Assessment of Mercury Storage Containers

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Outline of Assessment

1. Review Compatibility of Mild Steel and Stainless Steel with Hg
2. Identify Metallurgical Threats to "Perpetual" Hg Containment
3. Summary of Representative Metallographic Information from Examination of Flask Inventory

Assuring Compatibility of the SNS Target Components in Hg

Experimental Efforts

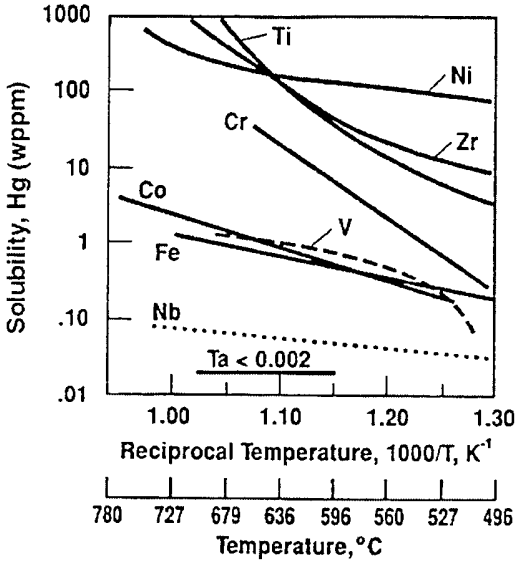
- Wetting / chemical compatibility
- Thermal gradient mass transfer
- Cavitation-erosion
- Embrittlement
  - assessment of tensile properties
  - evaluate fatigue properties / mechanisms
  - SCC of various materials (liquid and vapor)
- Support in-beam tests with metallography/SEM

Documentation (1998 – present)

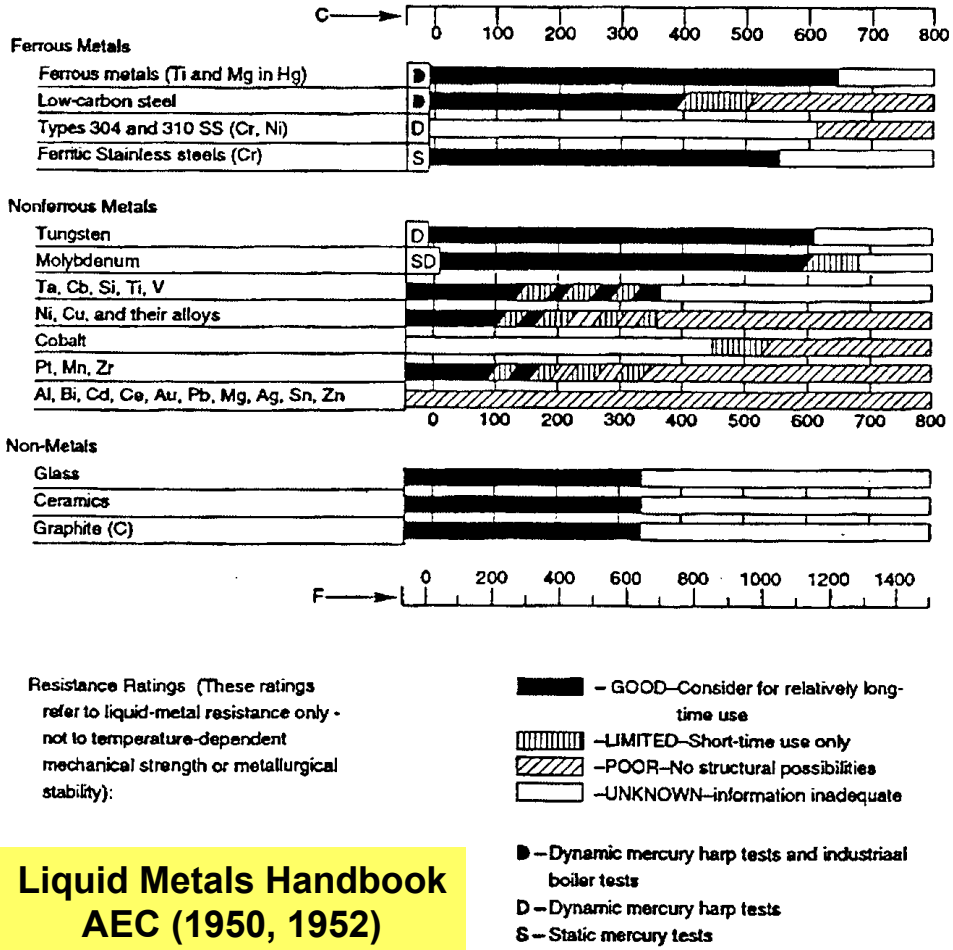
- 14 ORNL/TM reports
- 8 journal publications
- many topical presentations

Hg is Compatible with Iron and Mild Steel up to ~ 400°C

- immeasurably small corrosion rates near RT
- solubility of Fe in Hg << 0.1 ppm at RT
- Hg does not chemically wet steel at RT in the presence of air



Weeks (1967)



Liquid Metals Handbook
AEC (1950, 1952)

Evaluation of Flasks Confirms Absence of Steel Interaction with Hg

Following up to ~50 years service, no failures due to Hg observed among sampled flasks:

- **no gross failures patterns – only one among many thousands of flasks breached (fabrication flaw)**
- **absence of wall thinning below Hg level**
- **no pitting/cracking associated with Hg**

Primary Metallurgical Threats to "Perpetual" Hg Containment in Steel Flasks

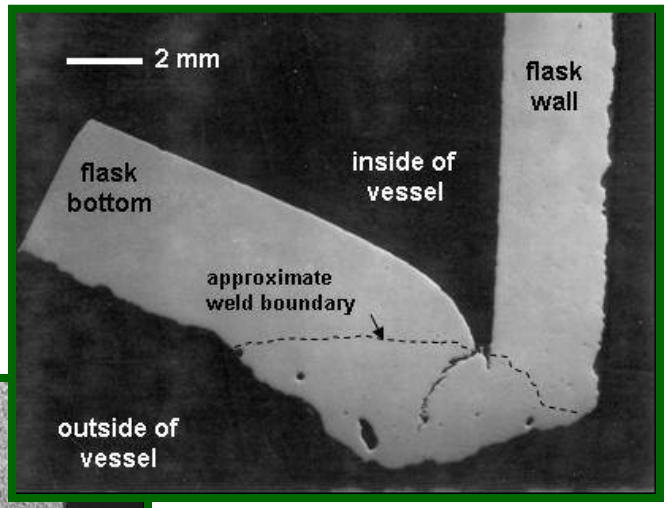
- External corrosion due to moisture/condensate
  - nominal atmospheric corrosion of steel ≤ 0.5 mil/y
  - increased time of wetness increases corrosion; avoid condensate collection

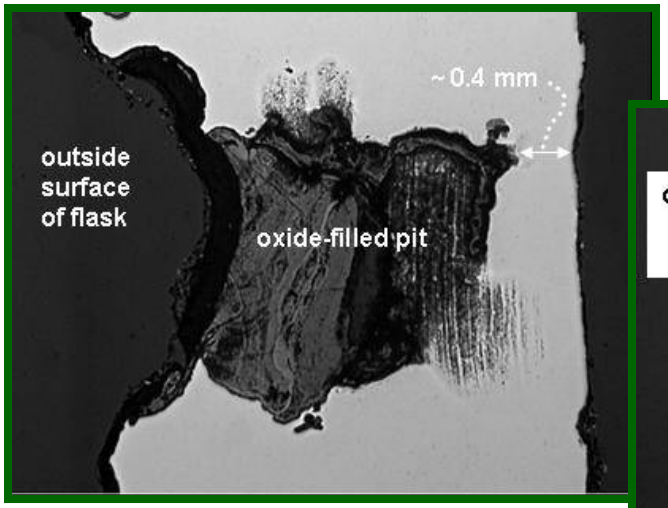
- Poor quality/improper welds
  - incomplete penetration, lack of fusion, slag inclusions
  - notches/cracks
  - welds embrittled by hydrogen or improper composition and/or welding technique

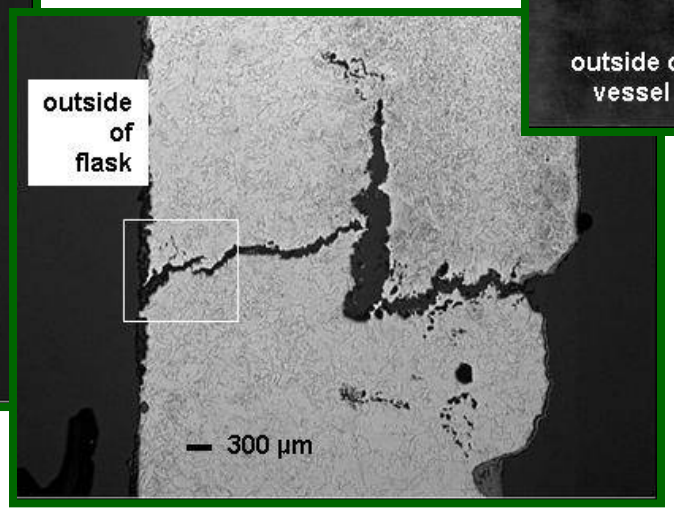
Evaluation of Existing/Aged Steel Flask Inventory

- Systemic defects with welded and forged joints identified
  - result from manufacturing errors and absent QA
  - fissures, porosity, slag inclusions
  - lack of penetration, improper joint alignment

- Some vessel types also exhibit substantial corrosion degradation from prior service
  - generalized wall thickness reduction
  - localized pitting, hydrogen blistering







Despite Shortcomings
Potential Utility as Static Storage Vessels Remains

- Only 1 of almost 129,000 found to have leaked in recent inspection
- External corrosion easily controlled
  - paint, mill-scale
  - indoor storage, natural ventilation
- Internal corrosion not a long-term degradation factor
  - steel immune to elemental Hg at modest temperatures
  - solubility of Fe in Hg is miniscule
- Surprisingly robust construction
  - hydrostatic test results indicate leak at > 100x pressure required for static storage
- Inspect after transportation/handling
- Re-flask or secondary containment for most distressed population

Conclusions for Long-Term Storage

- Mild steel and stainless steel containers immune to ~ pure Hg for anticipated exposure conditions and are appropriate for long-term storage

- Manage construction of new containers
  - require appropriate specifications and quality assurance
  - incorporate design considerations for handling and stacking as necessary

- Manage external corrosion

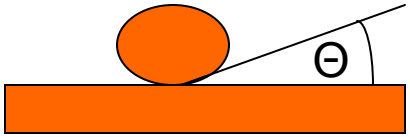
- At least until more information is available, avoid acceptance of “unknown” compositions of Hg

- Some older vessels may also be appropriate but evaluation and special handling or inspection may be required

Questions
And
Discussion

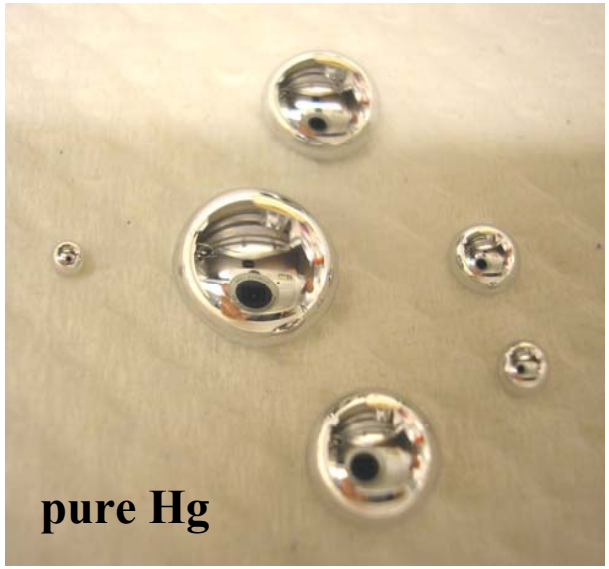
A few support slides
for SNS activities follow

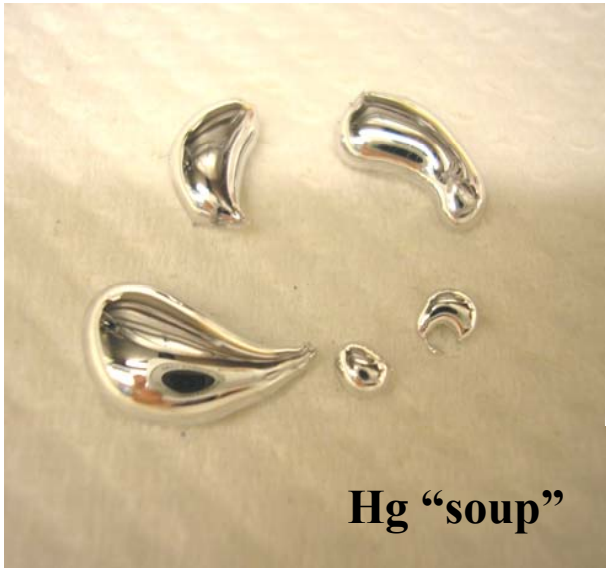
Wetting and Hg Chemistry



contact angle

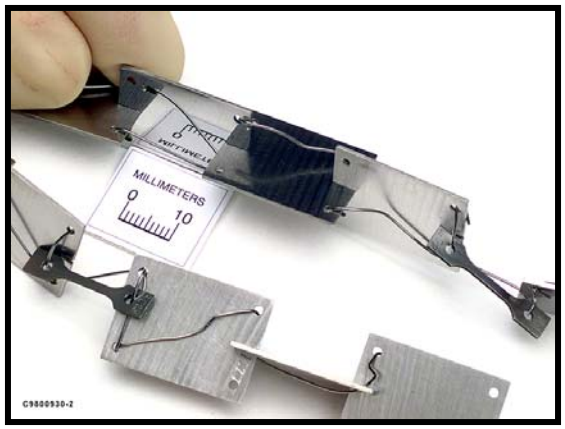
- Hg in contact with *many* engineering materials investigated
  - modest temperatures and/or presence of oxygen mitigate wetting
  - oxide films are barriers to interaction
  - solute affects Hg character but not wetting
- Cleaning with HgX (ultrasonically) effective

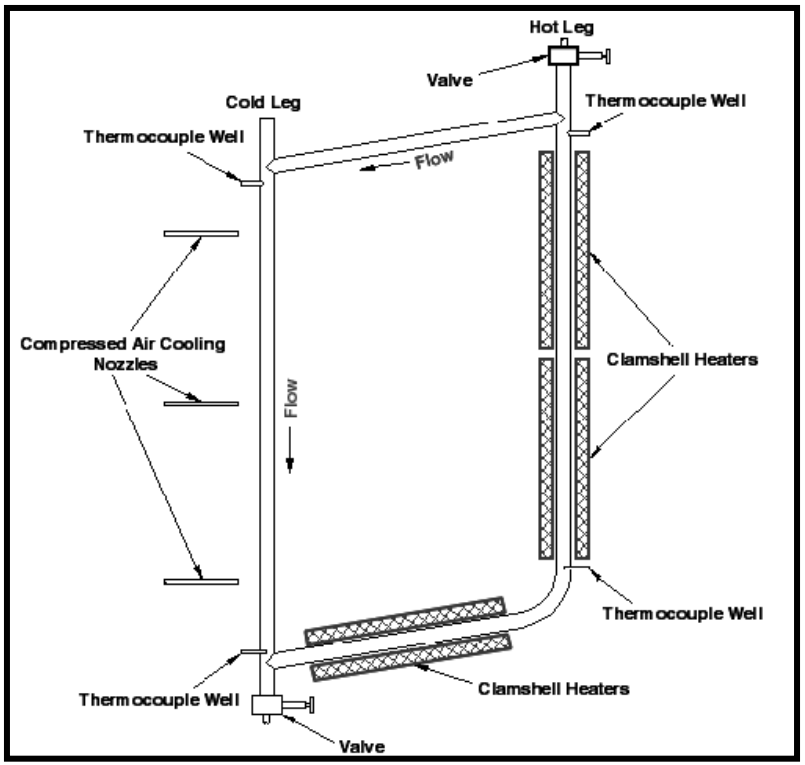

pure Hg

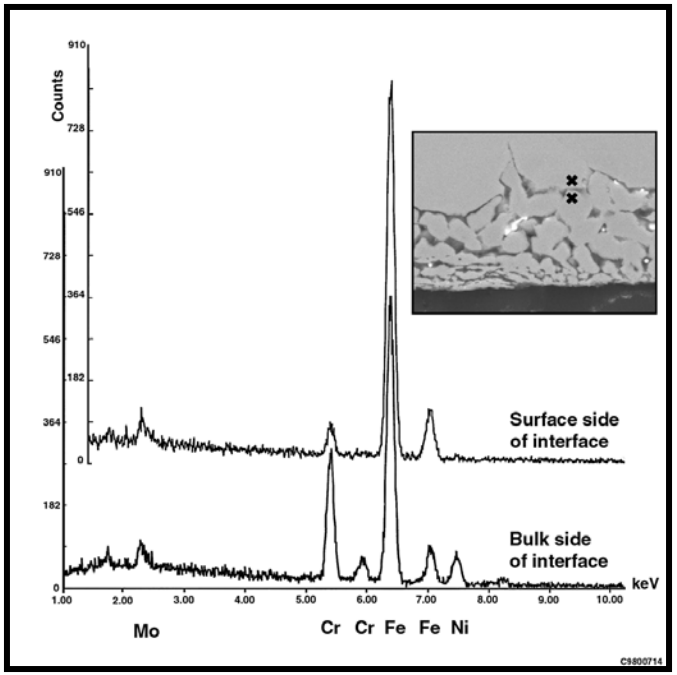

Hg “soup”

Thermal Gradient Mass Transfer – TCLs with Hg

- Stainless steels (~316L) immune to corrosion in Hg < 250°C
  - variety of compositions, heat treatments, surface conditions
- Above ~250°C, wetting and <u>minor</u> corrosion (Cr, Ni leaching)

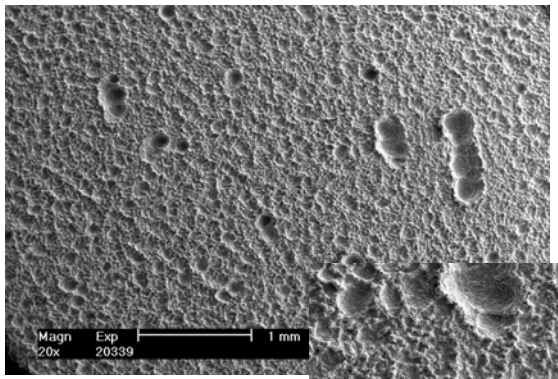


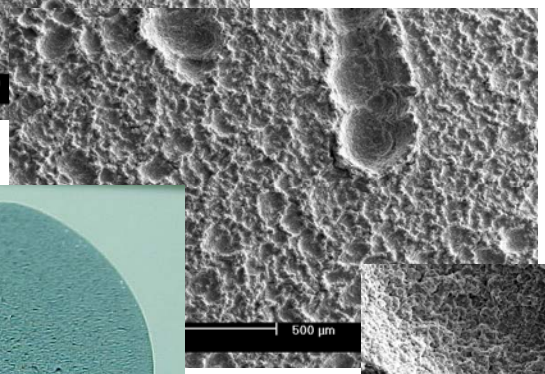


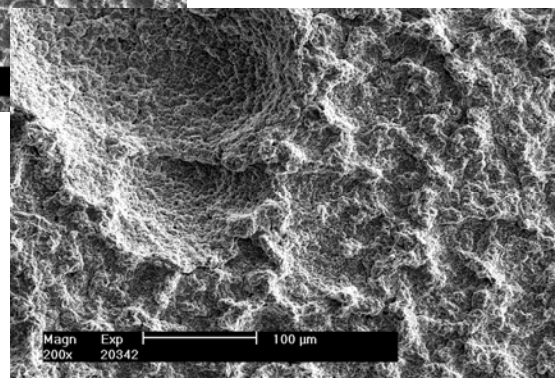


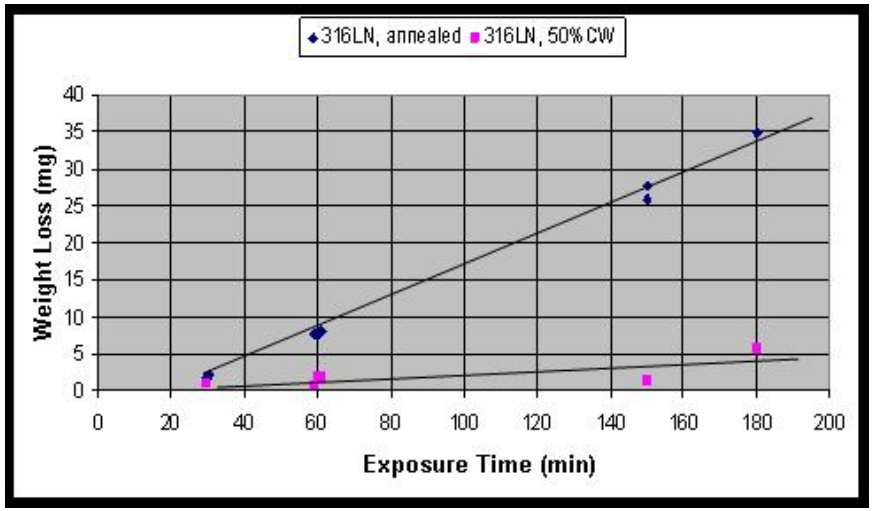
Cavitation Testing for Target Development

- annealed material has little resistance to cavitation-erosion
- cold work and/or carburizing surface treatments very effective
- hardness AND toughness of surface are critical factors
- cavitation conditions generate chemical wetting









Assessment of Potential Embrittlement in Hg

- for stainless and other resistant alloys, standard mechanical properties unaffected; fatigue life shortened and fracture mode changes at high stress
- aluminum readily cracks, pits