

Institution: University of Bristol

Unit of Assessment: 12) Engineering

Title of case study: Ice Pigging technology cleans up on a global scale

Period when the underpinning research was undertaken: 2001-2014

Datails of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by
		submitting HEI:
Professor G Quarini	Professor of Process Engineering	01/1993-present
Dr Stan Shire	Research Fellow	10/2001-09/2004
Period when the claimed impact occurred: 12/2014-07/2020		

Is this case study continued from a case study submitted in 2014? Y

1. Summary of the impact

Since the previous REF, the University of Bristol's patented 'Ice Pigging' technology has grown into a global industry; in 2015, the second largest water company in the world, Suez, bought the universal patent and acquired two Ice Pigging spin-outs. With an annual turnover of up to GBP6.5 million in this REF period, and directly employing around 100 people, the innovative pipe cleaning method is now used by water companies throughout the world, including the US, Australia, Chile, Spain, Japan, Singapore and Italy, achieving environmental benefits, time savings and increased profitability. The versatility and cross-sectorial benefit that Ice Pigging offers has led to it also being adopted in the heating, food, cosmetic, chemical, and paints industries.

2. Underpinning research

Cleaning and unblocking pipelines is a necessity within industry, with two methods being traditionally relied upon. The first involves propelling a solid piston-like object, or 'pig', through pipes, which must be reasonably straight and of constant diameter. The pig can be damaging to pipe walls and requires purpose-built launch and receive stations. The second method is liquid flushing, which uses huge volumes of water, and which, in large-diameter pipes, can fail to achieve the required velocities for effective cleaning. Following the flushing, harsh chemicals such as caustic soda are used to dissolve any residue. In addition, there is the issue of process efficiency; for industrial applications, the pipework may need to be cleaned on a regular basis and in certain applications, such as in food factories, the lines may require cleaning on a daily basis.

The question was then, how to clean equipment with difficult topologies (varying pipe diameters, bends, valves) in a way that reduces water consumption and the need for harsh chemicals, and that requires less time. The method should also be Clean in Place (CIP); the equipment doesn't have to be disassembled for cleaning. Professor Quarini conceived the 'ice pig' to address these issues. The technology was patented in 2001 **[1]**, and over the years 2001-2013, his research group was awarded government grants **[i-iii]** that enabled the ice pig to be developed, trialled, and adapted for cross-sector use.

The Ice Pig concept

Ice Pigging is a CIP method that uses a concentrated suspension of ice particles in a solution containing a freezing point depressant (usually salt), otherwise known as an 'ice slurry'. The slurry is introduced to a pipeline and quickly forms a plug that can be pushed through the pipework with a pressure differential. The slurry can form a plug whenever possible, while also flowing through restrictions and complex topologies when required. Whereas solid pigs become lodged, in the event of a blockage the ice pig simply melts away, thus avoiding costly excavation

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works. Further, unlike conventional pigs, the ice pig can be introduced into complex networks of pipes through existing valves, thus avoiding expensive enabling work.

Development of the ice pig for industrial use

Over 2001-2004, DEFRA funding **[i]** enabled Quarini's research group to conduct preliminary trials of the ice pig's efficiency at cleaning fouling materials relevant to a range of industries, including jam and fats, meat, toothpaste, and fine slit and sand (Fig.1). The trials indicated that the ice pig was highly adept at removing 'soft' fouling; using a volume of ice typically less than one tenth of the volume of water required for flushing **[2]**. They also found that the ice pig held together, was self-healing, and maintained its identity under most flow conditions **[3]**. The group then investigated the distance an ice pig could survive as a plug-like entity before melting. Based on experiments and modelling of ice slurries flowing in un-insulated steel pipes, they developed a numerical model to predict ice pig longevity. Dr Stan Shire (Research Fellow 2003-2008) worked on generic aspects of ice slurry flows and developed correlations relating the complex coupling between pressure drop, flow rates and ice fraction, which were needed to establish the operational regime of the ice slurries which were the 'ice pig'. The key conceptual breakthrough was better understanding the rheology so as to customise both the rheology of the ice pig itself as well as the equipment to store and pump the slurry **[4]**.



Figure 1. A thick Ice Pig going through a meat-processing pipe

In 2006, the spin-out PCIP was formed to disseminate, licence and commercialise the technology. The same year, the first trials were conducted on live water mains in the Bristol area. These trials showed that Ice Pigging:

- improved water quality;
- reduced water and disinfectant usage;
- reduced downtime during cleaning programmes;
- did not require excavation for access to mains, instead being injected and extracted through existing hydrants.

These promising results were published together with data enabling engineers to scale and size the ice pig for full-scale trials **[5]**. By the end of the 2000's, the technology was recognised as a significant innovation for the process sector, earning a number of prestigious awards:

- Engineer Award for Process and Production (2009)
- Water Industry Achievement Awards for Most Innovative Technology of the Year (2009)
- International Water Association Project Innovation Award (2010)

In 2010, three postdoctoral Ice Pigging researchers (Ainslie, Deans and Herbert) set up another spin-out, ADHQ, to provide expert design, assembly and commissioning of Ice Pigging systems for companies wanting to deploy the technology. ADHQ partnered with a local small company, Barvick Engineering, to manufacture bespoke Ice Pigging equipment at scale (see Section 4).

3. References to the research

1. **Quarini G** (2001), *Cleaning and separation in conduits*. US patent number US6916383. The patent is also granted in a number of other territories including the UK, Japan, Germany, France, Italy, Spain, Japan, South Korea



- 2. **Quarini G** (2002). Ice pigging to reduce and remove fouling and to achieve clean-inplace, *Applied Thermal Engineering*, **22.7**, pp.747-753 <u>https://doi.org/10.1016/S1359-4311(02)00019-4</u>
- 3. Shire S, **Quarini G**, Ayala R (2005). Experimental Investigation of the Mixing Behaviour of Pumpable Ice Slurries and Ice Pigs in Pipe Flows, *Proceedings of the IMechE, Part E. Journal of Process Mechanical Engineering*, **219.3**, pp.301-309 https://doi.org/10.1243/095440805X8665
- 4. Evans T, **Quarini G**, Shire S (2008). Investigation into the transportation and melting of thick ice slurries in pipes, *International Journal of Refrigeration* **31.1**, pp.145-151 <u>https://doi.org/10.1016/j.ijrefrig.2007.06.008</u>
- Quarini G, Ainslie E, Herbert M, Deans T, Ash D, Rhys D, Haskins N, Norton G, Andrews M, Smith M (2010). Investigation and Development of an Innovative Pigging Technique for the Water-Supply Industry, *Proceedings of the IMechE, Part E. Journal of Process Mechanical Engineering*, 224.2, pp.79-89 <u>https://doi.org/10.1243/09544089JPME312</u>

Grant information

- i. Quarini G, Pigging with Pumpable Ice (AFM163), DEFRA, 2001-2004, GBP323,851
- ii. **Quarini G**, *Ice pigging: Culture change, integration in food manufacturing processes, enhanced value with studies on product & sanitising pigs* (AFM279), DEFRA, 2011-2012, GBP206,000
- iii. **Quarini G**, *Trial and demonstrate ice pigging in the dairy sector with the objective of achieving energy and cost savings*, UK Government/Regional Growth Fund, 2012-2013, GBP198,000

4. Details of the impact

Ice Pigging has revolutionised the way that pipes are cleaned in the UK and worldwide. During this REF period, it has expanded into a lucrative global industry, creating new jobs and providing cost and time savings for businesses not only in the water industry, but also in heating, food, cosmetics, manufacturing, chemical and power generation.

Expansion of global Ice Pigging industry

In 2015, the Ice Pigging industry was acquired by Suez (formerly Aqualogy), the second largest water company in the world, for GBP[text removed for publication]. The company purchased the complete (universal) patent for the technology, covering all geographical and sectorial areas. It also acquired both the PCIP and ADHQ spin-outs founded by University of Bristol Ice Pigging researchers. PCIP had ongoing consultancy contracts and licences at the time, all of which were taken up by Suez. All existing ADHQ staff accepted well-paid roles at Suez.

Suez's Ice Pigging industry has reported an annual turnover of up to GBP6.5 million, combining turnover in the UK, the US, Australia, Chile, Spain and Italy. They currently employ up to 100 people in the Ice Pigging sector **[A]**. The Operations Director at Suez states that: *[Ice Pigging] has been a game-changer for our business. The benefits of Ice Pigging have led us to develop the technology globally, secure business with key customers and obtain repeat contracts. We look forward to continuing to provide Ice Pigging technology for our customers going forward and are grateful for the research undertaken by the University of Bristol which led to the development of this technology.* **[A]**

Aside from Suez and its customers, Ice Pigging has had significant economic impact for the regionally-based manufacturer Barvick Engineering, which originally collaborated with Quarini to develop the Ice Pigging equipment. Barvick has continued to supply equipment for Suez, with



Ice Pigging equipment sales accounting for around 20% of the company's turnover over the past six years **[B]**.

Improved business performance of the water and sewerage industry

Between 2014 and 2019, Suez cleaned 100-200km of customer pipework per year in the UK, or approximately 900km of pipe in total over the period **[A]**. Customers include Welsh Water, Hafren Dyfrdwy, Northumbrian Water, Affinity Water, Anglian Water, United Utilities, Southern Water, South East Water, South West Water and Wessex Water **[A]**. Internationally, Suez has delivered Ice Pigging extensively in Europe, the US, Japan, Australia and Singapore, cleaning a total of 4,500km of pipes globally during the REF period **[A, C]**.

Over 2016-2017, the largest water-only supplier in the UK, Affinity Water, used Ice Pigging to conduct one of the largest mains-cleaning exercises within the water industry in recent years. One of the project's highest risk elements was cleaning the cast iron/coal tar lined mains without adversely affecting water quality. Most companies choose the "not able to clean" approach or choose to relay or reline the pipes, at significant cost. In this case, Ice Pigging enabled effective cleaning of the pipes without affecting water quality. Over 950km was cleaned overall, 'this includes over 120km of trunk mains and, in particular, over 80km of cast iron / bitumen / coal tar lined mains cleaned without incident. The project has delivered significant cost savings as result of direct contracts with specialist contractors and the contract model will be adopted for similar works going forward.' [D] Aside from these benefits, zero customer complaints were received during the entirety of the works, environmental impact was reduced (with no harsh or synthetic chemicals required), and approximately 5,000 tonnes of excavated waste material was prevented from going to landfill [E]. Furthermore, excavations were limited, as existing hydrants and valves were used to insert and retrieve the ice pig.

Other Ice Pigging success stories across the industry include:

- Dee Valley Water saw a reduction in the number of discoloured water complaints, from 4.9 per 1,000 customers in 2013 down to 1.32 in 2015 **[F]**, following an extensive mains cleaning operation to rid pipes of residual manganese.
- Hafren Dyfrdwy (which brought together Severn Trent and Dee Valley Water in 2018 and now serves almost 85,000 homes) [F], completed 14 overnight Ice Pigging cleaning runs in Wrexham in 2019, which removed over two tonnes of sediment from 17.3km of pipes. 'We're really happy to say we had zero customer complaints relating to the cleaning process or traffic management, and many customers weren't aware that work was being done in the area. The cleaning programme will continue next year and will help to ensure the network is significantly cleaner, which means we can continue to provide customers with great quality water.' [G]
- Welsh Water undertook a programme of works that involved cleaning 385km of potable water mains (2018). Their Contract Manager states: 'A typical ice pigging run takes less than an hour to complete, meaning the impact on the key measure of 'customer minutes lost' is minimal. This, along with less holes being dug outside customers' properties, has ensured the projects have been successfully delivered with reduced disruption.' [H]
- Starting in 2013, Yarra Valley Water (Australia) launched a full-scale programme to Ice Pig approximately 400 km of water mains per year for five years. Following the programme, the company reported a significant reduction in water quality complaints, which in some cases were virtually eliminated **[I]**.

Improved business performance of the heating industry

Ice Pigging has also been effective in the commissioning of district heating systems. This sector is rapidly growing in the UK and is seen as one of the key target areas for reducing CO₂ emissions in densely populated areas. Each new district heating system involves networks of flow and return pipework between the energy production plants and individual buildings/developments. The standard approach for commissioning these networks involves using a high velocity chemical flush through side stream filters, which can take up to two weeks and has relatively high-power requirements. With Ice Pigging, Suez can clean the same networks to an equal or better standard in just a few hours, requiring no chemicals and very little

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energy. Customers include Eneteq, Vital Energi, ENGIE and Pinnacle Power, together with work on flagship projects including Wembley Park and Heathrow Airport **[A]**.

In 2018, ENGIE used Ice Pigging to undertake a pre-commissioning clean to remove swarf and construction debris from 1,560m of 300mm diameter pipework. This was part of the Angel Lane District Stratford project to extend the existing heating and cooling pipework connection as part of the construction of a 33-story tower block with 181 apartments. A total of 64kg of sediment was removed. Works took place without exceeding the normal operating pressure of the pipework or causing damage to the pipe walls. Existing fittings for all pipe connections were utilised, and therefore no enabling works were required for the operation. All pipes were cleaned within one day, whereas a conventional flush of the network would have taken approximately one week and required high flows and pumping costs. Additionally, 30-50% less water was used than would have been required using typical flushing techniques **[A]**.

Since 2017, Eneteq Services Ltd have used Ice Pigging on many of their newly installed networks, and have found that the method generally allows for the full network to be cleaned in a single day, provides a zero risk of blockages caused by the process, and also accommodates to all diameters of pipes, bends, valves and any other fittings. Eneteq has since applied Ice Pigging on high profile developments at Wembley Stadium and Heathrow Airport and states: '*We will be continuing the use of Ice Pigging technology in cleaning operations and have several already in the planning stages.*' [J]

Improved business performance (time and cost savings) in other industries

Ice Pigging has been trialed with great success in other sectors including food and beverage, chemical, cosmetic, manufacturing, power generation and defense. In 2016, Yeo Valley wanted to improve their flushing method for cleaning remaining product from production lines. An Ice Pigging trial resulted in reduced waste, water use and chemicals, as well as improved product recovery. Ice Pigging equipment was then supplied and installed at the site **[A]**. In the same year, [text removed for publication] conducted onsite trials of Ice Pigging, which demonstrated that a 20% time saving was possible, resulting in the potential to increase production output with no additional investment. As a result, bespoke Ice Pigging equipment was installed at the site in 2017 **[A]**. In 2018, Suez supplied Ice Pigging equipment to Johnson Matthey, a global leader in chemicals and materials. The method proved to be a "game changer" in recovering material from pipe systems. Most importantly, it was able to reduce the long flushing times of up to eight hours to a matter of minutes, resulting in improved production efficiency **[A]**.

5. Sources to corroborate the impact

- A. Suez Corroborating Letter (October 2020), Operations Director
- B. Barvick Engineering Corroborating Letter (March 2020), Director
- C. Suez webpage <u>Network Cleaning</u> [Accessed 26 August 2020]
- D. Ice Pigging Article (July 2017), <u>Suez, Affinity Water and Maces Collaboration Results in</u> <u>Award Win for 2017 Utility Pipeline Projects Award</u> [Accessed 25 August 2020]
- E. Water Industry Journal Article, <u>*Rising to the pipework clearance challenge*</u> [Accessed 25 August 2020]
- F. Water and Wastewater Treatment Article (July 2016), <u>Project Focus: Pipeline boosts</u> resilience for Dee Valley Water [Accessed10 June 2020]
- G. Hafren Dyfrdwy Article, <u>'Ice Pigging' Removes Over 2 Tonnes of Sediment From</u> <u>Wrexham Pipes</u> [Accessed 10 June 2020]
- H. Water and Wastewater Treatment Article (January 2018), <u>Welsh Water uses ice</u> pigging for mains cleaning programme [Accessed 10 June 2020]
- I. Ice Pigging <u>Case Study: Drinking Water, Yarra Valley Water, Australia</u> [Accessed 27 August 2020]
- J. Eneteq Corroborating Letter (2020), Operations Manager