Slurry Pipeline Helps Remedy Corrosion At Record Height

Slurry receiving tanks at Coloso.

by Jack Boggan, Project Engineer, Fluor Daniel Williams Brothers, and Ralph Buckwalter, Fluor Daniel Mining and Metals, Sugar Land, Texas

The world's longest and highest operating pressure copper concentrate slurry pipeline was put into service in March 1995 in northern Chile, a vital part of Mina Escondida Limited's (MEL) project Phase III expansion, which upon completion, made Mina Escondida the world's largest producing copper mine.

The mine is located approximately 165 kilometers (102 miles) east-southeast of Antofagasta, Chile, on the western slopes of the Andes Mountains. The pipeline begins at the mine at an elevation of 3,080 meters, (10,434 feet) running westward to MEL's expanded filter and leach plant facilities at Coloso, at sea level, approximately 20 kilometers (12.5 miles) south of Antofagasta.

The Escondida project includes an open pit mine, in-pit crushing and conveying, covered stock pile, concentrator, the slurry pipeline, a 5-9's (meaning 99.999 percent pure) copper electro-winning plant, a filter plant, bulk concentrate storage and a deepwater ship-loading facility.

A concentrate slurry pipeline was installed for the initial plant operation in 1989. It consisted of a 6-5/8-inch and 7-5/8-inch unlined steel pipeline. After the initial operation, high internal corrosion was identified and mitigative measures were investigated. A recommendation to install a high density polyethylene pipe (HDPE) lining would control the corrosion. The control of the rheology of the slurry was determined to be critical as was the concentrator process since the concentrate produced has a high pH which caused heavy internal scaling.

These were some of the basic design considerations for the new increased capacity pipeline system required for the plant expansion. Also addressed were concerns such as the possible corrosion problems that found a complexity of combined chemical, electrical, and bacterial corrosion. The heavy scaling of the existing pipeline would necessitate acid cleaning of the pipeline and cause excessive wall loss.

Long down-time with the product in the pipeline could set up a galvanic action with the copper sitting in the bottom of the steel pipe. Each unscheduled maintenance shutdown and start-up could cause excessive wear in the bottom of the pipe and higher wear in the slack flow areas. Additionally, bacteria found in the slurry were both aerobic and anaerobic; treatment costs were both expensive and could cause environmental problems.

A major concern was for the plant outfall in protecting the Coloso fishing village and beach area. Therefore it was decided that the planned expansion would be a replacement pipeline utilizing an HDPE-lined system. The selected system will provide an operating cost savings in treating and giving a more friendly environmental water discharge which might be used for other purposes.

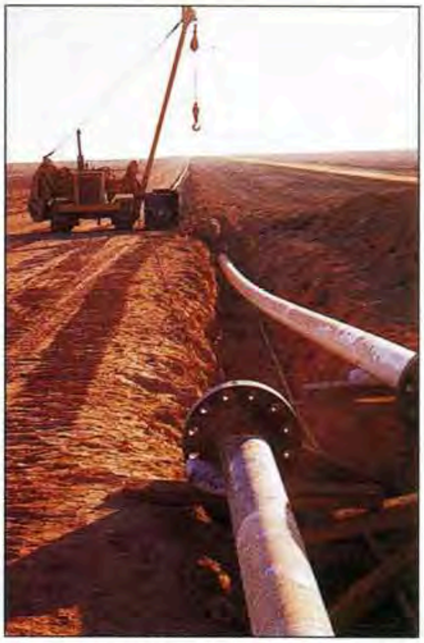
Slurry Pipeline System Description

Three valve stations were used to section off the pipeline, thus limiting the static head to an acceptable allowable pressure. Each pipeline station block valve had to be opened in sequence from the lowest point to the highest point and shut down in sequence, beginning with the highest point. This allowed telescoping the pipeline wall thickness, thus saving a significant cost in the steel pipe.

The steel pipeline was joined by flanges to allow insertion of the proper HDPE liner pull lengths which were up to one kilometer long. The flange arrangement allowed the joining and transitioning of the HDPE pipe. Before placing the pipeline into service, the total line except for the valve station piping, was hydrostatically tested to prove the integrity of the untested flanges at the test section tie-ins. The valve station fabrication was pretested and tie-in welds were radiographically inspected prior to beginning of service.

The 167 kilometers (103.4 miles) of 9-5/8-inch outside diameter (O.D.), ERW steel pipeline was sized with various wall thicknesses (0.250, 0.281, 0.312, 0.344, and 0.375) utilizing API 5L X-60 line pipe. The outside diameter of the HDPE liner (pipe) was sized to match the inside diameter (I.D.) of the steel pipe. The HDPE liner was 0.280-inch wall thickness except in the slack flow areas and near valve stations. A heavier wall thickness (0.420-inch) HDPE was used for these high-wear zones.

The external coating of the steel line pipe was tape-coated over the ditch. A fiber optic cable for the communications link between the mine-site and port facility was also installed in the ditch prior to backfill. The pipeline was designed to operate at a pressure as high as 3,700 psig with rupture disk set points up to 4,000 psig. ANSI class 1500 # valves and flanges were used. The pipeline was hydrostatically tested up to 4,208 psig in the heavier wall sections. Due to the high static head near 5,400 psig, the wall thickness of the steel pipe was designed to meet the requirements of the transient - flowing pressures.



▲ **The fused line is about to be pulled through the reduction box at the side boom, shown in the far background. The cable from the flange to box will then pull the liner into the steel line.**

◀ **Flange connection.**

Rupture disks were installed to protect each pipeline section should the lower end of the pipeline become plugged or accidentally shut down with full static head in two sections or more. Otherwise, a rupture disk would release the pressure and protect the pipeline section. Rupture disks had to be used instead of relief valves due to the severe service of the copper concentrate slurry.

Additionally, each valve station had three block valves: an isolation valve, a seal valve, and a wear valve. The wear valve is more heavily used and operated in slurry service. The seal valve, located immediately upstream of the wear valve, is used to shut in the station so the wear valve can be replaced.

The construction contractor was United Pipeline Systems USA, Inc. headed by Dale Kneller, president. From the technical evaluation, United's "Tite Liner" system was the preferred liner system because it didn't allow cycling of the HDPE pipe wall that could reduce the life of the liner. The liner friction constrained the liner from expansion and contraction due to changes in temperature and greatly reduced the shear force on the HDPE flanges. United's knowledge and Tite Liner construction experience provided technical expertise in finalizing the HDPE pipe installation and construction.

Unique Features

Some of the unique features were the hydraulic modeling and pipe sizing, the steel-connecting flanges, the tight liner installation and matching liner O.D. to the steel I.D. Also, the transitioning of the various sized I.D. and wall thickness of the steel and HDPE pipe, the inspection and monitoring spools, the air and hydrostatic testing, and the choke pressure reducing station.

The hydraulic modeling and sizing of the pipeline was based on the previous rheological testing performed for the original pipeline. Since the new line was parallel to the old line, elevations and approximate lengths were known and available for a very accurate model in the preliminary design and cost estimate. The chosen design was a full flow system (no intermediate choke stations), the model was manipulated to handle slurry concentrations from 60-65% and maintain acceptable velocities (minimum operating velocity 1.89 m/s).

Lower velocities will allow solids to settle out and create heavy wear on the bottom of the pipe. The wall thickness design was based on the transient flow pressures with an additional 100 meters for a surge and safety factor and the maximum static head each isolated section would experience.

On the upstream side at each valve station, a rupture disk was installed ahead of each isolating valve. This will protect and prevent the pipeline section from the combined static head of two or more sections. The rupture disk burst pressures were derived from the model surge analysis and set slightly higher to prevent nuisance ruptures. These pressures were checked to assure code compliance for the maximum allowable operating pressure (MAOP) of the pipe section.

It is also noteworthy that in late July 1995, the area experienced a 7.8 earthquake that resulted in no damage to the flanged HDPE pipeline. **P&GJ**