Technical Information Regarding Coupon Testing

By A. S. Krisher, President ASK Associates
ASK Associates, St. Louis, Missouri (314) 576-7712

Corrosion Testing, Why?

Corrosion tests are conducted for a number of reasons, some of which are:

1. To provide an insight into corrosion mechanisms.
2. To compare resistance of one alloy to another under standard conditions (in alloy development work for example).
3. As a quality control test for a given heat of alloy.
4. To provide a basis for estimating service life of process equipment.

The discussion which follows relates primarily to reason No.4, although the same principles apply in tests conducted for other reasons.

General Requirements for Coupon Tests

There are a number of "good practice" requirements which apply to all coupon testing.

1. The chemistry and processing history of the material in the coupon must be known.
2. The coupon must be positively identified, usually by code numbers stenciled into the specimen.
3. Data about the specific coupon test should be recorded in a permanent log book. Items which must be recorded are detailed information on the coupon (chemistry, mechanical properties, and processing history), dimensions of the coupon, initial weight of the coupon, and initial surface condition. Location, condition of exposure, and time of exposure must also be recorded.

Type of Tests

Data of value in estimating the probable service life of a piece of process equipment can be generated in a number of ways.

1. **Operating Experience -** The most reliable information is generated by actual operating experience with equipment in identical service. In a sense the equipment is being used as a large, complex, expensive coupon. This is a costly and slow testing method, especially when data on several materials is needed.
2. **Model Equipment -** Model equipment installed parallel with actual equipment or in a small scale (pilot plant) operation can generate information almost as reliable as full scale equipment. Care must be exercised to assure that important variables are adequately simulated.
3. **Coupons - Field -** Coupons exposed in operating equipment are widely used. Care must be taken to install the coupons so that they are exposed to the corrosive conditions of interest.
4. **Coupons - Laboratory -** Coupons exposed to laboratory solutions from plant operations, or less reliable synthetic solutions which approximate the chemistry of plant streams, generate useful information if the tests are properly designed and conducted. Such tests allow study of the affect of changes in process chemistry on corrosion.
5. **Instrumental Test Methods -** Advanced methods, including electrical resistance and linear polarization scans, are valuable additions to corrosion testing methods. They can generate a continuous record of corrosion rate. They also can be used to gain insight into corrosion mechanisms. The precautions noted with regard to coupon tests also apply with these methods.

Surface Condition of Coupons

Surface condition for coupons is a subject of substantial debate. A typical vessel as installed in the plant will have large surface areas in original mill condition, smaller areas of weld heat-affected zone, and areas that have been ground during the fabrication process. It is possible to replicate all of these conditions on a coupon. However, in the interest of simplicity and consistency, it is fairly common to machine the coupon surface flat, leaving a standard ground surface as defined by the size grading of the grinding media. An example would be the "120 grit finish" achieved by grinding with a 120 grit belt. This leaves a flat surface with clearly detectable scratches, all in a consistent direction. Any deviation from this standard initial surface is attributable to the exposure in the environment. Any effect on corrosion due to the initial finish, or the as welded heat-affected zone finish, or the ground surface will be very temporary in a corrosive system.

It is also worth noting that if the surface condition (i.e., the mill finish) does provide an improved corrosion resistance over the metal without this surface condition, such a situation will have questionable reliability in an operating system. When this surface condition is damaged mechanically or chemically, the corrosion resistance will revert to that of the parent metal without the special surface treatment.

Coupon Mounting

Coupons should be mounted in such a way that they are securely held and are electrically isolated from contact with all other metals (except when the purpose of the test is to study galvanic corrosion). Mounting materials (brackets, bolts, etc.) and insulating materials should be selected to be fully resistant to the environment. Failure of any of these components will lead to loss of data or loss of electrical isolation.

Time of Test

In general, coupon tests should be run for a minimum of 1 week. In many cases, it will be worthwhile and desirable to evaluate the effect of time of exposure which can be done by means of a controlled interval test.

Economics of Corrosion Testing

Corrosion testing is not cheap. More specifically, materials for a field rack with ten coupons will cost about $150 with 316 hardware or $250 with Hastelloy C-276 hardware. If a field test program required ten such racks, the total cost would be $1500 to $2500 plus the direct costs (rack assembly, rack installation and removal, record keeping, evaluation, reporting, etc.) These costs should be evaluated in terms of the benefits derived from the information generated by the tests.

In today's process industry, direct maintenance costs associated with a premature corrosion failure usually run to (at least) tens of thousands of dollars, and frequently into the hundreds of thousands. The business losses associated with such failures can easily be ten times the direct maintenance costs.

Considered in this fashion, it seems evident that the expenses of corrosion coupon testing can be easily justified.

Coupon Evaluation after Exposure

At the end of the test, observations of the coupon before cleaning should be recorded (photographically if appropriate). Samples are cleaned by various means (detailed in appropriate specifications) to remove all deposits and corrosion products from the unreacted metal. After cleaning, the coupon is weighed again and the corrosion rate is calculated from the weight loss.

$$\text{Corrosion rate} = \frac{\text{Weight loss, (g)} * \text{(K)}}{\text{Metal Density,(g/cm}^3\text{)} \times \text{Metal Area (A)} * \text{time exposure (hr)}}$$

The constant can be varied to calculate the corrosion rate in various units:

Units Desired	K-Conversion Factor
mils/year (mpy) (A = in2)	5.34×10^5
mils/year (mpy) (A = cm2)	3.45×10^6
millimeters/year (mmy) (A = cm2)	8.76×10^4
inches/year (ipy) (A = cm2)	3.45×10^3
inches/month (ipm) (A = cm2)	2.87×10^2

Note that this calculation yields an average rate, assuming perfectly even metal loss from all surfaces. Examine coupons under low power magnification and record evidence of localized attack. End grain attack, localized weld attack, intergranular corrosion, accelerated attack in stressed area (at the stenciled numbers), and localized attack associated with the mounting hardware should be noted if present. The depth of penetration of localized attack should be determined by means of microscopic examination or metallographic examination.

Advantages of Coupon Testing

Coupon tests are low in cost, simple to conduct, and allow the simultaneous evaluation of numerous materials and variations of a single material. Alloy chemistry variations and metallurgical variations (ie., the effect of heat treatment, microstructure, welding and stress) can be considered. Coupon tests are easily adapted to evaluate specific types of corrosion, such as crevice corrosion and galvanic corrosion.

Summary

Coupon testing remains a powerful tool in the corrosion engineer's tool kit. Intelligent and systematic use of this tool provides data which allows a knowledgeable and experienced engineer to make reliable predictions of field performance.

To Dig Deeper

There is a large body of literature dealing with corrosion coupon testing. The references listed below will serve as a useful introduction.

1. **Ailor**, W.H. Ed. Handbook on Corrosion Testing and Evaluation J. Wiley, 1971.

2. **ASTM G1-81**, "Preparing, Cleaning, and Evaluating Corrosion Test Specimens," American Society for Testing and Materials, Philadelphia, PA.

3. **ASTM G4-84**, "Conducting Corrosion Coupon Tests in Plant Equipment," American Society for Testing and Materials, Philadelphia, PA.

4. **ASTM G-30**.

5. **ASTM G31-72**, "Laboratory Immersion Corrosion Testing of Metals," American Society for Testing and Materials, Philadelphia, PA.

6. **ASTM G46-76**, "Examination and Evaluation of Pitting Corrosion," American Society for Testing and Materials, Philadelphia, PA.

7. **ASTM G-58**.

8. **ASTM G78-83**, "Crevice Corrosion Testing of Iron-Base and Nickel-Base Stainless Alloys in Seawater and Other Chloride Containing Aqueous Environments," American Society for Testing and Materials, Philadelphia, PA.