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ICE Pigging in Drinking Water Distribution Network

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Abstract:

Water quality in distribution networks must be maintained for both system performance and public health. Conventional techniques for cleaning pipelines, like air scouring, solid pigging, and unidirectional flushing, frequently require excessive amounts of water, risk damaging the pipeline, and cause operational problems. Ice pigging is a new, environmentally friendly method that uses a slurry of water and ice to remove deposits efficiently and with little disruption to service. Ice pigging's potential as an economical and ecologically responsible water system maintenance method is highlighted in this paper's analysis of its fundamentals, uses, benefits, drawbacks, and practical applications.

Keywords **— Ice pigging, Pipeline Cleaning, Water Quality, Sustainable maintenance.**

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INTRODUCTION

One of the most important tasks of contemporary water distribution systems is to guarantee safe, dependable, and clean drinking water. Sediments, biofilms, and corrosion products build up in pipelines over time, lowering hydraulic capacity, lowering water quality, and raising maintenance expenses. To preserve system effectiveness, safeguard public health, and increase the lifespan of infrastructure, these problems must be resolved

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Traditional cleaning techniques like mechanical pigging, air scouring, and unidirectional flushing have been used extensively. Nevertheless, there are significant drawbacks to each approach, ranging from high water usage and service disruptions to pipe damage concerns and challenging access to intricate networks. These drawbacks emphasize the need for cleaning solutions that are more adaptable, efficient, and sustainable.

A contemporary answer to these problems is ice pigging. This method uses less water, minimizes downtime, and prevents structural damage by employing a semi-solid slurry of ice and water to scour inside pipe surfaces, remove deposits, and restore hydraulic efficiency. The technique is also safe to use and environmentally benign because the ice melts harmlessly into drinkable water. Ice pigging is an affordable and environmentally friendly way to maintain good water quality in drinking water distribution systems, as evidenced by an increasing number of field applications around the world.

I. TECHNIQUES FOR CONVECTIONAL CLEANING

Although it mobilizes loose deposits, unidirectional flushing (UDF) uses a lot of water. Stronger turbulence is produced by air scouring, which introduces air-water slugs; nevertheless, it is less appropriate for pipes with a large diameter. Solid pigs are used in mechanical pigging to efficiently scrape deposits; nevertheless, this method requires pipe access, is prone to obstructions, and results in service outages. Because of lingering issues, chemical cleaning is limited in portable systems.

THE FUNDAMENTALS OF ICE PIGGING

A dense slurry of ice crystals suspended in water—typically including 10–30% ice by volume—is used in ice pigging. As it travels under pressure, the slurry scrubs the inside surface and conforms to the pipe's shape, acting as a semi-solid stopper. The ice melts into drinkable water after washing, preventing problems with disposal or chemical treatment. Because of this, ice pigging is both efficient and sustainable for the environment.

MECHANISM AND OPERATIONAL PARAMETERS

Ice fraction, crystal size (usually 0.1–1 mm), injection velocity (0.5–3 m/s), and pressure (2–6 bar) are important factors that affect ice pigging performance. Using scraped-surface exchangers or slurry generators, ice slurry is made, kept in insulated tanks, and then pumped into the pipeline via valves or hydrants. Pressure and temperature sensors are used to track flow in order to guarantee plug integrity and consistent cleaning.

APPLICATIONS

Ice pigging is used for emergency cleaning following contamination, pre-commissioning of new mains, and routine pipeline maintenance. It is also used as a cleaning-in-place (CIP) technique in the dairy and food industries. Its efficacy in eliminating biofilms, sediments, and corrosion products, as well as in lowering turbidity and regaining hydraulic efficiency, is demonstrated by case studies.

ADVANTAGES

Ice pigging reduces service interruption, consumes 50–80% less water than flushing, has great cleaning efficiency, and is kind to pipe infrastructure. The slurry is appropriate for intricate networks since it can negotiate curves, valves, and diameter changes. It needs no chemical additives and generates very little waste in terms of the environment.

LIMITATIONS

Notwithstanding its benefits, ice pigging has drawbacks, including expensive startup costs, the need for specialized equipment, the need for skilled workers, and the ice slurry's temperature sensitivity. It may encounter logistical difficulties in remote locations and is less efficient in pipes with extremely large diameters.

STUDY OF A CASE

In comparison to flushing, field applications in Pune, India, showed turbidity reductions of more than 85%, hydraulic capacity restoration of up to 95%, and water savings of about 70%. Significant decreases in customer complaints and operational outages have also been recorded by utilities in the USA and the UK. Thus Ice Piggging has potential for sustainable water management on a worldwide scale.

A COMPARATIVE STUDY

Ice pigging uses less water and works better against sticky deposits than flushing. It works with a larger variety of pipe diameters than air scouring. It requires fewer access points and eliminates the possibility of blockage when compared to solid pigging. All things considered, ice pigging reduces the drawbacks of traditional techniques while incorporating their advantages.

PROSPECTS FOR THE FUTURE AND GAPS IN RESEARCH

Future studies should concentrate on improving Computational Fluid Dynamics (CFD) models of flow dynamics, creating portable ice-producing systems, optimizing slurry properties, and carrying out long-term life-cycle and cost-benefit evaluations. Another possible approach is integration with smart water network management and digital monitoring.

CONCLUSION

By combining the thorough scouring of mechanical pigging with the low water demand of flushing, ice pigging is a high-efficiency,

environmentally friendly technique for cleaning drinking water pipelines. It eliminates biofilm, sediments, and mineral deposits using a slurry of tiny ice crystals without causing long-term damage to pipe walls or service interruptions. When compared to traditional flushing, field studies—such as the Pune Municipal Corporation case—show turbidity reductions of over 80% and water savings of almost 70%.

Although it necessitates certain tools, knowledgeable operators, and meticulous temperature control, its advantages for the environment, versatility in handling different pipe materials and sizes, and quick return to service make it an affordable choice for contemporary water utilities. Thus, ice pigging stands out as a useful, chemical-free method of pipeline extension and water quality maintenance.

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