# ARIES-AT
# MATERIAL OPTIONS FOR STABILIZING SHELLS

***I.N. Sviatoslavsky***

**Presented by Lester Waganer (Boeing)**

**Fusion Technology Institute**
**University of Wisconsin, Madison WI**

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# *Subjects Covered*



- **Material options for the ARIES-AT stabilizing shells**

- **Properties such as resistivity, thickness, with and without cladding and mass per toroidal cm, as functions of temperature**

- **Cooling options**

- **Recommendations**

# *Material Options for Stabilizing Shells*

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**Requirement as specified by C. Kessel (PPPL):**

**Assuming 400 C the required thickness for W is 5.5 cm to keep plasma vertical instability growth time in the right range.**

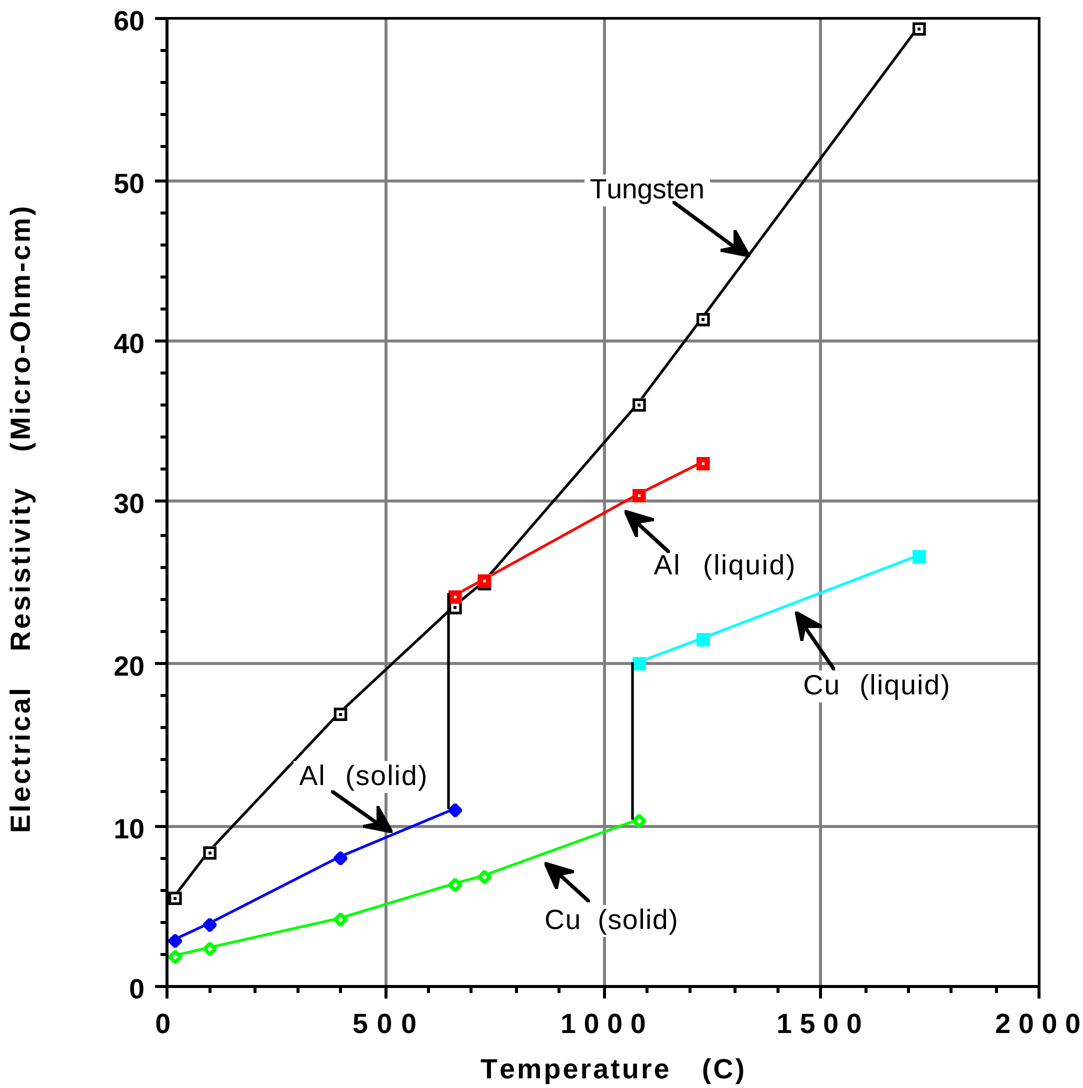
**What are the options**

**Tungsten:** **High temperature refractory metal, high resistivity, high density ($\rho$ = 19.3 g/cm$^3$), potential for radiative cooling**

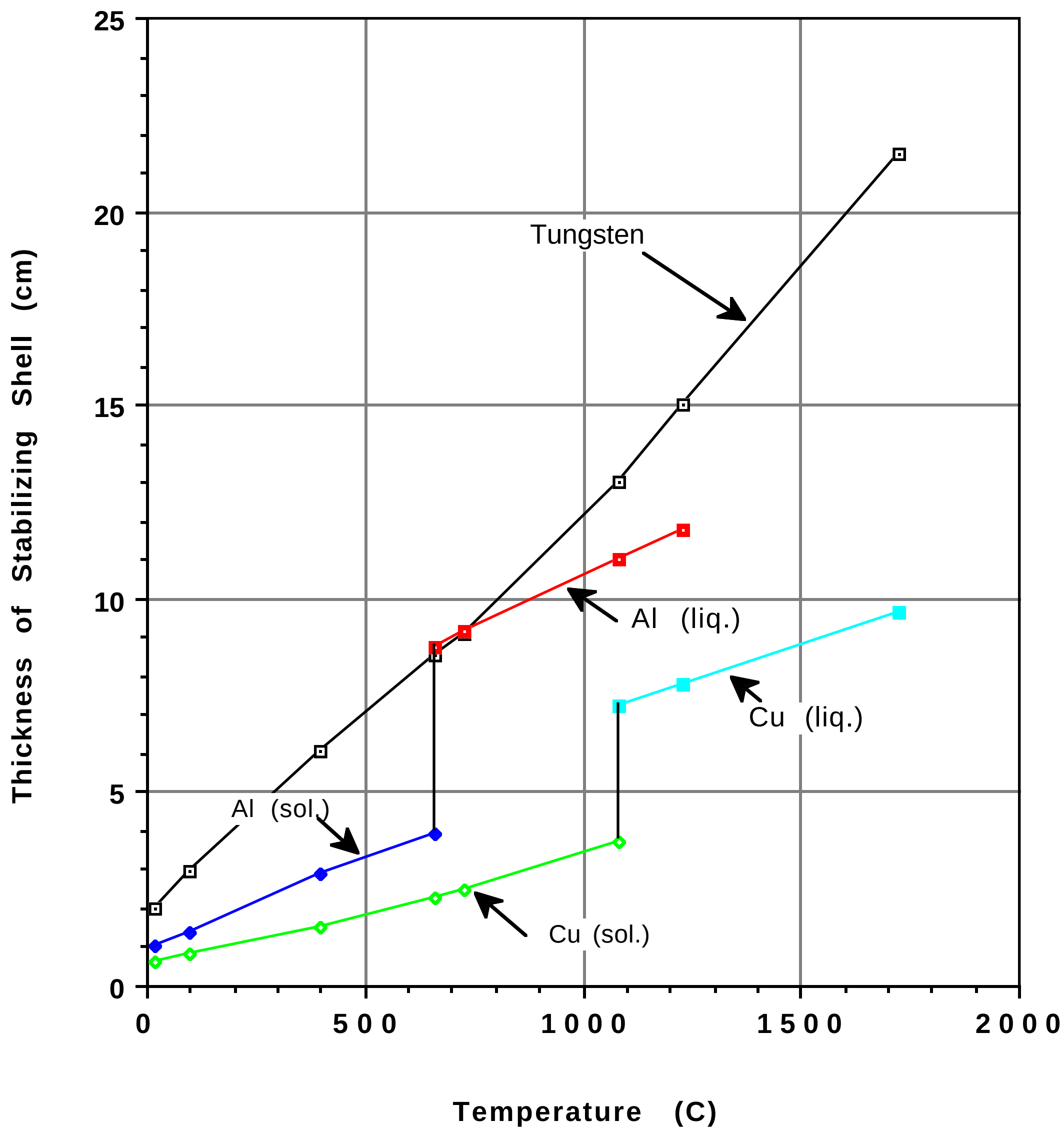
**Aluminum:** **Low temperature in solid form, high temperature in liquid form, liquid form resistivity comparable to W, low density ($\rho$ = 2.7 g/cm$^3$), requires a cladding material in case of LOCA/LOFA**

**Copper:** **High temperature both solid and liquid form, resistivity lowest of all, roughly 50% of Al and much lower than W, medium density ($\rho$ = 8.9 g/cm$^3$), in solid form suffers from radiation embrittlement, and resistivity increase with radiation, may require cladding in case of LOCA/LOFA**

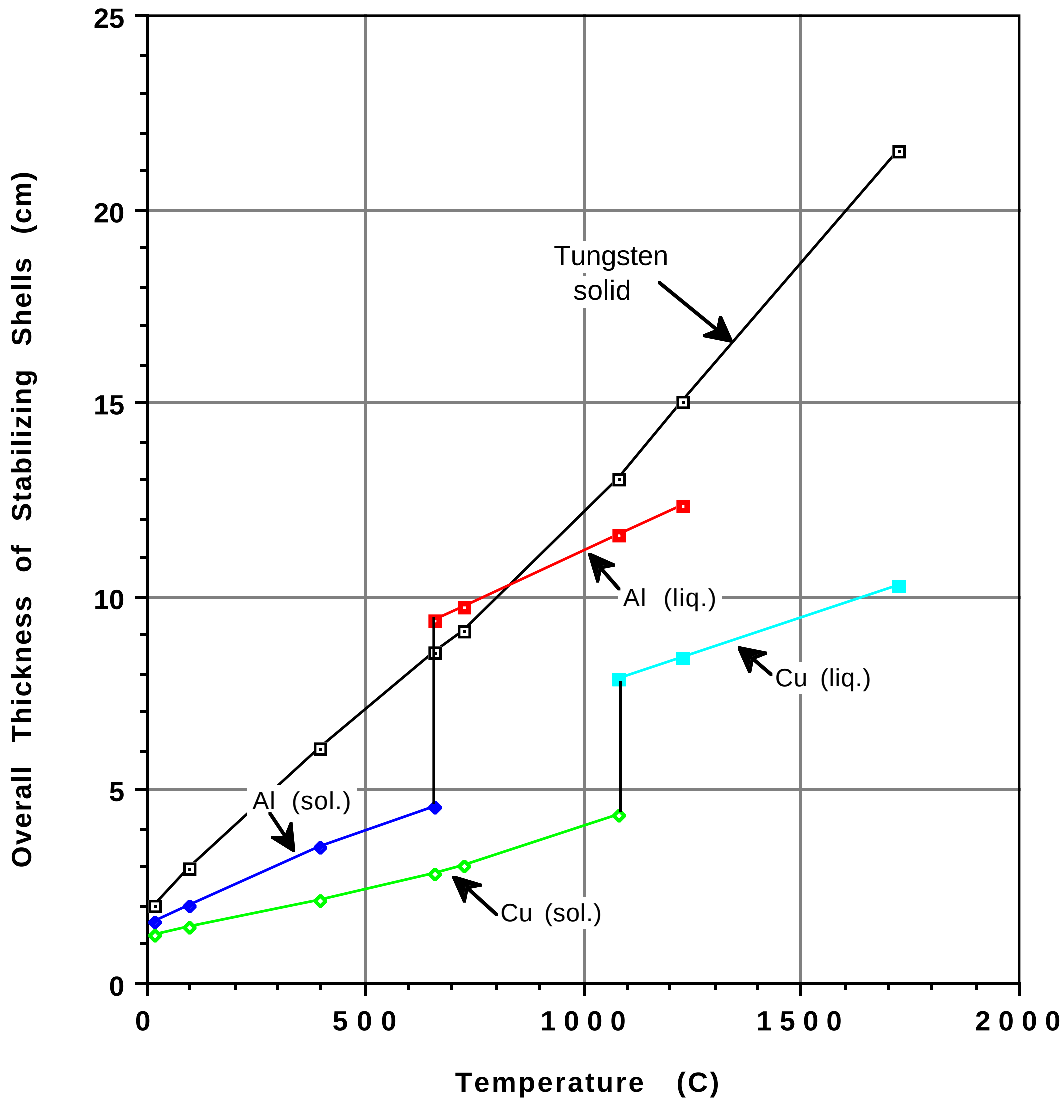
**Electrical Resistivities of solid W and solid and liquid Al and Cu as functions of Temp.**



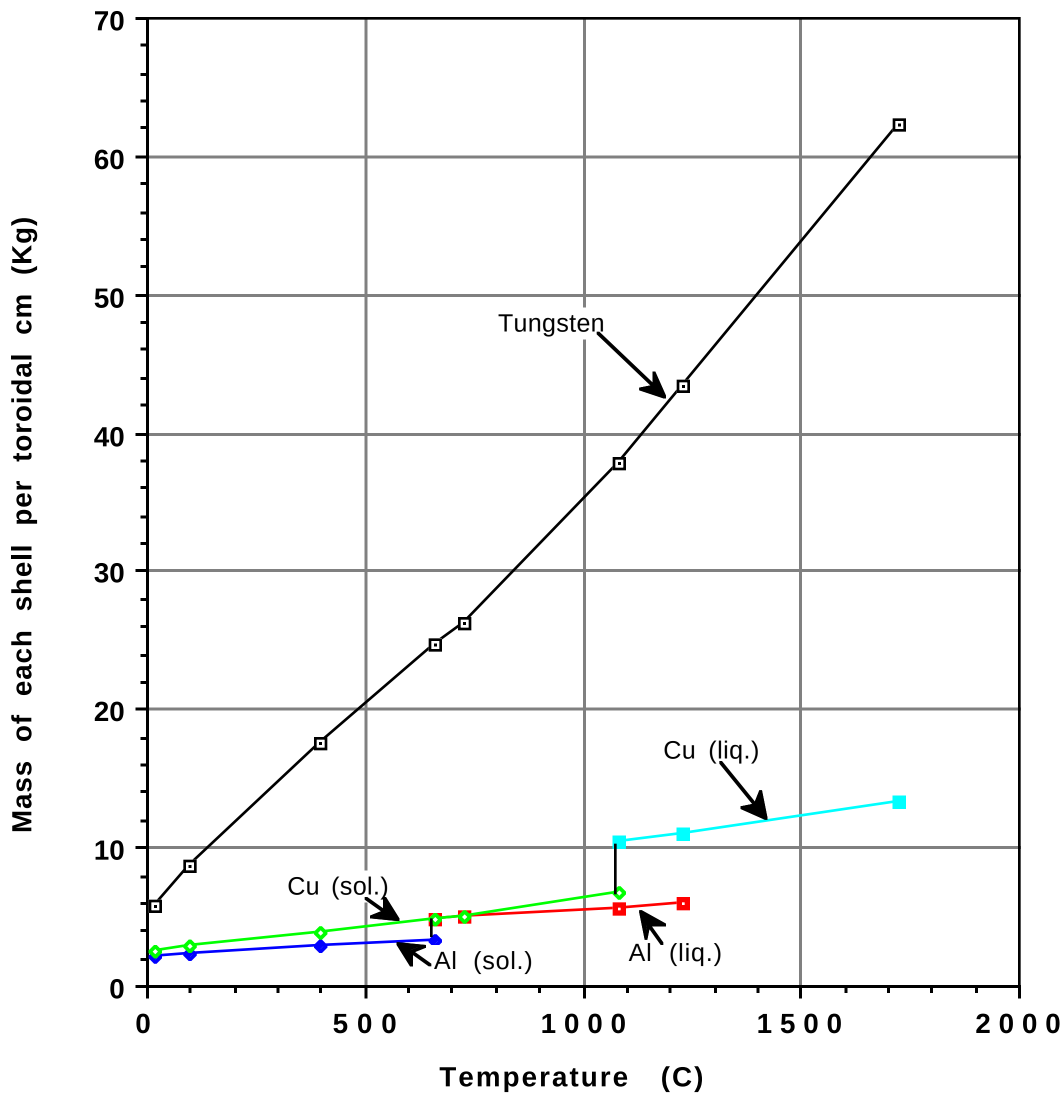
## Thicknesses of Stabilizing Shells Exclusive of Cladding Material



## Overall Thickness of Stabilizing Shells with a 3 mm Cladding Thickness on the Al and Cu



## Mass of Stabilizing Shells (Kg) per Toroidal cm Including Mass of W Cladding



# *Trade Study*

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| | Temp. Range (C) | Shell Thickness w/o Cladding (cm) | Cladding Required | Shell Thickness w/ Cladding (cm) | Mass of Shell kg/cm (tor) | Cooling Options |
|---|---|---|---|---|---|---|
| **Tungsten** | **200 – 1400** | **4.0 – 17.5** | **No** | **N/A** | **11.0 – 50.0** | **Water cooling**<br>**He or LiPb cooling**<br>**Radiative cooling possible** |
| **Aluminum (Solid)** | **200 – 600** | **2.0 – 3.8** | **Yes** | **2.6 – 4.4** | **2.2 – 3.2** | **Water cooling**<br>**He or LiPb cooling** |
| **(Liquid)** | **700** | **N/A** | **Yes** | **9.2** | **6.2** | **He or LiPb cooling**<br>**Compatible with W or Mo cladding up to 700 C** |
| **Copper** | **200 – 1000** | **N/A** | **Yes** | **1.7 – 4.0** | **3 – 6.2** | **Water cooling**<br>**He or LiPb cooling** |
| **(Liquid)** | **1100 – 1300** | **N/A** | **Yes** | **8.0 – 8.5** | **10.8 – 11.2** | **He or LiPb cooling**<br>**Compatible with Mo cladding up to 1300 C**<br>**Radiative cooling possible** |

# *Recommendation*

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***First Option:***

- **Liquid Cu in Mo cladding at 1300 C. Mo tubes cooled with He or LiPb. Investigate radiative cooling. 8.5 cm thick and 11.2 kg/tor·cm.**

**Radiation effect: Ni has a melting point of 1455 C and Co 1495 C.**
**Zr has a liquid density of 6.48 g/cm$^3$ compared with Cu which is 8.2 g/cm$^3$.**
**Ni and Co will precipitate as solids and Zn will segregate by gravity. With the absence of these transmutants, the resistivity will not change.**

***Second option:***

- **W at low temp. 200 C – water cooled, 4 cm thick, 11 kg/tor·cm**
  **400 C – He cooled, 6.1 cm thick, 17.5 kg/tor·cm**