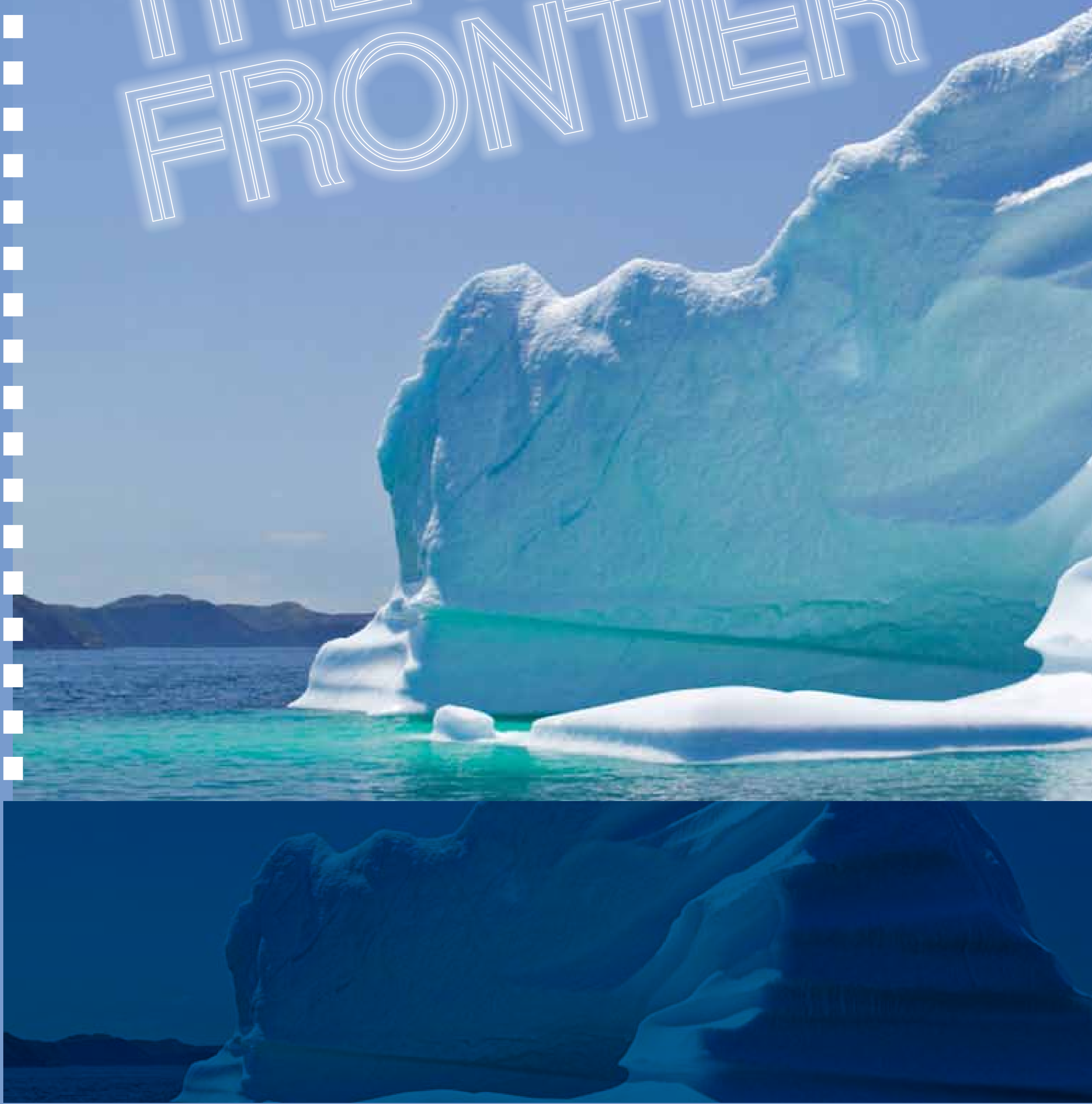
PROTECTING PIPELINES FOR THE NEXT FRONTIER



Michael Paulin, Damien Humby and Joseph Cocker, INTECSEA Canada, and Glenn Lanan, INTECSEA Inc., describe the process of trenching for the protection of pipelines in ice environments.

In the Arctic, sea ice is driven by wind and current forces and tends to pile up, creating pressure ridges. This happens primarily during freeze-up and break-up seasons, while the sea ice sheet is highly mobile. These pressure ridges have keels extending below the water surface, which move with the ice sheet. In other regions, glacial ice in the form of icebergs can have a keel that extends hundreds of metres below the water surface. Occasionally, these ice keels intrude into water with depths less than the ice keel draft and form a gouge (also known as scour) in the seafloor soils (Figure 1). The most common method used for protecting pipelines from ice keel damage in ice gouge environments is to trench them to a selected depth below the mudline.

As an ice keel comes in contact with any point in the seabed, vertical and lateral stresses are applied to the soil at the keel base.

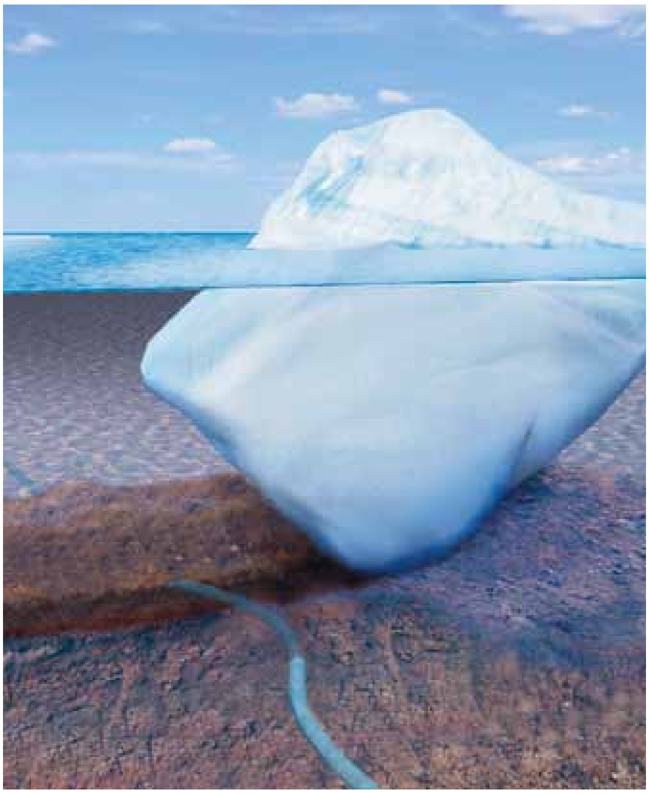


Figure 1. Artistic illustration of pipeline gouging showing deformed pipeline beneath ice gouge.

The result is a distribution of vertical and lateral soil displacements with depth beneath the ice keel, typically termed sub-gouge deformation. This deformation can impose forces on the pipe body and result in deformation of the pipeline. The configuration of the pipeline after gouging, and hence the bending strain in the pipeline, depends on the pipeline properties, the soil characteristics, the depth of the ice gouge, and the depth of the pipeline below the mudline. The pipe must be trenched sufficiently beneath the ice keel to limit the imposed pipeline strains to within acceptable limits.

Summer trenching

Several trenching techniques can be used during the Summer. Some are applicable only to pre-lay, i.e., before the pipeline is installed, whereas others are best suited to post-lay installation. These methods include, but are not limited to:

- Conventional excavation.
- Hydraulic dredging.
- Ploughing.
- Jetting.
- Mechanical trenching.

A pre-lay method or post-lay immediately following installation of the pipeline would most likely be required for Arctic conditions (depending on the area) since the pipeline would otherwise rest on the seabed and be potentially exposed to the action of ice keels moving into the area.

Conventional excavation

Hydraulic backhoes, clamshell bucket dredges or similar methods can be used to excavate a pipeline trench in shallow waters. In Summer, the equipment can be operated from a flat-deck barge, which can maneouvre by winching itself forwards and using spuds to remain on location while digging. Intruding ice could affect the operation depending on the station-keeping ability of the barge and the ice management plans. Alternatively, with shore crossings, berms could be built in the nearshore area that could be used as platforms from which to dig the trench.

Conventional excavation is a proven, but time-consuming, method and productivity is similar for Winter or Summer construction. Also, the reach of an extended or long-reach backhoe is limited (practically) to a combined water and trench depth of approximately 15 m. Special consideration may need to be given to areas where ice-bonded permafrost may be encountered.

Hydraulic dredging

The most common hydraulic dredges used for the excavation of pipeline trenches are cutter suction dredgers (CSD) and trailing suction hopper dredges (TSHD). The CSD excavates the trench with a rotating cutter head on the end of a ladder extended to the seabed. The cutter head breaks the soil, and pumps transport the soil/water slurry through a pipe up the ladder and through a discharge pipe. The end of the discharge pipe is typically located within a couple hundred metres from the dredge and is moved often to prevent excessive dredged spoil from accumulating in one area. Spoil can also be discharged into barges, which can then travel to a disposal area. This has the advantage of limiting the amount of sediment in the water column. Silt curtains have been used successfully to limit sediment dispersion during soil dumping. CSDs are typically limited to water depths from 6 to 35 m.

TSHDs excavate the trench by lowering a suction head to the seabed and pumping slurry into a hopper in the vessel's hull. When the hopper is full, the suction head is raised and the vessel sails to a designated spoil-dump area to empty the hopper. The dredge then returns to the pipeline route and continues dredging. The slurry can also be side-cast or discharged to smaller vessels for disposal. Since the suction pipe is not rigid, the position of the suction head cannot be controlled exactly, thus resulting in a wide trench. TSHDs are often limited to water depths from 6 to 155 m.

Ploughing

Ploughs can also be used to lower a pipeline into a trench. This is usually accomplished post-lay but they can be used for pre-lay trenching as well. Ploughs are usually preferred when the pipeline route is long, due to their relatively quick advance rate. A plough could be used in either Summer or Winter. The primary determining factors for plough design, and ultimately its size, are the type of soil and the desired trench depth. This, in turn, affects the force required to pull the plough.

Historically, ploughs have achieved a trench bottom depth on the order of 1 to 2 m with an average ploughing speed on the order of 200 m/hr.[1] Some multi-pass ploughs have the capability of achieving a trench depth of 2.5 m if the soils are soft enough to allow ploughing, but also strong enough to remain stable until the pipeline touches down in the bottom of the trench. Brown and Palmer (1985) have indicated that multi-pass ploughs for Arctic pipelines capable of trenching 4 to 6 m are feasible, depending on geotechnical conditions. Pipeline trenching ploughs tend to be quite large; approximately 100 to 300 t dry weight and 10 to 30 m in length.

Ploughing requires a marine support vessel capable of supplying the large pull loads to move the plough along the pipeline route. Also critical is having a large crane or A-frame capable of deploying and recovering the plough.

Jetting

This method involves either pulling a jet sled along the top of a pipeline after it has been installed or flying a jetting ROV along the specified route before or after laying the pipe. High pressure water jets liquefy the soil and air lift or eductor pumps remove it from under the pipeline. In the case of post-lay jetting, the pipeline lowers itself to the bottom of the trench as the jet sled advances.

Multi-pass techniques can achieve a trench depth of 3 m in select soil conditions. Jetting only works in certain soil types and is ineffective against large boulders and bedrock. As a supplement to other trenching techniques, localised jetting may be carried out to fluidise the trench bottom in order to lower a pipe that is spanning between local trench floor high points following pipeline installation.

Due to the very large fluidised sediment load created, environmental concerns may be an issue. Another consideration with jetting is the management of the excavated material. The spoils are in a fluidised form and if there are backfill requirements, soil may need to be barged in to backfill the pipeline trench.

Mechanical trenching

Mechanical trenching is commonly used for burying cables and umbilicals, and has been used on pipeline trenching projects. There are two main types of mechanical trenchers; barge-mounted chain cutters, and tracked, crawler style trenchers. Both of which generally rely on hydraulic power to operate their cutters and tracks (where appropriate).

The barge-mounted mechanical trenchers can be used in water depths up to 100 m. They often feature high volume jetting capability for the removal of overburden and a large chain cutter for stiff soils or rock. The crawler style trenchers are capable of operating in water depths up to approximately 1500 m and often use high pressure jetting, as well as chain cutting. The hydraulic power requirements make these trenchers very large, often requiring large buoyancy tanks to keep the trencher from sinking into the soil and collapsing the trench, and to facilitate handling of the machine. These trenchers are large pieces of equipment and require a large marine vessel, which must have a large A-frame to launch and recover the trencher.

Mechanical trenching to achieve a trench depth of 3 to 4 m is considered to be the conventional limit of what installation equipment can achieve.

Winter trenching

Several trenching techniques can be used during the Winter and some are variations on the Summer methods presented above. Again, a pre-lay method or post-lay immediately following pipeline installation would most likely be required for Arctic conditions.

Ice-based excavation has been performed on several pipeline projects using hydraulic backhoes working from stable land-fast sea ice. The sea ice was artificially thickened to support the trenching and pipelay activities. A slot on the order of 3 m wide was cut in the ice using a mechanical trenching machine. The ice was cut into blocks and removed using backhoes. The blocks were then moved by front-end loaders and trucks to locations away from the work site to prevent excessive deflections of floating ice in the working areas.

The trench was then excavated using backhoes. This construction method permitted a continuous trenching, pipelaying and backfilling programme. Excavation could start at more than one location concurrently. This trenching activity is characterised by water depth, as this affects backhoe efficiency. The backhoe boom length needs to be increased in deeper water, which requires changing out the associated bucket size. Shorter-reach backhoes with larger buckets are used in shallower water. In deeper water, an extended-reach boom and smaller bucket is used.

Most of the excavated trench soil needs to be temporarily stored on the ice before backfilling. The material excavated from floating ice could be trucked off and stored temporarily on bottomfast ice in a designated area. Alternatively, if stored on floating ice, consideration must be given to sinking or creep (deflection) of the ice. Once a section of the pipeline is installed in the trench, backfilling using recently excavated trench spoils would commence.

Future direction

Petroleum Research Atlantic Canada (PRAC) is a not-for-profit corporation that facilitates and funds petroleum research and development (R&D) on behalf of its members. PRAC has initiated Phase 1 of a Joint Industry Project (JIP) for the 'Development of a Trenching System for Subsea Pipelines, Flowlines and Umbilicals in Ice Scour Environments'. The JIP is sponsored by Petroleum Research Atlantic Canada on behalf of the operators of the offshore Newfoundland and Labrador, Canada projects.

This JIP is considered groundbreaking due to the deep pipeline burial requirements for ice gouge protection in areas such as the Grand Banks, Labrador Shelf, Greenland, and the Beaufort Sea, for example. The development of new burial technologies will be an enabler allowing for safe and economic hydrocarbon development in these areas and other cold offshore regions. To achieve this, a trenching/burial system is required, which is capable of:

- Trenching to depths greater than current industry norms (burial depths greater than 3 m with potential trench depths as much as 7 m).
- Trenching in highly variable soil conditions that may include sand, gravel, clay, glacial till and bedrock, including the possible presence of boulders.
- Trenching in water depths beyond the majority of trenching requirements (water depths from 5 to 300 m).
- Operating in harsh marine conditions (for example, the Western North Atlantic).

A trencher or trenching system is considered to be not only the active piece(s) of equipment on the seafloor that creates the trench or provides the burial, but also everything else that is required for transport, survey (pre- and post-), deployment (power, tracking, monitoring, etc.), operation, backfill (if required), and retrieval.

Summary

Pipelines located in ice environments need to be protected from potential ice gouging created when a moving ice keel interacts with the seabed. The integrity and operability of the pipeline can be affected by direct contact between the ice keel and the pipeline, or from loading imposed on the pipeline through soil deformation caused by ice gouging. The conventional method used to protect against ice gouging damage is through pipeline burial.

The majority of conventional methods of pipeline burial accomplish a maximum of 2 to 3 m of pipeline burial. Dredges can be used but they have water depth limitations and limited linear advance rates. Land-based equipment has been used for shore crossings, but is limited to shallow water depths where temporary construction berms or stable land-fast sea ice can be used as a working platform.

The research and development needed to bridge the gap between what is currently available in trenching technology and what is needed to effectively and economically bury pipelines, flowlines, and cables in an ice gouge environment is a significant undertaking. A joint industry project has been initiated to prove a trenching system that can trench pipelines to depths beyond industry norms, in water depths up to 300 m, in highly variable soil conditions and under harsh marine conditions.

The development of new burial technologies will be an enabler allowing for safe and economic hydrocarbon development in the Arctic and other cold offshore regions. WP

Acknowledgements

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Reference

1. BROWN, R. J. and PALMER, A. C., 'Submarine Pipeline Trenching by Multipass Ploughs', *17th OTC, Houston,* pp. 283 - 288, (1985).