CORROSION CONTROL METHODS FOR UNDERGROUND STORAGE TANKS

by

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CORROSION SERVICE

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BACKGROUND

The corrosion susceptibility of steel storage tank systems is now well recognized by government regulatory agencies since most Provincial governments in Canada have introduced legislation making it mandatory that new tank installations incorporate corrosion control equipment and that existing tanks and piping be upgraded to mitigate the impact of corrosion on the serviceability of the storage systems. The significance of these regulations are being repeatedly reinforced by ever increasing environmental constraints.

GENERAL CORROSION CONTROL METHODS

There are a number of standard corrosion control solutions that can be applied to storage tank systems and the choice of technique or combination of techniques will depend to a large extent on whether a storage system is new or existing and to a lesser extent on the environmental sensitivity of the location. A number of these corrosion control techniques are discussed below.

Material Selection

The tank and piping material can be selected for its corrosion resistance when one is considering new or replacement installations. The principal choices are between steel and fiberglass reinforced plastic (FRP), although double-walled steel, double-walled FRP tanks, and stainless steel have been used on a limited basis. Another material called Nylon 6 has been used in a reaction molding process to produce a tank which has just recently been introduced into the market for testing. In all cases for steel tanks in new installations, cathodic protection is a mandatory requirement.

There is also the option of placing steel tankage inside a reinforced concrete vault which is drained. These steel tanks are usually not backfilled and hence do not require cathodic protection.

Environmental Control

Certain environmental aspects on both new and existing installations can be controlled to mitigate corrosion. For instance, backfilling the tankage with the appropriate backfill such as sand in the case of steel tanks and pea gravel in the case of FRP tankage ensures a homogenous environment. The uniform backfill around a steel tank can eliminate the development of isolated corrosion cells owing to differential soil conditions. In addition surface paving and effective drainage can lessen the corrosivity of the environment by preventing the soil around the tanks and piping from becoming contaminated with corrosion accelerators such as chlorides from deicing salts. Also any improvement in drainage particularily at tank depth tends to keep the soil dryer thus minimizing the corrosion rate.

In fact, many tanks that survive for than 20 years are usually found to be in soils which are are relatively dry because of good drainage. Environmental control measures unfortunately are not recognized by the regulatory bodies as sufficient corrosion control.

Inhibitors

Inhibitors have a limited use for corrosion control on underground storage systems except for internal corrosion. An alkaline sodium nitrite inhibitor has been demonstrated to inhibit internal corrosion in domestic fuel oil tanks.* Inhibitors for external control are not practical, both because of a need for repeated application and also because of the possibility of introducing a pollutant into the environment.

Coatings

There are three fundamental types of protective coatings, namely; metallic, organic, and inorganic. For external corrosion control, organic coatings such as epoxy and urethane are the most widely used. ULC Standard S616-M, 1981 is a coating standard that covers the testing required to qualify any organic coating. Metallic coatings, such as zinc galvanizing, have been used in the past, primarily for piping. A recent panel of experts on corrosion assembled by the U.S. Environmental Protection Agency commented that the zinc galvanizing was inadequate corrosion protection. This expert panel stated that "galvanized pipes should not be used in the underground piping of UST systems because the zinc coating does not serve as a cathodic protection anode and in the long term, the galvanized pipe has the same corrosion rate as bare iron and steel pipe. Since all new

* *Internal Corrosion in Domestic Fuel Oil Tanks, R. Wieland and R. Treseder, Corrosion, NACE, Vol. 10, 1954, p406.*

UST installations containing underground metal piping must be cathodically protected, there is no advantage in using galvanized pipe. Furthermore, it was recommended that all existing unprotected UST systems with underground galvanized piping be retrofitted with cathodic protection".*

Concrete is the most common form of inorganic coating but it is not usual, in this country, to apply it to steel tanks and piping, although it is a common practice in England, where a minimum of 6" of concrete must surround all tanks and piping. Normally when steel is surrounded by concrete, it develops a passive film which inhibits corrosion activity.

The application of a protective coating to the external surface is a practical solution only on new installations, although internal linings have been applied to existing tankage. Indeed this application of an internal lining is generally recognized by most provincial regulatory bodies as an acceptable method of up-grading existing steel tanks. For instance the latest petroleum storage regulations for Nova Scotia allow upgrading of tanks by "lining the tanks in accordance with API-1631, recommended practice for the entire lining of existing steel underground storage tanks".

Electrochemical Protection

The only electrochemical technique that can be applied to both new and existing underground storage systems is cathodic protection which involves the forcing of a DC current

* *Proceedings and Recommendations of the Expert Panel on Corrosion for Policy and Standards Division, Office of Underground Storage Tanks, Environmental Protection Agency, EPA Contract No. 68017383, July 16, 1987.*

to flow across a metal/electrolyte interface causing a required change in potential across the interphase as shown in Figure 1. There are two basic types of cathodic protection

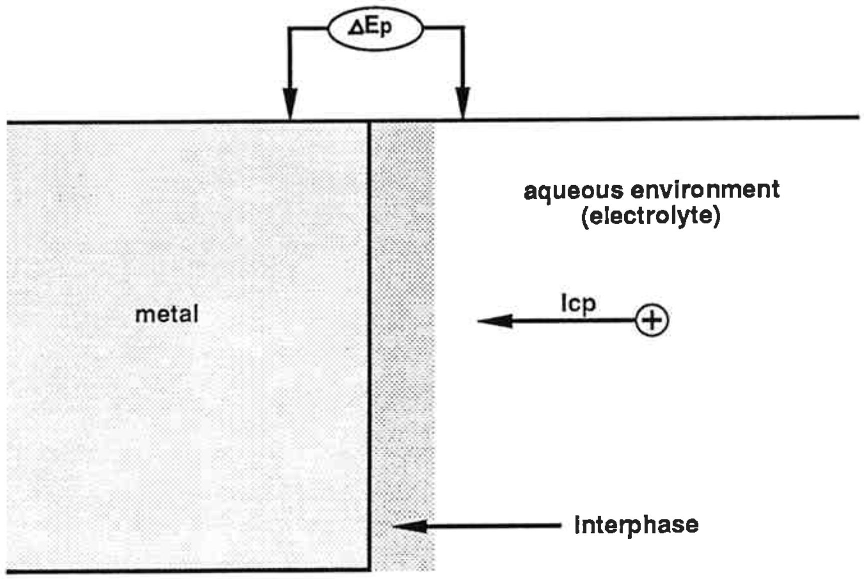
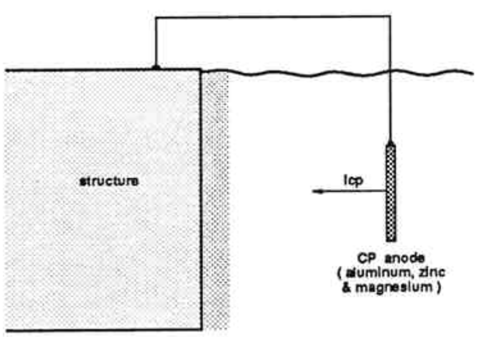


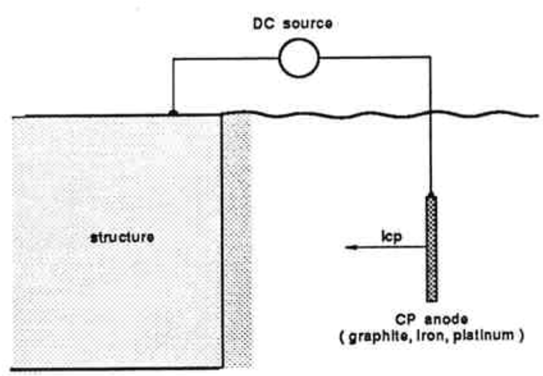
FIGURE 1

systems namely, sacrificial and impressed current as illustrated in Figures 2(a) and 2(b).



SACRIFICIAL CATHODIC PROTECTION

FIGURE 2(a)



IMPRESSED CURRENT CATHODIC PROTECTION

FIGURE 2(b)

Sacrificial cathodic protection systems consist of attaching rods that are cast or extruded made of alloys of metals having a high corrosion reactivity (anodes) to metals with a lower corrosion reactivity (structures) thus forming a corrosion cell in which the structure requiring protection is forced to become a cathode surface in its entirety. When protecting ferrous structures alloys of magnesium, zinc and aluminum (sea water only) are commonly used. These materials corrode to produce a corrosion current which flows to the structure causing a beneficial potential shift across the interphase, thereby reducing corrosion. In most soil applications these anodes produce only a few milliamperes of cathodic protection current and are therefore limited in their application to protecting small structure surface areas.

Sacrificial cathodic protection is generally applied in accordance with ULC Standard S603.1 M1982 entitled "Standard for Galvanic Corrosion Protection Systems for Steel Underground Tanks for Flammable and Combustible Liquids". Sacrificial systems are usually applied to new tanks since they would be difficult to retrofit to existing tankage unless the existing tankage had been coated originally in accordance with the S603.1 Standard.

Impressed current cathodic protection systems utilize an external source of power, usually an AC transformer/rectifier combination, which supplies DC current to corrosion resistant anode materials such as graphite, high silicon cast iron and platinum. These materials have a low electrochemical consumption rate compared to sacrificial anode materials and hence provide a longer service life at the generally large CP currents at which impressed current systems operate. Typically a single impressed current system can protect steel surface areas, many times larger than can a single sacrificial anode.

Impressed current cathodic protection is most commonly applied in a retrofit manner to existing tankage in accordance with PACE report no. 87-1. This technique can also be applied to ULC 603.1 tanks or to the occasional location where a bare and unprotected steel tank can be nested with some existing tanks, and the entire group cathodically protected.

Summary of Corrosion Control Methods

The foregoing corrosion control methods are all in use to some degree but not necessarily in an isolated manner, but rather in combination. For instance, new steel tankage as fabricated under the ULC 603.1 standard, combines sacrificial cathodic protection with an external organic coating and also incorporates some internal structural enhancement to prevent internal corrosion perforation in the vicinity of the fill pipe(s).

NEW INSTALLATIONS

The primary choice for new storage system facilities is principally between a steel tank protected in accordance with ULC 603.1M Standard and an FRP tank. On average there would appear be a marginal cost advantage to using the steel tank because of the added installation cost associated with supplying pea gravel for the FRP tanks and also because the FRP tanks, particularly in the smaller capacities, are a little more expensive than steel. Nevertheless, the expectation of having an FRP tank last a minimum of 30 years, which appears to be not only a practical but also a conservative estimate, has considerable appeal to owners of fuel storage systems.

On the otherhand, there is no reason that the ULC 603.1M tank would not last equally as long or even perhaps longer providing the cathodic protection system was replaced when required. Theoretically, as long as the cathodic protection is maintained on the outside of the steel tank then it should last indefinitely and certainly in the case of steel, there is a measurable structural advantage over FRP. It should be recognized that plastic materials will exhibit a deterioration in their structural properties with time and hence the question remains as to how rapid the deterioration is, particularly in the case of FRP and potentially in the case of Nylon 6. At this point, this reasonable life expectancy is not known, although certainly a greater than 30 year life can easily be anticipated based on current performance of FRP tanks.

Steel of course has the advantage that its yield strength and ductile properties do not change with time and that the only major factor which limits the life of a steel tank is corrosion which can be controlled for an indefinite period of time providing cathodic protection is maintained.

The corrosion control features of the ULC 603.1M tank are illustrated in Figure 3. The external surface of the tank is coated with epoxy or polyurethane having a minimum dry film thickness of 0.3 mm and conforms to ULC Standard S616-M 1981 in other respects. In addition, there are nylon insulating bushings placed in all the tank entries in order to both interrupt any galvanic interaction between the tank and its associated piping, as well as to electrically isolate the tank from the piping to ensure that factory attached sacrificial anodes will effectively protect the tank. The cathodic protection system consists of two or more sacrificial anodes, bolted on opposite ends of the tank.

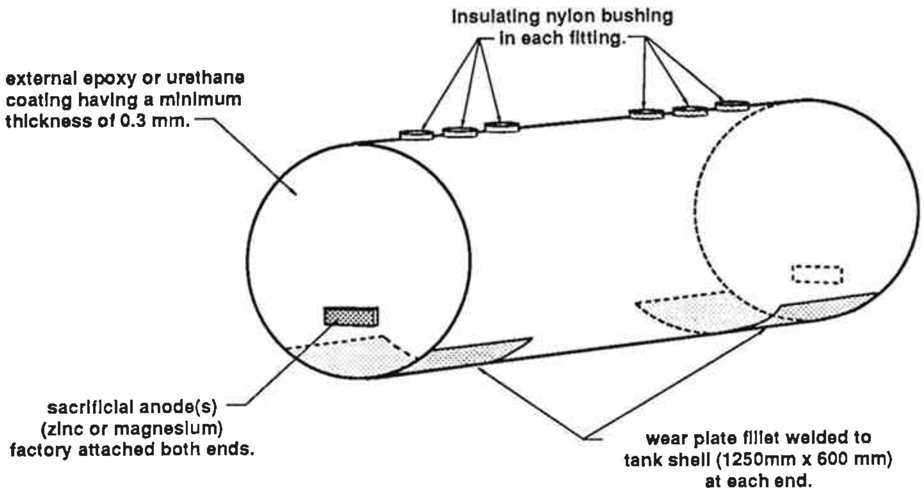


FIGURE 3 - SCHEMATIC OF CORROSION CONTROL FEATURES ON ULC 603.1M STEEL TANK

In the early ULC 603.1M tanks, magnesium anodes and polyethylene tape coatings were used almost exclusively, however the specification has evolved to an extent that zinc plate type anodes are the most common anode material and the coatings are either epoxies or urethanes. Internally protection is provided from the erosion-corrosion cell that is set up as a result of the gauging process by inclusion of two wear plates placed directly beneath each of the tank entries and fillet welded on all sides to the tank shell. The wear plates were only introduced to the ULC 603.1 M programme in the1982 revision and there is not sufficient information yet as to the success of this feature. It has been stated however by Mr. R. Wright of Underwriter's Labs of Canada at a recent expert panel gathered to discuss cathodic protection of underground storage tanks by Environment Canada that of over 34,000 listed 603.1 tanks none have leaked due to external corrosion.*

* *Report of the Meeting of the Panel on Cathodic Protection of Underground StorageTanks, September 11, 1987, Charlottetown, Prince Edward Island*

This performance history is very promising inasmuch as the first ULC tanks were being installed in the early '70's and this amounts to at least 15 years performance history on some tankage, although the early tankage did not have the internal wearplate and will be subject to internal corrosion. There have been a few instances of ULC 603.1 tanks having corroded internally. Nevertheless, it is apparent that as long as cathodic protection is maintained externally and providing internal corrosion features presently being built into new steel tanks or retrofitted to existing ULC 603.1 tanks are effective, then a steel underground storage tank should remain leak-free from a corrosion point of view indefinitely.

EXISTING INSTALLATIONS

Most provincial government regulations allow for the upgrading of existing underground steel tank installations by a number of methods, typically by:

a. replacement with ULC 603.1M steel tanks or FRP tanks

b. lining of the internal surfaces of the tank

c. the application of cathodic protection by the impressed current method

These upgrading methods are generally applied to tanks that have been installed either prior to the introduction of the ULC 603.1M standard and to any non-ULC 603.1M tanks.

Replacement

The most expensive method of upgrading existing tanks is by replacing the tankage. Not only are the excavating and material costs high, but there can be additional costs incurred when contaminated soil is encountered since there are an increasing number of government restrictions on disposing of hydrocarbon contaminated soil. Accordingly, upgrading by replacement cannot usually be justified on a cost-effective basis but rather is done when the capacity of the storage system needs to be increased, when a tank condition assessment has indicated that there is a high leak probability or when a leak test shows a failure. As mentioned above, replacement costs are often inflated if contaminated soil is encountered since its removal and disposal is often subject to intense scrutiny by environmental agencies.

Internal Lining

Lining of the inside surfaces of a steel tank is allowed in most regulations as an upgrading method. For instance, in Nova Scotia, the lining must be in accordance with API 1631 entitled "Recommended Practice for Interior Lining for Existing Steel Underground Storage Tanks". In Ontario, lining must be done in accordance with the Provincial Energy Branch Standard GH-10. Often the tank is only lined up to the half-way position on the tank shell because most of the internal corrosion is observed to be on the bottom of the tank. The GH-10 Specification refers to the same coating tests that are specified for the external coating of 603.1 tanks. In practice, the two principal lining systems consists of either a fiberglass mat either in one or two layers with the resin applied by a roller or epoxy with shredded fiberglass applied by spraying. The two layer fiberglass mats with the roller applied resin, resulting in a total lining thickness of 125 mils, is the superior lining system.

The major weakness of upgrading with an internal lining is that the lining relies on the structural integrity of the steel shell to maintain an effectively tight storage vessel. As external corrosion continues the steel substrate will become thinner leaving the tank subject to failure as a result of operational stresses.

Cathodic Protection

The installation of an impressed current cathodic protection system is allowed in almost all provinces as an upgrading method providing the system is installed in accordance with PACE Specification 87.1 entitled "Guidelines Specification for the Impressed Current Method of Cathodic Protection of Underground Petroleum Storage Tanks" . This standard, first introduced in 1979, has been adopted by many of the major oil companies for retrofitting on existing storage facilities that in most cases were determined to have either a low risk of leaking or have been tested as leak-free. The general arrangement of this impressed current system is outlined in Figure 4. The system utilizes a packaged impressed current anode consisting of platinum clad niobium wire inside a 2" diameter EMT conduit containing calcined petroleum coke. Typically these anodes are in the order of 10 feet long and are commonly installed in 2 or 3 inch augered holes. The length of the anode is important in obtaining uniform current distribution to both the top and bottom of the tank and the small diameter allows for insertion of the anodes between tanks where the distribution of protective current to the tank surfaces is most difficult. The anodes are connected to the positive terminal of a DC current controller and the negative terminal is connected to both the tanks and the tank piping using underground rated insulated cables. A zinc reference electrode must be inserted between each pair of tanks to sense the level of protection on either a continuous or intermittent basis.

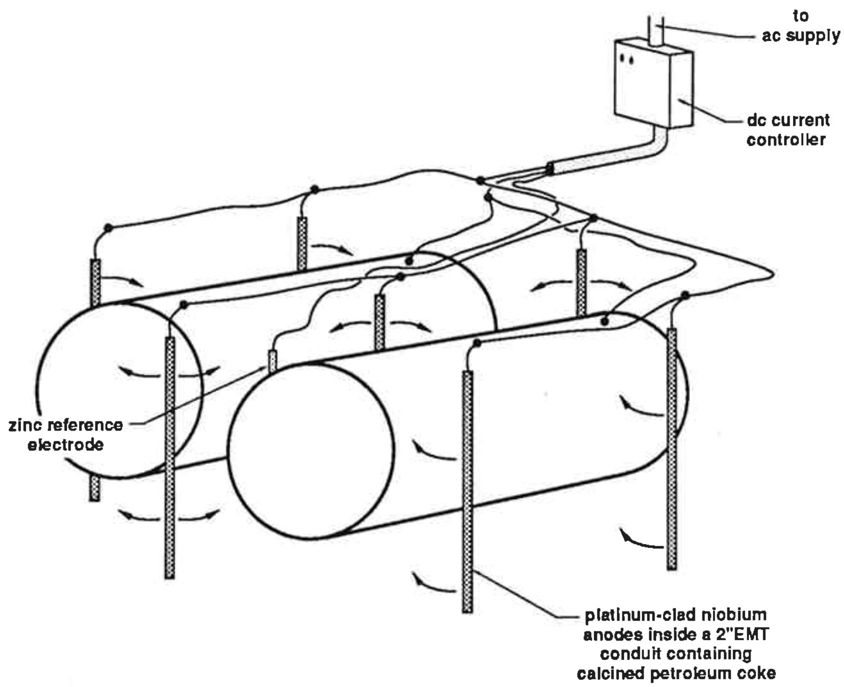


FIGURE 4 - TYPICAL IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM IN ACCORDANCE WITH PACE SPECIFICATION 87-1

Cathodic protection is by far the least expensive of the the upgrading methods but has the disadvantage of requiring periodic monitoring to ensure that the system remains operating at a level sufficient to arrest the corrosion. In order to simplify this surveillance process, remote monitoring equipment has been developed to allow the monitoring of the cathodic protection parameters via a telephone link.

The major weakness in the PACE 87-1cathodic protection system as shown is that it does nothing to address any potential internal corrosion problems. As the external corrosion is mitigated over a long period of time, it can be expected that the internal corrosion will eventually result in perforation unless some internal corrosion control measures are taken.

Implementing an Upgrading Programme

Before an upgrading programme involving lining or cathodic protection should be undertaken, tank evaluation analysis must be done. This must initially involve an analysis of the environmental risk presented by the storage system followed by appropriate soil test analysis using the Warren Rogers or PACE method. An example of an upgrading flowchart is shown in Figure 5.

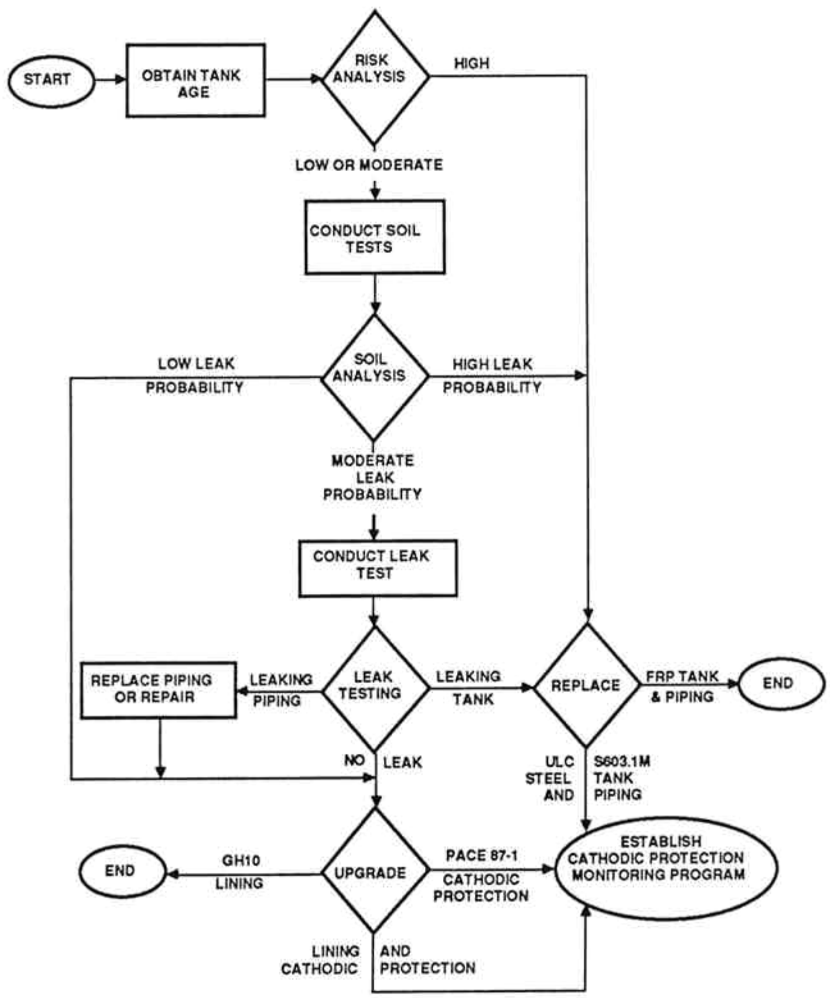


FIGURE 5 - UNDERGROUND TANK UPGRADING FLOW CHART FOR UNPROTECTED STEEL TANKS INSTALLED PRIOR TO MAY 1, 1974

If the soil analysis indicates a high leak probability then the tank should be replaced; if it indicates a moderate leak probability then an appropriate leak test should be conducted both on the tanks and on the piping. If the tank proves to be leak-tight then an upgrading option is chosen. Although the upgrading choices can be one of either the impressed current protection system or the lining, it can also be a combination of the both which is a much superior to either of them. Indeed a lined tank with cathodic protection on the external surfaces is probably superior to either the 603.1 tank or the FRP tank. Combining these two upgrading methods is still less expensive than replacing the existing tanks. It should be recognized that replacement of steel tankage using FRP tanks usually involves replacement of piping. If the piping is steel connected to FRP tankage then the steel piping requires cathodic protection and subsequent monitoring of its cathodic protection system. It is clear then that if FRP tanks are to be used, it would be a significant advantage to also use FRP piping.

Although the cathodic protection retrofit system in accordance with PACE 87-1 has been discussed relative to the existing tankage, it is usual when installing this system to also place anodes alongside the existing pipe runs.

Cathodic Protection Performance Monitoring

Whether or not the steel tank is a ULC 603.1 tank having sacrificial anode cathodic protection or existing tanks with PACE 87-1 impressed current cathodic protection system, there are ongoing monitoring requirements. In the case of the ULC 603.1 tank the electrical potential of the tank relative to a copper-copper sulphate reference electrode must be measured as illustrated in Figure 6. Three readings are taken, one at each of three

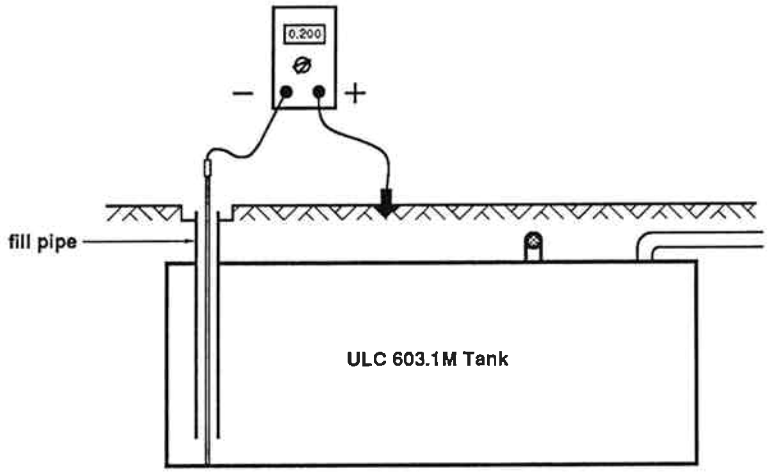


FIGURE 6 - MEASUREMENT OF TANK CATHODIC PROTECTION POTENTIALS

reference electrode positions (over each end of the tank and over the middle of the tank) with the connection to the tank being made via a temporary probe through the fill pipe making sure that the probe contacts the tank bottom. Generally this must be done following the installation of the tank before the installation is considered acceptable and then periodically ranging from every year to every two years thereafter. If the potential indicated on the voltmeter when taking this reading is more electronegative than -850 mV to a copper sulphate reference electrode, then the tank is considered under the current ULC Standard to be protected. As a result of some recent survey data recorded on tanks having zinc-plate anodes and an expected change in cathodic protection standards as published by the National Association of Corrosion Engineers (RP01-69)*, there is a likelihood that the zinc-plate anode will be modified to ensure sufficient current output to achieve a protection criterion of -900 mV to the copper sulphate reference.

* *NACE Standard RP-01-69 "Recommended Practice Control of External Corrosion of Submerged Metallic Piping Systems", 1988 Revision, Draft #9.*

The field data survey requirements for PACE 87-1 impressed current systems are more onerous than for ULC 603.1 tanks. It is still necessary to measure the potential at three locations over each tank but in this case the protection current must be interrupted and the potential observed after the immediate disconnection of the current source. This "instant off" potential is compared to the minimum potential criterion of -850 mV, with reference to a copper sulphate electrode. In addition, the power supply of an impressed current system must be monitored on a monthly basis. This requirement is difficult to comply with for most companies if done manually. The installation of remote monitoring equipment,however, makes this requirement more manageable.

COST OF UP-GRADING OPTIONS

Often the choice of up-grading option is based simply on economic considerations. As an example, a cost comparison assuming an existing two tank storage system has been evaluated for three different capacity tanks as shown in Table 1.

Tank Size IG	Replacement Steel (S603.1 M)	Replacement FRP	Lining	Cathodic Protection
1000	$13,600	$17,600	$6,985	$3,750
2000	15,800	18,500	7,865	4,145
3000	19,500	21,800	8,305	4,295

TABLE 1 - COST OF TANK UP-GRADING ALTERNATIVES (1987)*

It is apparent that on a strictly economic comparison cathodic protection has a clear advantage, albeit with the disadvantage that internal corrosion is not being addressed. Even

* *An Assessment of Alternatives for New and Existing Underground Fuel Storage Tanks in Accordance with the Requirements of the Gasoline Handling Act, R.A. Gummow, for the Ministry of Transportation and Communications of Ontario, MAY 1987.*

the combination of an internal lining and cathodic protection, which provides a superior storage system, is at least 30% less expensive than replacement with either FRP or steel S603.1 M tanks. The monitoring costs add to the cost of maintaining a steel storage tank facility and this bienniel expense must be included to provide a comprehensive cost comparison picture. Accordingly, when costs are calculated on an annual cost basis, cathodic protection still has a substantial advantage as indicated in Table 2, assuming a 10% interest rate. Furthermore the combination of cathodic protection and an internal

Tank Size IG	Replacement Steel (S603.1 M)	FRP	Lining	Cathodic Protection
1000	$1,558	$1,867	$741	$563
2000	1,791	1,062	834	595
3000	2,184	2,419	881	616

TABLE 2- ANNUAL COST OF UP-GRADING ALTERNATIVES (1987)*

lining remains substantially less expensive than the replacement alernatives. In this example over a 30 year period the savings realized when cathodically protecting and lining two 3000 IG tanks would be more than $20,000.00 (1987 $). Inasmuch as the cathodic protection – internal lining combination is probably superior to either of the replacement options, there can be little debate as to which up-grading option should be chosen. Clearly, there are substantial savings to be realized by testing and evaluating storage system integrity to identify candidate tanks for up-grading rather than replacement.

* *Calculated using National Association of Corrosion Engineers (NACE) Stnadard RP-02-72 "Direct Calculation of Economic Appraisal of Corrosion Control Measures"*

SUMMARY

New FRP and ULC 603.1 steel tanks have proven to be relatively immune to corrosion activity and therefore owners of underground storage systems can reasonably expect to realize a minimum of 30 years of corrosion free service from new tank installations.

Up-grading of existing steel tanks is a mandated requirement in most provinces. Both internal and external corrosion must be controlled in order to safely extend the service life of existing tankage. Although both cathodic protection and internal lining can be used independently to up-grade existing tankage, the combination of both will produce a superior corrosion resistant facility probably exceeding the quality of new tankage and at a cost which is substantially less than replacement.