Quantitative Adhesion Testing of Coatings on Pipeline by Elaine C. Soltani, Semicro Corp.

Coatings are applied to the surface of pipeline to prevent corrosion due to environmental attack. An important property of a protective coating is its ability to maintain good adhesion when exposed to the elements over an extended period of time.

Adhesion testing of pipeline coatings in the laboratory can give important information about factors that affect coating performance. These factors include surface cleanliness, effectiveness of surface treatments, and coating application. Measuring adhesion in the field is a necessary part of routine maintenance inspection for coating integrity. A new class of instruments is available to make adhesion measurements in the field, data from which correlate with data obtained in laboratory measurements.

Method
A number of procedures have been developed to evaluate the bond strength (adhesion) of coatings. The tape test, scratch resistance test, and the bend test are among the most common qualitative tests.

Quantitative data is obtained by the pull-off adhesion test method described in the ASTM specification D 4541, "Pull-off Strength of Coatings Using Portable Adhesion Testers." Several commercial devices are currently available based on the pull-off method, 2 of which are described in the ASTM specification. A schematic drawing of the test geometry is shown in Fig. 1. First, a loading fixture (pull-stub or dolly) is attached to the surface of the coating with an adhesive. After the adhesive has cured, a tensile force is applied to the loading fixture axis. The force is gradually increased until the coating is detached or a specified force is reached. The quantitative measure of adhesion strength is computed from the maximum force applied and the actual surface area stressed. The stress (σ) applied to the coating is defined as follows:

$$\sigma = \frac{F}{A}$$

where,
- $\sigma$ = pull-off strength at failure (psi)
- $F$ = maximum force applied (lbs)
- $A$ = surface area stressed, i.e., area of loading fixture (in²)

---

**Fig. 1**
Schematic drawing of adhesion test

Courtesy of SEMicro
In addition to numerical data, the test result also describes the location and the mode of coating failure, i.e., adhesive or cohesive. Adhesive failure occurs at the interfacial bond between the coating and the substrate. Cohesive failure occurs within a single layer, that is, some of the coating remains on both fracture surfaces. The mode of failure reveals the weakest links in the coating system.

**Test Guidelines**

While adhesion testing can be performed with a number of commercially available instruments, these instruments are not all alike, and several factors must be considered in choosing among them. First, the instrument should apply the force at a reproducible rate. The force should also be coaxial with the loading fixture axis to prevent shearing or peeling stresses. Although the instruments are easy to operate, certain procedures should be followed to insure accuracy and reproducibility of results. These procedures are as follows.

- The coating should be cleaned before attaching the loading fixture. Cleaning procedures should not damage the integrity of the coating.
- Care should be taken in attaching the loading fixture. Twisting or turning the fixture introduces voids in the adhesive that contribute to premature failure.
- Excess adhesive around the loading fixture should be removed to have a reproducible stressed area.
- The time to test should be reproducible and within the limits set by the ASTM specification. The rate of stress should be less than 150 psi per second and the maximum load should be applied in 100 seconds or less.
- A very important parameter is the choice of an adhesive. Compatibility with the coating, cure time, and the testing temperature should all be considered for the particular coating and test environment.

**Conclusion**

A method has been described for quantitatively measuring the bond strength of protective coatings on pipelines. Portable adhesion tensile testers have proven to be a useful tool both in the laboratory and in the field. When used properly, the pull-off test provides a reliable, accurate, and reproducible quantitative means of evaluating coating adhesion.