LA-UR-16-20863

Approved for public release; distribution is unlimited.

Title:	Target Housing Material Options
Author(s):	Woloshun, Keith Albert
Intended for:	Report
Issued:	2016-02-11

Target Housing Material Options

K. Woloshun

4/26/11

With gas cooling, heat transfer coefficients are low compared to water. The benefit of gas from a heat transfer point of view is that there is really no upper temperature limit for the coolant, as compared to water, which is limited ultimately by the critical point, and in practice the critical heat flux. In our case with parallel flow channels, water is limited to even lower operating limits by nucleate boiling.

So gas can get as hot as the containment material will allow, but to get the density and heat transfer up to something reasonable, we must also increase pressure, thus increasing stress on the containment, namely the front and back faces.

We are designing to ASME BPVC, which, for most materials allows a maximum stress of UTS/3. So we want the highest possible UTS. For reference, the front face stress in the 12 mm target at 300 psi was about 90 MPa. The inconel 718 allowable stress at 900°C is 1/3 of 517 or 172 MPa. So we are in a very safe place, but the uTS is dropping rapidly with temperature above 900°C. As we increase target diameter, the challenge will be to keep the stress down. We are probably looking at keeping the allowable at or above the present value, and at as high a temperature as possible.

Currently we are running targets in air. In the plot of Figure 1 is shown the UTS of various steels that can be run in air. Clearly, inconel is far better than austenitic or ferritic (T91) steels.

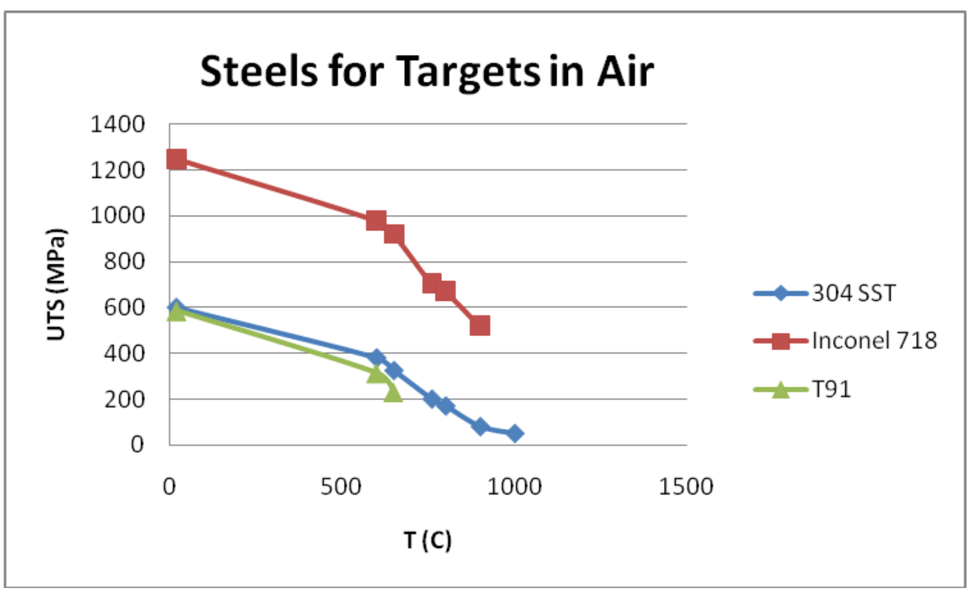

Figure 1. UTS of steels as a function of temperature.

The field of candidate materials broadens if the target is in vacuum. This allows for the possible use of refractory metals and their alloys. In Figure 2 is shown the UTS of various options. the tungsten-nickel-iron alloy values are a limiting (high) example of the family of such alloys, including this with copper (i.e. W10Cu, W20Cu, etc.). The Mo46Re alloy is by far superior in UTS in the neighborhood of 1000°C. the other obvious choice is TZM (almost pure Mo, but with a bit of titanium and zirconium). TZM is more likely to be available and will definitely be less expensive. For comparison, the steels and refractoriy metals are combined in one chart in Figure 3.

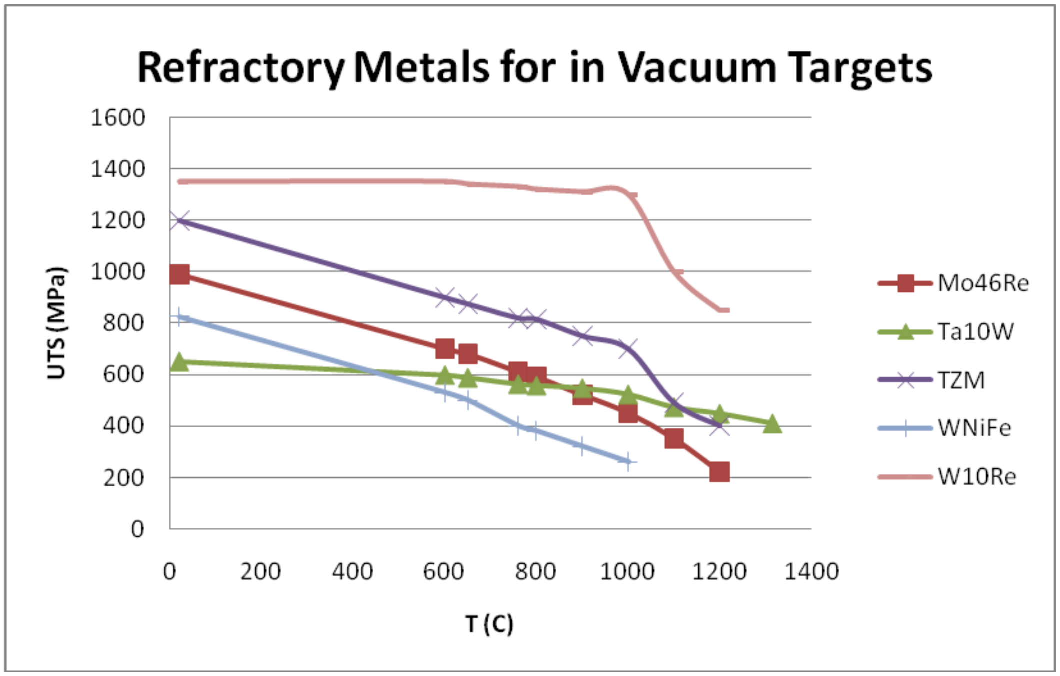

Figure 2. Refractory metal alloy UTS as a function of temperature.

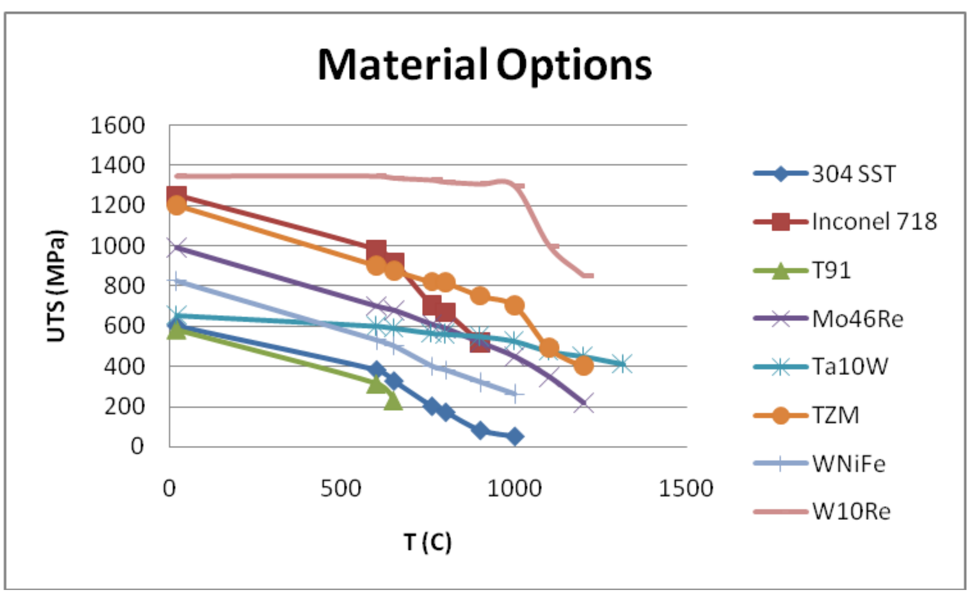

Figure 3. All metals, UTS as a function of temperature.

Assuming that a housing can be designed for the plant target beam and target diameter within an allowable stress of 180 MPa, inconel 718 is limited to about 900 C. A satisfactory design is probable, but is yet to be proven, for inconel, either in air or in vacuum. If refractory metals are to be considered, TZM and Mo-Re alloys are excellent candidates in principle. Availability and cost of material must be investigated.

The refractory metals all oxidize exothermically above some temperature in the range of 500 to 600°C (more or less). So any refractory target housing at or near 1000°C must be kept at all times in high vacuum (10^{-6} torr of better).

Note that there has been no optimization of target design up to now. Operating pressure, gas velocity , geometric configuration and other factors can be adjusted in addition to selecting the material. The possibility of water cooling the faces has been suggested. Another approach may be to shape the gas flow so that the faces preferentially get higher flow velocity than the central part of the target, thus increasing face cooling without increasing the overall gas mass flow rate.