Summary T1 : Material choice and processing

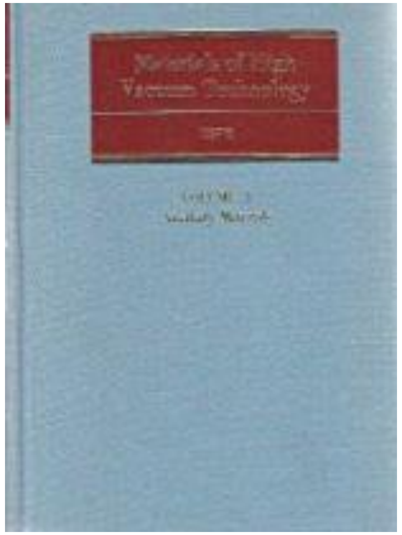
Beampipes for Gravitational Wave Telescopes 2023, Wed. 29/03 am

Conveners: Stefano Sgobba, CERN EN-MME

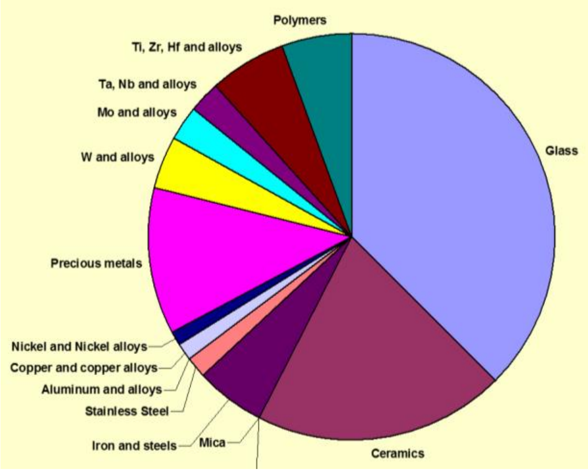
Daniel Henkel, Material Forensics LLC

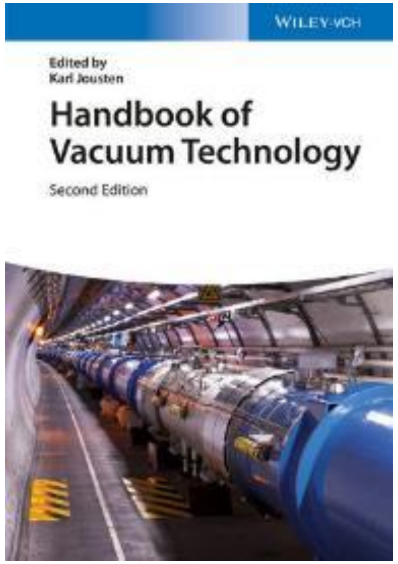
General considerations for material and process selection

- Ease of degassing
- Low intrinsic vapor pressure
- Low foreign gas content
- High gas tightness (leak rates < 10^{-9} mbar·l·s^{-1})
- Adequate strength at high as well as low T
- Thermal expansion coefficients
- High melting and boiling points
- Purity of the material
- Clean surfaces
- Corrosion resistance
- Exact knowledge of the material properties, critical selection, careful control
- Very constant properties of the raw materials, to be specially prepared
- Ease of fabrication, cost
- Iron and steels widely present in the 60ies. Stainless steel dominant today



Espe, Materials of High Vacuum technology, vol. 1, Pergamon Press, 1966





K. Jousten ed., Handbook of Vacuum Technology, Wiley, 2008-16

General rules for the selection of materials for vacuum technology

Microstructure of Mild Steels and Potential for Magnetite as a Passive Coating in CE, D. Henkel, Mon. 13:35 - 14:10

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Materials and their production processing for ET's beampipes, A.T. Perez, Mon. 14:10 - 14:35

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Design of beampipes for GWT	*Guillaume Julien Deleglise*	*30/7-018 - Kjell Johnsen Auditorium, CERN*	14:35 - 15:15
Coffee break		*30/7-018 - Kjell Johnsen Auditorium, CERN*	15:15 - 15:40
Vacuum challenges for next generation Gravitational Wave Telescopes	*Rainer Weiss*	*30/7-018 - Kjell Johnsen Auditorium, CERN*	15:40 - 16:00
Manufacturing and welding options	*Gilles Favre*	*30/7-018 - Kjell Johnsen Auditorium, CERN*	16:00 - 16:20
On-site production of quasi-continuous UHV pipes	*Marion Purrio*	*30/7-018 - Kjell Johnsen Auditorium, CERN*	16:20 - 16:40
Design of optical baffles and their integration in beampipes	*Mario Martinez-Perez*	*30/7-018 - Kjell Johnsen Auditorium, CERN*	16:40 - 17:00
Options for surface finishing of beampipes for gravitational wave telescopes	*Leonel Marques Antunes Ferreira*	*30/7-018 - Kjell Johnsen Auditorium, CERN*	17:00 - 17:20

Outcome, first remarks

- Consider sustainability ("Green Steel for Europe") of steelmaking process (ore v. recycled)
- Aluminum alloys to be included in the discussion
  - Long history as a vacuum material
  - Cost effectiveness
  - Suitable grades could be identified (EN AW 6061/82 – T6; EN AW 5083 - H111)
  - Was brought up at Livingston but found to be incompatible with other vacuum components
  - Valves, gauges, pumps, bellows… will remain in stainless steel
  - Need of bimetallic transitions
  - Welding solutions tbc for mass production (FSW)
  - Not suitable for ballistic resistance
- Otherwise discussion focused stainless vs. mild steel

Outcome, mild steel

- Standard oil pipelines produced in a massive way
- 450-600 miles of pipe orders are common, most typically 42” (1.1 m) diameter
- Starts with strip steel, spiral welding from inside and outside
- NDT (UT 100 %, RT, hydrostatic). Manufacturer provides complete QA record for each pipe
- In 2018/19, 47 MUSD for 50 miles delivered to the site (~1 MUSD/mile)
- Thermomechanically rolled
- Epoxy outer coating
- Any surface treatment could be applicable, some non-standard solutions will increase the cost

- Consider magnetite type passive layer on interior surface
- Stable over time? What does the surface of clean steel pipe look like after months or a year? Accelerated ageing tests may help understand corrosion kinetics
- Must determine protocol for uniform, stable layer
- Magnetite studies will have to determine the proper surface finish

- Importance of a reference state, to be maintained from pipe (or strip) production until installation, operation, venting etc.
- May be able to determine feasibility of obtaining a proper surface finish during final furnace process

Outcome, transversal considerations

- To be the most cost effective the product should be:
  - Hot rolled
  - Produced from a strip in a sufficiently wide dimension (-> spiral v. longitudinal welding)
- Importance of roughness, specially for mild steel: develop a know-how of the effects of surface finishing on vacuum performance
- We can customize surface finish through the manufacturer

- Epoxy on outer wall should provide sufficient leak protection
- Careful check of the pipe substrate prior to applying epoxy
- Expected to provide sufficient adhesion, including during baking, since it is fused

Onsite versus offsite manufacturing

- We have data to compare: LIGO beamtube was made on site; Virgo tubes were purchased, then shipped to site
- Onsite does not look applicable to mild steel pipes due to strength and thickness of pipe steel and downstream operations
- Some finishing operations (last welds, cleaning steps…) may be possible on site

- For stainless, onsite can be envisioned
  - Reduce transportation (costs, impact on environment)

- Optimal pipe production would be synchronous with the needs of the project
  - Avoid costly storage in densely populated areas
  - Cost of storage must be carefully considered
  - Effects of storage on properties of pipe must be understood

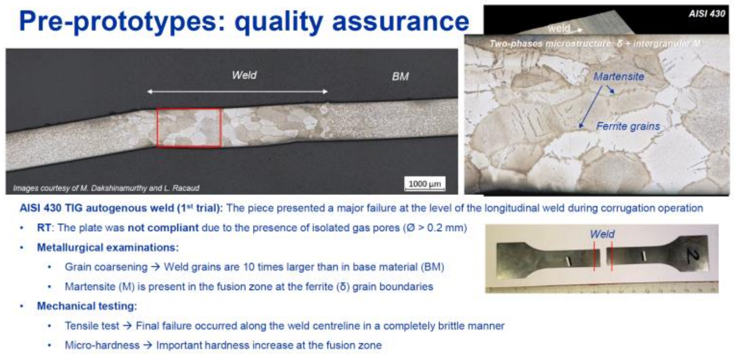
Off-the-shelf versus tailored/specified products

- For mechanical specifications, consider using ISO/API pipe standards
- For material specifications, consider customization of:
  - Composition to optimize (magnetite) passive layer
  - Max. hydrogen content?
  - Grainsize?
  - Inclusion limits?
  - Surface texture?

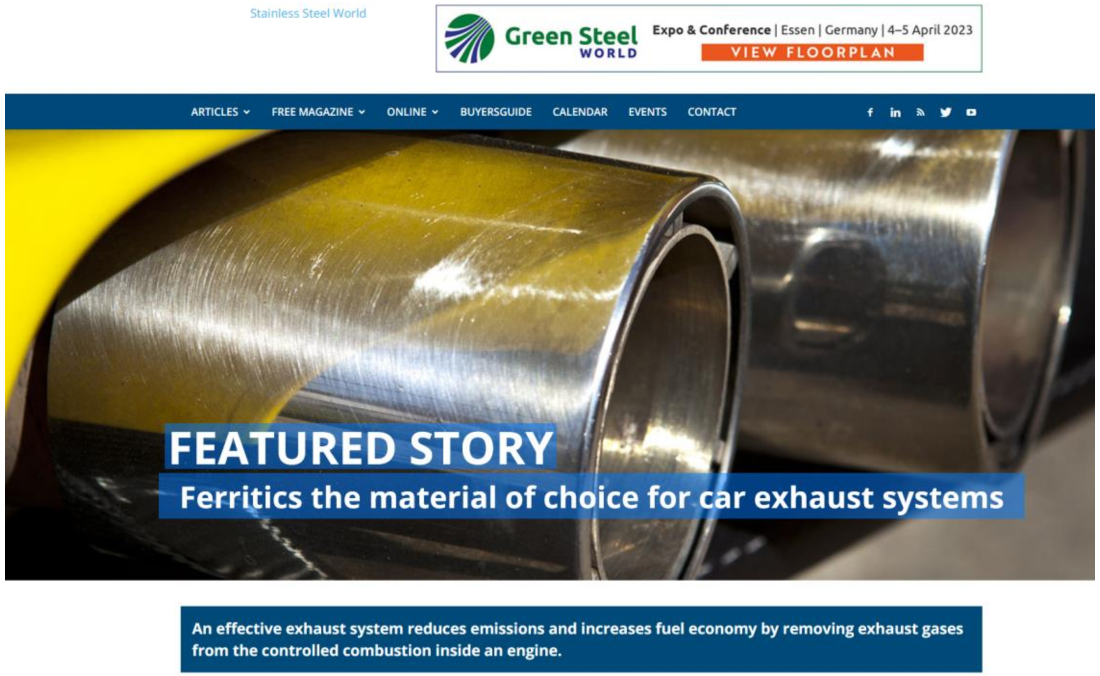
- Understand first what is strictly needed, off the shelf may be good enough…

- Avoid high strength mild steel grades unless strictly needed (weldability ⇓, hydrogen embrittlement ⇑)

Stainless steel solution(s)



- **Ferritic**
  - Issues with the weld test on AISI 430 at CERN, out of the shelf, bright annealed
  - Not to be generalised
  - Massive production of automotive exhaust pipes in ferritic grades (TIG, laser, induction) submitted to severe quality testing -> readily weldable
- Check for alternative grades (Aperam, AISI 441?)
- Surface texture?
- Permeation through thickness to be studied (ongoing)



- **Austenitic**
  - High H outgassing, requires firing
  - Firing on line following solution annealing?
  - Identify manufacturing facilities for large stainless pipes
- **Duplex**
  - Little advantage for H outgassing
- **200-series**
  - More expensive than ferritic, austenitic structure

Engineering
Department