Water Erosion Experiment Update

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Motivation

- ISIS water cooled tungsten targets are clad with tantalum to avoid tungsten corrosion problems that occur when in direct contact with water
- Evidence of tungsten has been found in the TS2 water circuit suggesting that there may have been a failure of the cladding

Several possible reasons for the trace of tungsten in the cooling water are under investigation -

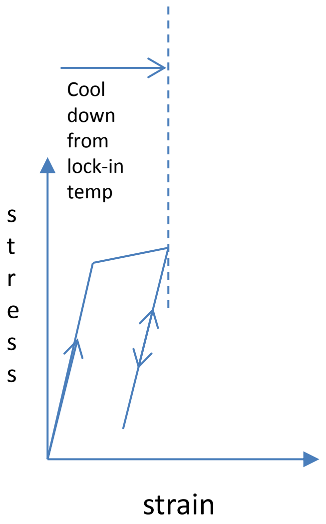
1. Tungsten deposited on the tantalum cladding during the manufacturing process is released into the water

2. Potentially significant plastic deformation of the tantalum during the hipping process

3. Significant beam induced cyclic strain resulting from 25K temperature jump per pulse

4. Water Erosion of tantalum at TS2 water velocity

Tantalum erosion resistance is also of interest for
-upgrades to TS1,
- and for more general interest,
SNS target 2 and ESS backup solution



Experiment

Aim – Investigate the resistance of tantalum cladding and tantalum coatings to erosion by high speed water cooling

Method – Use an impinging water jet to generate accelerated erosion rates

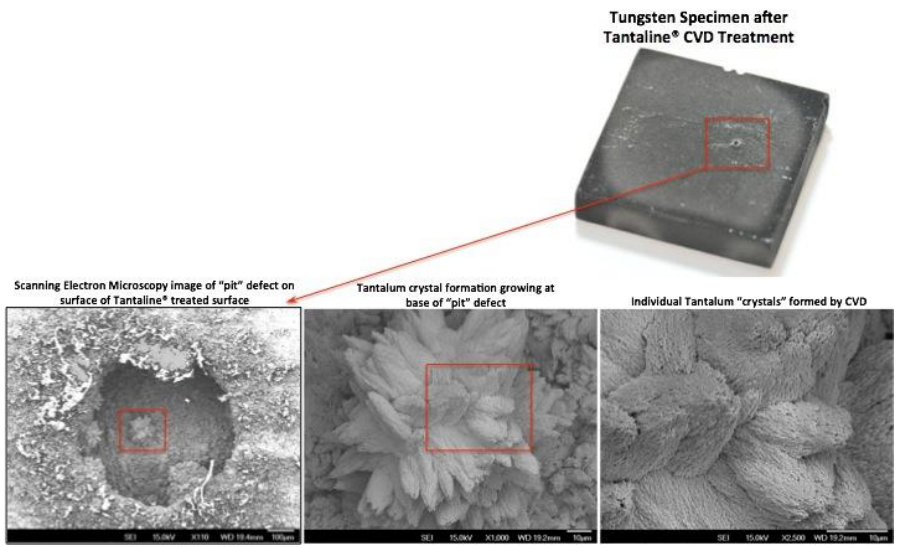
Outputs –

- Erosion rate vs water impingement velocity.
- Erosion rate vs water temperature.
- Erosion rate following acid exposure (hydrogen embrittlement).
- Comparison of erosion resistance of tantalum cladding and coatings.

Coating methods to be tested

Tantalum Hot isostatic press

Tantaline – chemical vapour deposition



Cold Spray

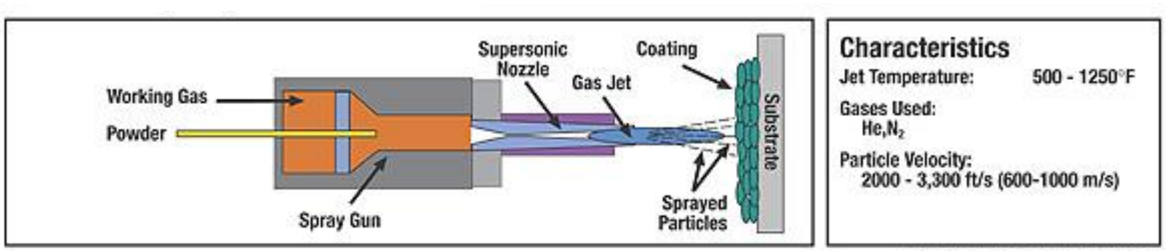
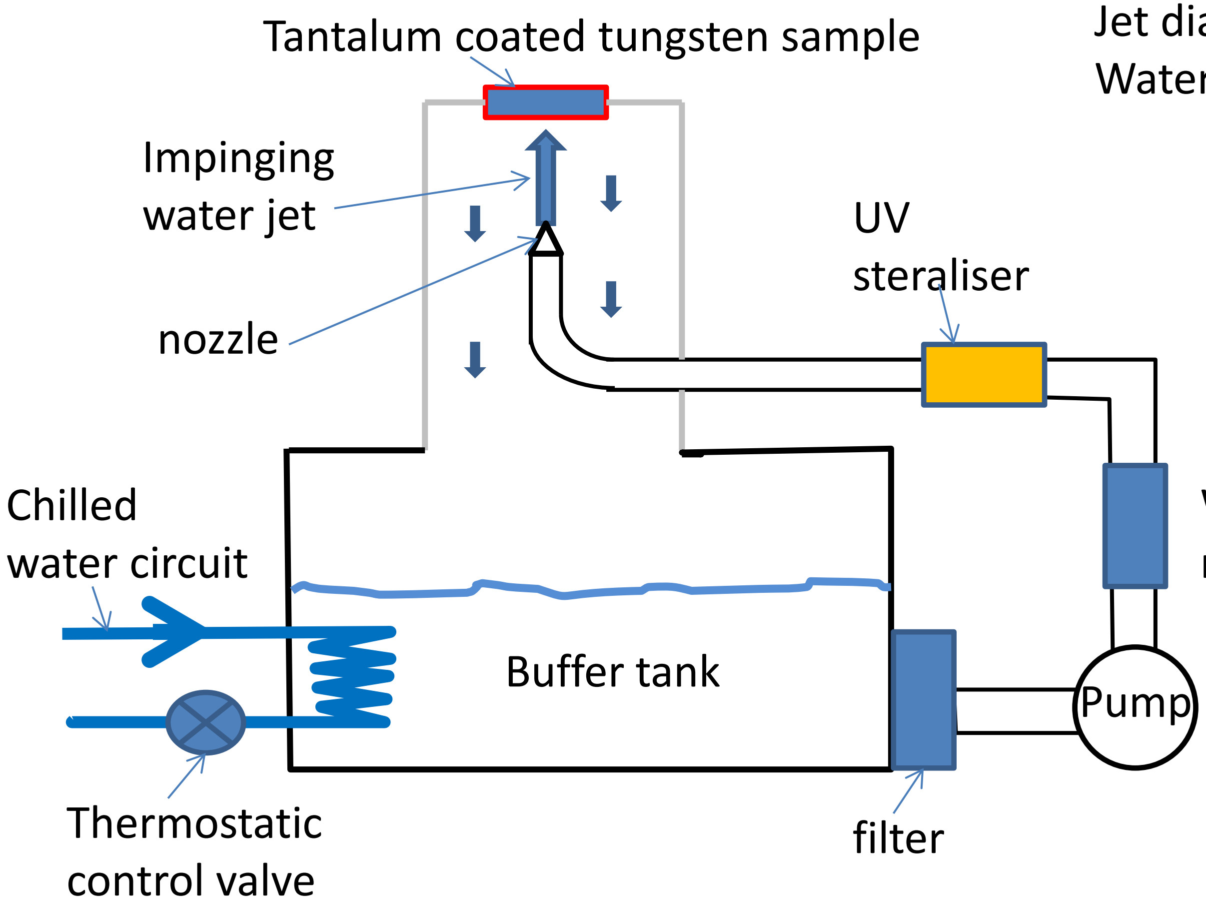


Photo Courtesy of ASB Industries

Silicon carbide coating

Water Erosion Rig

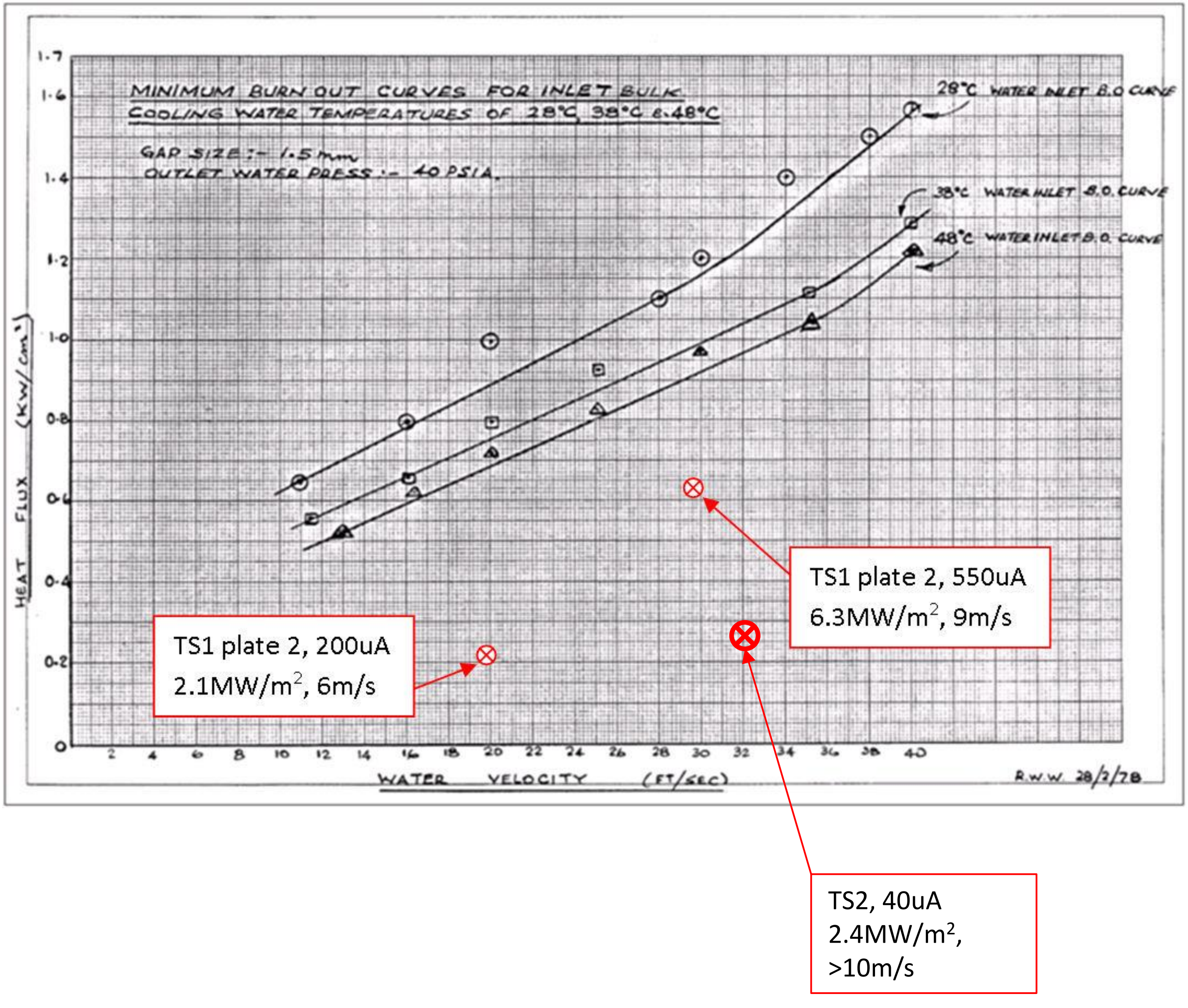
Jet diameter < 10mm
Water velocity: 1-50m/s



Status

Rig almost completely assembled – expect initial runs before christmas

Risk mitigation 2: Can water velocity be reduced?



Tantaline cvd

- **How is Tantaline applied?**
- *The* ***Tantaline process*** *is based on alloy bonding and chemical vapor deposition technology (CVD). Unlike coatings that are dipped or sprayed on, the Tantaline process actually vaporizes tantalum metal and then grows the tantalum metal onto the base material to create a* ***tantalum surface alloy.*** *The surface treatment is independent of geometry so internal and external surface could be treated.*

7. What is the thickness of the surface treatment?

- *The thickness of the surface that we find most efficient for most applications is 50um (0.002”). However depending on the application, thinner or thicker thicknesses are possible.*

Cold spray

- **Cold Gas Dynamic Spraying (CGDS) also known as Cold Spray is an emerging coating deposition process, which is recognised as a complementary technology to well established Thermal Spray processes. In cold spray high pressure gas is utilised to slightly heat up and accelerate the particles to supersonic velocities (400 – 1000 m/s). During impact at the substrates high kinetic energy of particles induces plastic deformation and localized flow of particle and substrate materials. This permit to form well adhered dense coating with unique mechanical, chemical and electrical properties.**
- **Moreover, due to minimised influence of thermally induced stresses in the coating and high deposition efficiency of the process, Cold Spray allows to deliver very thick coatings (several mm) or 3d objects in a cost-effective way.**
- **Number of various materials could be successfully sprayed with Cold Spray, i.e.:**
- **Pure metals (copper, aluminium, zinc, silver, nickel, niobium, tantalum)**
- **Alloys (Steels, Ni-alloys, Ti- alloys, MCrAlY's,)**
- **Composites (Cu-W, Al-SiC, Al-Al2O3)**

Tantaline Chemical vapour deposition process
'potential low stress alternative to hipping'

Tantaline's Surface Alloy Technology Through the evolution of acid resistant tantalum coating technologies **Tantaline's Tantalum Suface Alloy Technology** has been developed. This technology has the capability of producing very repeatable and consistent pinhole free surface of pure tantalum metal at thicknesses between (50um - 200um). Tantaline is geometry independent because it utilizes a gas phase process. The Tantaline process occurs on an atomic level virtually eliminating the chance of creating voids and oxide inclusions which allows Tantaline to creating a 100% dense, ductile and stress free surface.

Tantaline is the highest performing most corrosion resistant material availabe. With higher corrosion resistance than **nickel alloys, Hastelloy C276, titanium**, **zirconium**, gold and **tantalum metal** at costs that beat them.

Thermal Stability of Tantaline - Thermal Cycling

Ten samples were cycled 100x by heating in an oven to 250C (482F) and then quenching in room temperature water. After 100 cycles the samples were analyzed and compared to the baseline sample. The tantalum surface as well as the 316 stainless steel substrate are in excellent condition and show no signs of defects or distortion that may typically be seen on traditional coatings that are thermal cycling. This result was consistent on all ten samples.

Comparison	Tantaline Alloy Bonding	Clad	PVD Coating	Cold Spray Coating	Thermal spray Coating
Minimum layer thickness for corrosion protection (mm)	0.01	1.00	0.50	0.50	0.50
Coating of narrow holes possible	YES	NO	NO	NO	NO
Alloy zone between base and surface	YES	NO	NO	NO	NO
Risk of delamination	LOW	HIGH	HIGH	HIGH	HIGH
Risk of under corrosion	LOW	HIGH	HIGH	HIGH	HIGH
Tension level in the surface	LOW	LOW	HIGH	HIGH	HIGH
Risk of cracks in deposited tantalum	LOW	HIGH / LOW	HIGH	HIGH	HIGH
Net shape parts can be handled	YES	NO	NO	NO	NO
Large Installation can be handled	NO	YES	NO	YES	YES
Performance / Price ratio	GOOD	POOR	POOR	POOR	POOR

Bond Strength

Baseline adhesive samples range from 10000 - 12000psi. This is the force needed to fracture the adhesive.

Tantaline samples failed at 11,282psi and 12,307psi.

Tantaline usually applied to steel (SNS currently undertaking a study of bond strength when applied to tungsten)

No literature found on water erosion of tantalum or maximum allowable water velocity.

Proposed exchanging results with David McClintoch and Bernie Riemer at SNS

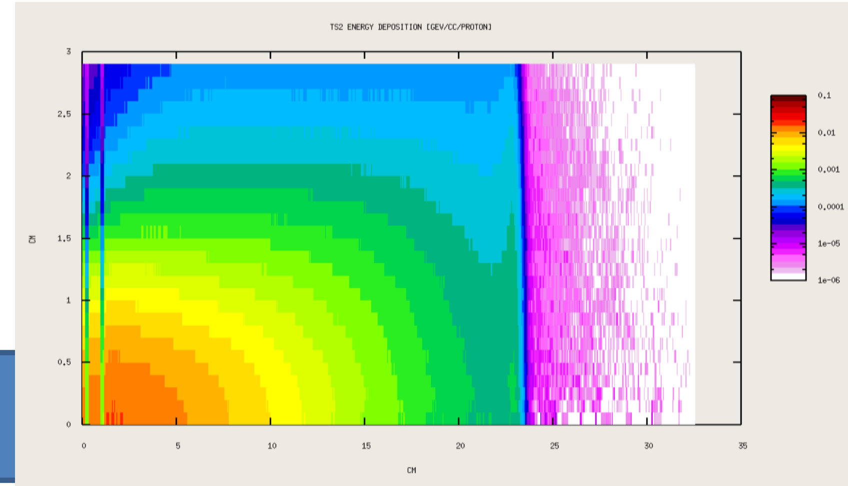
Mitigation of current TS2 target risks

1. Investigate if beam size can be increased
2. Investigate erosion resistance of tantalum cladding and tantalum coatings to determine if water erosion is a problem (guidelines for water velocity in copper pipe are well known, very little information available on tantalum),

- if erosion not a problem consider alternative thinner low stress tantalum coating
- if erosion is a problem propose reduced water velocity design

Risk mitigation 1: Can beam size be increased?

BEAM SIGMA =6MM
Target radius = 4.8Xsigma



Case 1
beam sigma = 6mm
Target diameter = 58mm

Case 2
beam sigma = 9.7mm
Target diameter = 58mm

Case 3
beam sigma = 6mm
Target diameter = 36mm