Recommended Practice and Procedure for the Use of Corrosion Coupons

In practice, the corrosion coupon is one of the most useful tools for monitoring corrosion. Coupons provide accurate results at a reasonable cost, are easy to use and can provide general information that is both quantitative and visual on many types of corrosion. The information obtained is reliable, providing adequate care has been taken in handling the coupons and the relevant exposure parameters have been accounted for.

Some knowledge of the type of corrosion problems that may occur in a line or system (and the type of monitoring which is best suited to these conditions) can be predicted at the design stage. While most other monitoring devices are designed to give information on one specific type of corrosion problem, the corrosion coupon can record details of several types of corrosion and should, therefore, be used from the outset of any corrosion monitoring program.

Coupon Insertion, Removal and Cleaning

When working with corrosion coupons, following procedures for insertion, removal and cleaning is critical in order to obtain accurate results.

Caproco coupons are supplied in hermetically sealed bags, and each coupon is individually wrapped in vapour phase inhibited paper to give it a shelf life of approximately one year. The seal on the bag should not be broken until the coupons are to be used, to ensure that atmospheric corrosion of the coupons is kept to a minimum.

When attaching coupons to the coupon holder, it is recommended that clean laboratory gloves (P/N 11239) are worn to prevent moisture and body oils present on the skin from coming in contact with the unexposed coupon. Gloves should also be worn when removing exposed coupons from the coupon holder.

Exposed coupons should be cleaned and weighed as soon as possible after their removal. There are several methods for cleaning coupons after their exposure. These fall into two basic categories: mechanical cleaning and chemical cleaning. Both approaches have advantages and disadvantages.

Chemical cleaning methods are sometimes unable to remove scale and dirt that has bonded itself onto the coupon surface. Mechanical cleaning, on the other hand, may remove metal from the surface of the coupon, although this can easily be accounted for by including a metal loss factor when calculating the corrosion rate of the coupon.

Type of Corrosion Coupons

1. Strip Coupons

Due to its large surface area, the strip coupon provides the most area of all coupon types on which corrosion can develop and be readily observed. The strip coupon also gives more accurate results of weight loss because it has a larger mass than other coupons.

2. Disc Coupons

The disc coupon can most closely simulate the conditions that are occurring on the pipe wall. Unlike other coupons, they can be flush mounted. This gives them the advantage of not interfering with any pigging that may be done on the line. The disc coupon is mounted on the coupon holder in a plane at right angles to the holder stem, thereby avoiding any necessity to orientate them with the system flow. Multiple disc coupon holders are very popular in lines which carry more than one phase, since a disc coupon can be positioned in each of the phases.

3. Rod Coupons

Rod coupons are generally used where a longer exposure time is required. Since six coupons can be mounted on a single holder, the insertion and removal of the coupons is staggered, with only two coupons being removed at any one time. This allows the operator to collect data from the coupons regularly, but at shorter intervals than would otherwise be possible.

4. Coupons with Applied Stress

Coupons with applied stress are proven to yield useful results in environments where stress corrosion cracking is suspected to occur. A strip coupon is clamped to a holder so that a stress simulating that of the pressure vessel or pipeline is present in the

coupon. The coupon is inserted and removed in the same way as other coupons so that the results produced with the coupon can be readily inspected and tested.

5. Coupons with Residual Stress

The coupon with residual stress has been purposely cold worked with a definite force. Consequently, this type of coupon contains elastic strain prior to exposure. While cold-working increases the hardness of the metal, it reduces its ductility. In an embrittling environment, the metal is susceptible to catastrophic failure. With the use of this type of coupon, the effects of the environment can be detected and when necessary, corrective action taken before any resulting failure occurs.

6. Scale Coupons

This type of coupon is useful in determining whether scaling in the pipeline or vessel is a significant problem by artificially encouraging scale to develop upon it. The coupon has several holes of various sizes to allow scale to accumulate, and is mounted similarly to strip coupons on a strip coupon holder.

Recommended Procedure for the Application of Corrosion Coupons

The procedure is similar for the various types of coupons and their appropriate holders. Coupon holders are mainly designed to be attached to solid plugs, but Caproco offers coupon holders that may be used with a hollow plug.

The instructions for insertion and removal of a coupon holder attached to a solid or hollow plug in systems under pressure are presented in detail in the "Caproco Retriever and Service Valve Operation" Manual.

1. The solid plug should be removed from the access fitting using the retriever and service valve as described in the operations manual.
2. The solid plug should be removed from the retriever, taking care not to touch the coupons on the coupon holder.
3. Inspect the coupons and coupon holder for mechanical damage. Note the condition of the coupon(s) (e.g. heavily coated with dirt, covered with scale, covered with greasy/non-greasy film, no deposits, etc.).
4. Remove the coupons from the coupon holder, taking care not to touch the coupons with bare hands or tools.
5. Wrap each coupon separately after making a note of the serial number on the coupon and its location in the line (e.g. top of line, bottom of line, 3 o'clock, etc.)
6. Unscrew the set screw on the coupon holder nut using an allen key. The coupon holder should then be removed from the solid plug (note: the coupon holder has left hand threads). The coupon holder should be brushed (when necessary) and wiped clean.
7. Remove the primary packing and O-ring from the solid plug. Inspect and replace either or both parts if they are damaged, worn or deformed.
8. The solid plug should be reassembled, tightening the coupon holder nut until it snugly holds the primary packing (note: the primary packing should not be allowed to spread open).
9. Tighten the coupon holder set screw with the allen key.
10. The coupons should now be firmly tightened onto the coupon holder. A pair of clean gloves must be worn by the person handling the coupons.
11. The assembly should be checked to ensure that it is firmly tightened with no loose parts.
12. If strip coupons are used, the orientation of the coupons should be marked on the "HEX" of the solid plug using a metal file.
13. The threads and O-ring on the solid plug should be wiped with grease.
14. The coupon holder assembly is now ready to be placed in the access fitting body. The retriever and service valve must be used (in pressurized systems) to install the solid plug with the coupon holder attached. The instructions in the Caproco Retriever and Service Valve Operation manual must be followed.
15. Final tightening of the plug in the access fitting should ensure that the coupons are aligned parallel to the process flow. (Note: do not loosen the solid plug in order to achieve orientation, as this may affect the plug seal in the access fitting).

Recommended Practice for Cleaning Exposed Coupons

1. Each coupon should be visually inspected, including verification of the serial number.
2. The coupons should have the insulation removed without exerting any force or causing any damage to the coupons themselves. If the coupons need to be handled, gloves must be worn.

3. The coupons should be immersed in a bath with a cleaning solvent such as methelyene chloride. The coupons should then be inserted into an ultrasonic bath with fresh methelyene chloride. The ultrasonic bath should be run for approximately three minutes.
4. The coupons should then be chemically cleaned in a 10% HCl solution or be placed in a blast booth where they are individually cleaned, using previously unused glass bead, at 40 psi (2.8 kg/cm^2).
5. The coupons should then be weighed accurately to 0.1 of a milligram (mg).
6. Inspect the coupon for a specific form of corrosion (e.g. pitting, etching, erosion, etc.).
7. Measure any pits using a pit depth gauge.

CORROSION RATE CALCULATION

The rate of corrosion is expressed in several different forms. The simplest in dimensionless units is the percentage change in weight of a coupon in an exposed time interval. This figure is usually extrapolated to give the percentage change per annum. Generally the rate of corrosion is more useful if the figure reflects the impact on a system's life span.

ABSTRACT

The corrosion rate depends on Faraday's Law:

Weight of metal dissolving (g) - K x I x t

$$K = \frac{\text{atomic weight of metal (g/mol)}}{\text{No. of electrons transferred} \times 96{,}500 \text{ Amp/Sec}}$$

where: I = current (amps) t = time(sec)

By dividing both sides of the equation by the coupon surface area, this gives the corrosion rate as equal to a constant multiplied by the current density (amp) / area (cm^2). In other words, the rate of weight loss from a given area is directly proportional to the current density.

The rate of weight loss from a given area, while valuable, does not give a direct correlation with the rate of penetration of the corrosion.

When this figure is translated to the radial depth of pipe wall lost per annum, this information becomes very useful to the corrosion engineer or operator in determining the life expectancy of the system. Corrective action can then be taken and re-measured to give an acceptable time to failure/replacement.

The corrosion rate calculated using corrosion coupons assumes uniform corrosion across the coupon (e.g. uniform corrosion of the pipe wall at the monitoring point). This approximation is acceptable for most circumstances to determine the average rate of corrosion. Of course, where a coupon shows evidence of pitting, the pit depth rate is more useful. The pit depth of the deepest coupon pit is measured, allowing the pit depth rate per annum to be calculated. Again, this figure correlates directly with time to failure for a given pipe wall thickness.

Corrosion Rate Calculation in Metric Units:

$$\textbf{umpa} = \left\{\frac{\text{weight loss of coupon (g)}}{\text{total exposed area of coupon (cm}^2\text{)}}\right\} \times \left\{\frac{3.65 \times 10^6}{[\text{exposure time in days}] \times [\text{density of metal} \left(\frac{\text{g}}{\text{cm}^3}\right)]}\right\}$$

(micrometers per annum)

Corrosion Rate Calculation in U.S. Customary Units: (most commonly used)

$$\textbf{mpy} = \left\{\frac{\text{weight loss of coupon (g)}}{\text{total exposed area of coupon (in}^2\text{)}}\right\} \times \left\{\frac{2.23 \times 10^4}{[\text{exposure time in days}] \times [\text{density of metal} \left(\frac{\text{g}}{\text{cm}^3}\right)]}\right\}$$

(mils per year)

Pitting Rate Calculation

$$\text{Pit}_{\textit{u}\text{mpa}} = \frac{\text{pit depth}(\textit{u}\text{m}) \times 365}{\text{exposure time in days}}$$

$$\text{Pit}_{\text{mpy}} = \frac{\text{pit depth(mils)} \times 365}{\text{exposure time in days}}$$

Corrosion and Pitting Rate Comparisons

	Corrosion Rate		Pitting Rate	
	mpy	*u*mpa	mpy	*u*mpa
Low	< 1.0	< 25	< 5	< 127
Moderate	1.0 - 4.9	25 - 126	5 - 7.9	127 - 201
Severe	5.0 - 10.0	127 - 254	8 - 15	202 - 381
Very Severe	> 10.0	> 254	> 15	> 381