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THE ONESTEEL WHYALLA 62 KM MAGNETITE SLURRY AND RETURN WATER PIPELINES

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This paper describes some design and commissioning aspects of a 62 km DN200 magnetite pipeline transporting 250 tph of magnetite concentrate from the Iron Duke mine to Whyalla. A parallel DN400 water pipeline returns water from the dewatered slurry plus additional water back to the mine. The pipelines were commissioned in August 2007. The equipment, operation and control philosophy for both pipelines are described. During pipeline commissioning, operating procedures were developed to ensure the slurry was within particle size and rheology specifications and allow the Operators to select the correct density for pumping in relation to the rheology of the particular concentrate being pumped. The transient pressures during shutdown are discussed.

KEY WORDS: magnetite slurry concentrate pipeline, return water pipeline

1. INTRODUCTION

OneSteel Limited operate a steel making plant at Whyalla, South Australia. The plant has operated for many years using hematite ore from nearby deposits. The start-up of mining of an associated magnetite deposit can supply the steel plant for another 25 years. The magnetite is transported from the mine to the steel plant via a new slurry pipeline. This paper describes some design and commissioning aspects of a 62 km DN200 magnetite pipeline transporting 250 tph of magnetite concentrate from the Iron Duke mine to Whyalla. A parallel DN400 water pipeline returns water from the dewatered slurry plus additional water back to the mine. Both pipelines are fully welded, unlined steel pipelines buried in a common trench. The slurry pipeline uses a single pump station with a piston diaphragm pump while the return water pipeline uses a single pump station utilising two stage centrifugal pumps. SSE performed detailed design of the pipelines and provided assistance during commissioning. The pipelines were commissioned in August 2007.

2. MAGNETITE SLURRY PIPELINE

2.1 DESCRIPTION

The slurry pipeline pump station is located adjacent to the concentrator at the minesite. The magnetite slurry is received from the thickener into two relatively small 10 m diameter x 10 m high agitated slurry storage tanks at the pump station. Each agitator is driven by a 45 kW motor. Two variable speed centrifugal charge pumps, one duty and one standby, receive slurry from the agitated storage tanks and deliver the slurry at a controlled pressure to the mainline piston diaphragm pump. The mainline pump is a Geho triplex piston diaphragm pump rated at 222 m^3/h driven by a 1050 kW variable speed motor and maximum discharge pressure is 15.3 MPa. Normal flow rate is 205 m^3/h representing 48 strokes per minute.

The slurry in the agitated storage tanks is received at a nominal concentration of 70%. The concentration of the slurry is adjusted by controlled dilution prior to the charge pumps. The pumping concentration varies between 55% and 65% depending on production and slurry properties. The nominal production is 250 tph of magnetite. The pump station includes lime and chemical injection facilities to control internal corrosion of the unlined pipeline. The pipeline operating procedures include regular monitoring for internal corrosion.

The 62km DN200 slurry pipeline is installed buried adjacent to the DN400 return water pipeline. Fibre optic cables are also installed in the common trench. The pipelines are laid at a nominal depth of 750 mm however burial depth varies up to 1200mm for protection reasons based on detailed consideration of the land use of each area that the pipeline crosses. The pipeline is externally coated with anti corrosion coating. The internal surface of the pipeline is bare steel. A variable corrosion allowance has been used along the pipeline. The design hydraulic gradient is shown in figure 1. The pipeline wall thickness is telescoped in order to reduce pipe steel requirements from 8.2mm to 4.8mm generally reducing towards the low pressure end. However thicker wall thickness pipe is installed in some locations for protection reasons.

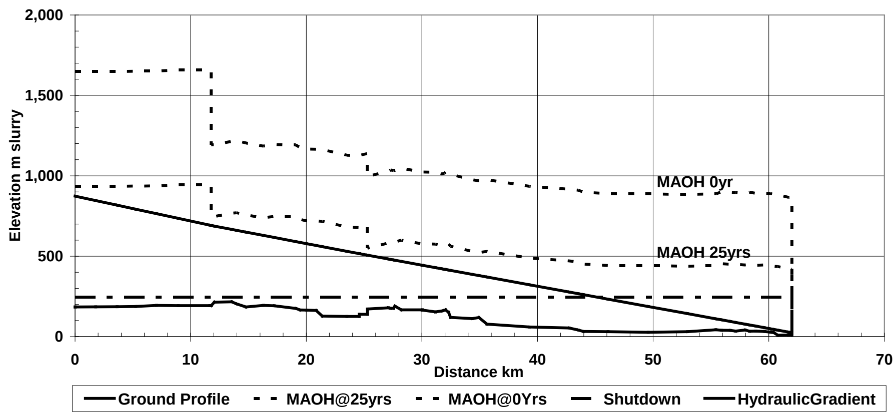

Figure 1 DN200 Slurry Pipeline Hydraulic Gradient

No air release valves are installed on either the slurry or return water pipelines and the pipelines follow the ground undulations with no special grading of the pipelines. No mainline isolation valves are installed along the length of the pipeline. A pig launcher and receiver are included at the start and end of the pipeline respectively. The control system sequences valve operations to prevent over-pressurisation and emergency pressure relief systems are also installed.

For the initial year of operation only a single mainline piston diaphragm pump is installed in the pump station. Consideration was given to the possibility of a long term failure of the single mainline pump with a line full of slurry and the potential methods available to flush the slurry from the pipeline. Analysis by SSE indicated that it would be possible to flush the slurry pipeline in sections using pressurised water from the parallel return water pipeline. The crossover connections between the slurry pipeline and the return water pipeline are installed at high points at km 13.8 and km 28.3. For later years a standby mainline pump is being installed.

The pipeline is automatically controlled under the supervision of the concentrator operators. The operator selects the concentration of the slurry to be transported. Flushing, batch and stop - start operations are supported. Automatic leak detection is programmed based on monitoring the input from flowmeters installed at the start and end of the pipeline.

2.2 SLURRY PIPELINE COMMISSIONING HYDRAULICS

The volumetric efficiency of the PD pump was determined by measuring the drawdown of a tank when pumping water. The volumetric efficiency was 95%.

With the slurry pipeline full of water a series of tests were performed to determine the average hydraulic roughness of the pipe. Flow rate was varied between 169 m^3/h and 225 m^3/h. Flow rate was measured by three methods: pump strokes and by flow meters at pump station and terminal. There was 1.5% variation between the three flow rate measurements resulting in determined average pipe roughness ranging from 0.053 mm to 0.067 mm.

Slurry friction loss predictions were compared with measurements with the pipeline containing four batches of slurry each of concentration 62.5%, slurry density 2000 kg/m^3. There were small slugs of water separating the four slurry batches with the volume of water estimated to be approximately 4% of pipeline volume. At a steady flow rate 179 m^3/h the pump discharge pressure was 7630 kPa. The predicted pump pressure based on a pipe roughness of 0.05 mm and allowing for the 4% volume of water was 7994 kPa. The measured pressure is 4.6% lower than predicted.

Two manual shutdown/restart tests were conducted with the slurry pipeline. The first test involved a 1½ hour shutdown from an original flow rate of 205 m^3/h with the pipeline only partly full of slurry with the remainder water. During restart the pump speed was ramped up to the original 205 m^3/h in 8 minutes. The peak pump discharge pressure was 14.5 MPa occurring 8 minutes after restart with the pressure then decreasing and approaching the equilibrium 10.4 MPa 24 minutes after restart began.

The second shutdown test involved a 27 hour shutdown from an original flow rate of 180 m^3/h with the pipeline completely full of slurry. Restart was achieved by ramping the pump up to the original 180 m^3/h over 20 minutes. Peak pressure was 11.7 MPa occurring 15 minutes after restart commenced. The pressure then reduced approaching the equilibrium 7.6 MPa 27 minutes after restart commenced.

3. RETURN WATER PIPELINE

The return water pipeline pump station is located adjacent to the pellet plant at Whyalla. Two sets of two centrifugal water pumps are installed, one set standby and one duty. The return water pumps are driven by 500 kW motors. Early in the project consideration of the economics and technical aspects of various operating options indicated that fixed speed pumps with flowrate determined by control valves was the most cost effective alternative. The pump station includes lime and chemical injection facilities to control internal corrosion of the unlined pipeline. The operating procedures include monitoring for internal corrosion. The flow rate of the pipeline can vary from 371 to 560 m^3/h. The maximum inlet pressure is 4000 kPa.

The 62km DN400 return water pipeline is installed buried adjacent to the DN200 slurry pipeline. The pipeline is externally coated with anti corrosion coating. The internal surface of the pipeline is bare with a uniform corrosion allowance applied. The design hydraulic gradient is shown in figure 2. Generally a constant wall thickness of 6.4mm is used for the return water pipeline, however thicker wall pipe of 9.5mm is specified for some locations based on the consideration of protection requirements.

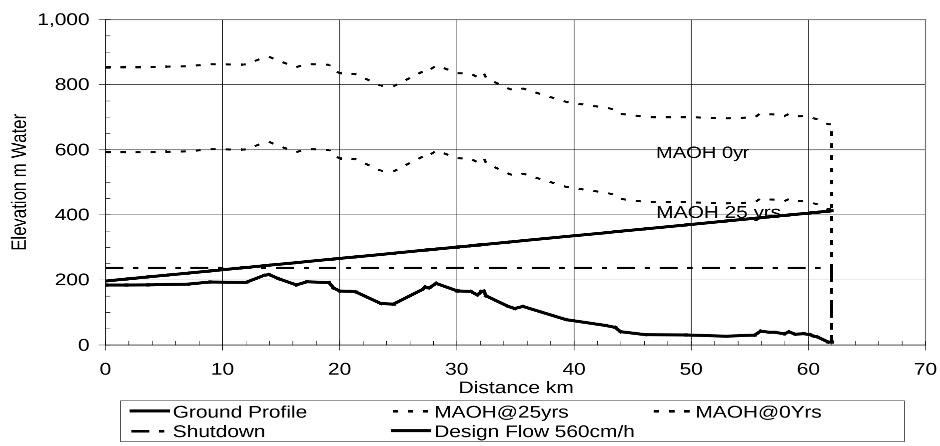

Figure 2 DN400 Return Water Pipeline Hydraulic Gradient

A pig launcher and receiver is included at the start and end of the pipeline respectively. There are no intermediate mainline isolation valves, scour valves or air release valves installed along the pipeline. For start up purposes pigs were run to clear the pipeline of any air. Air was also released during start-up from manual valves located at two high points at the crossover connections to the slurry pipeline.

The flowrate from the fixed speed pumps is automatically controlled by the control valve to the set point selected by the operator. Automatic control is also possible in response to varying tank levels. Quick acting surge relief valves are installed at the start and end of the pipeline. Automatic leak detection is programmed based on monitoring the input from magnetic flowmeters at inlet and outlet.

The pipeline route is downhill for the last 13.8 km to the minesite. For the lower flowrates this would result in the possibility of negative pressures in the pipeline. Maintaining a packed pipeline is desirable from an internal corrosion point of view. In order to maintain a packed pipeline during operation a control valve is installed at the discharge which automatically varies the back pressure based on flowrate.

4. SLURRY ACCEPTANCE TEST

The magnetite slurry is stored in two agitated storage tanks at concentrations around 70% then diluted to the pumpable range of 55% to 65% concentration with the maximum pumpable concentration determined by the requirement for the operating velocity to be at least 0.3 m/s above the laminar/turbulent transition velocity. The transition velocity depends on the yield stress of the slurry. A simple and quick method was required to enable pipeline Operators to measure the yield stress of the high concentration slurry in the tanks and translate the result to concentrations in the pumpable range so that the required pumping concentration could be input to the control system.

The slurry acceptance test involves taking a sample from the slurry tank, measuring the slurry density using a Marcy gauge, and then testing the slurry in the OneSteel Haake viscometer at a single speed (Speed 7). A single test speed was chosen because the magnetite slurry settles very quickly, even at high concentrations, and it was judged impossible for Operators to get accurate readings at a number of speeds. A means of relating the test result at the single speed 7 to the yield stress was then required. This was achieved by conducting a large number of tests during the commissioning period using both SSE's Contraves viscometer and the OneSteel Haake viscometer. The Contraves viscometer is an ideal instrument for testing slurries and, with experience, it is possible to obtain accurate plots of shear stress versus shear rate and extrapolate to zero shear rate to obtain the Bingham yield stress. The viscometer test results at Haake Speed 7 were related to the yield stress by the equation: Yield Stress (Pa) = 0.863 x (Haake Speed 7 Reading) – 1.57.

Figure 3 shows yield stress versus concentration data determined by the Contraves viscometer for various samples during the commissioning period. Although the yield stress varies significantly between samples, all data follow an approximately similar slope on the semi-log plot. The bold line shown represents an exponential slope relationship, Yield Stress = exp(0.189 x Concentration). This same average exponential relationship was then recast in terms of Haake Speed 7 reading versus slurry density to give the Slurry Acceptance Graph shown as Figure 4.

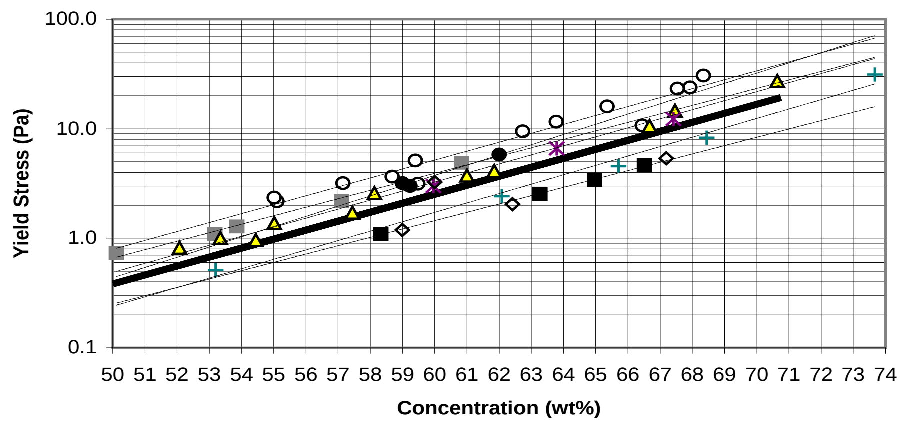

Figure 3 Yield Stress Versus Concentration Various Samples

As an example of the use of the Slurry Acceptance Chart suppose a tank sample has a density of 2300 kg/m^3 (concentration 70.6%) and gives a Haake Speed 7 reading of 20 as indicated by Point A in Figure 4 From Point A the grey line shown is followed down to lower densities to cross the maximum Speed 7 reading of 6 at a density of 2010 kg/m^3 (62.8%). This particular slurry can be therefore be pumped at any density between the minimum 1780 kg/m^3 (55%) and 2010 kg/m^3 (62.8%).

A second example involves a tank sample density of 2250 kg/m^3 (concentration 69.4%) and a Haake Speed 7 reading of 38 as indicated by Point B in Figure 4. Following a similar procedure as above it is determined that this higher rheology slurry can be pumped at any density between the minimum 1780 kg/m^3 (55%) and 1870 kg/m^3 (58.2%).

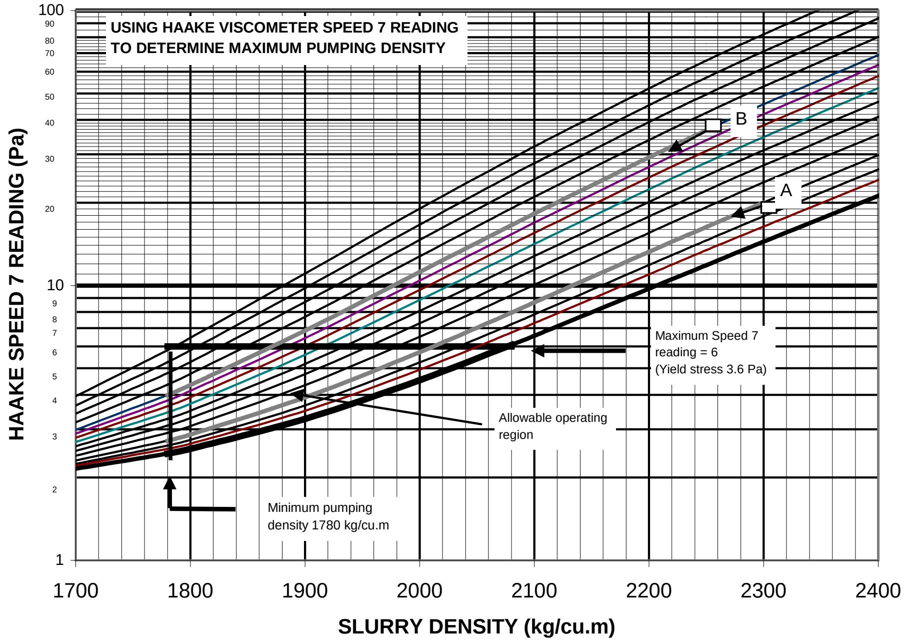

Figure 4 Slurry Acceptance Chart

5. SHUTDOWN SURGE PRESSURE

Because there is a 213.5 m elevation difference between the terminal and the high point along the pipeline, when the slurry pipeline is shutdown the terminal valve must be closed to prevent draining of the pipeline. Once the valve closes transient surge pressures occur throughout the pipeline with maximum surge pressures immediately upstream of the closed terminal valve.

Figure 5 compares pressure variations at the terminal following shutdown from a flow rate of 205 m^3/h. In both cases the terminal valve began closing 40 seconds after the pump stopped with valve closure completed 15 seconds later. When the pipeline was filled with water the transient pressure peaked at 2763 kPa, 2.28 minutes after valve closure, and then cyclically decayed before reaching an equilibrium pressure of 2033 kPa. When the pipeline was filled with slurry of density 2000 kg/m^3 (62.5% concentration) the peak surge pressure was 4662 kPa. From this peak the pressure then showed a steady exponential decay, apart from a very small pressure increase 2.87 minutes after valve closure, until a final pressure increase about 43 minutes after valve closure. The final equilibrium pressure was 1910 kPa.

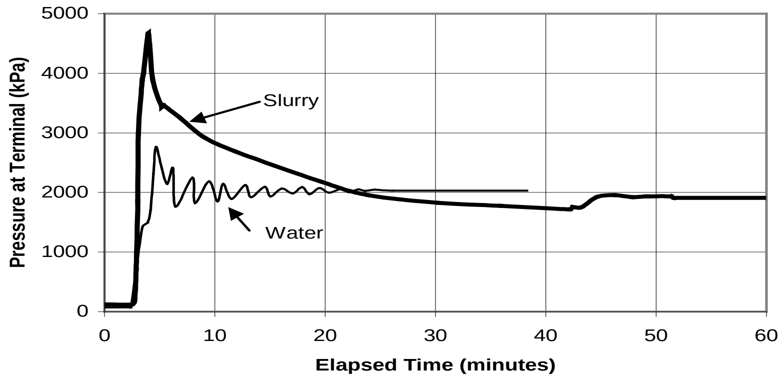

Figure 5 Comparison Shutdown Pressures Water and Slurry

The lack of cyclical pressure decay with the slurry shutdown is due to the fast settling nature of the magnetite slurry. When the first small pressure increase occurs 2.87 minutes after valve closure, the 62.5% concentration slurry has already settled to give about 5% free water at the top of the pipe. It can be assumed that as transient pressure waves traverse the pipeline they resuspend the settled slurry which then settles again. The pickup of settled slurry will dissipate energy and probably explains the lack of cyclical pressure decay. Note that the the final equilibrium pressure of 1910 kPa is similar to the 2033 kPa equilibrium pressure with a water filled pipeline. This indicates that the free water above the settled slurry, which after 40 minutes, is about 15% of the height, provides a continuous water pathway to transmit pressure from the high point to the terminal.

6. CONCLUSIONS

On commissioning of the DN200 and DN400 pipeline systems the performance easily meets the design throughput requirements. Shutdown tests have confirmed the slurry pipeline is capable of restart after a period of time with slurry left in the pipeline. The increasingly common requirement of including return water pipeline systems adjacent to slurry pipelines can allow for some benefits to the slurry pipeline operation. For example the ability to cross connect the slurry and water pipelines for a low cost water flushing capability. The cross connection can improve the viability of single piston diaphragm pump operations (no standby) for the purpose of minimising upfront cost, although in this case a second pump is to be installed. The air valves and scour valves that are often installed on water pipelines can be shown to be not required particularly for increasing operating pressure and when pigging facilities are installed. A simple and quick method was developed to enable pipeline Operators to measure the yield stress of the high concentration slurry based on the OneSteel Haake viscometer at a single speed. When considering transient pressures in the magnetite slurry pipeline the settling behaviour of the slurry can affect the magnitude of the surge pressures and the shutdown pressures.