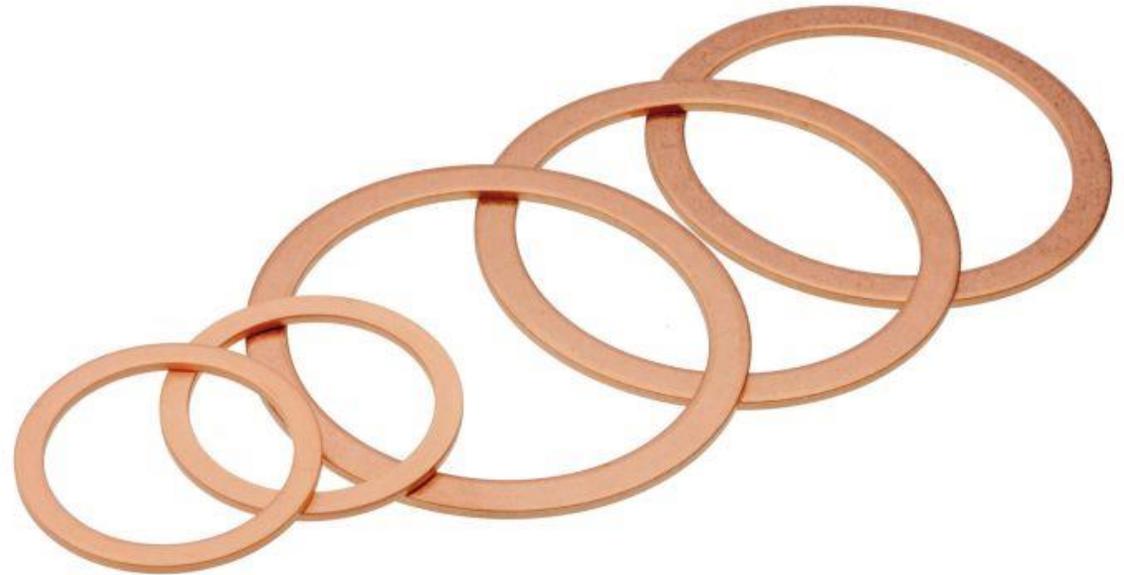
Caveat 5 – Fatigue

- Cyclic load
- Premature failure
- Load dependant
- Often ignored, hidden by big S.F.
- But... found recently on WISH...



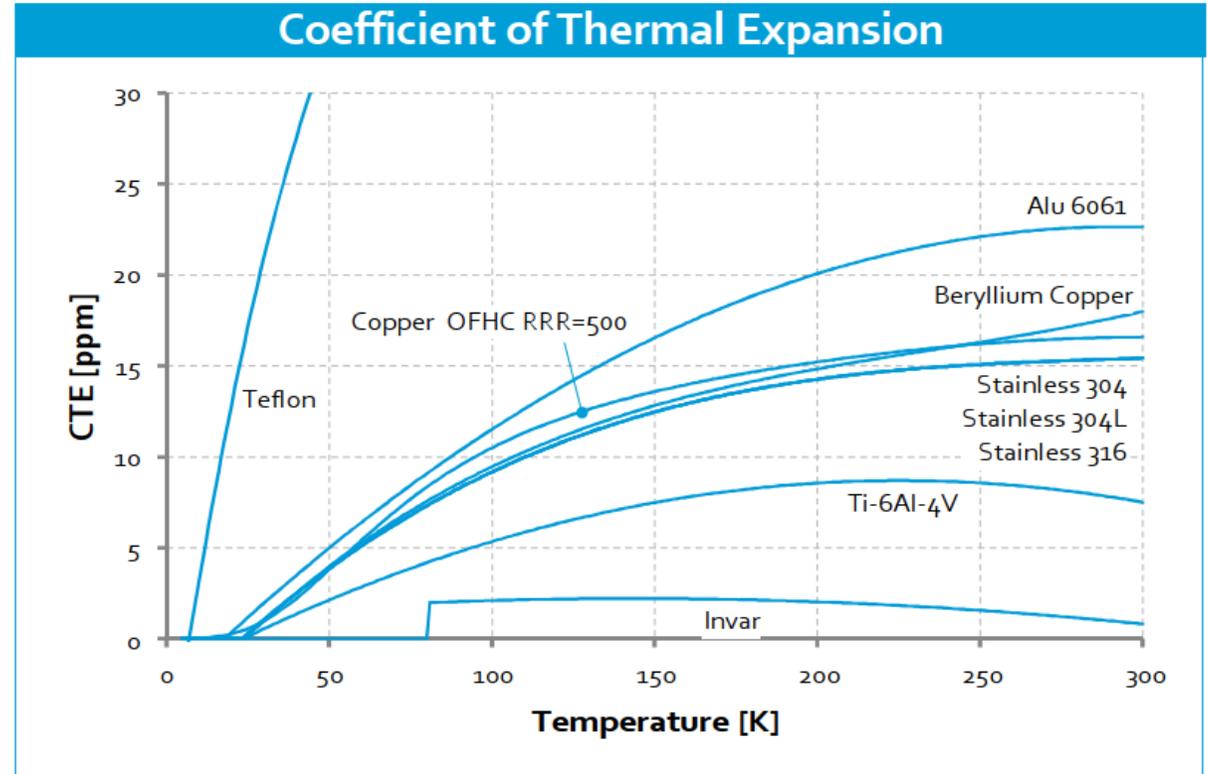
Material Properties

- ~~Strength (UTS & yield / proof strength)~~
- ~~Stiffness (elastic / Young's modulus)~~
- ~~Ductility~~
- ~~Toughness~~
- **Malleability**
- Thermal expansion
- Thermal conductivity
- Density
- Cost / Availability
- Background



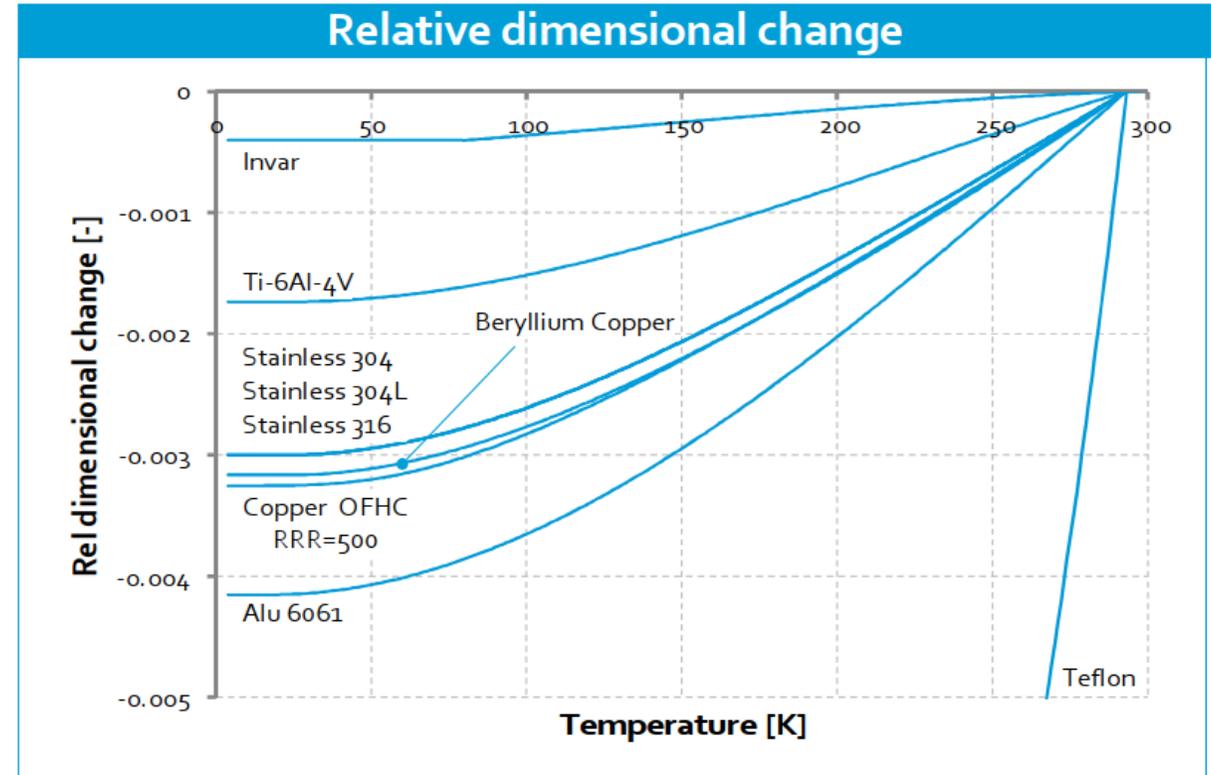
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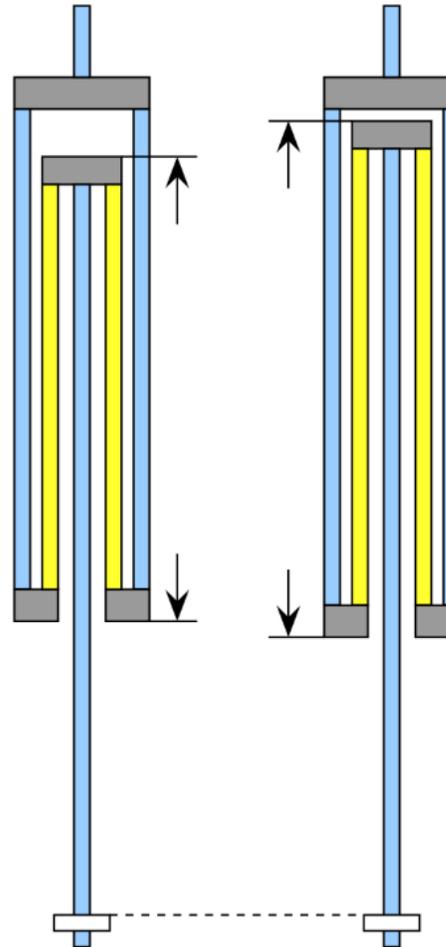
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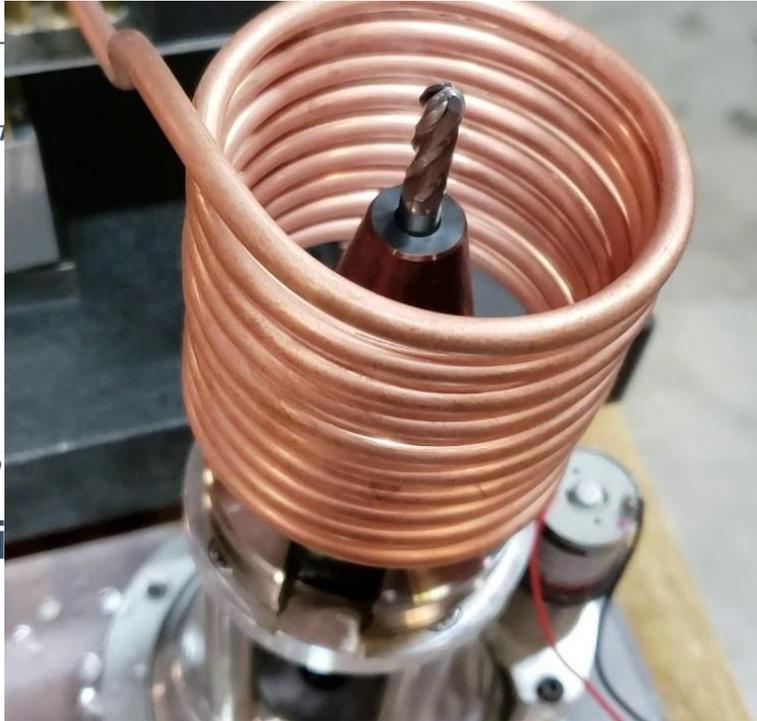
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- Grid-iron pendulum
- Dissimilar expansions balanced

Material Properties

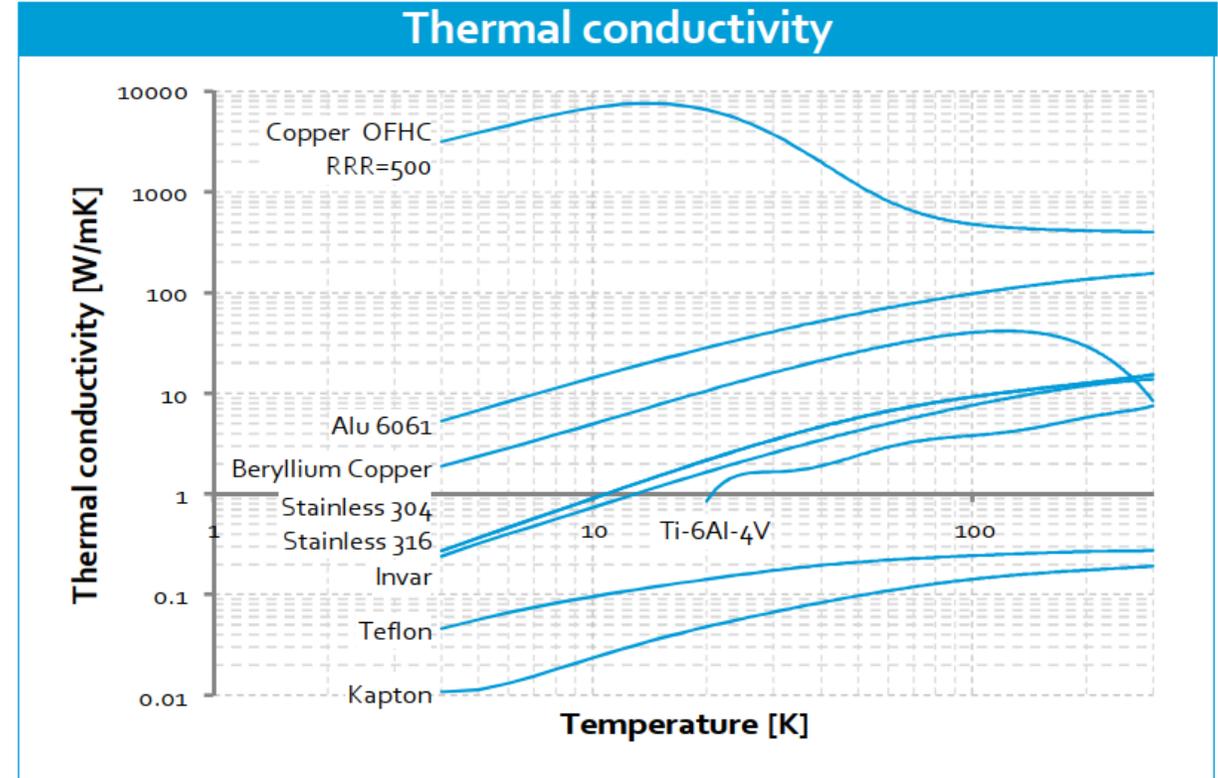
- Strength (UTS & yield)
- Stiffness (elastic modulus)
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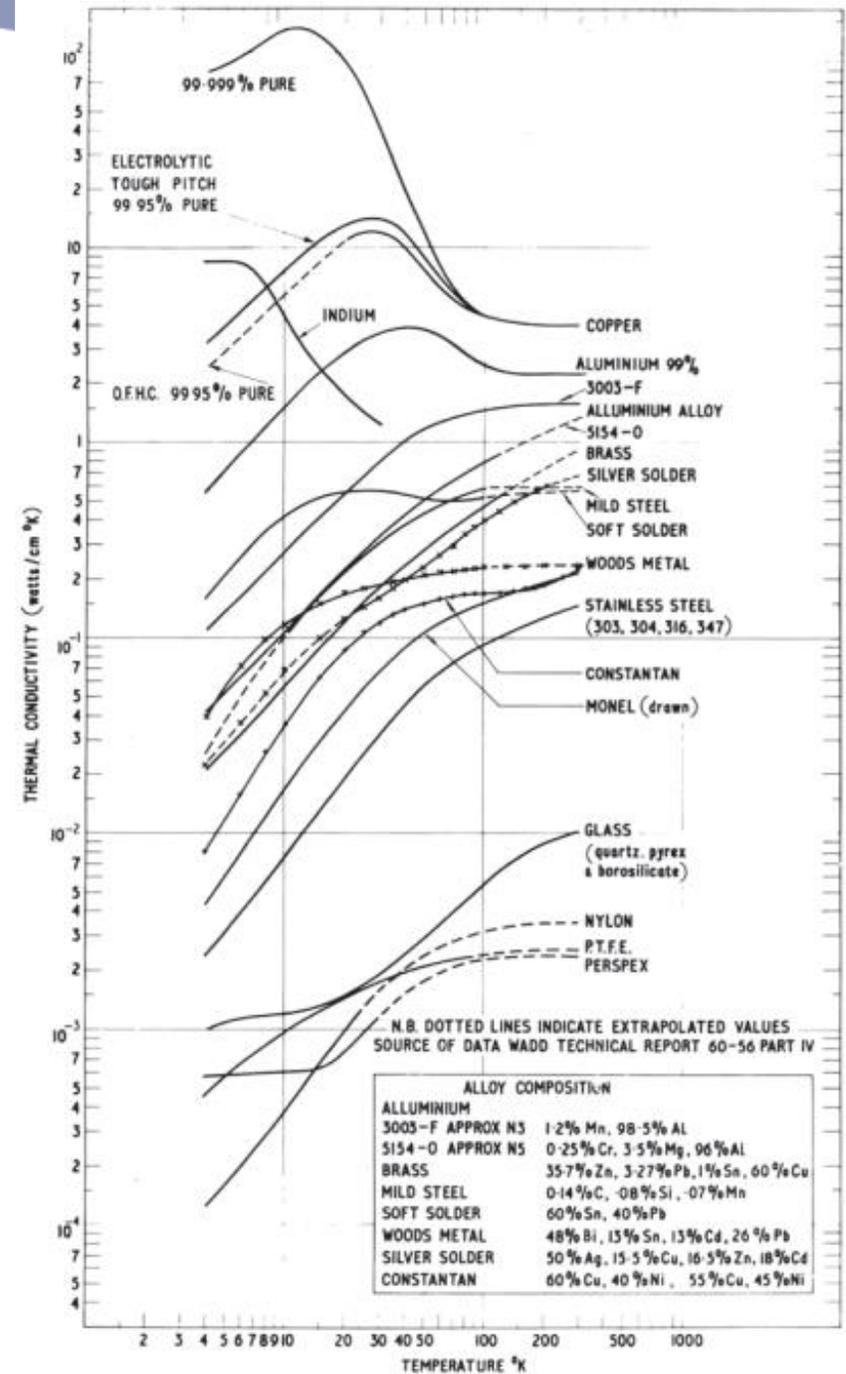
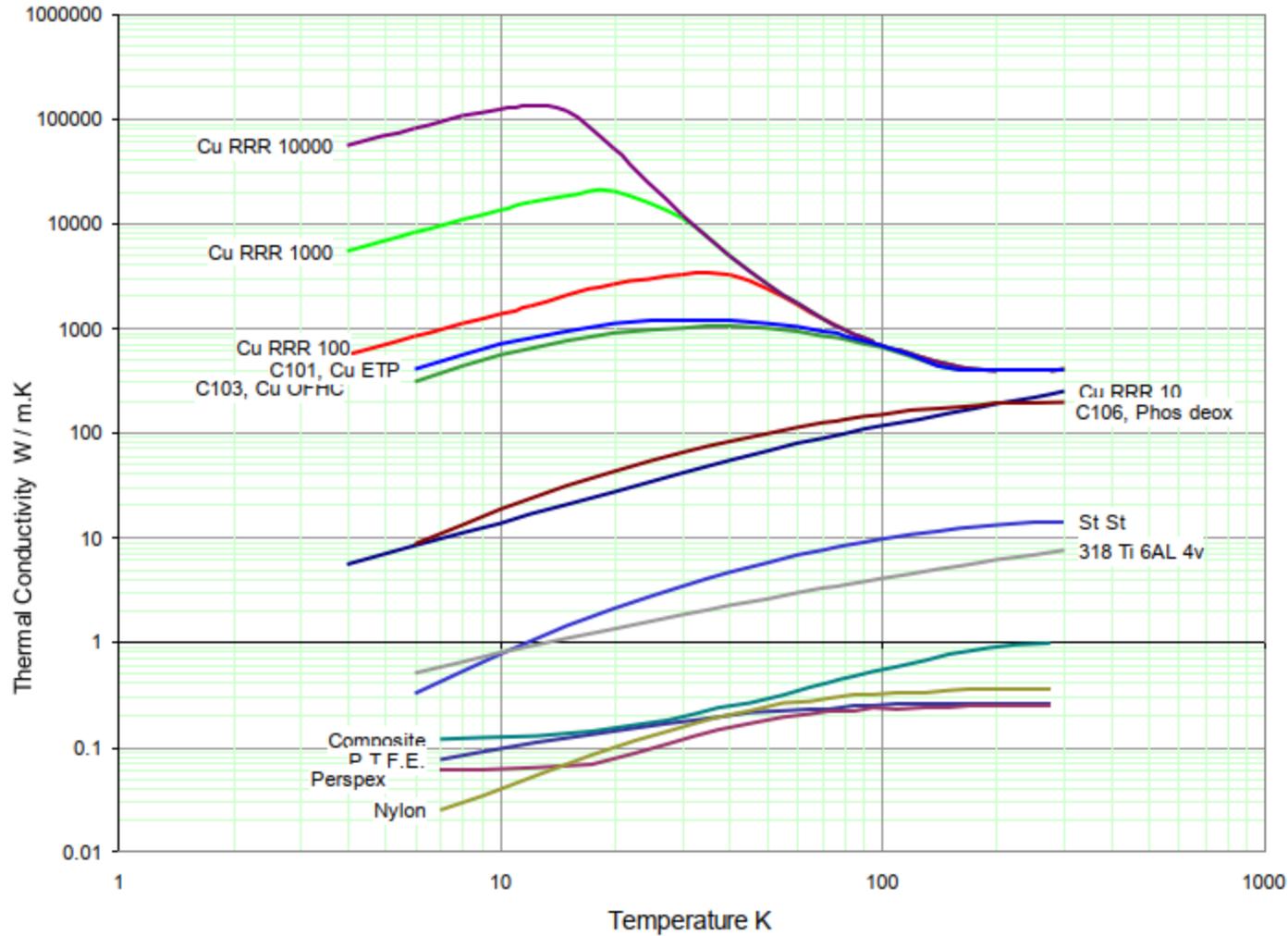
- Left: induction heat shrink
- Right: cryogenic heat shrink

Material Properties

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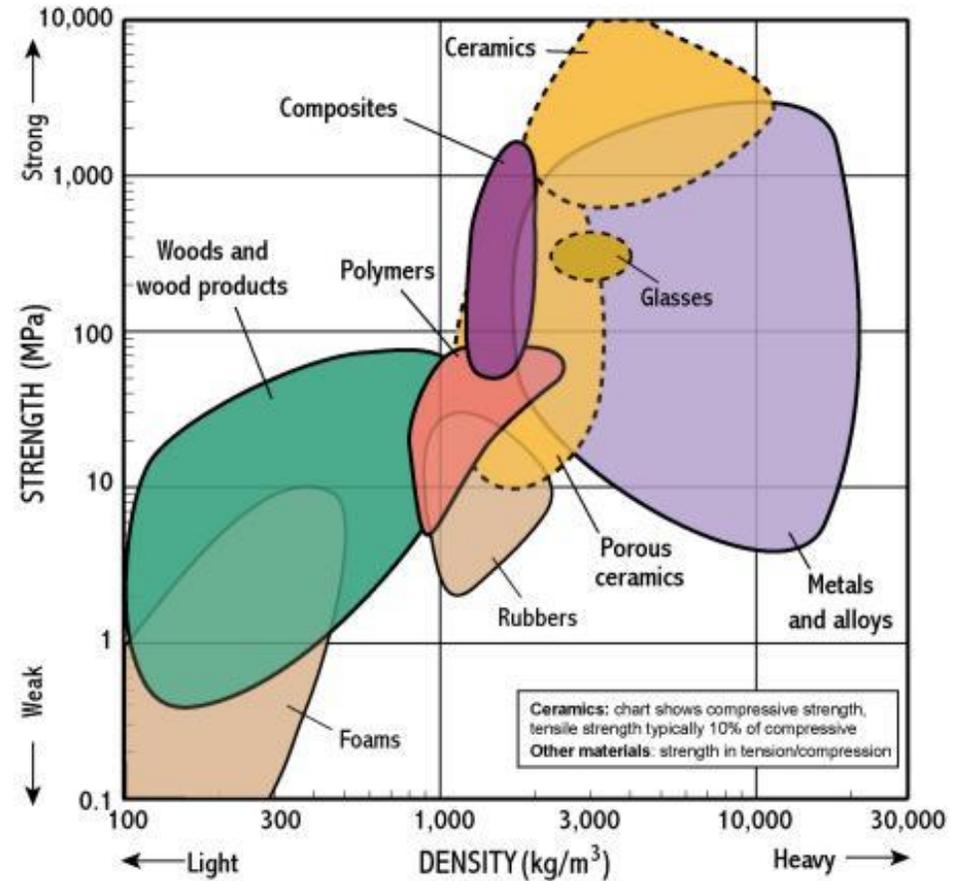


Material Properties

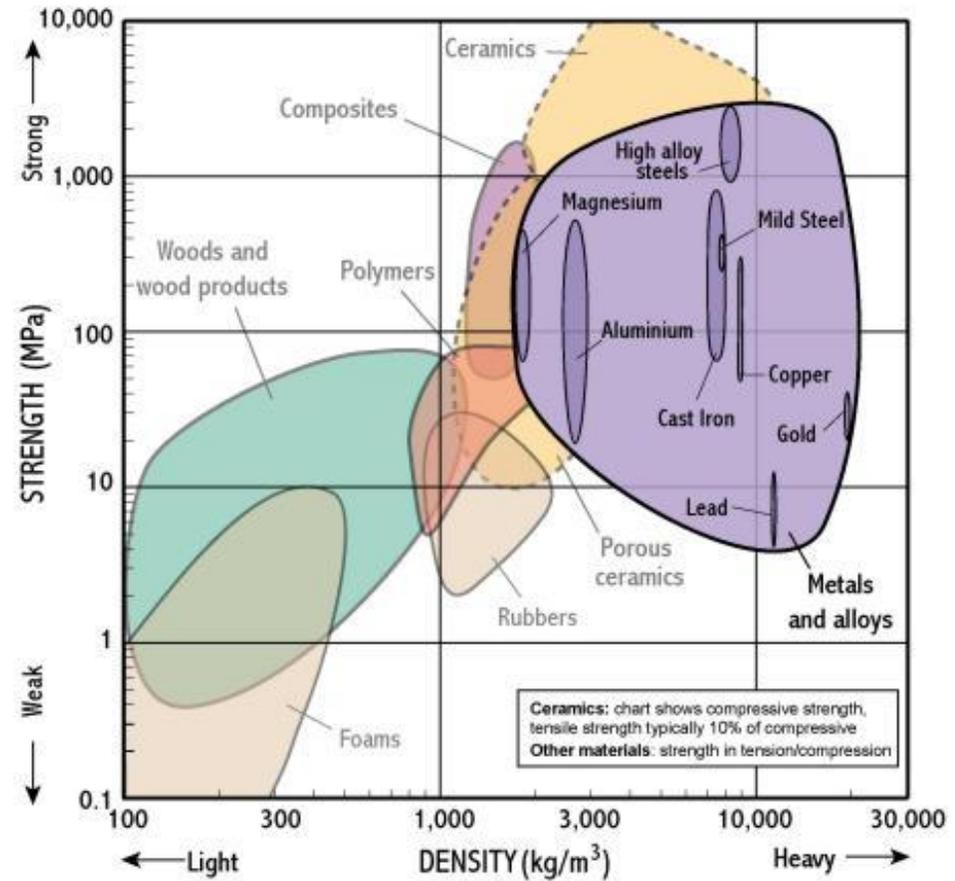
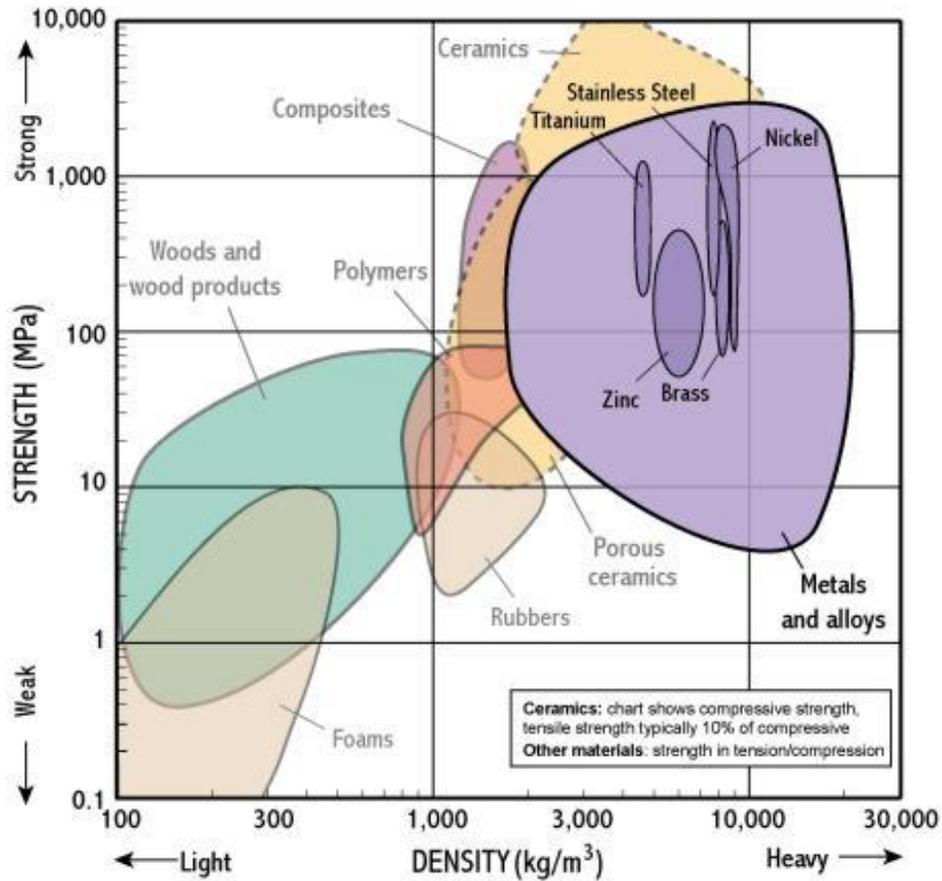


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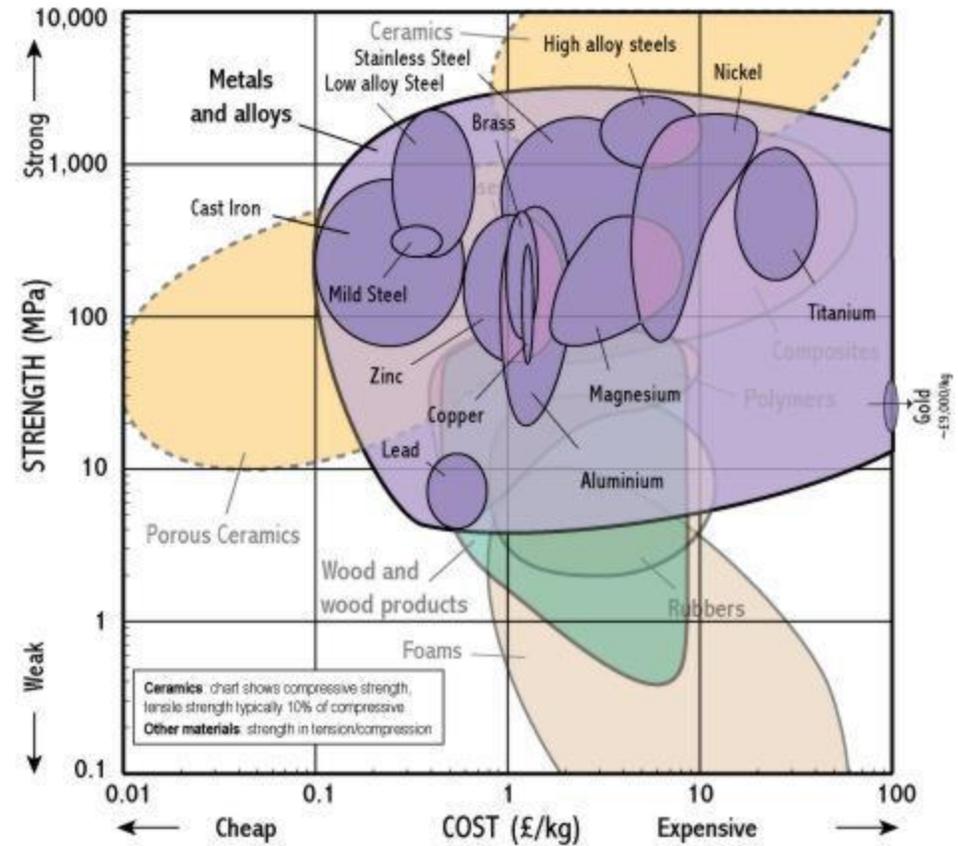


Material Properties



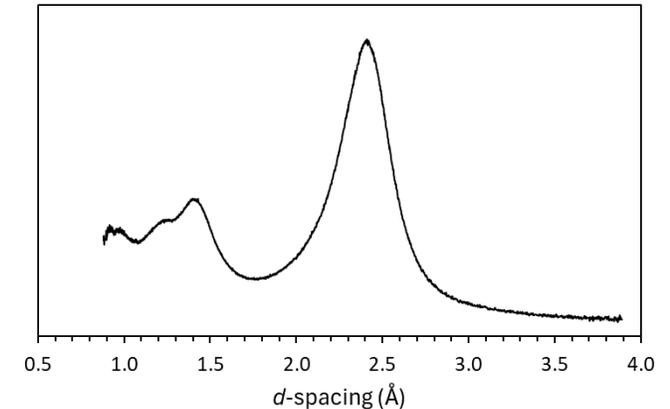
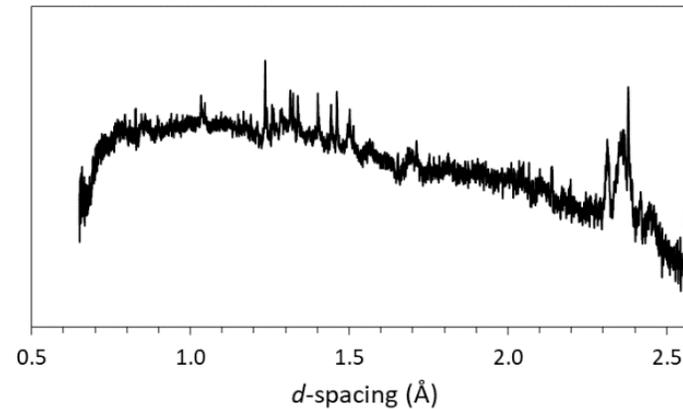
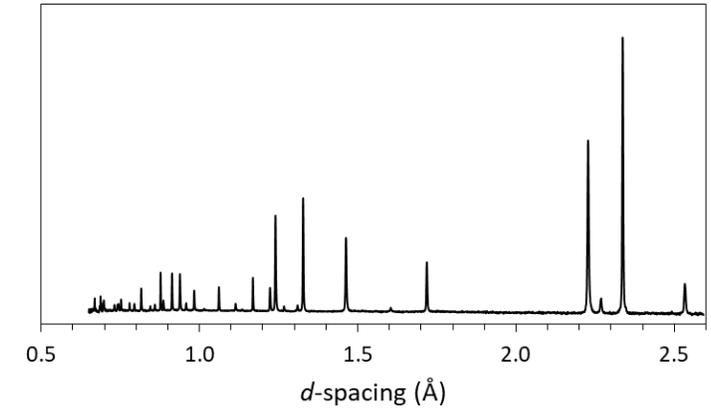
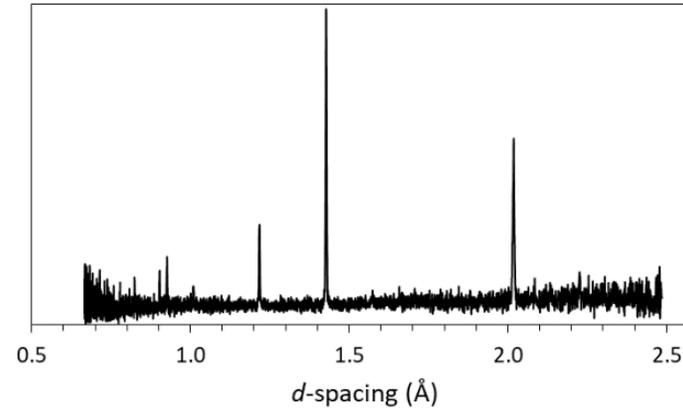
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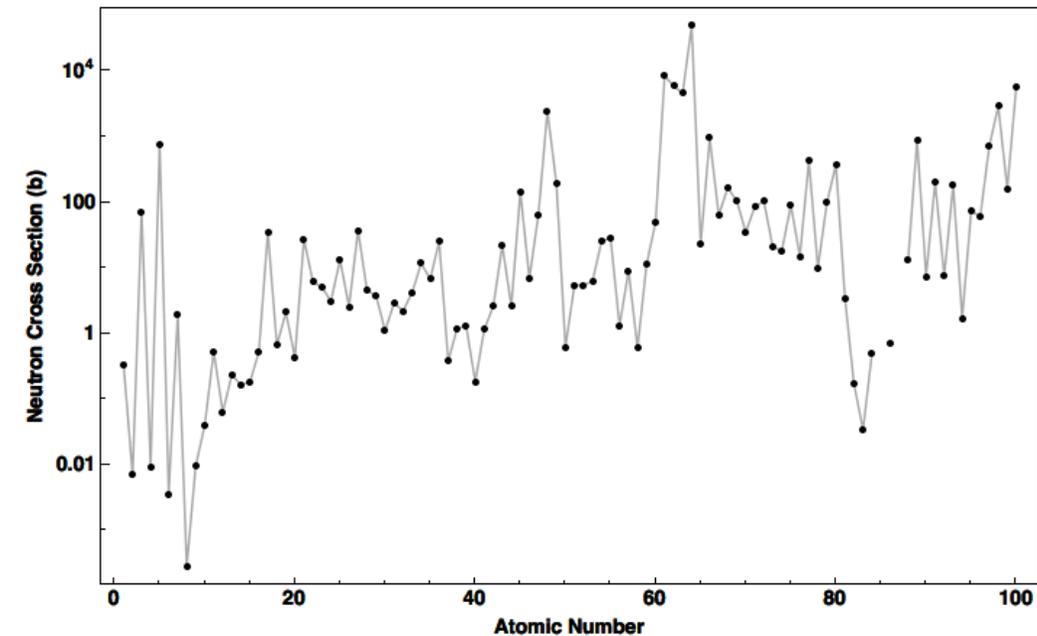
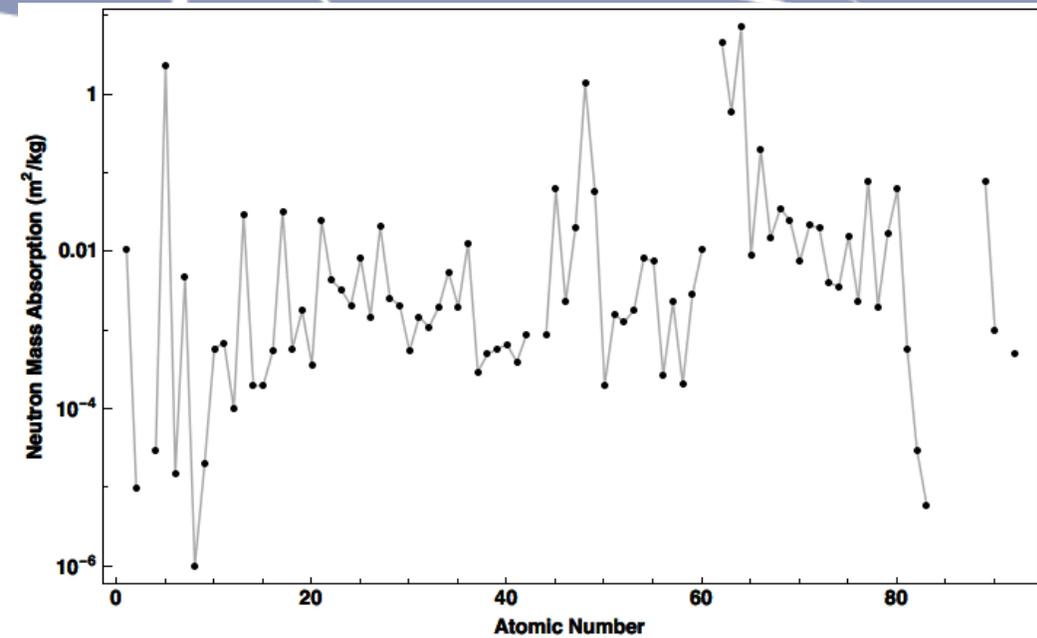
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- **Background**



Background

- Neutrons
 - Scattering cross section
 - Coherent
 - Incoherent
 - Scattering length
 - Coherent
 - Incoherent
 - Absorption cross section
- X-rays
 - Atomic number
 - Density
 - Excitation energy

Neutron scattering lengths and cross sections							
Isotope	conc	Coh b	Inc b	Coh xs	Inc xs	Scatt xs	Abs xs
H	---	-3.7390	---	1.7568	80.26	82.02	0.3326
1H	99.985	-3.7406	25.274	1.7583	80.27	82.03	0.3326
2H	0.015	6.671	4.04	5.592	2.05	7.64	0.000519
3H	(12.32 a)	4.792	-1.04	2.89	0.14	3.03	0



Material Data

- Minimum vs actual / typical strength
- Standards
- Design codes
- Material Certificates
- Supplier datasheets
- Historical NASA data etc
- NIST neutron data



S-Tech Corporation
INSPECTION CERTIFICATE

Page 1
No.15, Gong 1st Road, Environmental
Science and Technology Park,
Liouying Dist., Tainan City 736,
Taiwan(R.O.C)
TEL: 886-6-623-0000
FAX: 886-6-623-0011

245543

Messrs : Smiths Metal Centres Ltd.
Order NO : 2017000987
Grade : T1-6AL-4V AMS
Lot/Heat : NA0103S2A
FILE NO : 2017001284-Z
Size : 30.0 mm
P'cs : 27

P.O.NO. : 9901074422

Date : 12/29/2017
Size Tol. : + 0 mm / -0.052 mm
Weight : 279.60KG ; 616.41LB

Condition: Hot Rolled-Annealed-Peeled-Straightened-Polished-Inspected

Chemical Composition (wt%)(TOP)

Item	C	V	Al	O	N	H	Fe	Y
Min.		3.50	5.50					
Max.	0.08	4.50	6.75	0.20	0.05	0.0125	0.30	0.005
Result	0.02	4.04	6.63	0.18	0.01	0.0012	0.24	<0.005

Chemical Composition (wt%)(BOTTOM)

Item	C	V	Al	O	N	H	Fe	Y
Min.		3.50	5.50					
Max.	0.08	4.50	6.75	0.20	0.05	0.0125	0.30	0.005
Result	0.02	3.95	6.64	0.18	0.01	0.0015	0.23	<0.005

CHEMICAL COMPOSITION OTHER EACH : < 0.1%

CHEMICAL COMPOSITION OTHER TOTAL : < 0.4%

H(After Peeled) : 0.00197 %

Ti(Composition%) : Balance

Mechanical Properties Spec.

Item	Elongation(A)	Tensile Strength(Rm)	0.2% Yield Strength(Rp)	Reduction of Area(Z)
Condition	CENTER L	CENTER L	CENTER L	CENTER L
Spec.Min.	10	931	862	25
Spec.Max.		1160		
Result	16	1065	999	38
Unit	%	Mpa	Mpa	%

Item	Free of Alpha Layer	Microstructure
Condition	at (100X)	ETTC2
Spec. Max/Avg		
Result O.D.		
Result	PASS	A5
Result Avg.		
Unit		



Our quality management system has been certified by ISO 9001 and AS 9100 QMS.

For and behalf of
S-TECH CORP
QA Dept.
David King
Authorized Signature(s)



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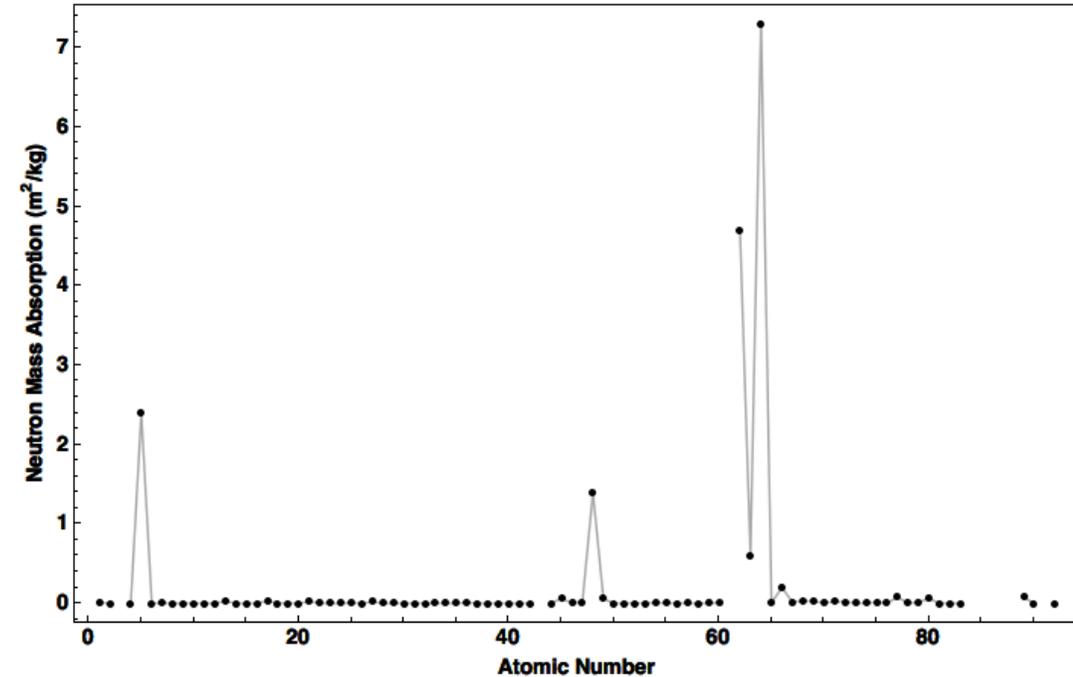
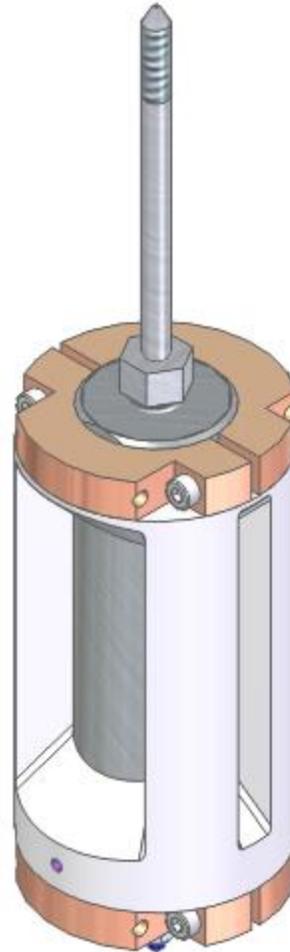


Common Materials – Neutrons

- Vanadium
 - Very low scatter
- Aluminium + alloys
 - Low incoherent scatter
 - Some coherent scatter – Bragg peaks
 - Cheap
 - Low-moderate strength, 50-550 MPa
- TiZr (52.2%:47.8%)
 - Null scattering
 - Coherent scattering cancels out
 - High strength, 700-900 MPa
 - Scare / expensive
 - Pyrophoric!
- Fused silica
 - Amorphous / non-crystalline
 - No Bragg peaks
 - Weak, 55 MPa (tensile)
 - Brittle!
- Ti-6Al-4V
 - Very high strength, 900-1100 MPa
 - High pressure gas cells
 - Coherent scatter – Bragg peaks
- Stainless steel 316
 - Chemical / hydrogen compatibility
 - Moderate strength, 500 MPa
 - Moderate temperature resistance, 800 °C
 - Cheap
- Niobium
 - Coherent scatter – Bragg peaks
 - High melting point, 2500°C
- Sapphire
 - Low incoherent scatter
 - Low absorption
 - SANS pressure windows
 - Moderate strength, 300 MPa (tensile)
 - Brittle!

Common Materials – Neutron Masking / Collimation

- Boron Nitride
 - HP grade is easier to pump out
 - Easy to machine
 - High temperature resistance
 - Fragile
- Boron Carbide
 - More absorbing than BN
 - Hard to work with, abrasive
- Gadolinium
 - Foils
 - High melting point
 - Extremely absorbing!
- Cadmium
 - Low melting point, 320°C
 - Easy to form by hand
 - Toxic!

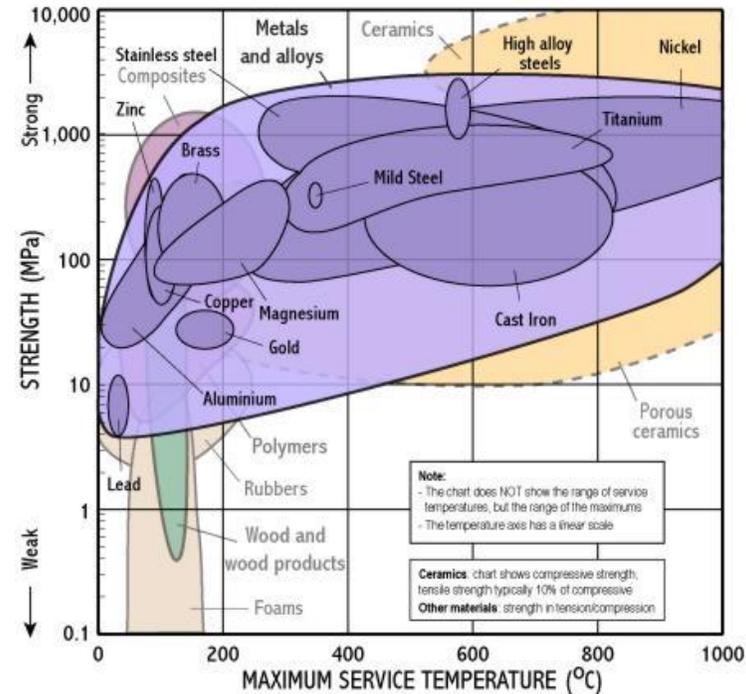


Materials To Avoid – In Neutrons

- Most things!
- Strongly absorbing
 - Boron (borosilicate glass!)
 - Cadmium
 - Gadolinium
 - Hafnium
- Strong incoherent scattering
 - Hydrogen
- Strongly activating
 - Cobalt (some Inconel alloys, MP35N)

Common Materials – Structural Metals

- Aluminium
 - Common, thermally conductive, weakly paramagnetic
 - 1000 series / pure – high thermal conductivity, weak
 - 5000 series – excellent weldability, moderate strength
 - 6000 series – strong, weldable (reduces strength)
 - 7000 series – very strong
- Steel
 - Common, poor thermal conductivity
 - 300 series stainless (austenitic) – ductile
 - 400 series stainless (martensitic) – hardenable
 - Maraging – strong
- Nickel
 - Very strong, poor thermal conductivity
 - Ni-Cr-Al (Russian alloy)
 - Inconels
 - MP35N
- Copper
 - common, excellent thermal conductivity, weakly diamagnetic
 - OFHC – best thermal conductivity
 - Beryllium copper – very strong
- Titanium
 - common(ish), strong(ish), weakly paramagnetic



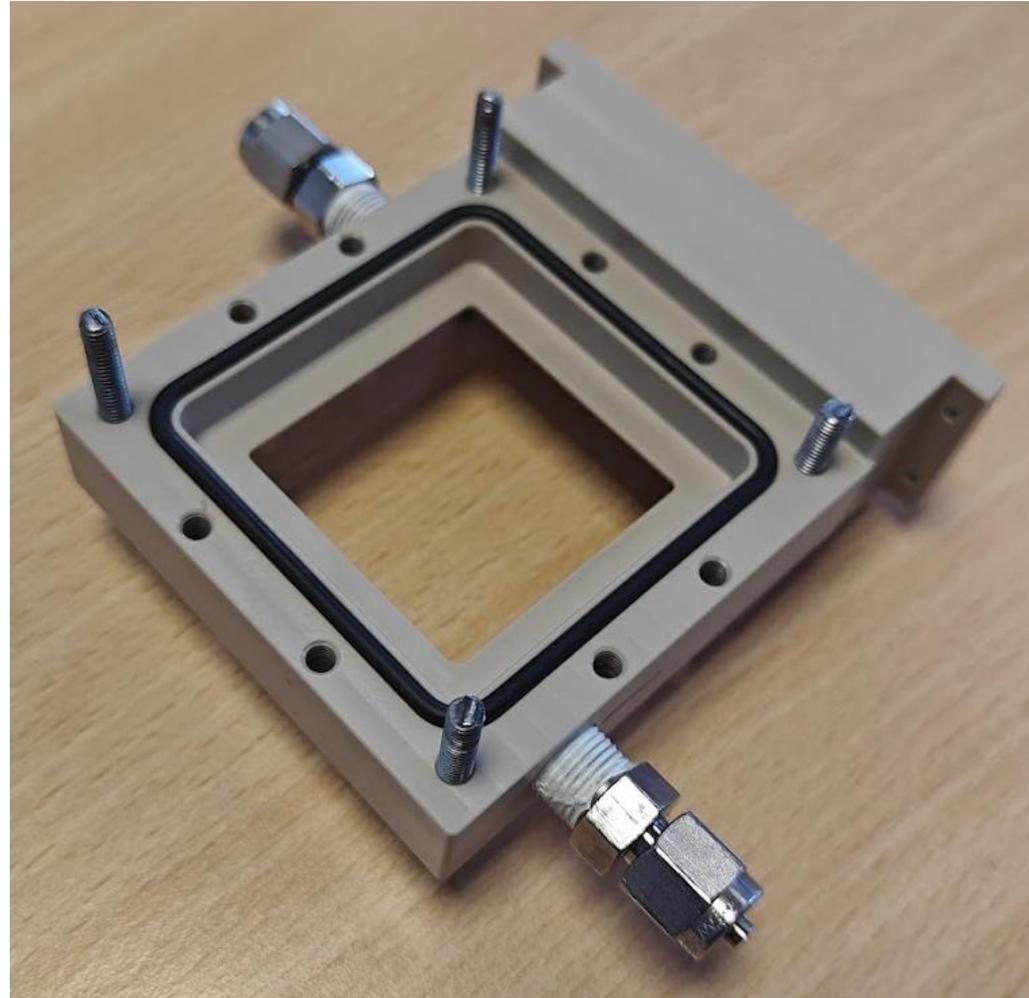
Common Materials – Ceramics / Glasses

- Macor
 - Machinable
 - Insulating
- Zirconia toughened alumina
 - Strong
- Tungsten Carbide
 - Very strong
- Fused silica
- Single crystal silicon
- Sapphire
 - Strong
 - Optical windows



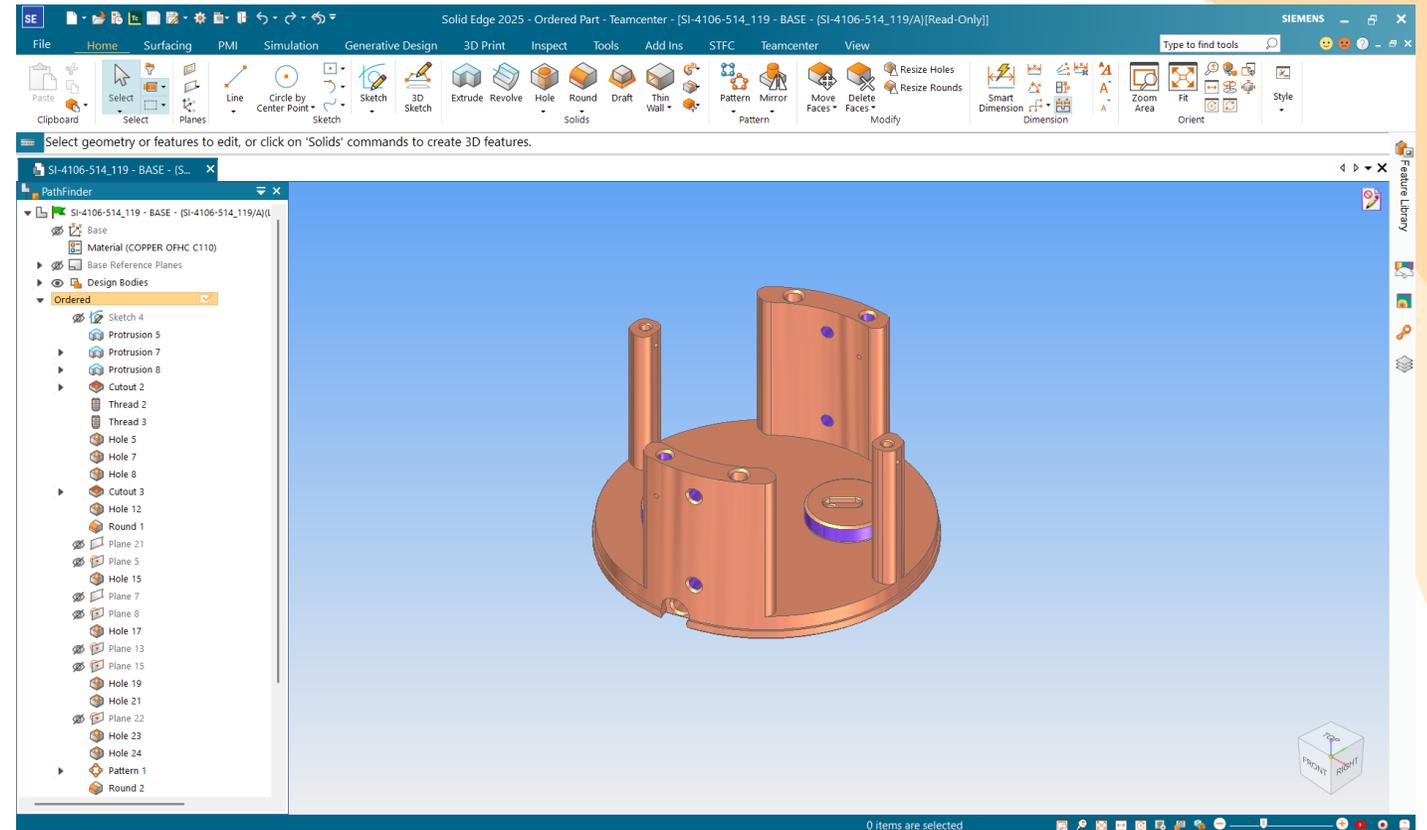
Common Materials - Plastics

- PEEK
 - Strong
 - Chemically resistant
 - UHV compatible
- PTFE
 - No hydrogen
 - Very low friction
- Nylon
 - General purpose plastic
- Polyacetal
 - General purpose plastic
- ULTEM
 - 3D print plastic
 - Vacuum compatible



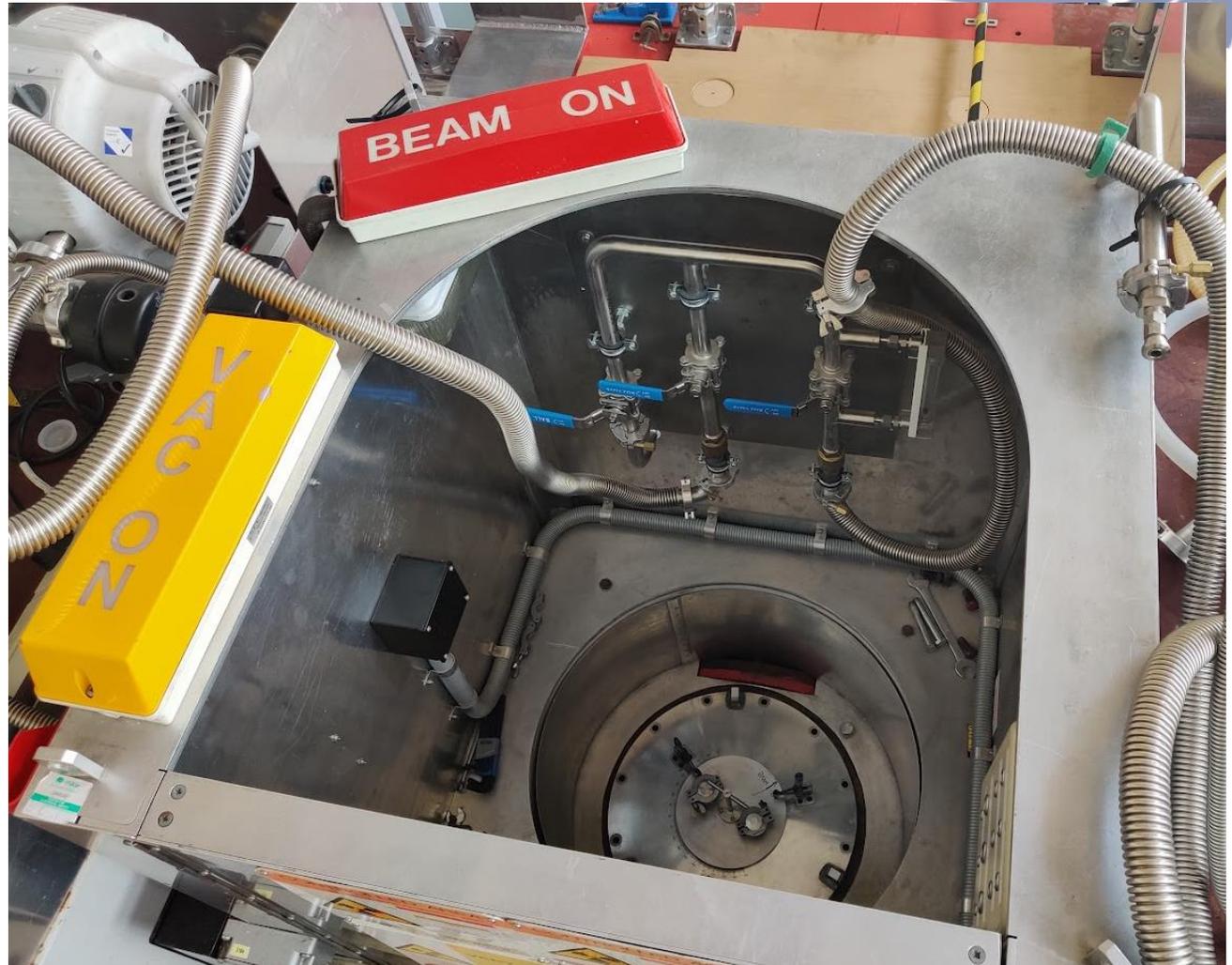
Design Considerations

- Interfacing Equipment
- Beam, Detectors, Obstructions
- Sample Geometry
- Environmental
- Material joining
- Sealing
- Chemical Compatibility
- Sample Manipulation
- Design for Manufacture
- Design for Assembly
- Accurate Assembly
- Design for Disassembly



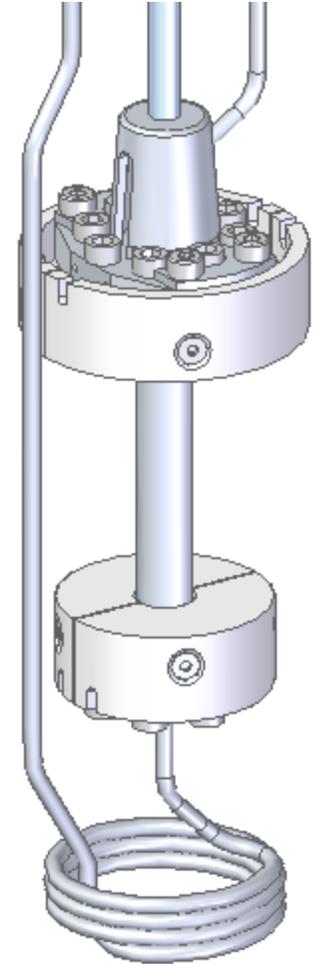
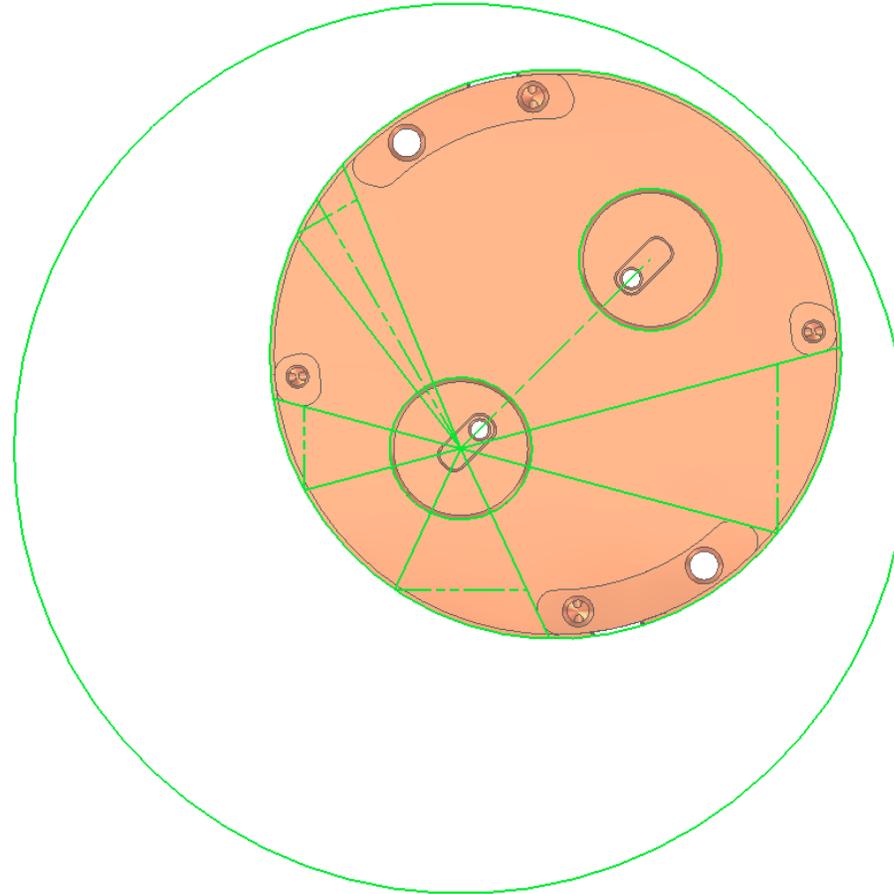
Interfacing Equipment

- Open air / tabletop system?
- In a vacuum chamber?
- Top loading system?
 - Bore size?
- Bottom loading system?
- Restrictions / clearances
- Environment provided?
 - Furnace?
 - Cartridge heaters?
 - Flexibility on support equipment



Beam, Detectors, Obstructions

- How big is the beam?
 - Dictates how big a sample container needs to be
- Where are your detectors?
 - Orientation of supports
 - Orientation of flow / return tubes
- What else is in the area?
 - Restricted access?
 - Room for support equipment?



Beam, Detectors, Obstructions

- SXD – Detectors everywhere!

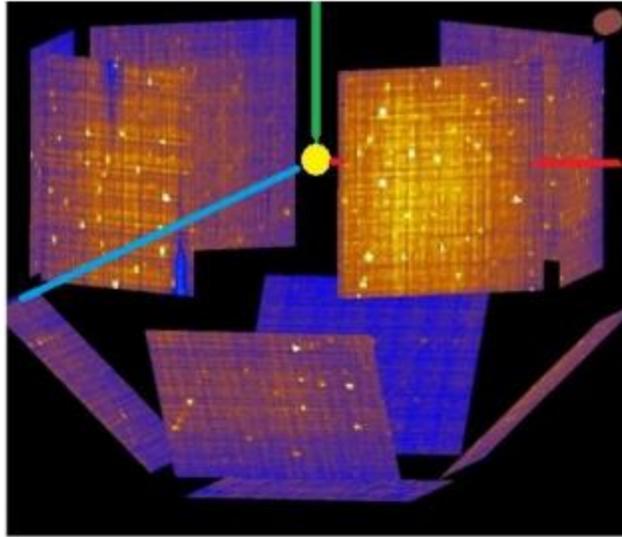


Figure 3 - SXD Sample Position: Side View

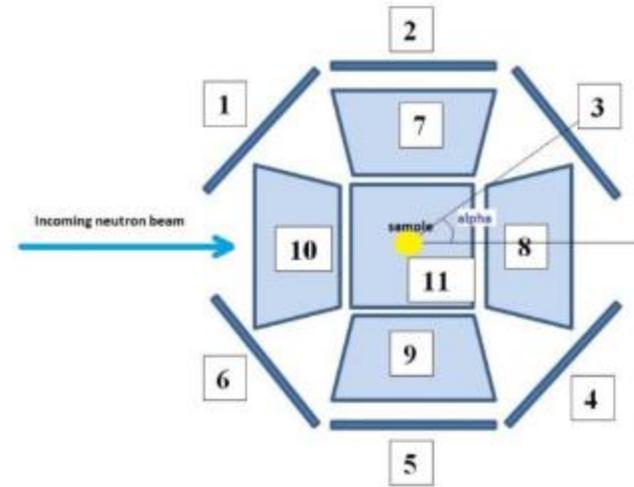


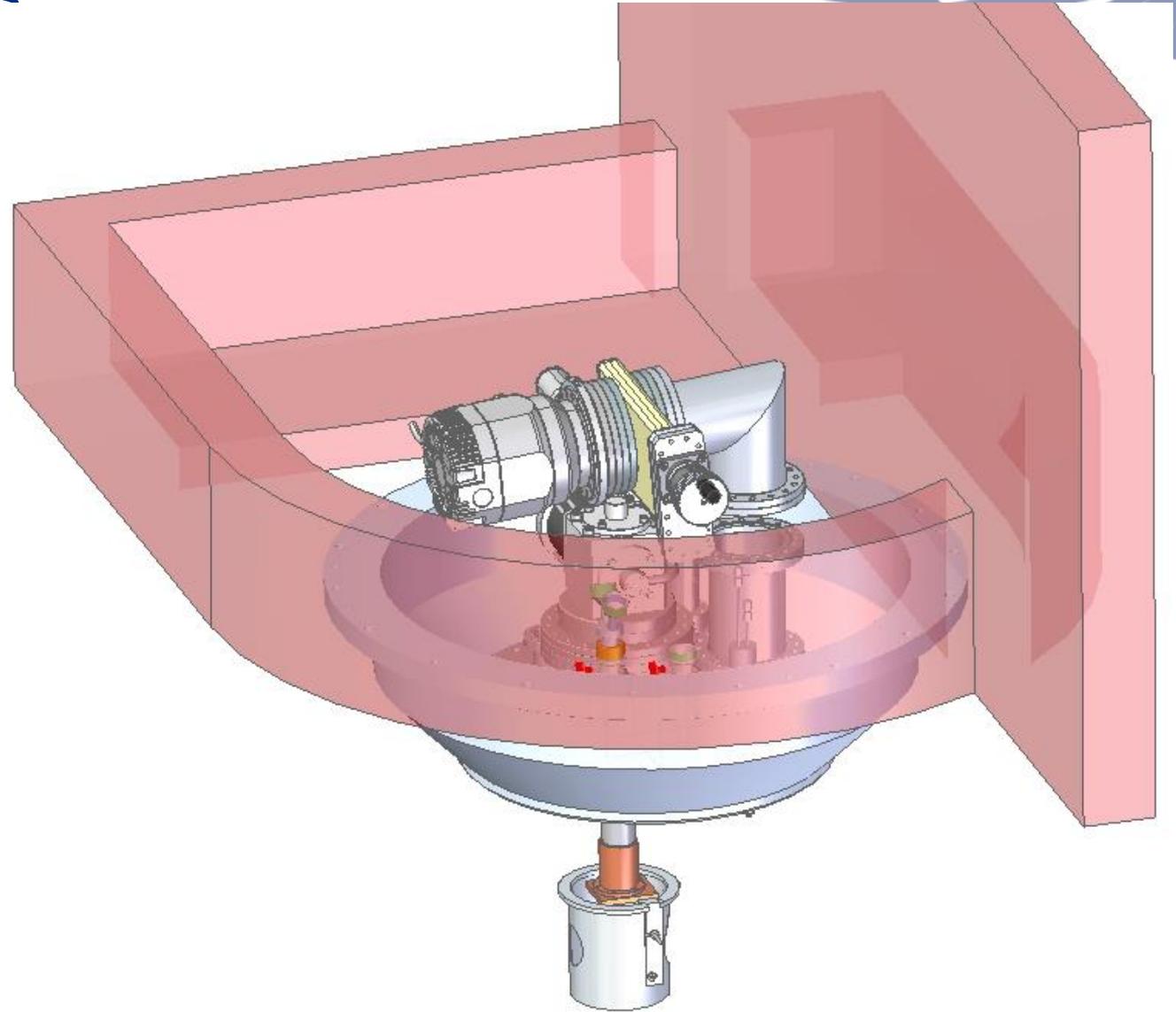
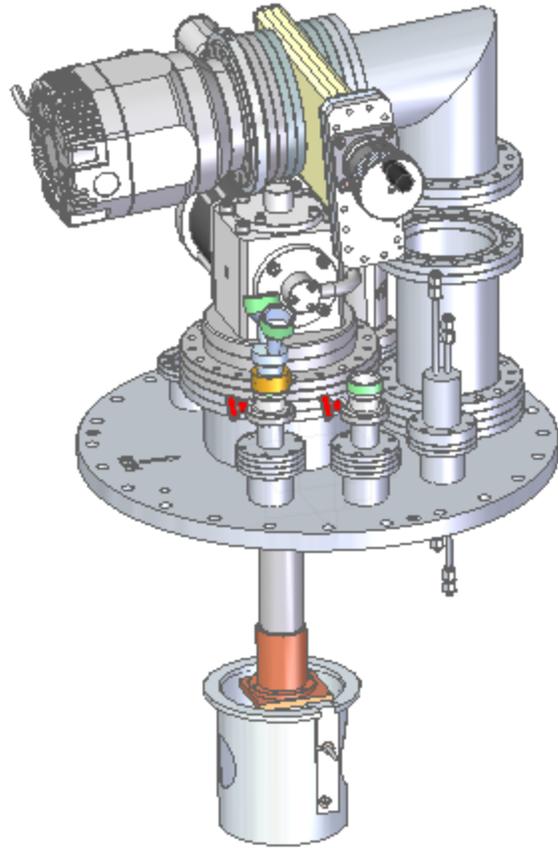
Figure 4 - SXD Sample Position: Top View

Beam, Detectors, Obstructions

- Nimrod & SANS2D

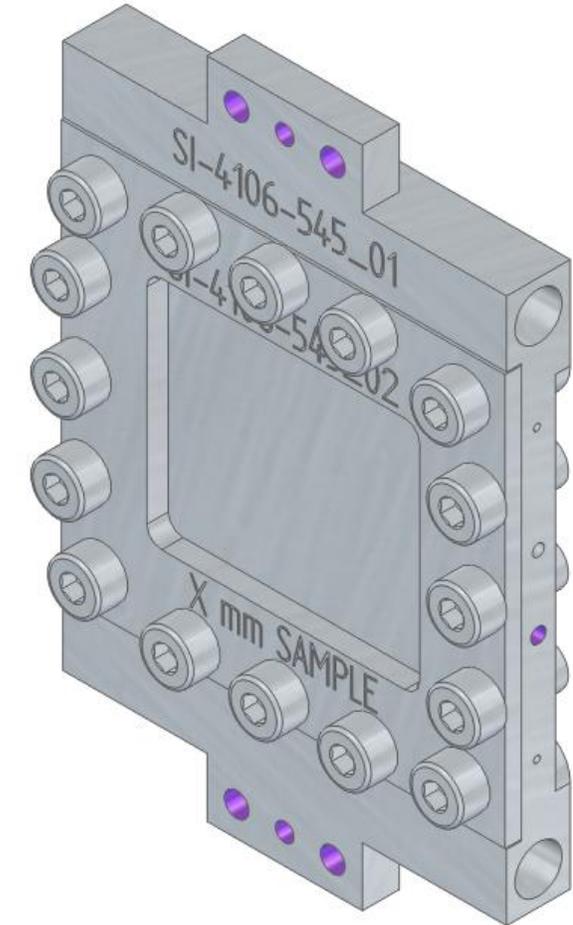
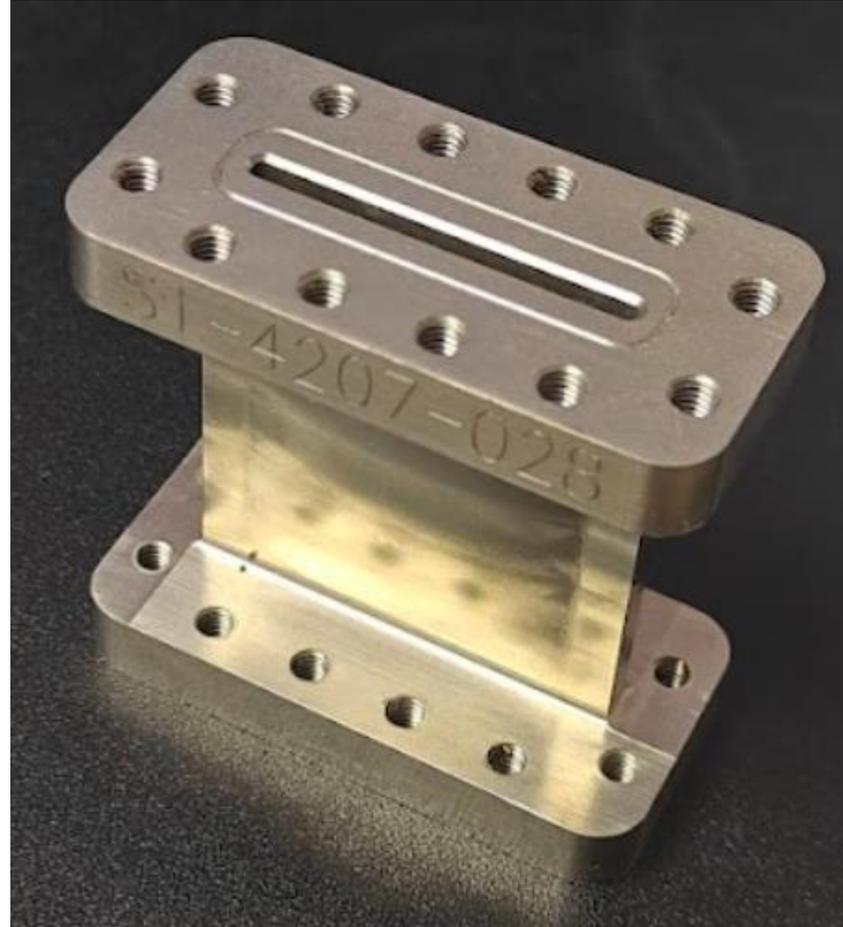


Beam, Detectors, Obstructions



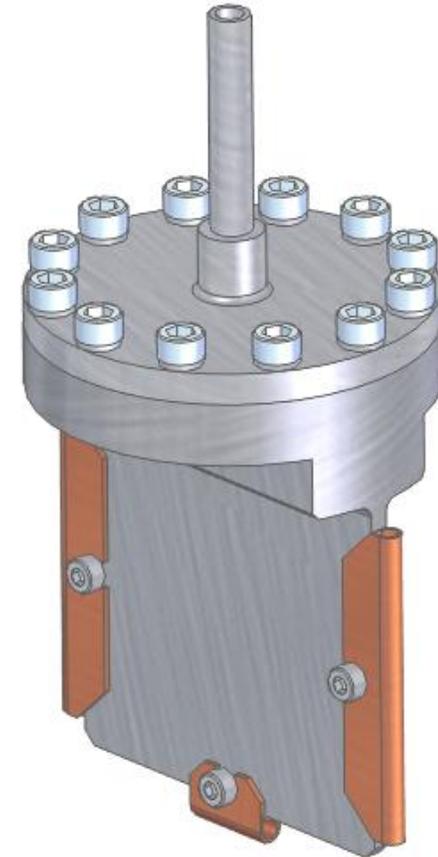
Sample Phase

- Solid
 - Freeform
 - Powder
- Liquid
 - Sealing
 - Viscosity
- Gas
 - Sealing



Sample Geometry

- Dependant on:
 - Sample format / availability
 - Type of instrument
 - Detector arrangement
 - Required conditions
- Common shapes:
 - Freeform
 - Flat
 - Low angle detectors
 - Cylindrical
 - Simple
 - Annular
 - Reduces multiple scattering from sample
 - Liquid / film bed
 - Reflectometry



Design Considerations – Pressure

- Local regulations!
 - 0.5 bar = pressure vessel (PER / PED)
 - 250 bar*litres stored energy = admin!
- What is the pressure?
- Stay in SEP where possible
- Container going into vacuum chamber?
 - + 1 bar pressure!
- Standardise equipment
 - Tube: imperial or metric
 - Fittings: Swagelok, HP cone
 - Spares for valves, PRVs, etc

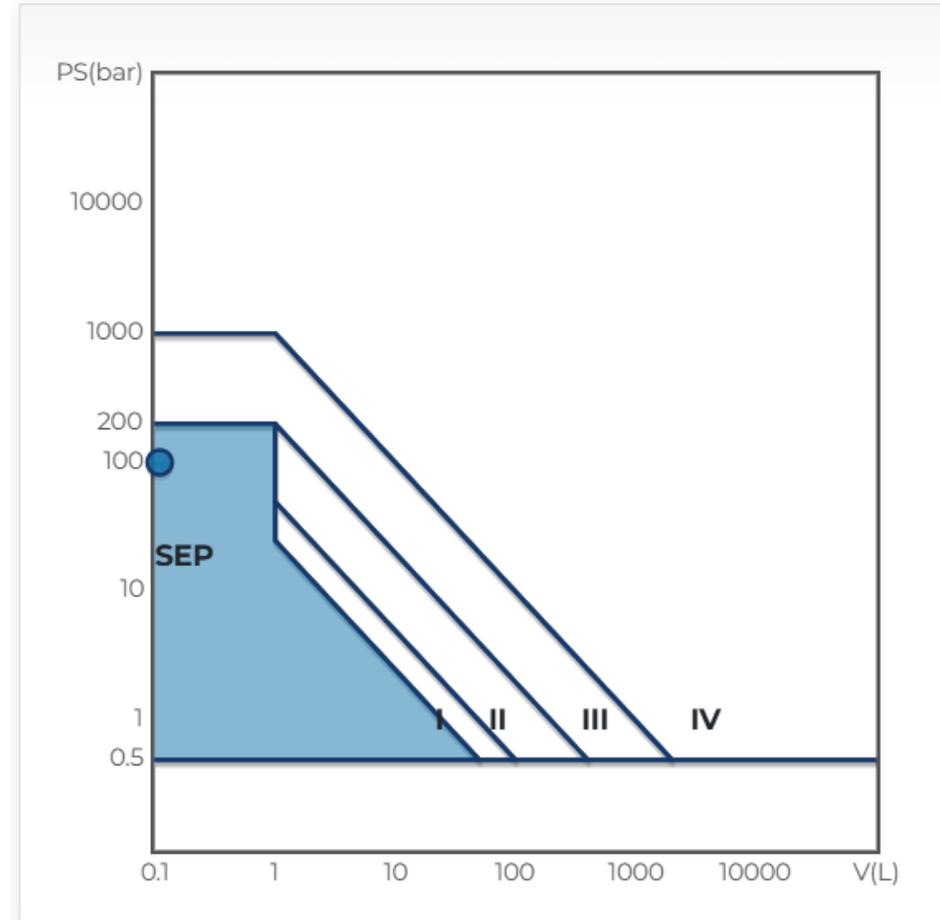


Chart 1 - Vessels for Group 1 gases

Design Considerations – Pressure

- Design Codes
 - EN 13445
 - PD 5500
 - ASME BPVC
- Thin wall ($D/t > 20$)
 - Hoop stress
- Thick wall
 - Lamé equations
 - Autofrettage
- Stress limits
 - Yield/1.5
 - UTS/2.5
- Proof test
 - 1.25 x PRV pressure + temperature correction

Design pressure:	$P_d = 5.5 \text{ bar}$
Design strength @ 100 °C:	$f_{316} = 143 \text{ MPa}$
Internal diameter:	$D_i = 42 \text{ mm}$
Minimum wall thickness: (PD 5500:2024, Equation 3.5.1-1)	$e_{cyl} := \frac{P_d \cdot D_i}{2 \cdot f_{316} - P_d} = 0.081 \text{ mm}$
Actual minimum wall thickness:	$e_{cyl} = 0.45 \text{ mm}$
Verification check of wall thickness:	if ($e_{cyl} > e_{cyl}$, "Pass", "Fail") = "Pass"

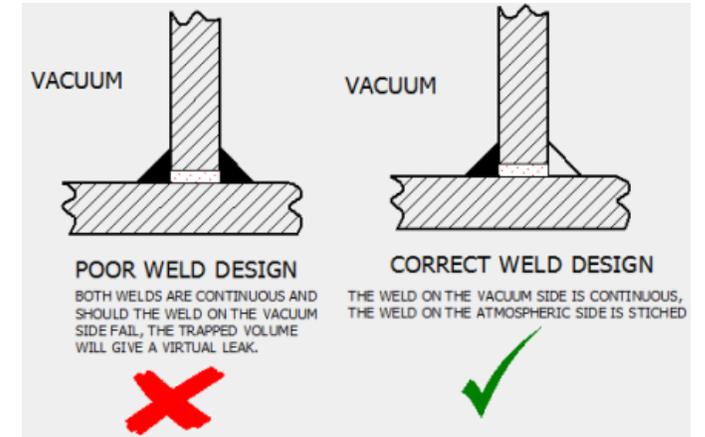
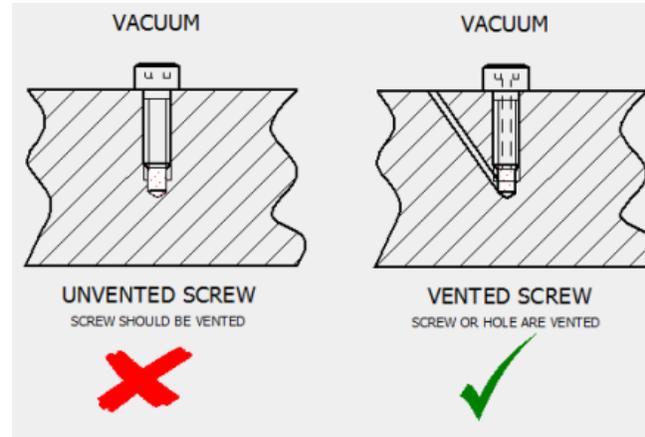
Design Considerations – Vacuum

- Not included in pressure regulations! (UK / EU)
- Pressure vs vacuum failure? Think water bottle
- Tensile vs buckling failure
- Calculations more complicated
 - Buckling can be dominant
 - Young's modulus important
- Vacuum chamber needs thicker wall than equivalent + pressure
- Use additional safety factors!
- Sealing – coming up



Design Considerations – Vacuum

- Very dependant on vacuum level!
 - Medium – High: good practice
 - High – UHV: critical
- Welding
 - Cleanliness critical
 - Use of flux etc
- Reduce virtual leaks
 - Bottom of threaded holes
 - Welds
- UHV cleaning
- Bake-out
- Increase conductance
- Good thermal management, lost convection

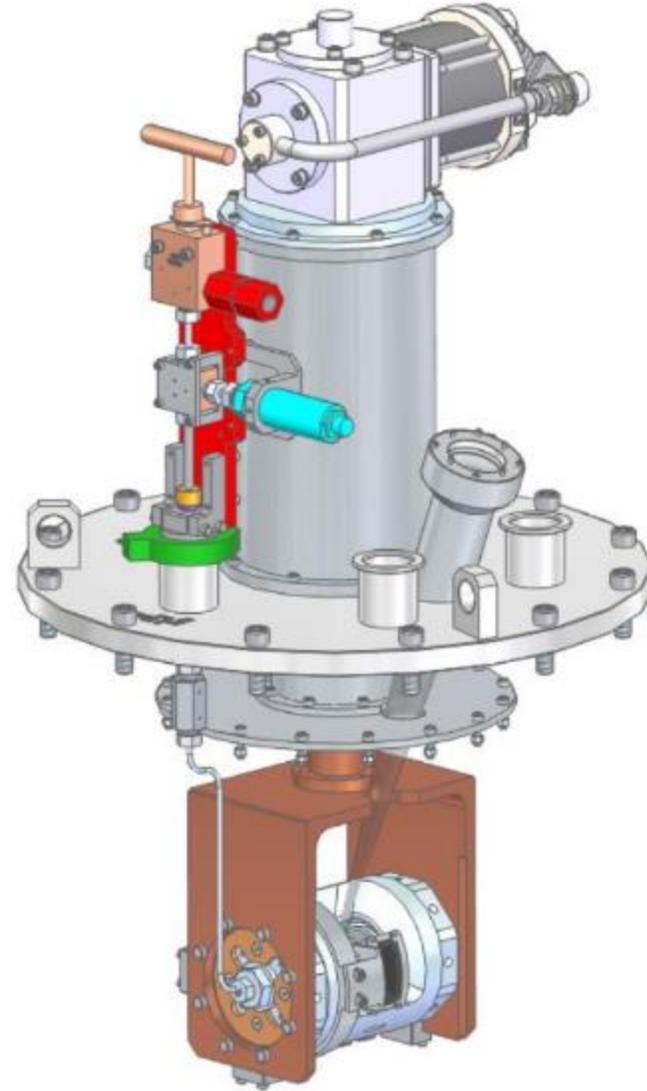


Materials To Avoid - Vacuum

- Cadmium - above room temperature
 - Low melting point
 - High vapour pressure
- Zinc - above room temperature
 - High vapour pressure
 - 7000 series aluminium (!)
 - Brass (!)
- Materials that offgas strongly
 - Solder / brazing fluxes
 - Lubricants
 - Most plastics (particularly UHV)

Design Considerations – Low Temperature

- See other talks!
- Cryostat bore diameter?
- Mount directly to CCR?
- What type of sensors?
 - Cernox
 - Pt100
 - Rhodium-iron
- Heaters
 - Temperature control
 - Fast warm up



Design Considerations – High Temperature

- See other talks!
- What is the temperature?
- Pressured
 - How can we seal?
- Sealed ambient
 - How do we seal?
 - Weld shut?
 - Gay Lussac's Law!
 - 1000°C -> 4.24 bar
- Vented
 - Will the sample evaporate?
 - Corrosion resistance of system?
- T++ = Refractory metals?

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Design Considerations – Magnetic Field

- See other talks!
- Use non-magnetic materials!
 - Copper alloys
 - Aluminium alloys
 - Titanium alloys
 - Plastics
 - Ceramics
- Stainless steel: austenite work hardens to martensite
- Careful choice of sensors

Sealing

- KF Flange
 - Vacuum only
 - -10 to 150°C
- CF Flange
 - Vacuum
 - Moderate pressure, 200 bar(!)
 - Cryo to 500°C
- O-ring, polymer
 - Vacuum to 200 bar
 - -10 to 150°C, possibly higher
- O-ring, metal (copper, gold, platinum, ...)
 - UHV to 100s bar, maybe 1000 bar?
 - High temperature, Tm of metals
- Indium
 - 10s bar
 - Cryo to 100°C
- Bridgman
 - Cyro to 180°C
 - 10 kbar +
- Pressure fittings
 - Swagelok
 - HP cone

Joining Techniques

- Adhesives
 - Epoxy
 - Masterbond – (UHV ish)
 - Stycast - cryo
- Soldering / brazing
 - Lots of different types
 - Different melting points
 - Staged assembly
 - Can be dirty
- Vacuum brazing
 - Clean!
- Welding
 - Tell people it's a sealing weld!
 - Control cleanliness
 - Tradition TIG/MIG etc gas purge
 - EB & laser – clean!



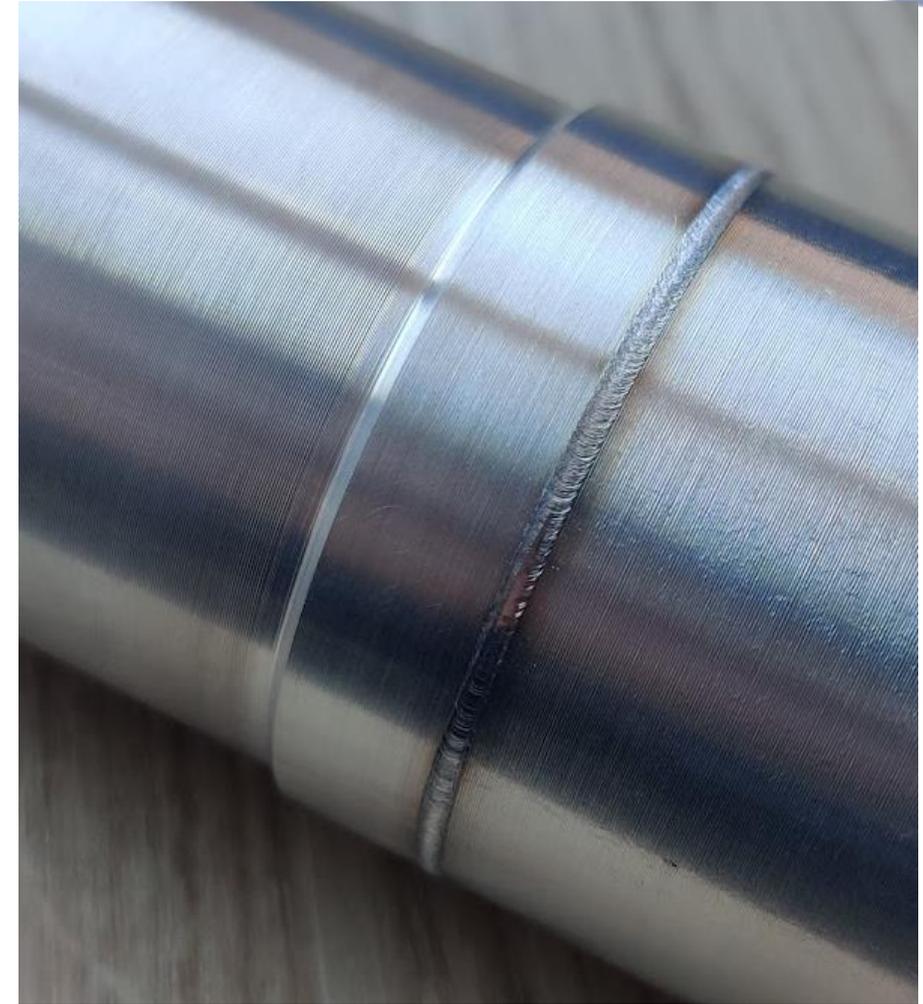
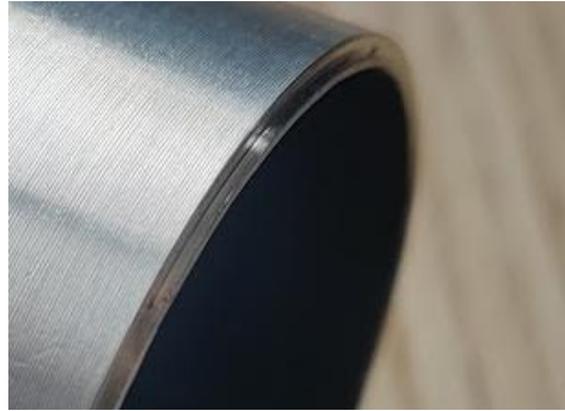
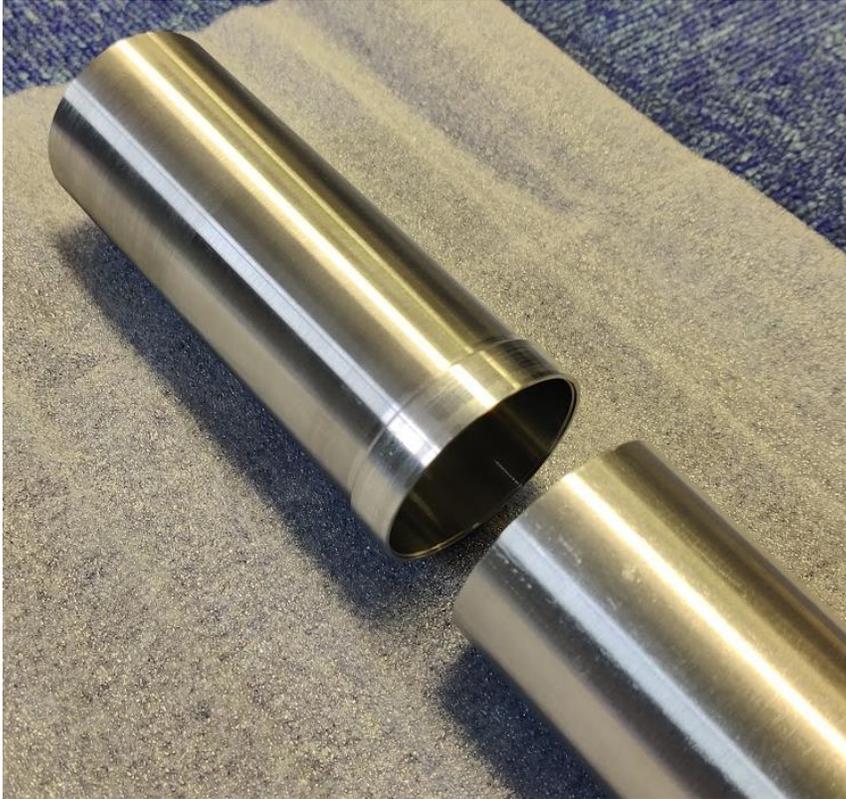
Joining Techniques - EB



Joining Techniques - EB

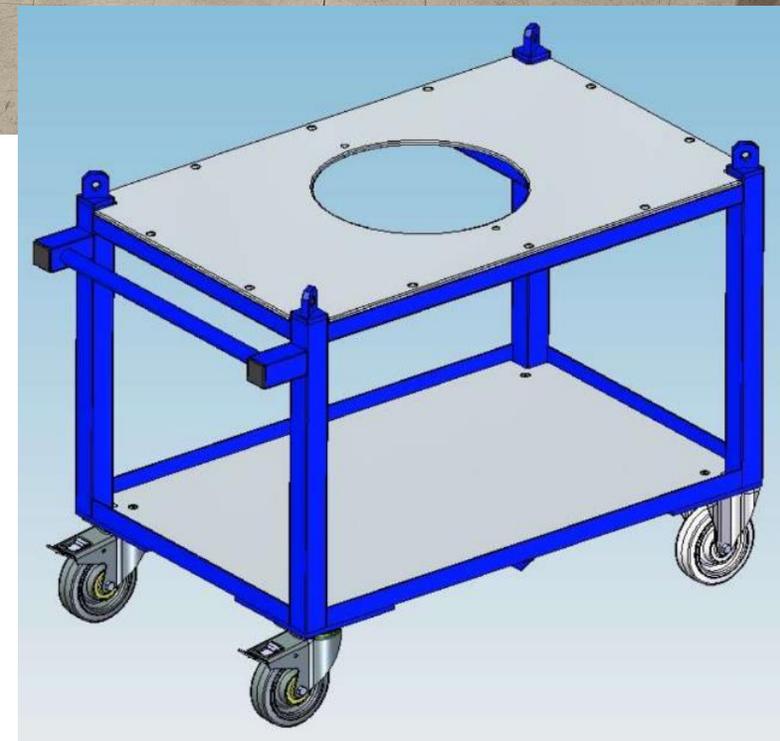
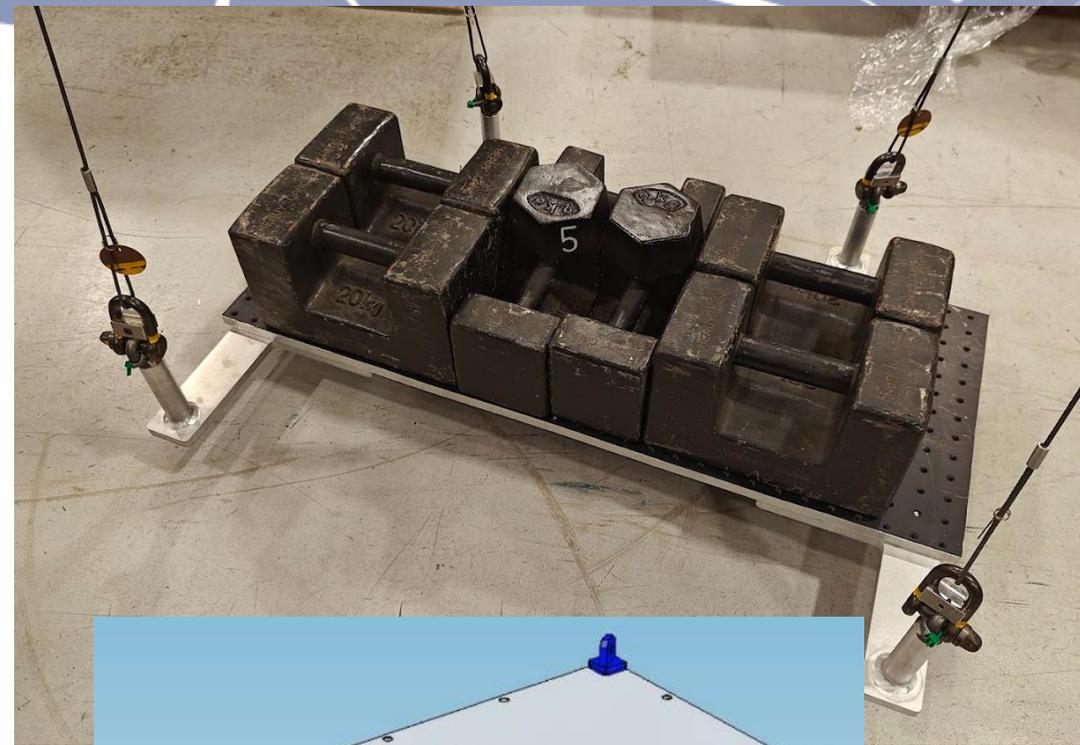


Joining Techniques - EB

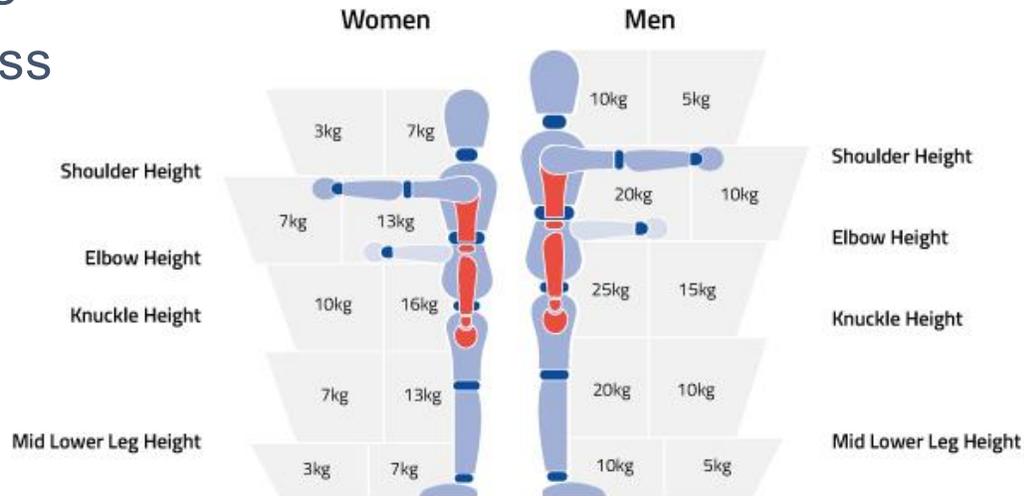


Design Considerations – Lifting / Storage

- Follow local regulations!
- General structural analysis
 - Thread shear
 - Tensile
 - Bending
 - Buckling
- Centre of gravity
- Tip over angles
- Crane access

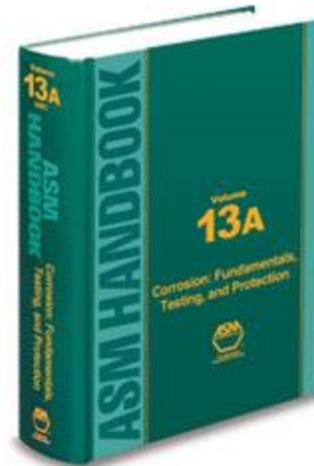
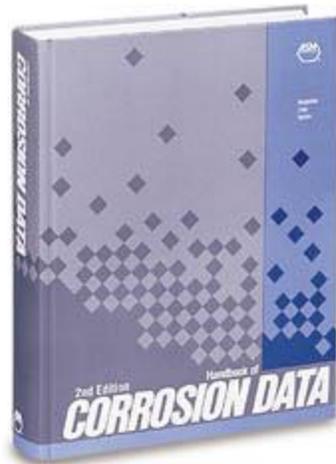
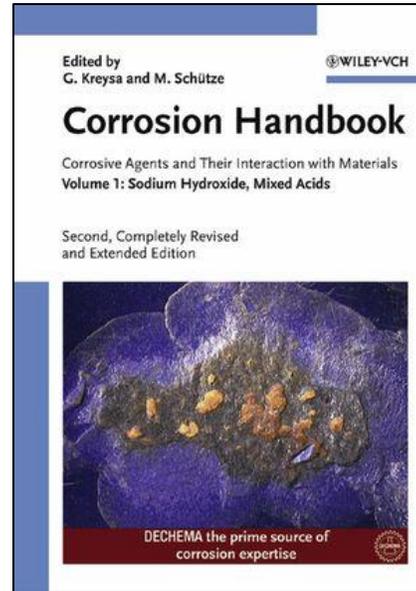


Lifting and Lowering Risk Filter



Chemical Compatibility / Corrosion Resistance

- Can affect experiment data
- Can contaminate sample area
- No go to guide
- More niche, more difficult
- Books
- Online tables - seals



APPENDIX E 

CHEMICAL COMPATIBILITY GUIDE

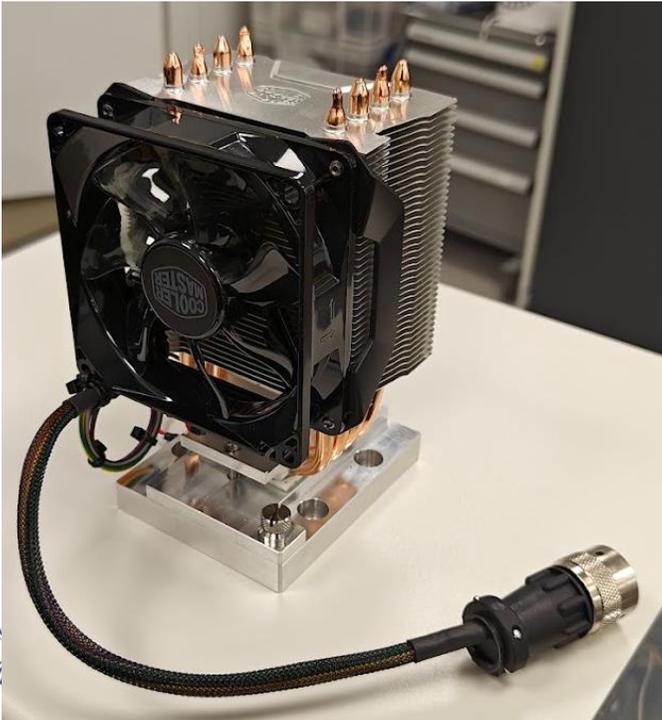
DISCLAIMER: This chart is intended to provide general guidance on chemical compatibility and should not be used for product selection. The chart is based on industry data and may not be applicable to your specific applications. Temperature, fluid concentration and other process conditions may affect the material compatibility. If there is uncertainty about the suitability of the material with the process chemical, Macnaught recommends physical testing of the sample material with the chemical. If further assistance is required, Macnaught's Technical Support Team can provide advice to assist with selection.

✓ Recommended
 - Data not available
 ✗ Not recommended

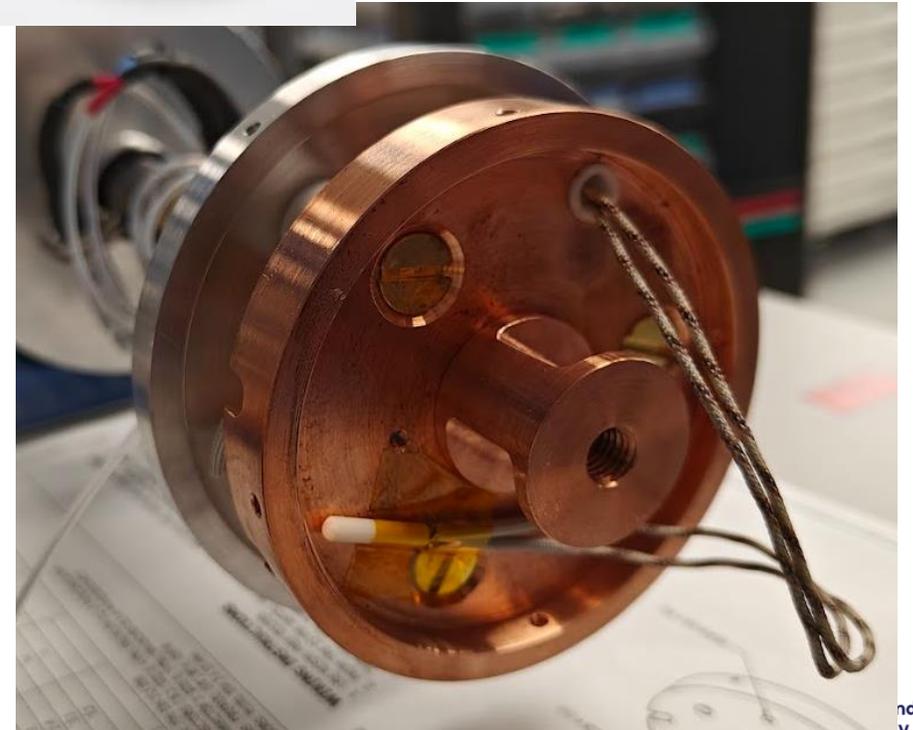
	316 STAINLESS STEEL	PPS RYTON	ALUMINIUM 6061 SERIES	HASTELLOY C-276	CARBON	VITON	PTFE	FKMM		316 STAINLESS STEEL	PPS RYTON	ALUMINIUM 6061 SERIES	HASTELLOY C-276	CARBON	VITON	PTFE	FKMM
Acetaldehyde	✓	✓	✓	✓	✓	-	✓	✓	Aluminum Chloride 20%	-	✓	-	✓	✓	✓	✓	✓
Acetamide	✓	-	✓	✓	✓	✓	✓	✓	Aluminum Fluoride	-	-	✓	-	✓	✓	✓	✓
Acetate Solvent	✓	-	✓	✓	✓	-	✓	-	Aluminum Hydroxide	✓	✓	✓	-	✓	✓	✓	-
Acetic Acid	-	-	✓	✓	✓	✓	✓	-	Aluminum Nitrate	✓	✓	-	-	✓	✓	✓	-
Acetic Acid 20%	✓	✓	✓	✓	✓	✓	✓	✓	Aluminum Potassium Sulfate 10%	✓	-	-	-	✓	✓	✓	-
Acetic Acid 80%	-	-	✓	✓	✓	✓	✓	-	Aluminum Sulfate	✓	✓	✓	-	✓	✓	✓	✓

Mounting

- Directly to pin / goniometer stage
- Stick
 - M8
 - Double ferrule, HP cone
- Mounting plate

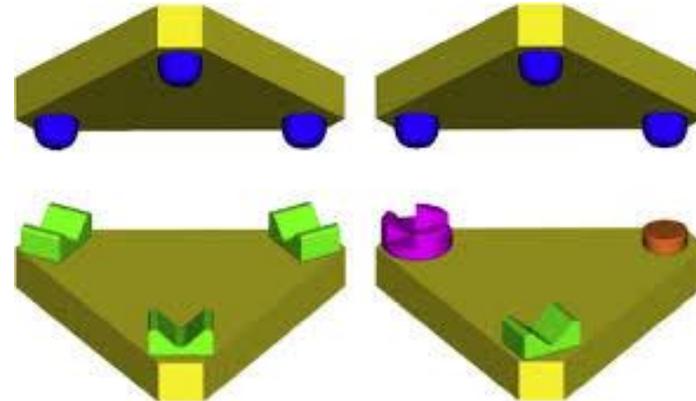
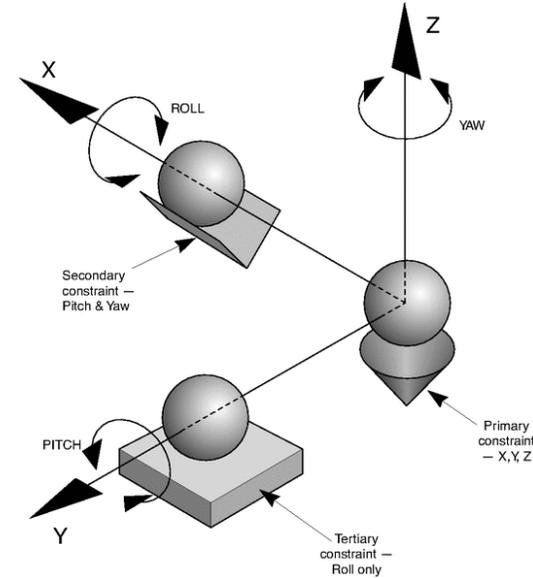


@isis
sis-neutron-and-muon-source



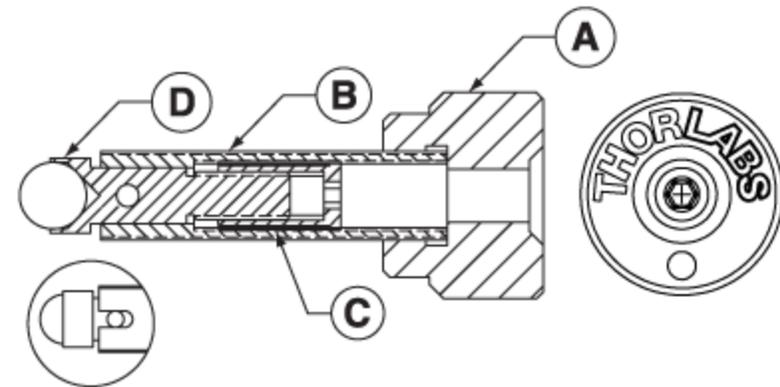
Kinematic Seats

- Stable tripod base - not over constrained
- Extremely repeatable
- Hardness important
- Maxwell vs Kelvin geometry
- Maxwell can be fully machined, or use rollers
- Balls can be mounted on screws for adjustability
- Secured using mass, magnets, cam lock, ...



Fine Adjustment

- Fine threads – 200 μm / rev
- Differential thread adjustment – 25 μm / rev
- Micrometer driven



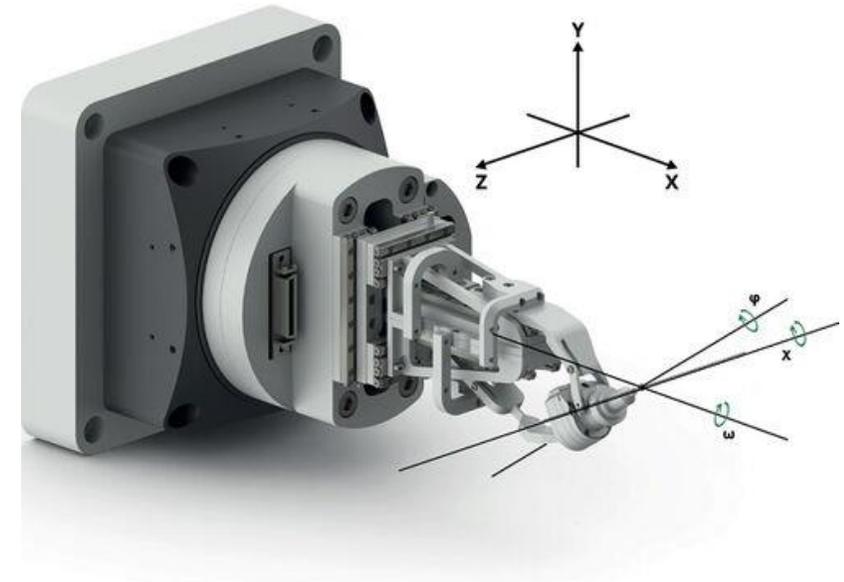
Sample Manipulation - Manual

- X, Y, Z linear stages
- Rotation stages
- Goniometers
- Order important!



Sample Manipulation - Automated

- Piezo / motor driven
- Kappa vs Eulerian
- Cryo / vacuum compatible – low load!



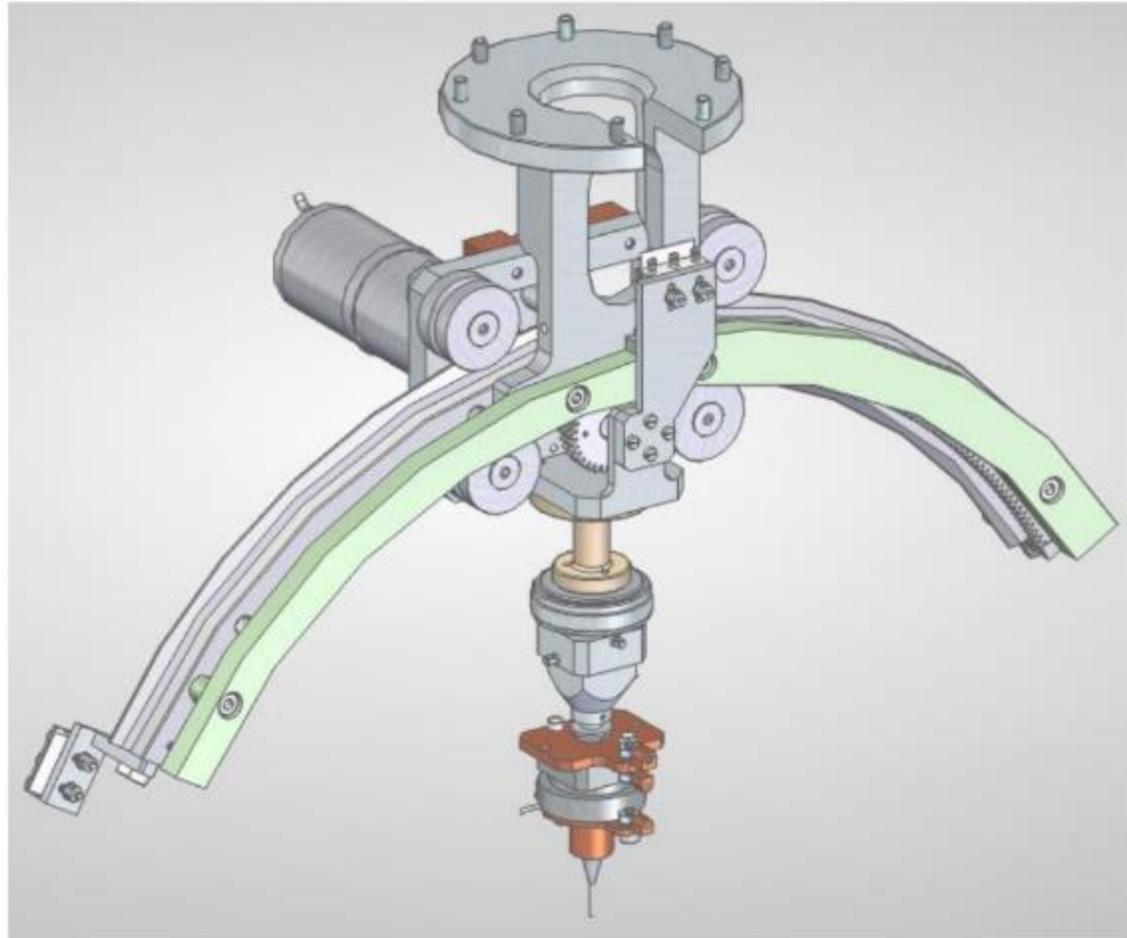
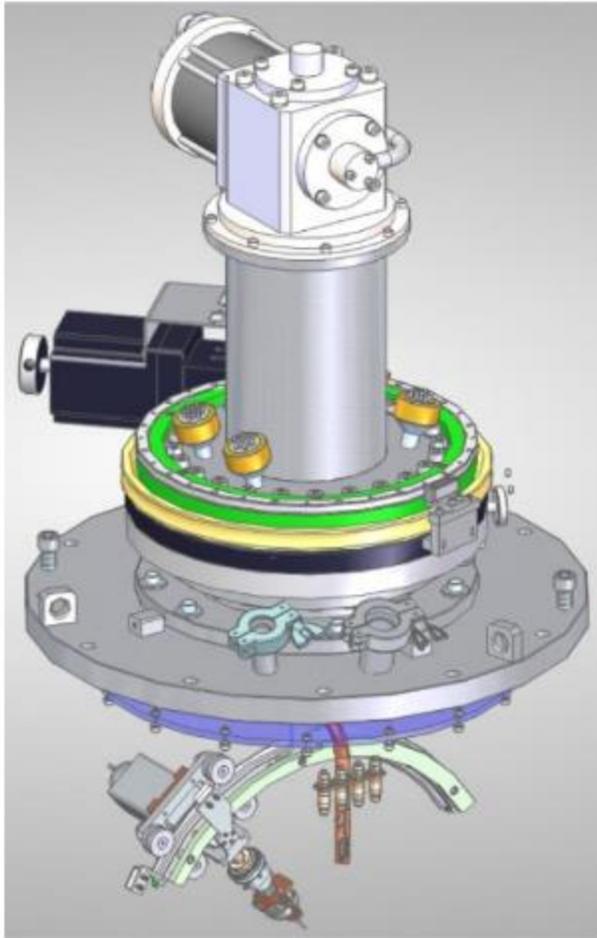
System Manipulation

- Rotary Platform
 - Manual or motorised
 - 360° rotation
 - DN40CF – DN200CF
 - Differentially pumped – UHV compatible
- Eulerian cradle at ILL
- X, Y, Z stage
 - + tilt / goniometer

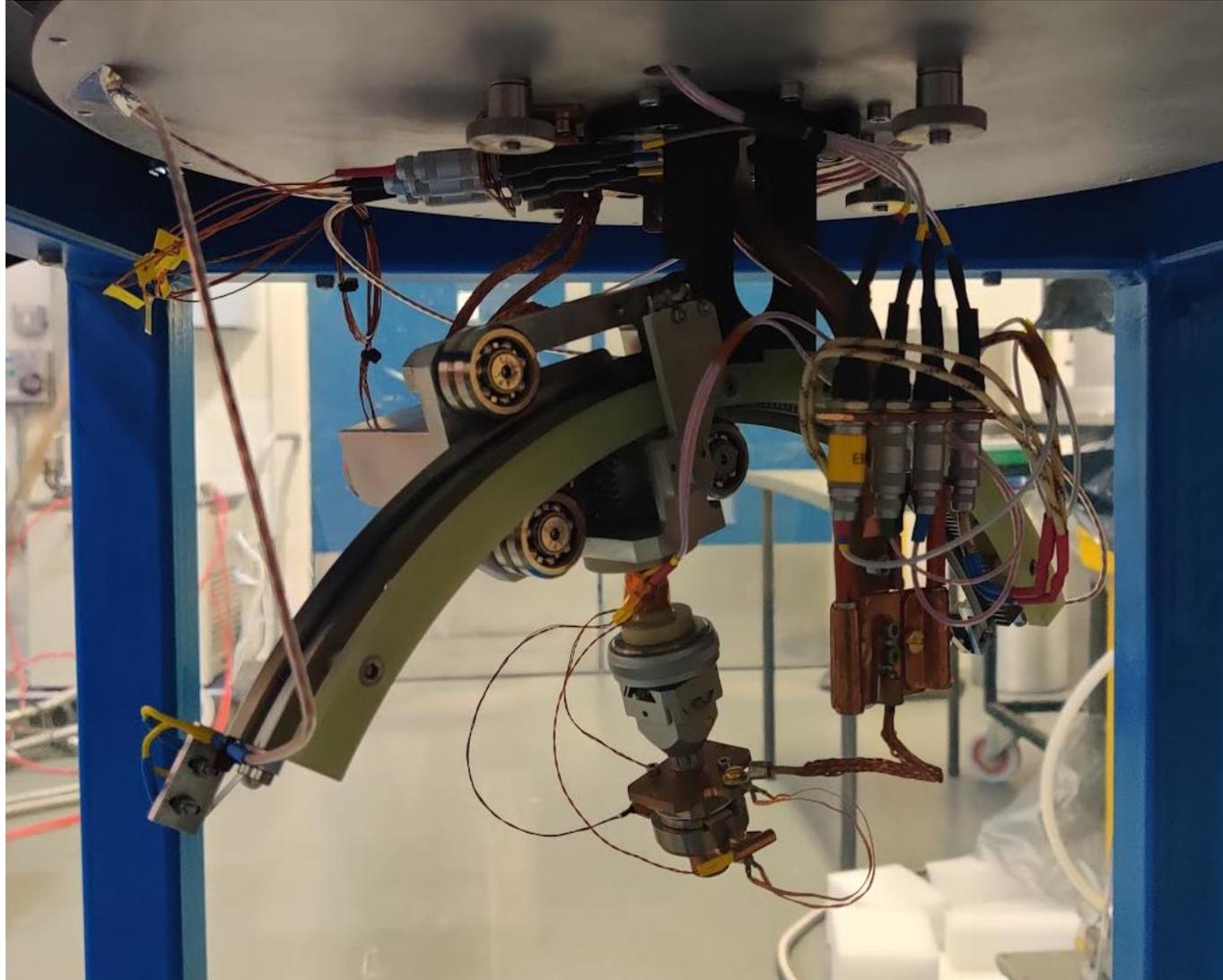


Cryo goniometer

- Or you try to make your own!



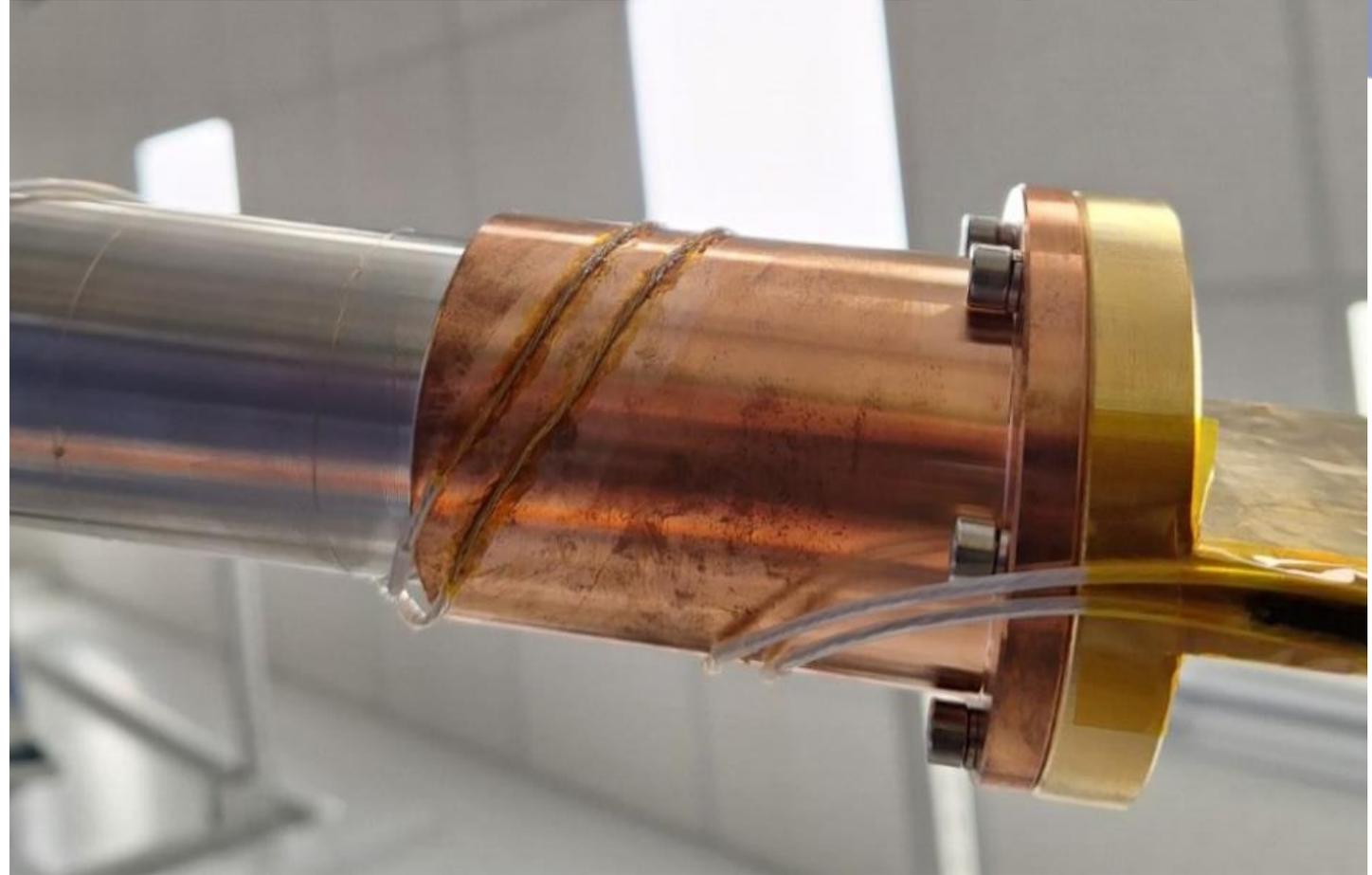
Cryo goniometer



Electronics

- Sensors
- Heaters
- Motion
- Electrochemical

- Leave room for wires!
- Internal wiring
- Thermal anchoring
- Standardise connectors
- Standardise pins
- Pinouts on drawings help



Design Phase

- Know what needs designing
- Done calculations
- Know where it needs to fit
- Performance metrics

- Now...
- Design for Manufacture
- Design for Assembly
- Design for Disassembly?!
- Accurate Assembly
- Safety

Design for Manufacture

- Someone has to make it!
- Manufacture
 - Appropriate methods
 - Number of operations
 - Sharp internal corners
- Tolerancing!
 - Tight – expensive
 - Loose – loose fits
- External radii or chamfers?
- CAD nominal vs mid-limit
- Unnecessary contours force CNC
- Threaded holes – fully dimension, tolerance
- Thread inserts in aluminium



Design for Manufacture



Design for Assembly

- Poka yoke
- Assembly order
- Tool access
- Tool sizes
- Tolerance stacks
- Clearances
- External chamfers save knuckles
- Glovebox assembly!

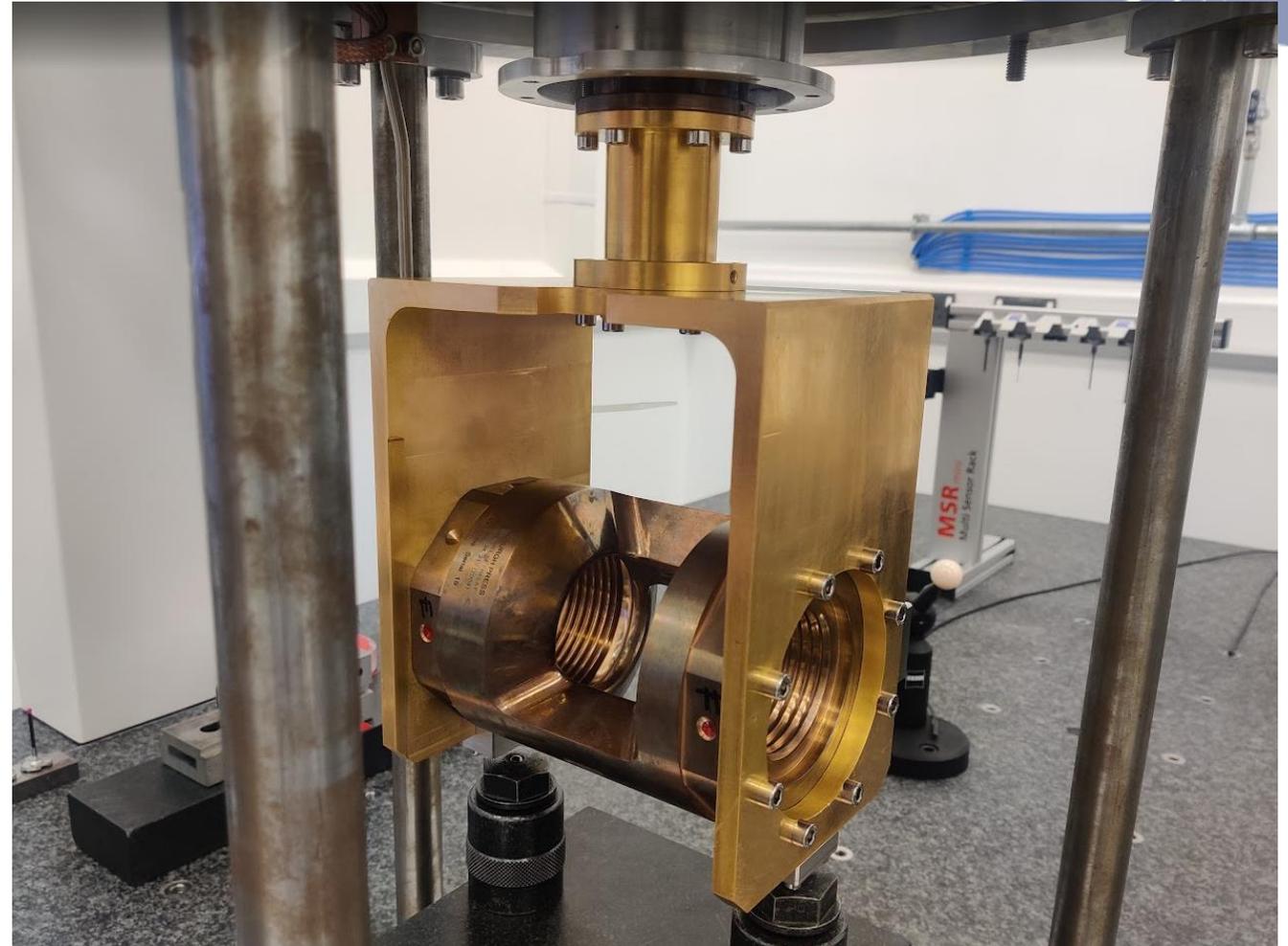
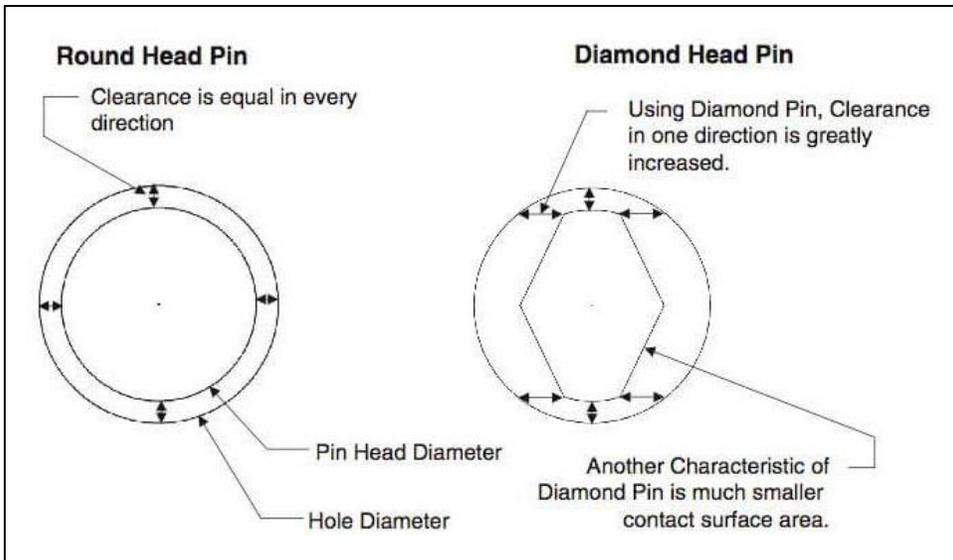
Design for Disassembly

- Jacking points
 - High temp cells
- Activated cells



Accurate Assembly

- Feature based
 - Recess + Boss
- Dowel pins
 - V. tight tolerance requirements
 - Diamond pins
- Metrology lab
- Metrology + dowel pins?



Accurate Assembly

Do not use threads for accurate assembly

Safety

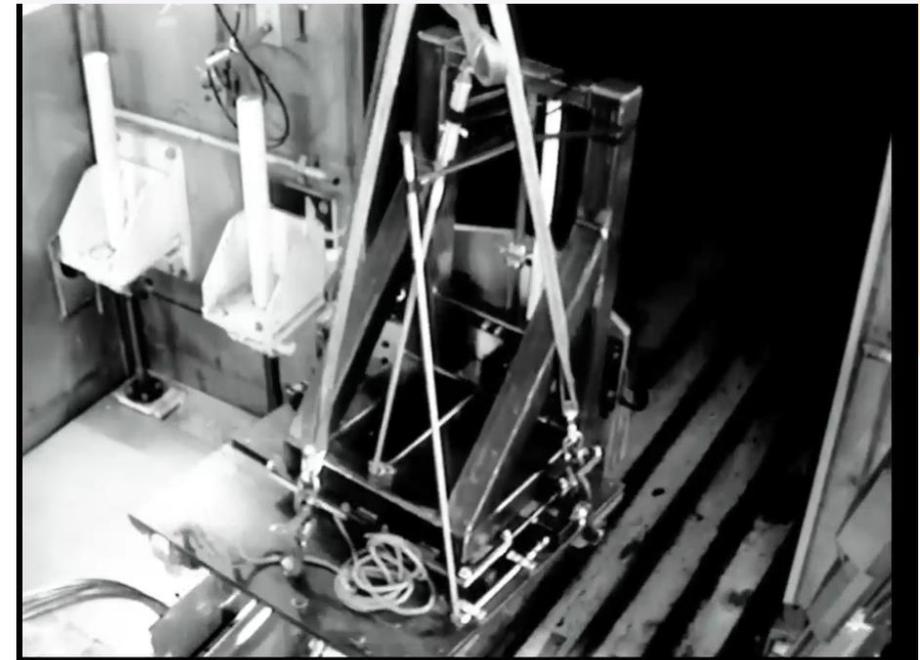
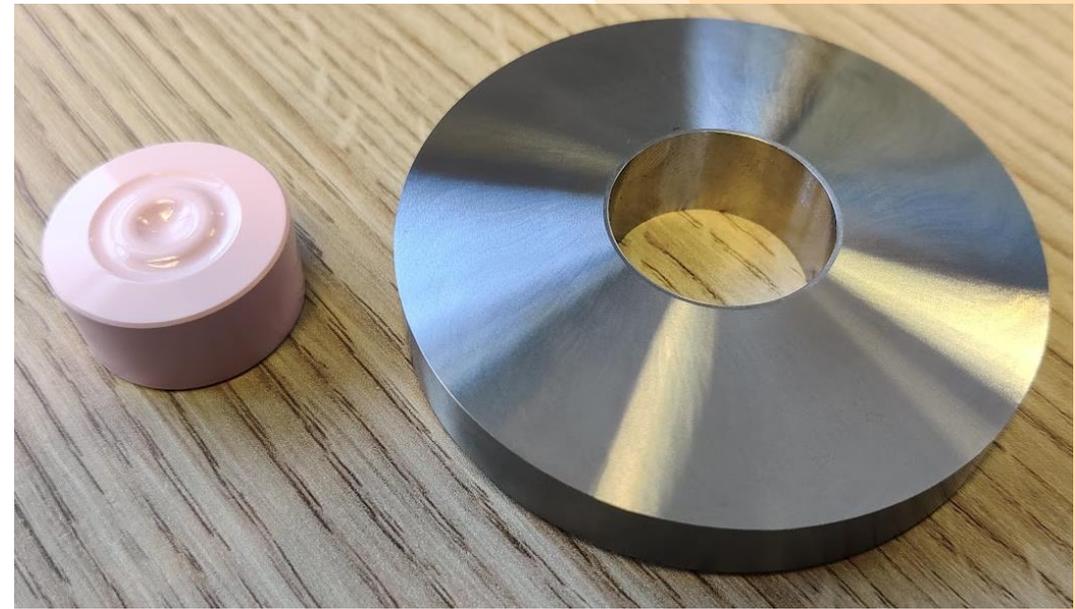
- Think about safety, there are a lot of risks:
 - Hot things
 - Cold things
 - Pressurised things
 - Vacuum things
 - Sharp things
 - Flammable / explosive things
 - High voltage things
 - Moving things
 - Magnetic things (even small magnets!)
 - Corrosive things
 - Poisonous things
 - Vibrating things
 - Heavy things
 - Radioactive things
 - Awkward things
 - Loud things
 - Asphyxiating things
 - Laser things

Safety

- Follow local regulations
 - Work equipment / machinery
 - Lifting
 - Pressure
 - Explosive Atmospheres
- Industrial standards / compliance
 - AFNOR, ANSI, ASTM, BS, DIN, EN, ISO, JIS, ...
- Design codes
- Safety factors
- FMEA
- Risk Assessments
- Method Statements / Procedures

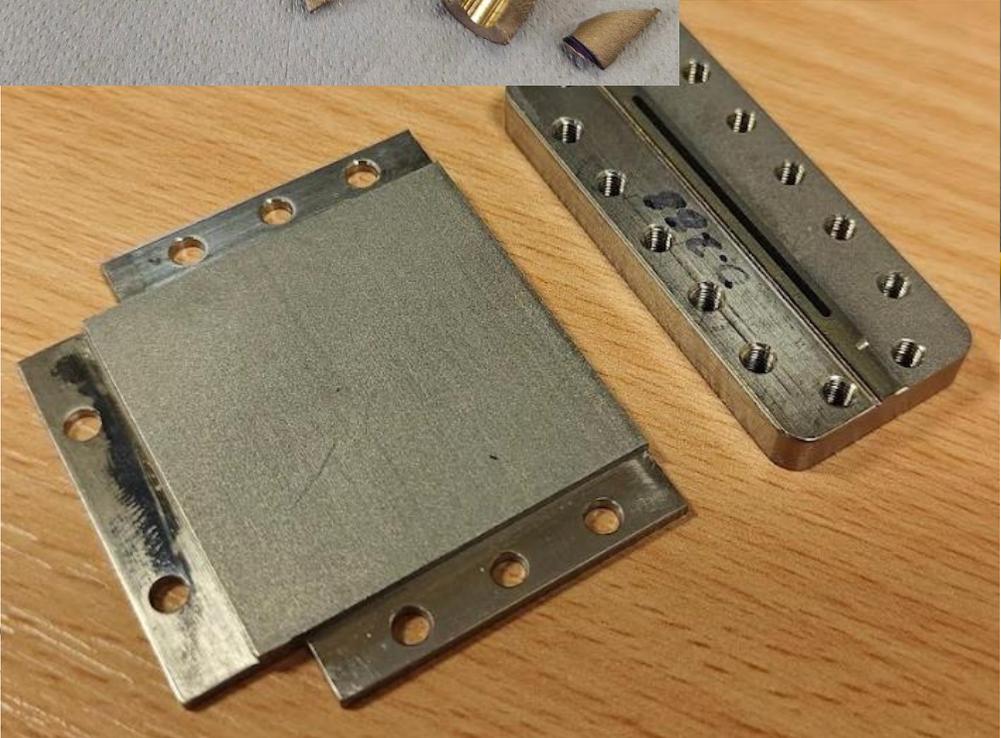
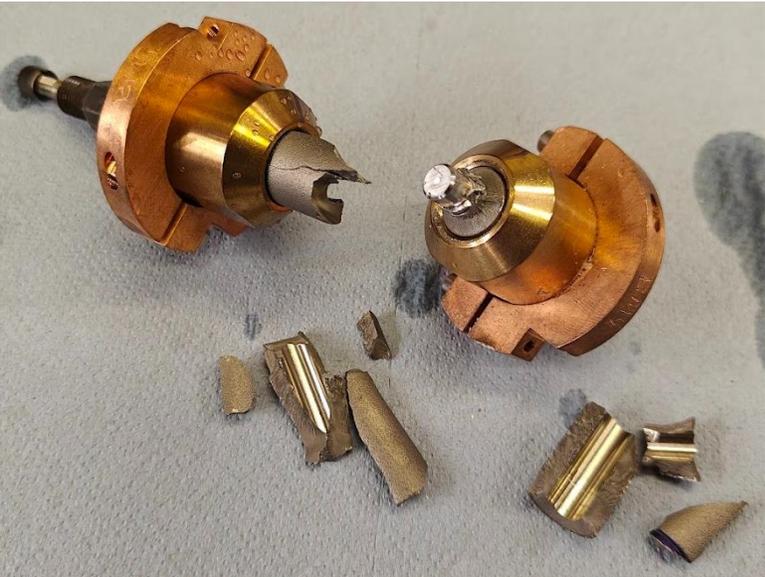
Things that went wrong Lessons Learnt

- Single sourcing
 - Companies close
 - Prices go up
- Users break things!
 - Especially wires
- Users steal things!
- Surfaces can be too smooth?
- Documentation matters
 - TS1 upgrade
 - TS1 trolley
 - Reproducibility crisis?



Things that went wrong - Lessons Learnt

- Fatigue, again. HRPD
- Decapitated TiZr cells
- Welds don't always work



Things that went wrong Lessons Learnt

- Okay the fatigue was worse than I said...
- TZM that shouldn't have exploded
- Niobium cell that turned to powder
- Rate everything! GEM



~~Things that went wrong~~ Lessons Learnt

- Ask stupid questions
- Document failures
- We're trying our best!