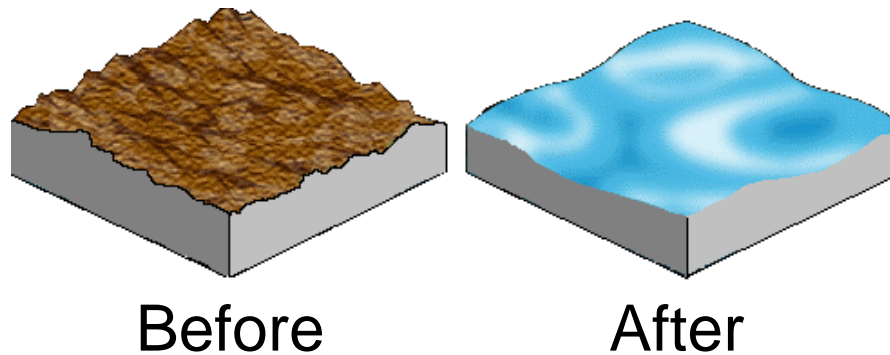


Electropolishing Using Ionic Liquids

John Collins
C-Tech Innovation Ltd
Chester, UK



- ❑ Opposite to electroplating i.e. dissolves metal off.
- ❑ Metal preferentially removed from peaks to create a smoother (polished surface).
- ❑ Done for visual effect, decreased wear, better hygiene and improved corrosion resistance.
- ❑ Vast majority of industrial electropolishing carried steel.



- ❑ Uses sulphuric and phosphoric acids
- ❑ Low current efficiency (10 – 20%) due to O_2 evolution at anode.
- ❑ Leads to a mist of H_2SO_4 - corrosive
- ❑ Polishing mechanism involves film formation at the anode.
- ❑ Current process involves tank containing 1-50 tonnes of electrolyte
- ❑ Large amounts of Fe/Cr containing acidic effluent and sludge are currently produced.

- ❑ Range of liquids have been studied but it is only the glycol based liquids which show polishing characteristics.
- ❑ Optimum liquid is Ethaline 200
- ❑ $1\text{ChCl} + 2(\text{HOCH}_2)_2$
- ❑ Fortuitous due to cost, toxicity, availability and physical characteristics



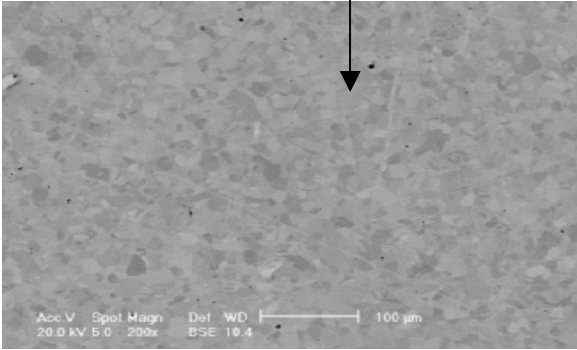
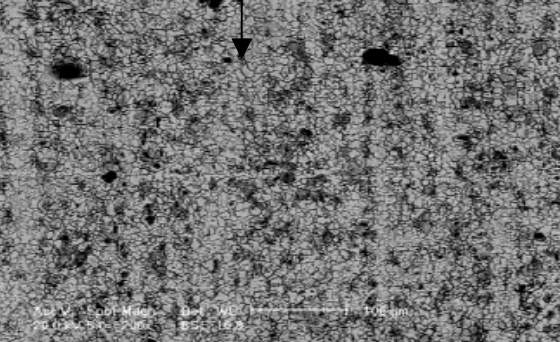
Physical Property	Acid	Ethaline 200
Viscosity (cP)	54	48
Conductivity (mS cm^{-1})	20	5.99
Density ¹)(g cm^{-3})	1.76	1.1

Electropolishing

Pre-polished



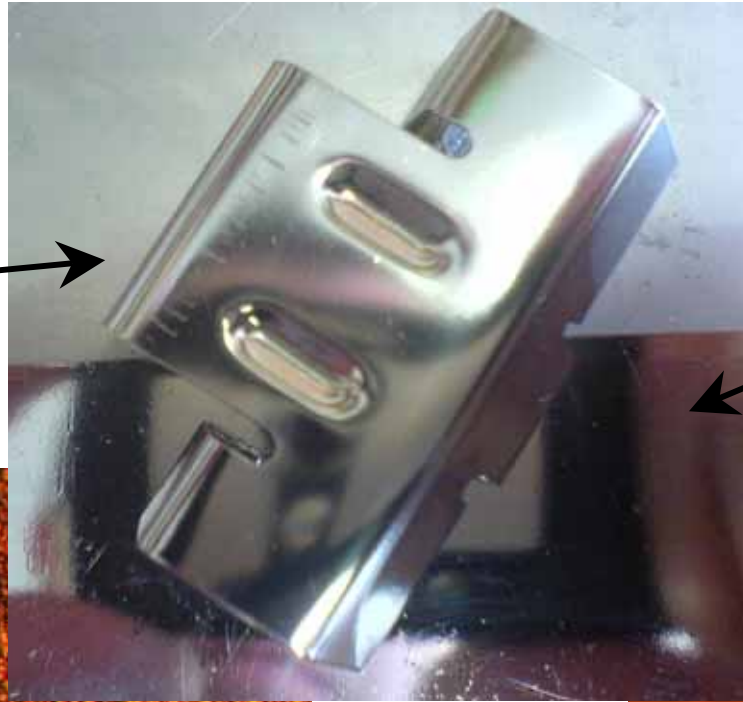
Electropolished



C-Tech Innovation
...advantage through technology

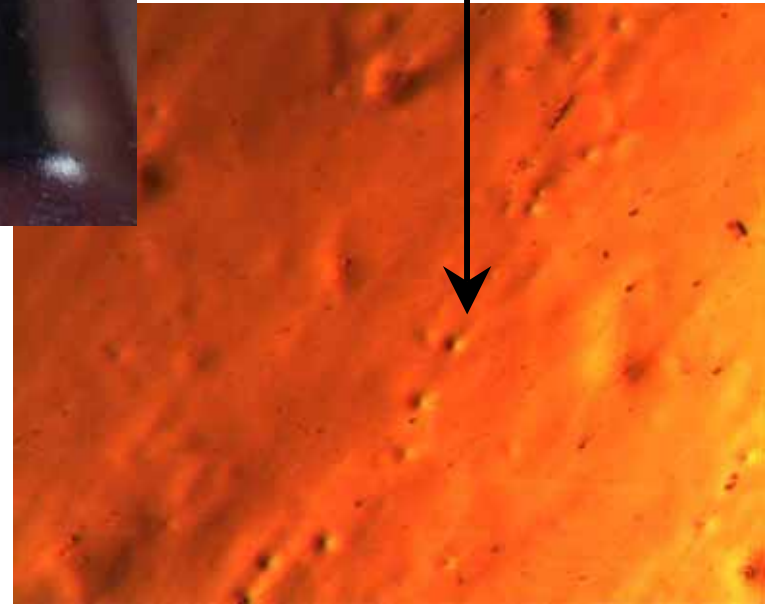
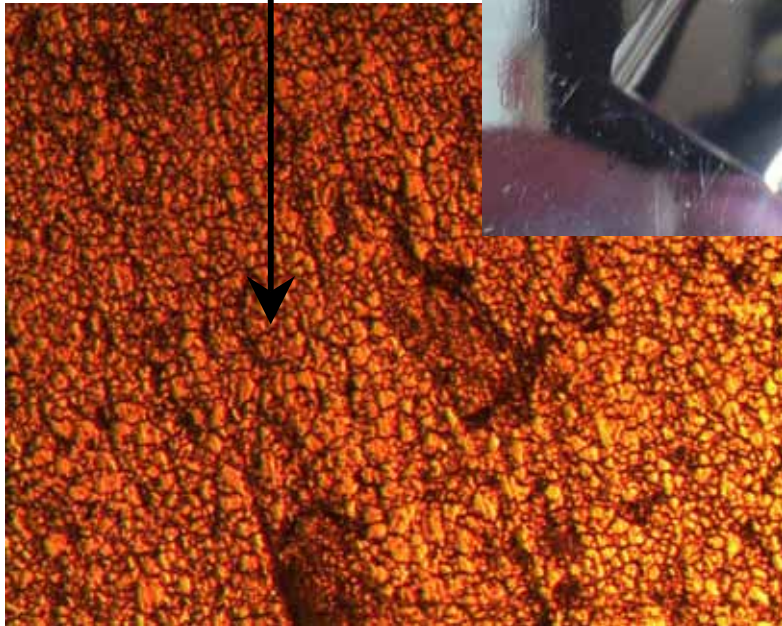


Electropolishing



Electropolished

Unpolished

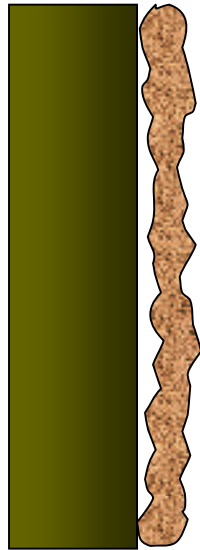


C-Tech Innovation
...advantage through technology

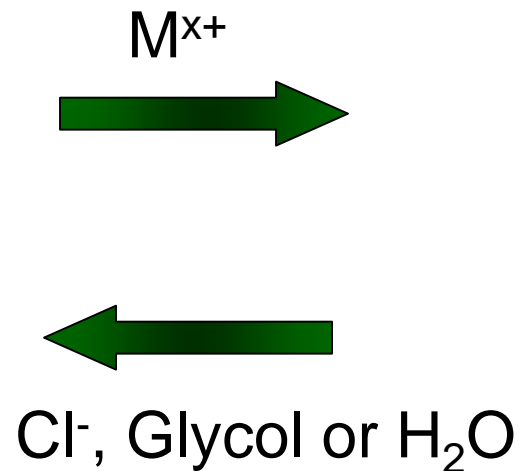


- To optimise the process conditions it is necessary to understand the dissolution mechanism

Electrode

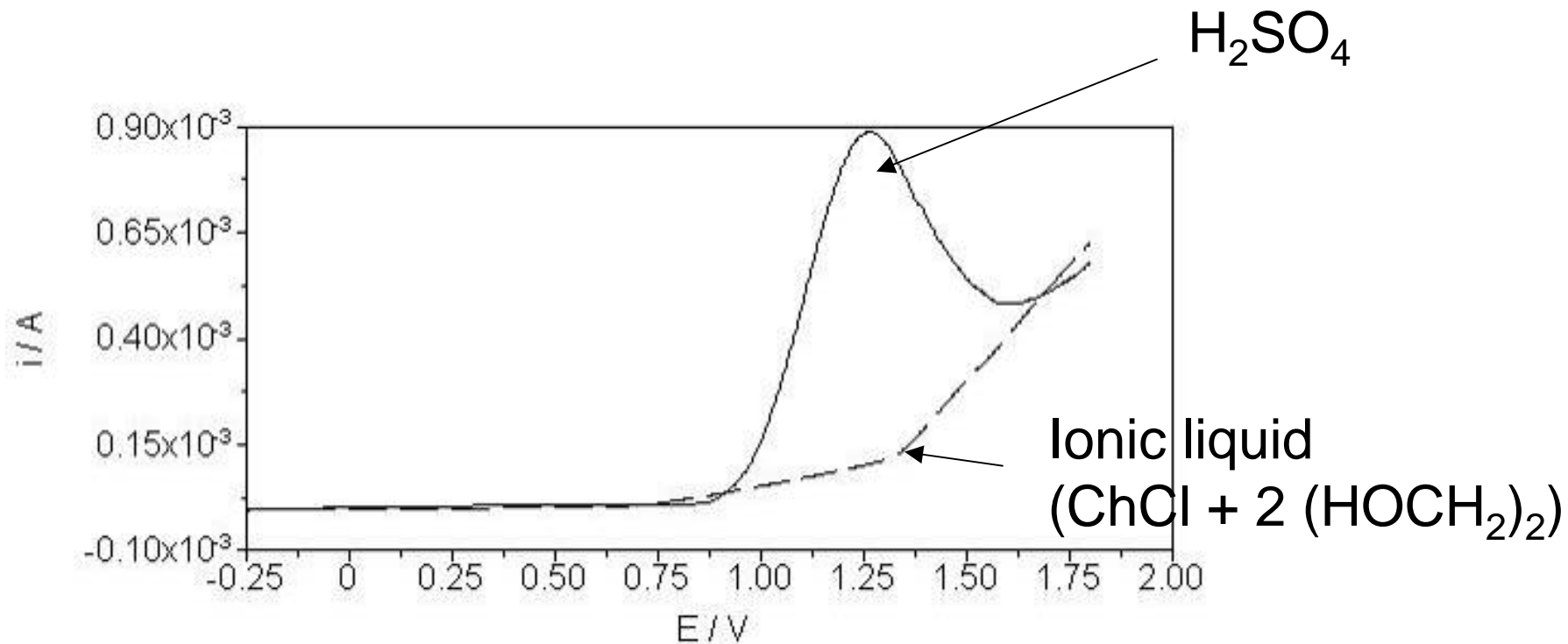


Film



- In water a film is known to form at the electrode surface, but the nature of the film and the mass rate limiting species are disputed

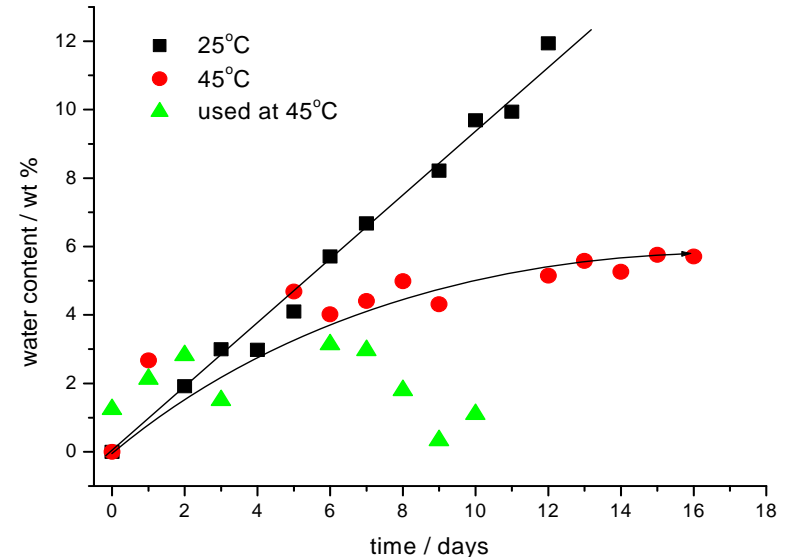
Apparently different polishing method 316 Stainless steel at 10 mV s^{-1}



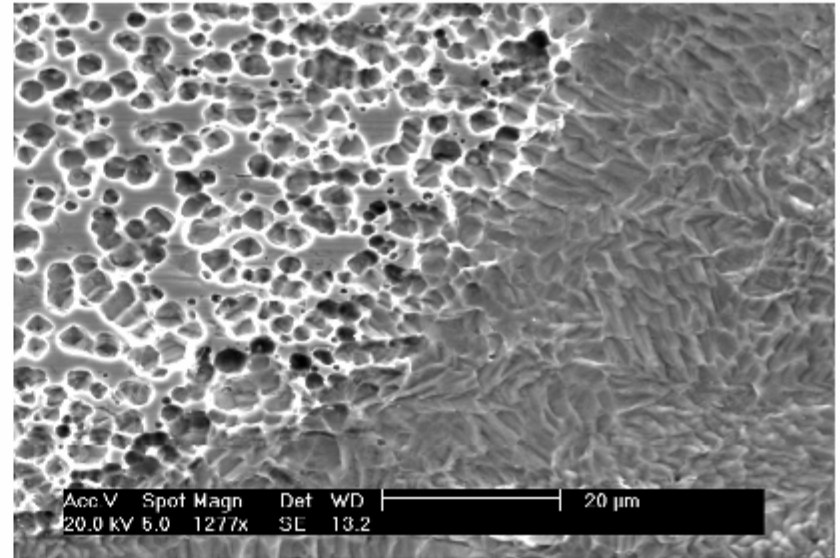
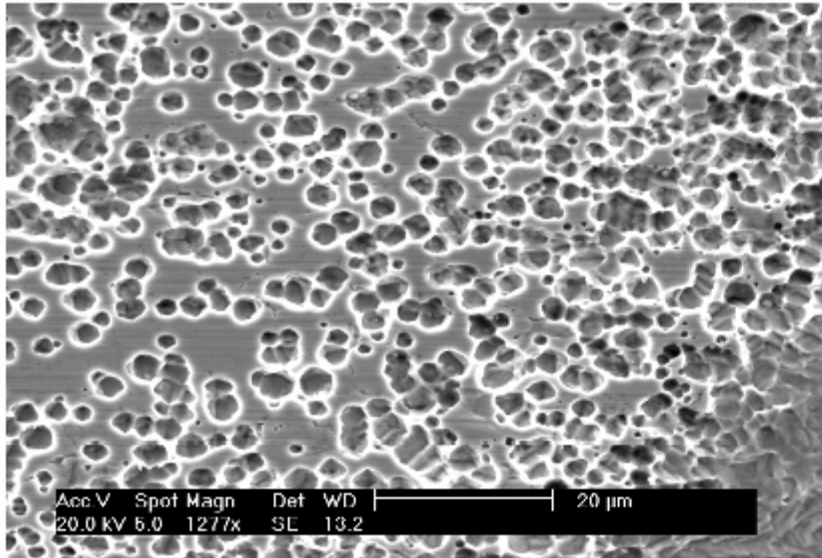
- ❑ No evidence of film formation therefore confirming that mechanism is different
- ❑ Using an ionic liquid saturated with Fe/Cr shows a similar response to that in a fresh solution – metal transport not mass limiting
- ❑ Electropolishing is equally good when liquid is saturated.

See University of Leicester for more details of possible polishing mechanisms

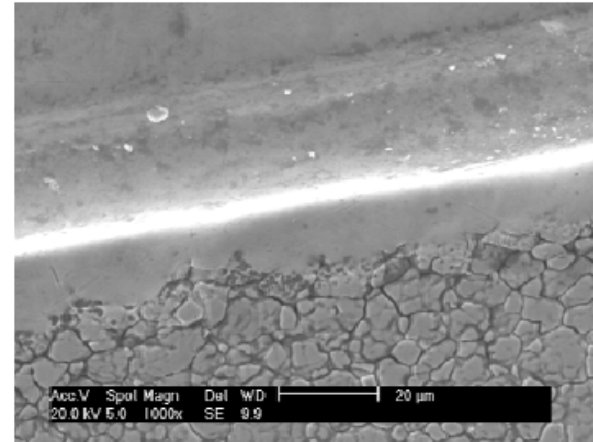
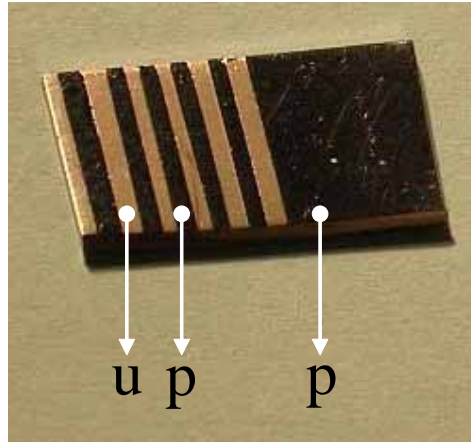
- ❑ Ionic liquids are hygroscopic but the adsorption of water is slow and reaches an equilibrium composition of c.a. 5 wt% when the bath is at 45 °C.
- ❑ Up to 5 % water does not detract from the polish quality (in fact it improves it)
- ❑ Above 10 wt% the liquids do not electropolish.



- ❑ Optimum polishing obtained at $70 > \text{c.d.} > 50$ mAcm^{-2}
- ❑ C.f. $> 100 \text{ mAcm}^{-2}$ in acid



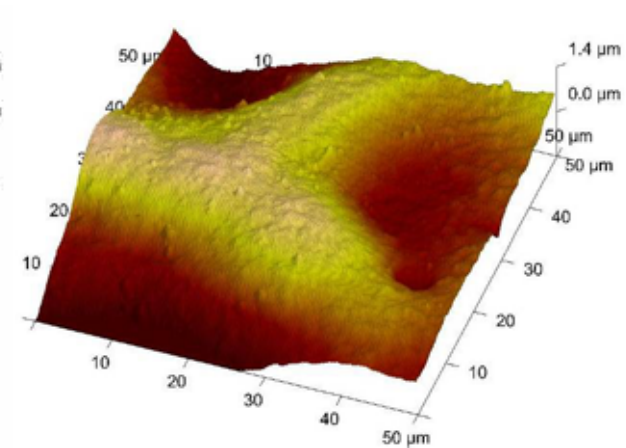
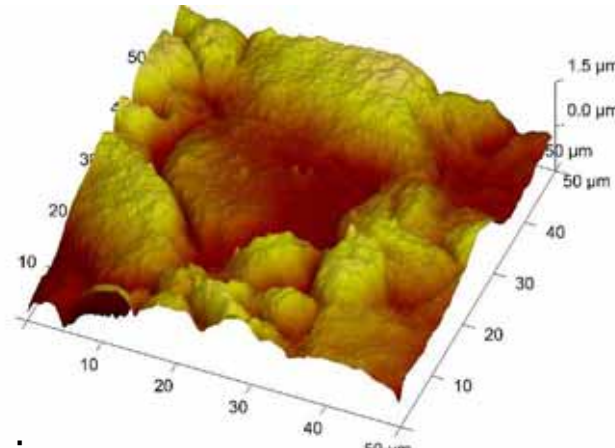
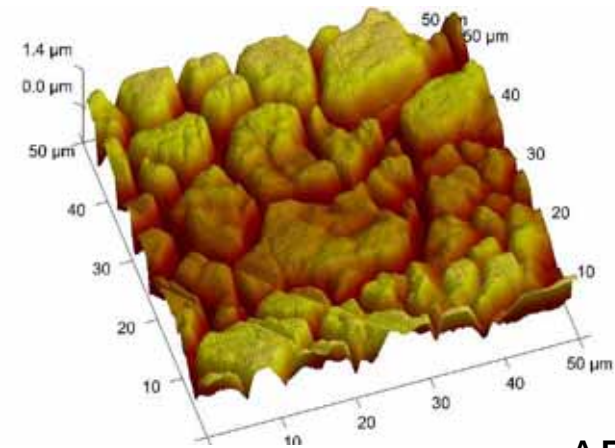
- ❑ At low c.d. the surface became dull due to pitting
- ❑ Partial oxide coverage leads uneven metal dissolution



Unpolished

Polishing

Polished



AFM images

- o Excellent results on a small scale, pressed components with internal surfaces.
- o On larger scale testing, results are virtually identical.
- o Electro-polishing achieves results comparable to acid-based polishing media.
- o Results on cast pieces very good compared with conventional electro-polishing.



- ❑ Uniform removal of oxide film before polishing is critical to the quality of the polishing.
- ❑ Initial work used a higher potential etch before the polish. While this worked well at laboratory studies, it was not suitable for production.
- ❑ The pre-etch has been replaced by addition of around 1% of a simple additive.
- ❑ Process conditions :

Current density 50 – 100 mA/cm² @ typically 6V

Time 10 – 15 minutes

Temperature 35°C

No agitation

Stainless steel cathodes

Current Efficiency 80-90% with marginal gassing.

Conventional	Ethaline based
Degrease ?	Degrease
Pickle (Nitric/HF) ?	Pickle (HCl 5%)
Rinse	Rinse & Dry



Currently operating on 1300 kg at Anopol in Birmingham

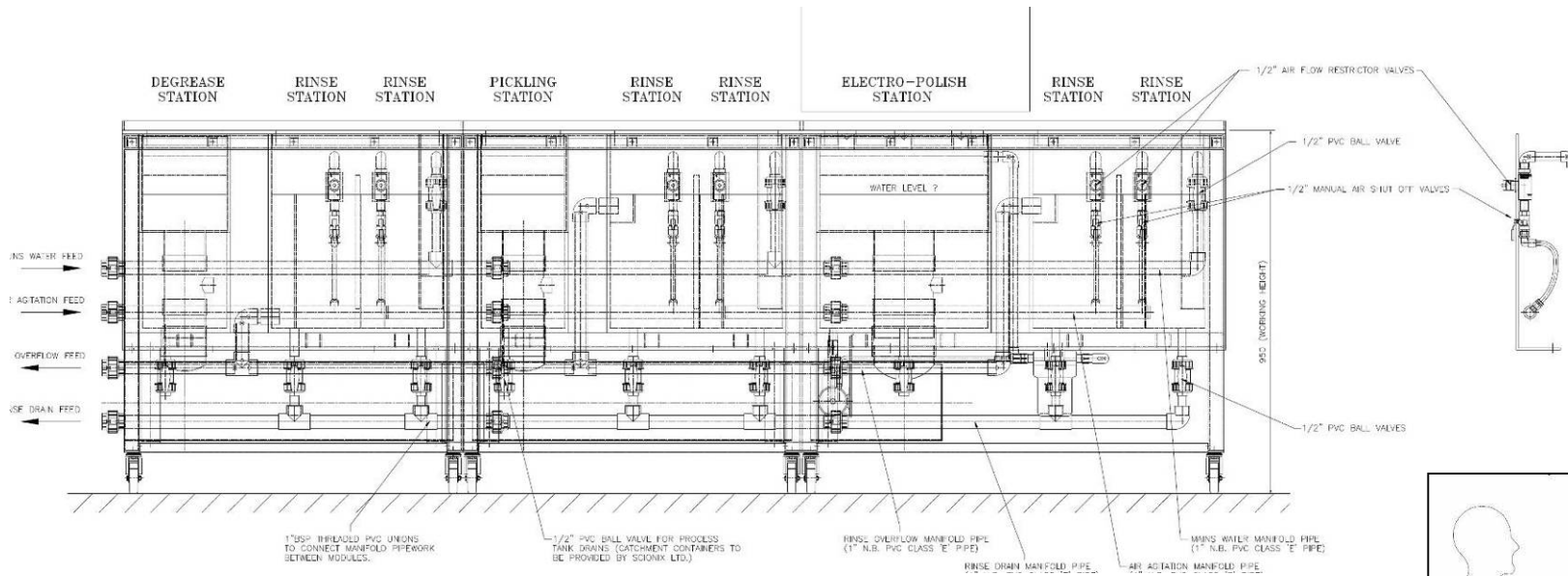
Standard tank, pump and fittings (PE, PP and nylon)

Stainless steel cathodes

Titanium anode jig

Negligible gassing at anode



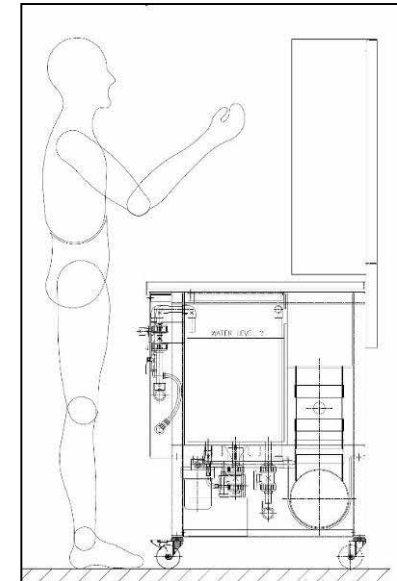


Mobile demonstrator:

- Three detachable units
- **Degrease** rinse, rinse
- **Pickle** rinse, rinse
- **Electropolish** rinse, rinse

Features:

- Cascade rinse
- Extraction
- Air agitation
- Low-ripple rectifier
- Temp. control and filtration





Automated modular system (50 l)



1. phosphoric acid degreaser
2. rinse
3. electropolish
4. rinse
5. spray rinse
6. nitric acid passivation
7. spray rinse
8. rinse



Encoder rings polished at 6V for 10 minutes

- ❑ Ionic liquid has high solubility for metal ions
- ❑ The iron glycolate complex forms a sludge at the base of the tank that can be filtered and isolated
- ❑ The liquid still operates despite use for > 1 year

Metal	Saturation conc. / ppm
Iron	66746
Chromium	9150
Nickel	3135

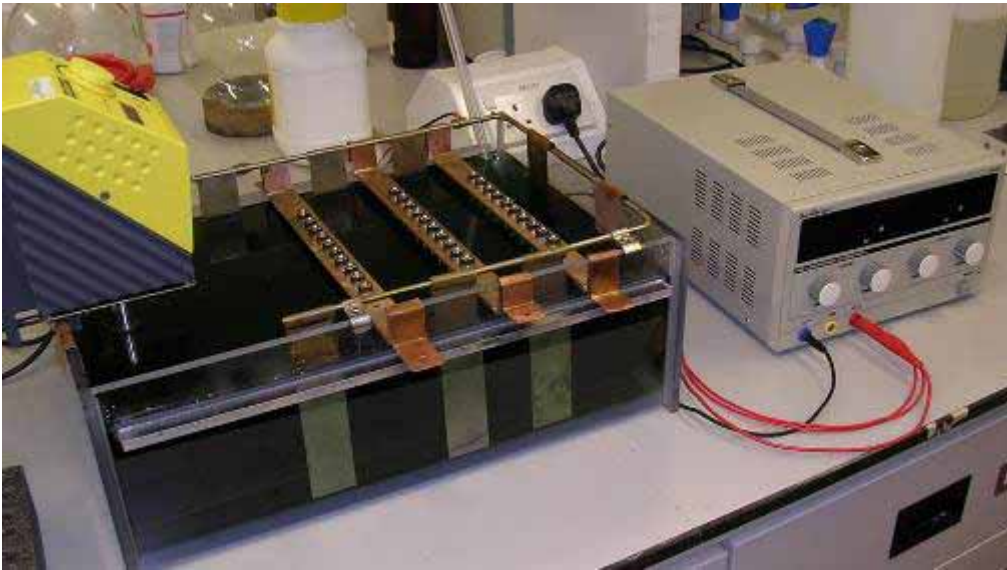
- ❑ Recycling process has been developed using water to precipitate the metal



- ❑ Water is then distilled from the liquid
- ❑ No electrolytic breakdown products have been detected
- ❑ Process results in a loss of glycol primarily through precipitation with the iron and some physical loss through distillation

- ❑ Improved current efficiency (90+%) (economic)
- ❑ Benign liquid – ChCl /glycol (social)
- ❑ Less gas evolution (environmental)
- ❑ Metal recoverable (environmental)
- ❑ Electrolyte regeneration (environmental).
- ❑ Better surface finish (market)
- ❑ Non-corrosive (social).
- ❑ Also suitable for high nickel alloys (market)

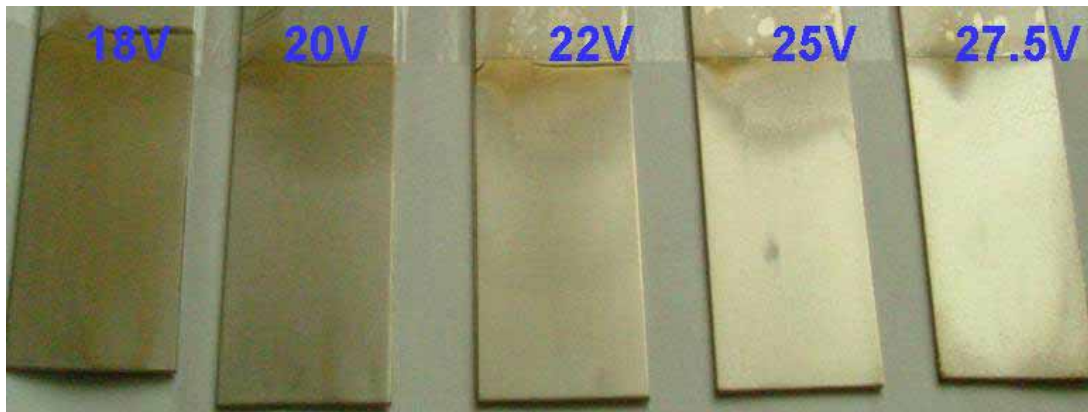
- ❑ New process developed for high performance Ni/Co alloys – Big-end bearing fixing bolts for an F1 engine manufactured
- ❑ All trials on polishing of high Ni content alloys have all been successful!
- ❑ One of the most reliable / consistent IL electropolishing processes.
- ❑ Good solubility of Ni oxide in Ethaline



- ❑ E200 can polish Titanium but high potentials and high current densities are required to remove the oxide layer.
- ❑ Additives can reduce the potential required to strip the oxide.
- ❑ Uniform oxide removal is the key to successful titanium polishing.



↓ Polishing



- ❑ Reliable / consistent electropolishing of pressed and cast 300 series stainless steel parts in Ethaline 200.
- ❑ Simple additives give excellent finish comparable to current industrial process (aqueous acid), scale-up successful for small pieces and castings
- ❑ Polishing of high Ni content alloys successful and consistent.
- ❑ Very encouraging results continue for polishing of Ti and Ti alloys.
- ❑ Demonstrator unit built which will initially be used within the IONMET consortium.



- EU FP6 NMP programme for funding of IONMET.
- University of Leicester for much of the work presented here. In particular Prof Andy Abbott, Dr Karl Ryder and Dr Katy Mckenzie.
- Jacques Halut of Protection de Metaux, France for some of the work on titanium.
- Dr Karen Brace and Pete Eddowes at C-Tech for assistance with titanium and stainless steel polishing.
- Brian Swain & Daniel Wheeler of Anopol.