Use of Corrosion Inhibitors on the Trans Alaska Pipeline

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Inhibitors are used on the Trans Alaska Pipeline to protect low-flow areas, dead legs, the annular space in road casings, and contingency equipment. Low-flow areas and dead legs are protected with a water-soluble corrosion and scale inhibitor, a mild biocide, and an oxygen scavenger. A vapor phase corrosion inhibitor (VpCI) is used to protect the annular space in road crossings. Contingency equipment is protected during long-term storage with either a VpCI or an oil-based film.

Corrosion inhibitors are used in several operational areas of the Trans Alaska Pipeline. During normal pipeline operation, warm crude oil with small amounts of salt and water travels through the pipeline. The salt and water can accumulate in areas of low flow such as bypass piping and future pump piping connections. If not controlled, corrosion can damage operating equipment and cause expensive and potentially disruptive repairs.

If left unprotected, the warm pipe in moist soil can corrode externally. Belowground sections of the pipeline are protected with coatings and cathodic protection (CP). Road casings may interfere with the CP system (Figure 1). Inhibitors are used to control corrosion inside the road casing.

Contingency equipment is stored in unheated warehouses or outdoors. Both vapor phase corrosion inhibitors (VpCIs) and inhibited oil films have proven useful in protecting contingency equipment.

Effects of Inhibitors

An inhibitor is a substance that, when added in small concentrations, decreases the effective corrosion rate. Inhibitors fall into four general categories based on mechanism and composition. These categories are 1) barrier layer formation, 2) neutralizing, 3) scavenging, and 4) other environmental modification.

BARRIER INHIBITORS

Barrier layer formation inhibitors form a layer on the corroding metal surface, modifying the surface to reduce the apparent corrosion rate. They represent the largest class of inhibitive substances.

Adsorption-type inhibitors are the most common barrier layer inhibitors. In general, these organic compounds are adsorbed and form a stable bond with the metal surface. The apparent corrosion rate decreases as surface adsorption is completed (Figure 2).

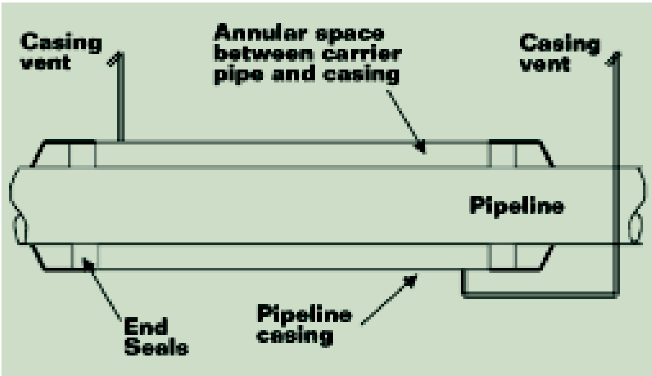
VpCIs are adsorption-type inhibitors with high passivating properties. These inhibitors form a stable bond with the metallic surface. Generally, they have a high vapor pressure that allows the material to migrate to distant metallic surfaces. Therefore, VpCIs require no direct contact with the metal surface to be protected.

Conversion inhibitors also form barrier layers. They passivate the metallic surface by developing an insoluble metal oxide on the surface. Typical examples of this type of inhibitor are organic phosphates and chromates.

NEUTRALIZING INHIBITORS

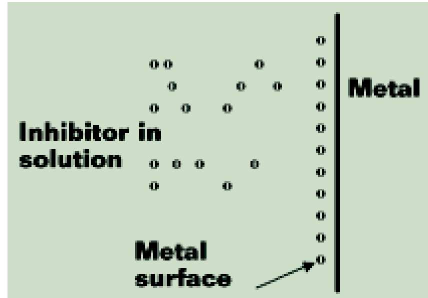
Neutralizing inhibitors reduce the hydrogen ion in the environment. Typical neutralizing inhibitors are amines,

FIGURE 1



Below ground road casing. Annular space between the casing and the carrier pipe can be protected with a VpCI or filled to mitigate corrosion in the annular space.

FIGURE 2



Adsorption-type inhibitors are a common form of barrier layer inhibitor.

ammonia (NH_3), and morpholine. These inhibitors are particularly effective in boiler water treatment and weak acid solutions but have not been widely used on pipelines.

SCAVENGING INHIBITORS

Scavenging inhibitors remove corrosive ions from solutions. Well-known scavenging inhibitors include hydrazine and sodium sulfite. These two inhibitors remove dissolved oxygen from treated boiler water.

Sodium sulfite reaction:

$$Na_2SO_3 + \frac{1}{2} O_2 = Na_2SO_4 \quad (1)$$

Hydrazine reaction:

$$2\,(H_2NNH_2) + \frac{1}{2} O_2 = 2NH_3 + H_2O + N_2 \quad (2)$$

Low Flow or Dead Legs

During pipeline operation, water accumulates in isolated piping and dead legs (non-operational piping installed for future expansion). As crude flows by isolated piping or dead legs, the small amount of salt and water present in crude oil accumulates in these areas. Because of the high salt concentration, corrosion can occur rapidly. If left unchecked, damage to the piping will occur.

A water-soluble corrosion inhibitor combined with a scale inhibitor, a biocide, and an oxygen scavenger, can prevent corrosion in the piping. These materials are a proprietary blend of organic polyphosphates, alkyl quaternary ammonium chloride ($[RNH_3]Cl$), and sulfite (M_2SO_3). This inhibitor can treat saltwater-carrying systems in the oil field. The organic polyphosphate forms a barrier to protect the pipe surface. Alkyl quaternary ammonium chloride RNH_3Cl and M_2SO_3 act as a biocide and an oxygen scavenger.

This inhibitor was diluted with water and injected directly into dead legs and future pump connections (Figure 3). Periodic testing of the inhibitor concentration was specified to assure continued protection.

Road Crossings and Casings

To protect the pipeline from mechanical damage, road casings were installed at all major road crossings. These casings were separated from the pipe with insulators, and the pipe ends were sealed with Link-Seals† (Figure 4). These seals are intended to keep water out of the casing and help provide electrical isolation for the pipeline from the casing. As the system ages, the effectiveness of these seals becomes more difficult to verify.

To prevent the corrosion inside the casing, several possible treatment methods were reviewed. These methods included 1) removing the casing, 2) filling the casing with a filler, and 3) introducing a VpCI.

Removing the casing is generally not cost-effective because it disrupts the road crossing and requires extensive excavation. Cutting to remove the casing also endangers the pipeline.

Casing fillers are generally mastic-, asphaltic-, or petrolatum-based. Normally, these materials thicken in cold weather and make application in arctic winter conditions very difficult. The cost of shipping large volumes of filler to Alaska makes this material relatively expensive.

VpCIs work in both the water and the vapor space and are available in concentrated powder form. The inhibitor can be mixed on-site for immediate application. When compared to casing removal or filler application, this material is relatively inexpensive.

Applying VpCIs to Road Crossings

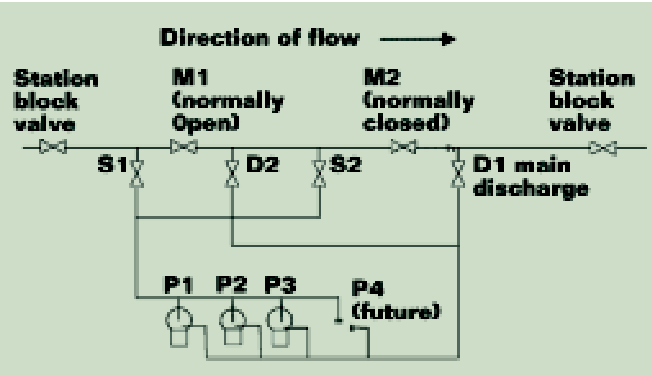
VpCIs were first applied through existing casing vent pipes. The inhibitor was measured and poured into the casing vent pipe, and a small rubber ball was inserted to act as a piston. The vent pipe was then pressurized with nitrogen to push the ball and the inhibitor into the road casing.

After several years, water samples were taken from several of the road casings. These samples were analyzed to determine how much inhibition remained. The level of inhibitor needed to protect the road crossing was set at 200 ppm. However, inhibitor remaining in some of the casings was as low as 2 to 3 ppm. At the same time, several other road casings showed inhibitor concentrations as high as 6,000 ppm.

The apparent low level of inhibitor concentration in several of the road casings could be traced to problems encountered with the filling operation through the vent pipe. Many of these vent pipes are more than 300 ft (91 m)

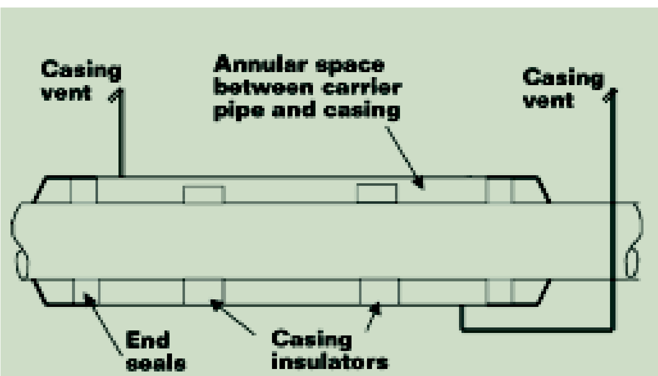
† Trade name.

FIGURE 3



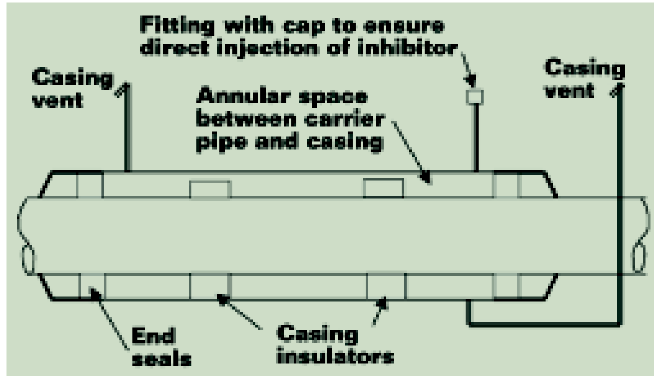
Dead legs and low flow area are injected with inhibitors to control internal corrosion. Dead legs include future mainline pump (P) 4 suction and discharge piping installed during construction of the pipeline. Low-flow piping includes the secondary discharge piping (D2) and the piping behind M2.

FIGURE 4



End closures on road casings. Ends seals and insulators are intended to electrically isolate the road casing from the main pipeline.

FIGURE 5



Road casing modifications to improve injection with inhibitor. To improve injection with inhibitor a new fitting was attached to the casing allowing direct injection of inhibitor.

long and have been subject to damage. Vent pipe blockage has occurred as a result of bending (caused by settling or traffic loads), mud infiltration, or rock slides.

A second application of inhibitor was necessary where low levels of inhibitor were found. To ensure direct inhibition of the road casing, the vent pipe was modified (Figure 5). Generally, the upper vent pipe was replaced with a vent pipe going directly from the casing to the surface. If this was not possible, a new vent pipe going directly to the surface was added. New inhibitor was poured directly into the casing. This modification provides direct access for testing and should result in more accurate tests.

Protecting Contingency Equipment

Contingency materials—large valves and other items that have long delivery times—are stored for ready access. In the past, large valves have been stored with an oil-based inhibitor coating on critical surfaces. In areas such as seats, the oil can be wiped off by the valve seating action; this removes the inhibitor, allowing the seat area to corrode in a manner similar to crevice corrosion. Valve gate pitting can occur in these locations.

Large valves are routinely hydrotested to ensure a leak-proof pressure-tested valve. To improve the valve's corrosion protection, the hydrotest water has been saturated with a VpCI. The hydrotest simultaneously pressure tests and inhibits the valve.

Valves used for draindowns, bypasses, and other temporary applications are cleaned, inspected, and inhibited with a powder VpCI before being returned to contingency storage. The powder form of the inhibitor quickly protects the valve from corrosion.

Conclusions

Corrosion inhibitors have improved the reliability and accessibility of the piping and contingency equipment. Dead legs are now protected and available should the need for a new pump arise. Corrosion of piping inside a road casing has been mitigated with minimal expense. Contingency equipment is available from storage with minimal maintenance and preparation.

Because of the low concentration of inhibitors in the dead legs, there has been no detectable effect on the crude oil. In addition, using biodegradable VpCIs in road crossing casings and contingency equipment has produced no adverse environmental effects. Finally, the most important consequence of using corrosion inhibitors on operating equipment has been a decreased corrosion rate.

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Personal communications with NALCO.

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