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# ARCHIMEDES AND THE PIPE-STRING

by Todd Randell, Iplex Pipelines NZ

A look at the importance of pipeline buoyancy mitigation to lower pipe-to-borehole friction and reduce pullback resistance.

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## ABOUT THE AUTHOR

This article is an adaptation of Todd Randell's paper 'Taking advantage of pipe-string buoyancy during long difficult HDD installations'. Mr Randell has had more than 30 years' experience operating within the water and pipeline market sector. He is a certified butt-fusion joining/welding technician and a licensed fusion trainer for FPVC pipe, endorsed by Underground Solutions Incorporated, USA. He conducts industry training programs, operating as a tutor presenting for industry training organisations in New Zealand. Mr Randell has a strong interest in Trenchless Technology and has worked on construction sites throughout New Zealand, Australia and the US. He currently works as a Technical Sales Engineer for Iplex Pipelines NZ.

## TEACHING AN OLD DRILL NEW TRICKS

While horizontal directional drilling (HDD) is one of the oldest 'new installation' trenchless technologies in use today, it continues to rapidly grow and develop. More than ever before HDD contractors are successfully completing installations of unprecedented length, depth and pullback force.

In straightforward HDD installations the pipe sections are pulled into the borehole without any buoyancy modification performed. In these cases the pipe string is filled with 'air'. Any resultant buoyancy creates a certain amount of frictional drag and a proportional amount of pullback force is required to complete the installation.

With thorough planning and detailed design, contractors are able to reduce pullback forces to increase the scope of various installation methods. A key component to reducing pullback force is the successful application of pipeline buoyancy mitigation. This technique, when used correctly, can also eliminate the risk of critical collapse during installation.

Pipeline buoyancy mitigation is best described as the successful water ballasting of a pipe string during the pullback process. By partially filling the pipe string with clean water, the increased weight reduces the string's overall buoyancy and displaces the upwards pressure of the drilling fluid, thereby reducing the pipe-to-borehole friction and lowering the required pull force.

Reducing the pull force can have a positive impact on all areas of an HDD project; it can result in a smaller outside diameter pipe selection, thinner pipe wall requirements, reduced equipment requirements and a smaller HDD rig selection.

This relatively new addition to the HDD arsenal is becoming increasingly useful as drillers embark on installations up to and beyond 2 km in length. These long drill shots come with an elevated amount of risk and require world class engineering practices to be successful. Sometimes large HDD projects are so challenging they can only be completed by a specialised team gathered from a small pool of international experts, and require the use of maxi-sized drilling rigs to reduce project risk.

## RESISTANCE IS FUTILE

A key component of HDD is the use of drilling slurry, also known as 'mud', to fill the borehole. Much like a boat, if the drilling slurry displaced by the pipe as it is installed is heavier than the pipe taking its place, the pipe will float. In an enclosed borehole this results in a buoyant force on the pipe as it is pushed into the crown of the borehole. This force creates a frictional drag, resulting in increased pullback resistance for the drill rig pulling the pipe.

The frictional drag is proportional to the amount of buoyancy the pipe is experiencing. Thus, by reducing the buoyant loading on the pipe section, the installer is also able to reduce the frictional loading on the pipe. »



**Opposite page:** Installation of DN475 SN16 FPVC being pulled in an urban environment.  
**Right:** Pipe string entering the bore hole.



Successful water filled pipe string ballasting techniques were utilised on the New Zealand case study.



The New Zealand case study included installation through rural and built-up urban environments.

Evaluating the potential buoyancy starts with the pipe material that is being installed; the buoyancy loading of thermoplastic pipe systems is more important to consider than that of steel pipe systems. This is due to the fact that the higher density of steel already acts to reduce the overall buoyancy, reducing the required pull back force.

In some cases buoyancy modification with high density pipe materials like steel will increase the pipe string weight, forcing the pipe to the bottom of the bore hole and increasing the frictional drag required to complete the installation. This is the opposite effect of successful pipeline buoyancy mitigation.

Buoyancy should be calculated based on the volume of drilling slurry that will be displaced by the pipe section, the estimated

density of the drilling slurry and the weight of the pipe (including any ballasting employed during installation).

### CRITICAL CONDITION

When embarking on relatively long, deep and difficult pipe installations, a key concern for the contractor is the risk of critical collapse during installation. Pipeline buoyancy mitigation helps to eliminate this risk by minimising the impact of excessive external pressure from the drilling slurry; the ballast water provides a counterbalance of internal pressure to resist external loading.

To ensure successful buoyancy modification and minimise the risk of critical failure during installation, contractors must follow the following four steps:

1. Ensure the pull head is watertight. If a watertight pull head is not possible, anchor a pneumatic test plug on the internal side of the pull head to ensure the separation of the water ballast from the drilling fluid.
2. Ensure the water level always remains below the drilling slurry level in the bore hole. If the water level is above the drilling slurry level the pipeline will be unnecessarily heavy, increasing frictional drag.
3. Insert a fill pipe inside the pipe string to the point where it enters the drilling slurry in the bore hole.
4. Fill the pipe string as it is installed, keeping a tight control using a flow meter and recording water volumes as the pullback progresses. »

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Pipeline buoyancy mitigation is already being applied successfully in challenging HDD projects across the world. One such project was the installation of a new gravity wastewater trunk main to service 2,500 homes in the North Island of New Zealand.

The installation was completed in three phases with shot lengths of 290 m, more than 1,000 m and 245 m respectively. Native geology ranged from hard East Coast Bay Formation (ECBF) rock, to very weak soft marine sediment.

The second installation passed through hard ECBF rock into soft marine sediment and was considered to be un-drillable in a single installation. Initial modelling of the installation indicated that pull forces would exceed the safe working loads of the preferred SN16 Fusible PVC™ Pipe (FPVC) pipe.

Successful water filled pipe string ballasting techniques had been utilised by the driller on past HDD projects and were deemed necessary for installation of the 1 km pipeline.

Before installation was attempted, buoyancy modification was performed on the first pipeline installation to ensure that the water ballasting method used was successful. Pull forces were monitored using a load cell and the actual pull force records indicated that a water filled pipe in the site conditions reduced pullback forces by more than the theoretical forces originally calculated. This determined that the water ballast method used would be suitable for installation of the second pipeline.

Other pre-construction modelling included a straightforward air-filled pipe pullback with predicted pull forces estimated at 75,000 kg. For this installation DN450 PN12 FPVC pipe was selected as it offered a safe axial load limit of 70,000 kg and determined that successful water ballast would be crucial. Buoyancy modification corrections were applied to the pre-calculated model where estimated pullback forces had reduced to 46,247 kg.

During installation of the second pipeline 50,000 litres of water were introduced into the pipe string to reduce buoyancy loading on

the pipe. This was approximately 30 per cent of the internal volume available within the pipe string being pulled.

The pull force pressures recorded were stable and very low, leading the contractor to conclude water filling approximately 400 m into the pull. The forces applied to the pipe were monitored using the same load cell used in first installation. The load cell was correlated to the thrust gauge readings on the drill rig. Final analysis of this data proved that a maximum force applied during the pipe pull was 24,500 kg.

This significant reduction in pullback pressure when compared to theoretical pressures calculated earlier was attributed to FPVC's low specific gravity, buoyancy modification performed while using water ballasting techniques and the preparation of a good clean borehole prior to pull back.

As the trenchless sector continues to grow it is likely buoyancy mitigation will continue to aid in the installation of difficult HDD projects, and will increasingly be used in projects that were once considered impossible. **T**



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PH: +61 7 3803 9400  
simon@jbattachments.com

MELBOURNE, AUS  
PH: +61 3 9947 6101  
troy@jbattachments.com

AUCKLAND, NZ  
PH: +64 9 278 4863  
jbparts@jbattachments.com