The Development And Initial Testing Of The Ice Pig Cleaning Method For Nuclear Reprocessing Plants

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- When can Ice Pigging be used?
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Why Pigging?

- Universal need for cleaning in almost every walk of life
- Attractive to adopt a physical method of removing solids, rather than attempt chemical removal
- Cleaning confined spaces can be challenging, especially if it is difficult to physically access
- Cleaning and removing sediments can be very challenging in our industry
Pigging Within Oil & Gas Industry
Mechanical Pigs

Little pigs, 2”

Scalable, 8-12”
Mechanical Pigs

Functionalised pigs
Mechanical Pigs

The ultimate pig
What Mechanical Pigs Can’t Do

Reduction of diameter

Sudden change of direction

Plate heat exchangers

Tees
The Nuclear Challenge
Decontamination and solids removal from pipes:-

- Contaminated with various fission products
- Trace active to highly active
- Complex and variable pipe systems
- Majority <4” diameter
- Pig must not get stuck
What Is Ice Pigging?

In simple terms, an Ice Pig is an ice slurry.

- Patented process developed by University of Bristol, UK
- A slurry of very small ice crystals (microns) held in the body of a fluid to create a slush
- Fluid is a salt solution to depress freezing point of the slurry and extend life, i.e. 0 deg C to -15 deg C
- Volume of ice (% Ice Fraction) is a measure of how solid or fluid the pig is
- Is dynamic and conforms to its enclosure like a liquid.
How Does It Overcome The Pigging Issues?

• Pumpable with minimal pressure, so can follow a process.

• Can never get stuck – just melts to an aqueous solution

• Conforms to changes in pipe topology

• Can be used whilst operational or minimal outage

• Can control properties to act like a piston, fluid or hybrid.
When Could Ice Pigging Be Used?

- Operations
  - Plant flushing
  - Washouts
  - After batch transfers

- Outage – removal of debris prior to or after maintenance

- Post Operational Clean Out

- Decommissioning
Underpinning Works

- Navigation of
  - Diameter changes
  - Orifice plates
  - Vertical legs (up & down flow)
  - Non-return valves
- Solids removal, including swarf
- Bulldozer effects
- Estimator – how much ice, melting effects
- Alternatives to common salt as a freezing point depressants
Changing Topology and Restrictions

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Changing Topology and Restrictions
Displacing Solids

Simulant slurry
70% solids

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Displacing Solids
Bulldozer Effects

- Important in small pipes.
- Impact varies according to material type. Sand is OK, sludge's are more sensitive.
- Mitigation via multiple passes with increasing Ice Fraction (fluid to hybrid to plug like properties).
- High shear uses 100-1000 times less water for same effect.
Alternative Freezing Point Depressants

• Freezing Point Depressants needed to control ice crystal size and limit fusing of ice crystals.

• A range of additives have been tested, typically to 5% by weight and include:
  • Nitric acid
  • Sorbitol
  • Ethanol
  • Acetic acid
  • Glycerol
  • Glycol
  • Etc.
Debris / Swarf Removal

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Estimator

Using established formulae, an iterative model constructed to take account of:

- Temperature
- Diameter and wall thickness of pipe / vessel
- Starting Ice Fraction
- Length of pipe
- Etc.

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<th>Value</th>
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<td>D, internal diameter of pipe</td>
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<td>tA, thickness of pipe wall</td>
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<td>tB, thickness of pipe wall</td>
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<tr>
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<tr>
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<tr>
<td>Tpush water</td>
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<tr>
<td>Load</td>
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</tr>
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<td>0.85 Cafetiere</td>
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<tr>
<td>Push rate</td>
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</tr>
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</table>
Scale of use

Litre scale

10te scale

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On-Going / Future Works

• Blend chemicals into the ice pig...with associated benefits (magic bullet)

• Blend sacrificial abrasive material into the pig; e.g. sand, for more aggressive cleaning

• Trials for ‘pig-trains’, delivering multiple chemicals in low volumes, each pig having a specific task; (e.g. alkali pig followed by neutralising acid pig)

• Carry out Active trials on cooling water systems.
Summary

- Ice pigging was a technology transfer from the water industry
- Multiple applications
  - Product recovery
  - Product separation
  - Sediment removal
  - Functional pigs and pig trains
- Never ever gets stuck
- Significant reduction in effluent volumes for washouts
- Entry and exit points can be any size
- Scalable process
- Sufficient underpinning for active trials.
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Any Questions?

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