BORIN® Manufacturing, Inc.

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TBE-0005

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Technical Bulletin 0005

Subject: Why Reference Electrodes Malfunction and Fail and Remedies for these Malfunctions

At ***BORIN Manufacturing®*** we have an on going research program to overcome many of the intrinsic as well as extraneous influences that affect the performance of reference electrodes. The ***Stelth®*** series of reference cells incorporate several patented or patented applied for features that do in fact mitigate against most of these problems.

First, with the introduction of the ***Dual Chloride & Hydrogen Sulfide ION TRAP*** feature we can now guarantee the ***Stelth®*** reference cells for thirty years. Hydrogen sulfide is always present in the soil and continually works against maintaining the stability of copper or zinc reference cells in general. On the other hand chlorides affect only Cu-$CuSO_4$ and Zn-$ZnSO_4$ reference electrodes. The ***Stelth®*** technology provides a **"Molecular Sponge"** (ion trapping shield) that prevent both chloride and hydrogen sulfide contamination.

Second, with the introduction of the ***"MRM" Moisture Retention Membrane*** which works to absolutely minimize contaminants of any kind from entering the internals of the ***Stelth®*** reference cell we can resolve a myriad of the problems discussed below.

Third, the use of ***Electric Mud™*** in dry soil conditions has solved problems in several regions from the Saudi Arabian deserts to the deserts of Australia and West Texas in the United States.

Fourth, with the development of the ***Stelth® IR Free probe*** technology, built to the **DIN 50925** Standard, literally dozens of problems, sometimes impossible problems, in taking potential readings have been solved.

If you have anything that can be added to this list please do not hesitate to write or give us a call as we would be delighted to expand the understanding of this technology. Also, if you have any questions that need to be asked, or need to discuss something on this subject, please give us a call at (310) 822-1000 or send a facsimile to 310-822-0789 or e-mail us at borin@borin.com.

In response to repeated requests to explain why reference electrodes fail or malfunction, the following conditions should be considered when investigating reference electrode failures. First, let us outline those conditions that affect all reference cells, regardless of the manufacturer, and then we can show what steps are necessary to take to avoid, correct, or eliminate these malfunctions or failures.

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☐ **Cause**: If the reference electrode lead wire is placed in the same conduit as the AC input to your rectifier you will get a swing of anywhere from 200 to 500 mV. This does not permanently damage the reference cell.
Remedy: When the lead wire is relocated correctly in a different conduit, the electrode will work fine.

☐ **Cause**: If the reference electrode lead wire is entangled with or placed in the same path as an anode lead wire, either sacrificial or impressed current, this will cause a milli Volt shift in the reading. Again, this does not permanently damage the reference cell.
Remedy: Relocate the reference cell's lead wire to a path of its own and this will correct the problem.

☐ **Cause:** When the reference cell lead wire is run in the same path as the return wire from the structure to the rectifier, you will experience anywhere from 100 mV to 1000 mV shift in the reading. This does not harm the reference cell.
Remedy: When the lead wire is relocated correctly the electrode will perform well.

☐ **Cause:** If the reference electrode is connected directly to the rectifier output, such as you would connect an anode, then your readings will be useless and so will your reference cell. When this is done the reference electrode is destroyed and cannot be salvaged.
Remedy: None!

☐ **Cause:** If the reference electrode lead wire is damaged, such as having been nicked during installation, and the electrode has any exposure to stray currents or if there are anodes close by the damaged area, the reference cell will begin to act like a capacitor producing readings that many times can reach a shift as high as 500 mV.
Remedy: The lead wire can be repaired if it is RHH-RHW by merely applying heat via a cigarette lighter. This will bond over the nick and it will be the strong point in the cable.

☐ **Cause:** If the reference electrode is inadvertently installed over a magnesium anode this will definitely cause a shift in your readings that would be in the magnitude of 200 mV to 300 mV. This event has not destroyed the reference cell.
Remedy: The reference electrode must be relocated at a safe distance from any anodes. This is an occurrence that happens frequently because many times the technician is trying to get both the anode and reference cell close to a hot spot.

☐ **Cause:** If the reference cell is located close to a magnesium anode-flex system (anode flex gradient), the system must be disconnected to obtain a correct reading. This does not harm the reference cell.
Remedy: The readings that it produces are only valid when the system is in the off state.

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- **Cause:** If the reference cell is located close to a point in the structure where there is severe damage to the structures coating, the readings obtained from this cell can vary as widely as 300 mV. No harm has come to the cell.
  Remedy: you merely need to relocate the reference electrode to obtain reliable readings. This is a hot spot so you take off potential readings that would reflect your worst potential. The on potential readings will be wrong due to the current flow to/from the holiday.

- **Cause:** If the reference electrode has been installed in soil contaminated by hydrocarbons, you can be assured the cell will be destroyed and be rendered useless.
  Remedy: None!

- **Cause:** If the Cu-CuSO4 reference electrode has been installed in soil that has a high content of chlorides, bromides and or sulfides greater than 100 ppm, you can count on a very limited life and the stability will begin to fall off almost immediately. The reference electrode will be destroyed.
  Remedy: None!

- **Cause:** When the reference electrode is installed in soil with acidic or alkali content outside the $4 < pH < 9$ range, the stability of the cell will begin to deteriorate and the reference electrode will be rendered useless.
  Remedy: None!

- **Cause:** Most engineers know that you should not install a Cu-CuSO4 or Zn-ZnSO4 reference electrode in sea water, on ocean beaches, near ocean beaches, in brackish water, swimming pool filtration tanks, separator tanks, sea water processing facilities, etc., but it is a very common occurrence. All of these locations share in common a high concentration of chlorides which very quickly alters the chemistry of a copper or zinc reference electrode.
  Remedy: The preferred solution is to employ a Ag-AgCl (silver-silver chloride) reference cell.

- **Cause:** Direct sunlight has a reactive effect on the chemistry of a Cu-CuSO4 or Zn-ZnSO4 cell. If you take readings where the sun is in direct contact with your portable reference electrode you will begin to see a shift in your readings that could be as high as 50 mV.
  Remedy: When you take these same readings where the cell is shielded from the sun you will see a return to a normal reading. In those cells that feature a clear window down the length of the electrode the effect is even more dramatic.

- **Cause:** The old practice of placing the reference cell in absolute virgin sand (cleaned and purified) while the structure was in native soil causes the reference cell to act much like a capacitor which would in many cases cause a 200 mV to 500 mV swing in your readings.
  Remedy: If both structure and reference electrode are placed in the same virgin sand there is no problem because the environment is the same, there just has to be enough moisture to sustain an electrical path (circuit). It is important to place the reference electrode in the same soil as the structure whenever possible.

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☐ **Cause:** If the reference electrode is installed in dry soil conditions you will begin to get potential readings that are invalid as the soil becomes more and more dehydrated. This is due to the contact resistance between the reference cell and the soil surrounding the reference cell, as well as the soil that is between the structure and the reference electrode all of which combine to cause an IR drop problem that degrades the potential readings.
Remedy: The only real solution to this kind of problem is to use an IR-Free reference electrode as defined in DIN 50925. This cell will bypass the resistance between the structure and the reference electrode as well as eliminating the contact resistance between the sensing area of the reference cell and the surrounding soil, allowing for a true IR-Free reading with virtually no moisture present.

☐ **Cause:** Many times reference cells are installed in flood zones where the makeup of the soil consists of fine silt and rocks of varying sizes. Running ground water many times erodes the silt creating a cavity where the electrode is trapped in. In this condition the sensing area of the electrode is isolated from the surrounding soil and electrical contact is lost when this cavity dries out. The reference cell is still fully operable but will only work when flooding returns to provide an electrical path.
Remedy: Relocating or reinstalling the reference electrode is the only solution for reliable and continuous service.

☐ **Cause:** Reference electrodes that are monitoring a structure (most commonly pipelines) that cross under or run under electrical transmission lines develop erratic behavior. This is caused by the electrical high-lines inducing voltage in the structure and causing the reference cell to shift its potential readings in a cyclical manner.
Remedy: The only solution for this condition is to use an IR-Free reference electrode that will filter out all interference's including the systems own rectifier activity. (See DIN Standard # 50925).

☐ **Cause:** If you are verifying the accuracy of a permanently installed reference cell, with a portable half-cell and you are getting shifts in your readings as high as 300 mV between the permanently install reference electrode and the portable half-cell, you are experiencing the IR effect on the portable cell reading. There is usually only one solution for this problem.
Remedy: When performing this verification procedure you must first shut your rectifier off to eliminate IR drop errors and to get a true reading from both cells. This is one of the most common errors made when this procedure is done. See Technical Bulletin number TB-0014 for a more in-depth discussion of this problem.

☐ **Cause:** If your cell is located in an area that has other active cathodic protection systems or if there is an exposure to stray DC currents from railroads, it will be almost impossible to get a true average potential reading, much less a IR Free reading (see DIN 50925 and NACE RP 0104-2004). When these phenomena occur there will usually be several reference electrodes in the same proximity that will appear to malfunction in the same manner (a substantial mV difference). Actually the cells are not damaged they are merely in an environment hostile to their ability to perform correctly.

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Given that the output of any reference cell is in the range of 3 micro Amperes, it is easy to see how extraneous influences, such as a train or interurban discharging high voltages and amperages into the ground, would distort and overwhelm the reference electrode.

Remedy: The only real solution to this kind of problem is to use an IR-Free reference electrode as defined in DIN 50925. This cell will filter out stray currents and allow for a true IR-Free reading.

☐ **Cause:** Reference electrodes used to control "Auto-Potential Rectifiers" might be subjected to severe current drain which dramatically reduces the life of the cell. It is important to understand that any current artificially induced through a reference electrode will permanently reduce the cells useful life and eventually kill it. For an in-depth technical discussion on this condition see technical bulletin number TB-0014.

Remedy: Once the reference electrode is exposed to this condition, without the proper internal impedance of at least 20 Meg Ohms, it will fail very quickly.

☐ **Cause:** A practice less common today than in the past, is the use of a low impedance meter (analog) to take a reading from a reference cell. A meter with a low internal impedance will allow a current that is excessive and beyond the design of the reference electrode's ability to handle it. This produces erroneous readings and will destroy the reference electrode.

Remedy: It is essential that the meter being used to read a reference electrode has at least a 20 Meg Ohms internal impedance to assure an accurate reading. Meters that routinely provide this feature are available from Miller, Fluke, Beckman and Agra.