TECHNICAL ARTICLE

BPS-TA3 May 2020

Backfill Pipeline Solutions

The History of Paste Reticulation Design and Materials Used in Australian Paste Systems

It has been 20 years since paste fill was introduced into Australian mining. In this article the author traces the history of materials used and the design basis behind these selections.

WHERE IT ALL STARTED

In 1998 the first two Australian paste operations were commissioned in Queensland and Tasmania. Both operations utilised the whole tailings stream from the ore extraction process, mixed this with cement and delivered a toothpaste-like consistency paste fill underground by gravity. Both operations followed the North American design philosophy that had been adopted in earlier paste fill systems in Canada where nominally 5 m^3 batches of paste were sent underground by gravity.

The pipe network underground, referred to as reticulation, was designed in accordance with ASME B31.3 and primarily used Schedule 80 seamless steel pipe meeting API 5L Grade B PSL1 and/or ASTM Grade B standards joined by Victaulic® high pressure HP70/HP70-ES couplings. A small amount of high-density polyethylene pipe (HDPE) was used for the last 20-30 m of each run, however the use of HDPE was limited.

As both systems were relatively shallow, the systems were designed to withstand the full pressure generated if there was a blockage at the bottom of the system.

Very little instrumentation was installed on these early systems, and the instruments that were used tended to be inaccurate and unreliable. It was thought that unique instrumentation was required to handle the paste like consistency of the product.

Over time the Queensland system, which was significantly larger than the Tasmanian system, had a significant number of pipe joint leakages. These were caused by rounding of the pipe grooves, which occurred from the large dynamic forces from the paste acceleration each time a new batch was dropped into the system. As a result, the use of flanges at major changes in direction were used and over time the whole system moved to double groove Victaulic 808 couplings.

THE FIRST AUSTRALIAN DESIGNED SYSTEM

In 2000, planning for the next paste fill system in Australia was started. This system in Kalgoorlie, Western Australia had the advantage of using all the learnings of the two initial systems.

The WA paste system, which is considered one of the most successful paste systems globally, had a significant focus on ensuring the underground reticulation system was designed to improve the ease of installation and to adopt improved levels of instrumentation so that the surface paste system operators had a real-time understanding of the conditions in the underground pipeline.

Furthermore, this system was designed as a continuous plant which removed all the significant dynamic loads on the underground reticulation caused by a batch system.

For this system the paste reticulation was designed in accordance with AS4041 – Pressure Piping. AS4041 is based heavily off British and American Standards. AS4041 allows the designer to determine the class of piping based on the nature of the fluid being conveyed. For the WA system Class 2P was selected based on the properties of the tailings slurry. Allowing this classification results in less stringent design requirements compared with ASME B31.3 and is more in alignment with the old ASME B31.11 which has now been superseded by ASME B31.4.

The WA system was not designed to handle the full pressure in the event of a blockage at the end of the pipeline. This was impractical due to the ultimate depth of the orebody. Therefore, a lower design pressure was selected with “burst” pipes positioned in safe locations throughout the system. The “burst” pipes were shaved down steel pipes with an outer shroud for protection in the event of an overpressure event. These “burst” pipes thus ensured that if an over pressure event occurred the pipe would fail in a controlled location and no underground workers would be exposed to the hazard.

The design continued to use steel pipes, however thinner walled Schedule 40 200 NB steel was used resulting in lower weight, thus improving the safety of installing the significant length of pipe required for this system. Victaulic HP70 couplings were used. The design aimed to maintain simplicity and thus a single coupling type was chosen. This compares to North American designs that often use multiple couplings on a single reticulation system.

Again, this system adopted only a small amount of HDPE pipe. The HDPE pipe was provided in nominally 6 m lengths and was joined using stub and backing flanges which was and continues to be a very common method of joining HDPE in surface applications.

Due to the lower schedule, improved availability and lower cost, electric resistance welded (ERW) pipe was used rather than seamless pipe.

For the bends, the pipe was bent using specialist fabricators within Australia. Initially 5D bends were used however, over time these moved to 3D bends. This is a major departure from North American paste systems which continue to use 5D bends as a standard.

All the pipe was galvanized to provide some level of surface protection but also to “stand out” from other mill finish steel pipe that was used underground for low pressure services. The high-quality finish of the galvanized pipe resulted in an installation that looked professional and improved the pride the installation crew had on their installation works.

This system was fitted with more traditional process plant flowmeters and pressure transmitters which proved to be far more accurate and reliable than the unique instruments used in the first Australian paste systems. These instruments fed live data back to the surface. Using this data and the high level of education employed to the operators, this system has operated for nearly 20 years with very few issues, blockages or failure of the “burst” pipes.

This first Australian designed system generated the standard and approach that has been followed by almost all the paste systems in Australia since.

PASTE DESIGN FROM 2005 TO 2018

On the paste systems that followed up until 2018, there were incremental improvements in the system design without any major design changes. As a general trend, designers have tended to stick with 150 NB (6 inch) or 200 NB (8 inch) Schedule 80 pipes for most operations and have taken less consideration of the install cost of the steel aspects of the paste systems. All steel pipe now used in Australian paste operations is manufactured in China.

Whilst the steel design tended to take less consideration of the install costs, there has been a significant increase in the use of HDPE pipe driven by the popularity of paste fill in continuous retreat mining operations. These mining operations tend to require significant lengths of pipe on every sub-level that are spaced at 15-25 m intervals. Having to install steel pipe on all of these levels results in significant costs for both materials and installation. Therefore, PN16 up to PN25 HDPE has been used on many paste operations to maximise the length of the HDPE that may be used. These areas are often barricaded to limit personnel exposure to this pipe. HDPE pipe is generally installed 3 to 5 times as fast as the steel pipe owing to the lighter nature of the pipe and typically chain is used rather than threaded bar and steel saddle supports.

Furthermore, most operations have moved to Victaulic 995/905 couplings that fit to plain end HDPE.

Over this time the steel bends have moved away from pipe being bent in Australia and rather the use of Victaulic cast schedule 80 bends. A 3D bend radius has continued to be used.

One consistent aspect of almost all the paste systems in Australia is very little wear is seen on the systems where there is full pipe flow. As a result, there is little consideration of wear required in well-designed paste systems outside of the boreholes where “freefall” and extremely high velocities occur.

Over this time there has been almost no change to the instruments adopted on the paste systems, with the major developments being the introduction of higher quality/cost dump valves.

MODERN PASTE RETICULATION SYSTEMS

In the past 4-5 years there has been a much larger focus on the introduction of technology into global mining operations. Within paste fill reticulation systems this is very much in its infancy. This owes a lot to the success of the greater than 50 paste systems in operation in Australia today. It also is a result of the focus being on other parts of the mining operations.

In a modern paste system, there is a renewed focus on designing a system that is both safer and lower cost to install rather than just developing a system that is "easy" to design. This renewed focus has resulted in several changes to how systems are designed, and the materials used.

A change adopted in several recent paste systems is the use of 125 NB pipe and the use of lower pressure Style 77/177 couplings. Previously, since 125 NB pipe and bends were less common than 150 NB, most systems were upsized. This generated several issues for some systems with coarse, heavy tailings. Significant settling would occur in the system and blockages would often result. With much improved supply channels from China now available, there is very limited difference in availability of the smaller pipe. This smaller pipe not only ensures the system is sized appropriately ensuring a robust operating system, but also the cost of materials is reduced, and the ease of installation improved.

In terms of the design standard AS4041 and steel pipe little has changed, although it is now very common that seamless pipe is used rather than ERW, since there is little difference in cost when sourcing direct from China.

Maximising use of HDPE continues to occur, with PN20 being typically the highest pressure rated HDPE being used. This results in up to 170-200 m of HDPE being able to be run at the end of the system. On long ore drives that exceed this length then steel pipe is still often used.

A more recent pipe innovation that is providing significant opportunities is steel reinforced polyethylene composite piping (SRCP). This is a composite HDPE and steel wire pipe providing the low weight advantages of HDPE with the high-pressure capability of steel. With a working pressure up to 7,000 kPa, SRCP can now be used to completely replace steel piping in long drives.

With SRCP now readily available and proven in several paste fill operations (one operation recently completed a trial of placing 70,000 m^3 through SRCP and the pipe still appeared brand new) a modern paste fill system is starting to look a little different. Whilst one operation in Africa has moved to SRCP as an almost complete replacement for steel, most designs are trending towards steel being used for the core trunk lines (i.e. body of the Octopus). For all the extensions outside the main trunk (i.e. arms of the Octopus), SRCP is being used. HDPE continues to be used for last 100-200 m of the system since HDPE continues to be the lowest cost pipe alternative.

SRCP is joined using the same Victaulic couplings as the steel pipe so that it fits seamlessly into both new and operating paste fill systems. It is typically supported in the same way as steel pipe with threaded bar and saddles although chain may be used in some cases.

With the system design pressures in some cases reducing (for gravity systems), the need for reliable burst pipes has also increased. In North America, the industry has tended to use specially designed burst discs. Industry feedback on these devices has generally been poor with "nuisance" bursts typical. As such many operations simply remove them. This lack of reliable performance and the high cost of the units in Australia has prevented their adoption.

Rather, it has become much more common to use standard HDPE and now SRCP "burst" pipes. These can be designed with suitably accurate failure pressures and are not impacted by wear. The major consideration is to ensure the normal operating pressure is not excessively above the maximum allowable operating pressure of the HDPE or SRCP. Over the past 7 years, this has not been an issue on any of the installed "burst" pipes.

In some cases, mine operators still have a reluctance to install "burst" pipes as it adds complexity and a level of management to the system. However, the benefits of specifying a more relevant design pressure compared to the normal operating pressure, rather than a worst-case scenario full system blockage are significant. They include much lower weight materials improving the safety and ease of installation, lower cost of the piping materials and a significant reduction in the installation time and cost.

In terms of instrumentation there are some minor developments in the areas of the method of communication, e.g. Wi-Fi and non-contact flowmeters. These improvements are all minor since a robust and low-cost instrumentation system has existed for many years. More focus on instrumentation is centred around in stope instrumentation and thus feeding real-time in-stope conditions back to the surface to allow optimisation of the filling and thus mining process.

Backfill Pipeline Solutions

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