Madewell Products Corporation Technical Bulletin:

Holiday Testing Coatings in Manholes, Lift Stations, & Other Concrete Sewer Structures

Authored By: Jon Steele,
President Madewell Products
Corporation

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Madewell Products Corporation
7561 Industrial Ct
Alpharetta, GA 30004
Phone: (770) 475-8199
Fax: (770) 475-8167
Email: sales@madewell.net
Website: www.madewell.net

Section 1: Introduction

To perform properly, coatings and linings in corrosive environments must be free of holes, missed spots, and voids. These flaws are referred to collectively as "holidays". There are two methods of inspecting for holidays: visual inspection and electrical holiday testing. Electrical holiday testing of coatings applied over concrete is usually performed in accordance with one of the following two standards: NACE SP-0188 or ASTM D 4787. Both of these standards cover both high voltage (spark) testing and low voltage holiday detection using a wet sponge type instrument. Low voltage holiday testing is restricted to coating films less than 20 mils. Because coatings and linings applied in sewer structures are almost always applied at thicknesses greater than this, low voltage holiday testing is seldom employed.

A high voltage holiday tester is an electronic instrument that is used to detect holidays in **non-conductive** coatings applied to **conductive** substrates. These instruments usually consist of an electrical source, a conductive probing electrode, and a ground that is attached to the conductive substrate. Surfaces to be tested must be dry and free of all oil, dirt, and other contaminants. As such, once a manhole to be holiday tested has been opened, it may be necessary to ventilate the manhole interior with fresh air for a period of time to dry the surfaces to be tested. The testing probe is typically a pliable brass brush or conductive silicone rubber flap with an insulated handle.

Holiday testing is performed by passing the energized conductive probe over the surface of the non-conductive coating at a rate of about one foot per second in overlapping passes. While the passes must overlap, the probe is generally only passed over the coating surface once. When the testing probe encounters an area of low dielectric strength, such as a pinhole, void, conductive inclusion, or thin spot, current flows, a spark is created, and the instrument issues an audible tone to let the operator know that a holiday has been found. Holidays are typically marked for later repair using a black felt tip marker.

Section 2: Setting the Testing Voltage

High voltage holiday testing of coatings applied to steel substrates is fairly straightforward because steel is a highly conductive substrate. When holiday testing coatings applied to steel substrates, NACE International Standard Practice SP-0188 recommends a specific test voltage for various coating thickness (in the range of 100 volts per mil of coating film thickness). **Concrete, however, is not a uniformly conductive substrate.** The standard that is specific to high voltage holiday testing coatings to concrete, ASTM D 4787, does not suggest specific voltages for different thicknesses. Instead, this standard recommends following the manufacturer's recommendations regarding testing voltage and suggests making and finding a known holiday to "verify that the instrument is properly grounded". The standard recommends that the known holiday be made using a 1/16" diameter drill bit.

Madewell Products Corporation recommends **adjusting the test voltage and verifying that the instrument is properly grounded** by making a known holiday and adjusting the

testing voltage so that it finds it reliably. **Use only enough testing voltage to reliably find a known hole.** In a manhole, it would be a good idea to make at least three known holidays: one near the top, one in the middle, and one near the bottom of the manhole. On larger structures, it might be a good idea to make more than three known holidays because the conductivity of the concrete substrate might vary from one area to another. This is especially true when part of the structure is below grade and part is above grade. You will probably find that the areas above grade require more voltage to find a known hole than the portions below grade because the concrete below grade will be dampened by groundwater and the concrete will be more conductive.

Some inspectors may not allow you to set the voltage in this manner because the specification calls for a specific testing voltage (note that the voltages in NACE SP-0188 are "suggested"). In this case, you may have to perform the test in accordance with the specification. However, if you set the voltage in accordance with the specification and you cannot find a known hole, it should be obvious to the inspector that the test isn't working. Most inspectors would be okay with allowing you to increase the voltage so that you are able to find a known hole.

Section 3: Calibrating or Verifying Holiday Detector Output

Both NACE SP-0188 and ASTM D 4787 mention using a high voltage volt-meter to verify the holiday detector output (ASTM D 4787 mentions using a "spark gap calibrator"). Unfortunately, this procedure it is not as straightforward as these standards suggest. First of all, most detectors on the market today do not allow the user to "fine tune" the output voltage. You adjust the voltage in steps that are set at the factory, and the instrument uses some sort of internal electronic system to ensure that the generated test voltage is accurately measured and continuously controlled. As is the case with most inspection instruments used in the field, the user cannot calibrate the instrument as that is done by the instrument manufacturer or by a third-party laboratory. The user can only VERIFY whether or not the instrument is working properly.

Modern holiday detectors are DC pulse type instruments. That is, the testing voltage is only applied to the probe between 20 and 60 times per second. And the pulse duration is very small – in the range of 20 to 200 microseconds. **This means that the testing voltage is off a lot more than it is on** (it is "on" only 1% to 2% of each second). This is done to prevent unnecessary stress on the coating being tested. A volt meter is not going measure the output of a high voltage holiday detector – you would need something like an oscilloscope to do that, and there is no point in measuring the output if you have no way to adjust it.

Making and finding a known hole does away with all of this and provides the operator with guidance as to how fast the probe should move across the coating surface in order to find holidays.

Section 4: Coating Thickness

The dialectic strength of most epoxy coatings is somewhere between 400 to 500 volts per mil. If you are testing an epoxy coating film that is 125 mils thick, it would not be surprising to

find that it takes a testing potential of 13,000 volts (or more) to find a known holiday. If you pass an electrode at this potential over a thin area, say 25 mils thick, this may be enough testing voltage to overcome the dielectric strength of the film. As a result, you may burn a hole through the coating and create a holiday. If you are finding a lot of holidays in one area, that might be an indication of low film thickness.

A holiday test should not be used to find thin spots in the coating. Coating film thickness should be controlled and measured by other means. Please refer to Madewell Products Corporation's Technical Bulletin "Controlling and Verifying Coating Film Thickness Over Non-Metallic Substrates" for more information on this topic.

Section 5: Grounding

NACE SP-0188 recommends attaching the ground to the structure's reinforcing steel if possible. This is often not possible, so SP-0188 also suggests placing the ground wire onto the concrete structure and placing a damp bag of sand over the bare ground wire to help make electrical contact. In a manhole, particularly one located in the street, it might not be possible to get access to the concrete substrate at all. Some contractors have made an effective ground by pinching the ground wire onto the manhole frame using the manhole cover. Others have had success by driving a grounding rod into the soil near the manhole. At any rate, testing the performance of the holiday tester by finding a known holiday will assure that the tester is properly grounded.

Section 6: Technical Precautions

High voltage holiday testing **should only be performed on new, properly cured coatings.** Coatings should be tested as soon as they are sufficiently cured. Degree of cure may be determined by performing a solvent rub test per ASTM D 5402 using methyl ethyl ketone and a clean white rage. After 20 rubs, no color should show on the clean white rag.

If not performed correctly, high voltage holiday test may become a destructive test. In a damp environment, especially in immersion, coatings tend to take on moisture and their dielectric strength drops over time. Coatings that have been placed into immersion service or damp environments **should not be subjected to high voltage holiday test.** They should be inspected visually only.

Section 7: Making Repairs

Repairs must be made within the recoat window of the coating being tested. Epoxy coatings applied in damp environments tend to form what is called an "amine blush". This is a film on the surface that can take many forms from mild discoloration to the appearance of an oily yellow film. Unfortunately, it is not always possible to see an amine blush. So, in a damp environment like a manhole, it is best to assume that the epoxy coating has blushed, even if it is not possible to see it. Before holidays are repaired, the surfaces to be repaired must be dry. Holidays should be repaired by first wiping the area with a clean rag dampened with denatured alcohol. Because denatured alcohol is a water scavenger, it will help ensure that the surfaces are both dry and clean. If the recoat window of the coating has

been exceeded, after solvent wiping, the area to be repaird should be mechanically abraded so a sufficiently rough surface profile is created to accept the repair material.

Coatings for repairing holidays are typically mixed in small quantities. It is very important to measure the exact amount of A and B components recommended by the coating manufacturer using disposable graduated mixing cups (mix by volume). After proper proportioning, the coating must be carefully and completely mixed (typically by hand). Once the holiday has been prepared for touch-up, the ink from the felt tip marker will typically be completely removed. As such, it is important to keep track of where the holidays are in the moments between the time the surface has been wiped and the repair coating has been applied.

Some specifications call for retesting the areas that were repaired. Again, this must be performed as soon as the coating is sufficiently cured, and the coating must be clean and dry. It is usually not necessary to mark repaired areas for retesting because repaired spots are relatively easy to spot. Note that both ASTM D 4787 and NACE SP-0188 **recommend only retesting the repaired areas.**

Section 8: Hazards Associated with Holiday Testing

High voltage electrical holiday detection (spark testing) produces sparks which can shock the operator or ignite a fire or explosion in a flammable or explosive environment. The voltages employed to test thick film coatings over concrete range from 10,000 to more than 20,000 volts. It is not possible to perform this test for very long (especially in sewer manholes) without eventually getting shocked. As such, persons performing this work should be in good health and be aware that getting shocked is probable. A sewer manhole might be an explosive environment if methane sewer gas is present or in the event that something flammable is accidentally (or intentionally) dumped into the sewer upstream of the manhole. As such, atmospheric testing and proper ventilation are imperative if this test is performed in a manhole. **If there is any question** that something flammable or explosive might enter the manhole from the sewer, it would be prudent to plug the sewer line both upstream and downstream to ensure that nothing can enter the manhole while the test is being performed. Obviously, all normal confined space safety procedures should be followed while the test is being performed.

Section 9: Discussion

It takes about 30 minutes or so to holiday test an average 8' deep manhole by the time all flaws are marked for repair. This is about the same amount of time it takes to apply the epoxy liner. If the specification calls for retesting repaired areas, this effort would be doubled. An alternative to electrical holiday testing would be to simply visually inspect the manhole lining and make repairs. If the manhole lining is carefully visually inspected shortly after installation, any defects that are not found will be small (note that it is possible to miss spots with an electrical holiday tester as well). After the manhole has been in service for one year, the applicator should go back and inspect it visually a second time. If the manhole is in an aggressive environment, any small

defects that were not found during the initial inspection will show signs of corrosion, and they will stand out like a sore thumb. Once these areas are repaired, the manhole lining will likely continue to perform for many years.

Section 10: Will Pinholes Always Cause a Failure?

Maybe not. The tub in Photo 1 was filled with 1.5" of Mainstay ML-72 Sprayable Microsilica Restoration Mortar and topcoated with 125 mils of Mainstay DS-4 Epoxy Coal Tar Coating. After the coating cured, holes of various sizes were drilled through the DS-4 to the mortar surface. The container was then filled with an 11.5% solution of sulfuric acid and water and covered to prevent evaporation. Photos 2 and 3 show the condition of the drilled holes after 30 months of exposure. The sulfuric acid reacted with the cement paste in the mortar at the bottom of the holes to form a corrosion product that is probably mostly calcium sulfate. This corrosion product takes up more space than the original cement paste. This swelling created small volcano shaped mounds around the holes. This damage would be easy to find and repair. The calcium sulfate corrosion product appears to have effectively plugged the holes. Because calcium sulfate cannot be attacked by sulfuric acid (it is already a sulfuric acid reaction product), they might stay that way for decades even if left unrepaired.

Photo 1

Photo 2

Photo 3