Fundamentals of Holiday Detection

This month's column was written by Lloyd M. Smith, Ph.D., of Corrosion Control Consultants and Labs, Inc., Herndon, Virginia, USA.

A coating must be applied as a continuous film to perform its intended function. Early failure will occur if there is a discontinuity—a holiday, as it is commonly called—such as a pinhole, void, crack, thin spot, foreign inclusion, or contaminant in the coating film. Many of these defects are not readily visible, but they can be located using holiday detection equipment.

Holiday detection is typically performed on coating systems designed for critical service such as immersion or chemical storage. It is also conducted on coating systems applied to steel that is in contact with soil and/or constantly wet. Examples include buried pipelines, the undersides of tanks, and sheet pilings.

This month's Applicator Training Bulletin discusses how holiday detectors work, the operation of low-voltage and high-voltage detectors on coated steel, holiday detection of coatings on concrete substrates, and repair of holidays.

Principles of Operation

Holiday detectors are instruments that use electricity to locate film discontinuities. Most coatings are poor electrical conductors, and so they act as insulators. On the other hand, a metallic substrate such as steel is conductive to electricity.

A holiday detector consists of a power source, a ground wire, a probing electrode, and an indicator. (Note: the terms "ground" and "grounding" in this article are synonymous with "earth" and "earthing.") Current would flow if the leads of the ground wire and the probing electrode were attached to the power source and their tips were touched. If the ground wire was connected to a coated piece of steel and the probing electrode was placed on the coating surface, the coating would act as an insulator, and no current would flow. However, if a holiday was present in the coating, there would be a pathway for the current to flow. Holiday detectors have an indicator such as a sound or a light to tell when current is flowing. So, when the indicator shows current flow, it means a holiday is present.

Some coatings, especially zinc-rich primers, are excellent electrical conductors because of the conductive nature of the zinc particles, and so holiday testing cannot be performed on them. However, if a topcoat of a non-conductive coating such as an epoxy or urethane is applied over the conductive primer, the holiday test would be valid. In this case, the holiday test would not distinguish between a discontinuity that reaches only to the primer and one that reaches to the substrate.

Low-Voltage Holiday Detectors

Low-voltage holiday detectors (Fig. 1) are used on coatings that are thinner than 500 microns (20 mils). They are powered by a self-contained battery with a voltage that ranges from 5 to 90 volts direct current, depending on the manufacturer. Low-voltage holiday detectors have either a buzzer or a light to show when current is flowing. The probing electrode consists of an open-cell sponge, similar to one used on a household sponge mop.

Fig. 1: Low-voltage holiday detector (Photos courtesy of the author)

The coating must be sufficiently dried or cured prior to running the holiday test because retained solvents in the coating can give false results. Check with the coating manufacturer about when a holiday test can be performed on a fresh coating. Also, measure the dry film thickness to make sure it is less than 500 microns (20 mils). If holiday detection is required for coatings thicker than 500 microns (20 mils), then the high-voltage method is recommended.

Follow the manufacturer's instructions for assembling the unit. Differences do exist among commercial instruments, but they all require attaching the ground wire to one terminal on the power supply and the probing electrode to the other.

The sponge must be wetted with tap water. Don't use distilled water because it must be able to support a cur-

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rent, and that requires some conductive impurities, which are removed when water is distilled. There is no need to add salt to the water to improve conductivity. Doing so would only spread a corrosive contaminant on the surface. However, the water must be able to flow into the smallest of pinholes, so a low-sudsing wetting agent (surfactant) is often added to the water. (Some people believe that a wetting agent is not needed if the coating thickness is less than 250 microns [10 mils]. Others do not recommend the use of detergent as a wetting agent because excessive detergent can block pinholes after testing, giving the appearance that the coating has "healed" itself.) Soak the sponge until it is soft, pliable, and saturated. Then squeeze the sponge to remove any extra water. The water should barely drip when the sponge is moved over the coated surface.

Turn on the power supply after the unit has been assembled, and check the instrument by touching the sponge to the clamp on the ground wire. This action should complete the electrical circuit and cause the light or buzzer to turn on. If it does not, check the connections, the wires, the battery, and the wetness of the sponge. There really are not many things that can go wrong.

Fig. 2: High-voltage holiday detector

To perform the holiday test, attach the clamp on the ground wire to the structure. It must be in direct contact with the metal. The easiest place to attach the clamp is a nut, a bolt, or an edge. Scrape or sand the paint away so the clamp has good contact with the metal. Be sure to repair these areas after the testing is done.

Also, make sure the instrument is properly grounded by touching a bare spot on the metal with the probing electrode. The bare spot can be anywhere, including the back surface of the structure. If there is no access to bare metal, make (and mark) a small holiday in the coating. This should be above the fill line of a tank or in an area where a discontinuity will have the fewest consequences. The easiest place is near the ground clamp, as that area will have to be repaired anyway. Periodically check that the equipment is still grounded properly.

Place the sponge flat on the surface and move it across at a moderate rate (i.e., 0.3 m/sec [1 ft/sec]). Apply sufficient pressure so that the surface appears wet just behind the sponge. Remoisten the sponge if it dries out. The indicator light or buzzer will activate when a holiday is found. Turn the sponge on end when this occurs and relocate the holiday. Mark the area with chalk or an easily removable material that is compatible with the repair coating.

Resume the holiday testing after the area has been marked. It will be necessary to dry the area near the holiday or to leave a small space so the current does not travel back through the water to previously found defects.

The holiday test must be performed over the entire surface. Therefore, it is best to perform the test in a regular pattern, similar to a pattern used for spray painting. Pay special attention to nuts, bolts, washers, rivets, etc. The sponge will not conform to the entire surface when dragged over a bolt or a nut and threaded shaft, for example. In this case, it is easier to use one of the ends of the sponge. It may be necessary to reposition the ground clamp due to the length of the ground wire. Don't forget to mark the areas where the clamps were attached so they can be repaired.

Some people prefer to perform low-voltage holiday testing before the final coat is applied. The reason is that if a holiday is found after the final coat is applied, the repair coating over the holiday will be thin. Testing for holidays and then repairing them before application of the final coat will achieve additional coating thickness over the holiday. However, for holiday testing between coating layers, use plain water without a wetting agent so as not to leave a thin layer of contaminant on the surface that might reduce adhesion.

High-Voltage Holiday Detectors

High-voltage holiday detection is used when a coating is thicker than 500 microns (20 mils). The basic components of high-voltage detectors (Fig. 2) still include a power supply, ground wire, probing electrode, and indicator. However, the power supply for these units will provide thousands or tens of thousands of volts, and the probing electrode will be made of copper wires or carbon-embedded rubber.

For personal safety, extreme care is needed when using high-voltage holiday detectors. These units generate relatively low current while in use, which is good because high current can be quite dangerous. However, when you use a high-voltage probe in an electrically isolated environment, you can become charged to the test voltage, which can cause you quite a shock from a build-up of static electricity. The shock itself is not particularly dangerous, but how

Safety Tip

Before conducting holiday testing in a confined space or other area where a flammable gas or vapour may be present, be sure that proper procedures are followed to thoroughly check (and if necessary purge) the atmosphere of the work area to prevent the holiday detector from becoming an ignition source.

it causes you to react can be quite dangerous, especially if it prompts you to jump or fall. Always keep the working end of the probing electrode away from your body and do not touch it when the instrument is activated. Read the operating directions carefully.

Not all high-voltage detectors have batteries, but most of them do these days. Some are powered by plugging them into an electrical outlet; some use rechargeable batteries; and some use dry cells. If there is a battery, check it for proper voltage output before running any tests. (Refer to the manufacturer's instructions.) Then connect the probing electrode and grounding cable to the terminals of the detector and switch the instrument on. Touch the probing electrode to the alligator clip on the grounding cable and make sure the instrument signal activates.

A high-voltage holiday detector causes the air between the probe and the substrate to conduct electricity, or break the air gap in the holiday, as it sometimes is called. The size of the air gap will vary with coating thickness, and breakdown of the air gap will depend on atmospheric conditions such as relative humidity. A non-conductive spacer such as a thin piece of plastic that is the same thickness as the coating layer can be placed on a bare steel surface to test whether the detector will cause a spark to jump through the spacer. If it does, the test voltage is too high.

Fig. 3: Performing holiday detection on a pipeline with a full-circle coiled spring electrode

Setting the proper voltage is critical because too high a voltage may actually produce a holiday in the coating film rather than test for it. The first step, therefore, is to determine the voltage to use. This is based on the thickness of the coating and its insulation properties. Set the instrument to the proper voltage according to the manufacturer's instructions for the coating thickness being tested, because using a high-voltage holiday detector on a coating that is too thin also can produce holidays in the coating film. Likewise, verify the voltage calibration in accordance with the manufacturer's instructions and calibrate the instrument if necessary.

Operating a high-voltage holiday detector is very similar to using a low-voltage holiday tester. The grounding cable is attached to the steel substrate and the detector is checked by touching the probing electrode to bare steel. Move the probing electrode over the surface in a single pass at a rate of approximately 0.3 m/sec (1 ft/sec). When the instrument signals a holiday, go over that area slowly while watching the head of the probing electrode. You will be able to see a blue spark and can then mark the spot for repair.

Special accessories are available for performing high-voltage holiday testing on pipes and pipelines. These include half- or full-circle coiled spring electrodes (Fig. 3). A special ground wire to give the operator more mobility can be used if the pipeline segments are grounded to earth. The ground wire is about 7 m (23 ft) long and is dragged along the ground rather than attached to the steel. If no holidays are found, occasional checks should be made by touching the probing electrode to the steel to see if a spark and signal occur. If not, the ground wire may be dirty or the soil may have very high resistance (i.e., be very dry). If so, a ground cable with an alligator clip attached to the bare metal will have to be used instead.

The hazards of high-voltage holiday testing cannot be overly stressed. Do not touch the head of the probing electrode, and keep the probing electrode away from your body at all times when the instrument is turned on. After the instrument has been turned off, always ground the probe before disassembling the unit to ensure that any residual charge has dissipated. Also, remember that there may be an explosive environment in an enclosed area or a confined space if the coating being tested hasn't fully dried and solvents are still present. Do not use holiday detectors in these circumstances.

Holiday Testing on Concrete Substrates

Coatings applied to concrete substrates can also be tested for discontinuities using either low-voltage or high-voltage holiday detectors, depending on the coating thickness. Concrete can be conductive depending on its moisture content, the type and density of concrete, and the location of the reinforcing steel (rebars or wire mesh).

Before coating, the concrete must be tested to determine if it is conductive. Set up the holiday detector by attaching the ground wire to the reinforcing steel, making sure it is not coated metal. If the reinforcing steel is not accessible, the ground wire can be placed on the bare concrete surface and weighted with a damp cloth or paper and a sand-filled bag, or attached to a metal rod or nail driven firmly into the concrete. Touch the probing electrode to another bare spot on the concrete and see if the instrument responds.

A conductive underlayment will be needed if the instrument does not respond. Most conductive underlayments are coatings containing carbon or graphite fillers or conductive polymers. The underlayment must be compatible with the lining material, as it will be part of the coating system. The underlayment can be a primer, if so formulated, or an intermediate coat, depending on how the coating manufacturer designs the system. The holiday test is performed as previ-

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Holiday detectors can find coating defects that may not be visible

ously described for low-voltage and high-voltage instruments, depending on the coating thickness, except that ground is now made to the underlayment.

In general, if the concrete is not conductive and a conductive underlayment is not incorporated into the system, then high-voltage holiday detection would not be possible.

Because of expansion joints or construction joints in concrete structures, there may not be electrical continuity between sections. Therefore, it will be necessary to check the response of the holiday detector when moving to a new panel. If electrical continuity does not exist, move the ground connection to the panel being tested.

Repairing Holidays

All holidays need to be repaired after testing is completed. Consult the coating manufacturer about how to perform the repair. Surface preparation for the repair may involve washing or it may include roughening the surface. The surface should be washed with clean water if a low-sudsing wetting agent was used for performing a low-voltage holiday test. Sometimes holidays are the result of abrasive particles trapped in the coating. In that case, they will have to be removed and the coating system reapplied to the areas where the holidays were found. It is important to repeat the holiday test after the repair work to show that it has been successful. However, only the repaired areas need to be tested again.

Summary

Holiday testing is used to find coating film discontinuities that are not readily visible. Holiday testing is usually performed on tank interiors, chemical storage vessels, and buried structures because of the importance of maintaining adequate coating protection in aggressive service environments. Low-voltage holiday testing is used when the coating system is less than 500 microns (20 mils) thick. High-voltage holiday testing is used when the coating system is thicker. High-voltage holiday testing requires special care not to damage the coating or cause personal injury to the operator.

Next month: Cleaning and Painting Galvanized Steel