Historic Corrosion Tools Tell the Story of Early Corrosion Control

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A Collection of Antique Instruments Illustrates the Rich History of the East Bay Municipal Utility District's Corrosion Department

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The world of corrosion engineering, finding its roots in electric street railways (also called trolleys or streetcars), came into existence and blossomed between the 1880s and mid-1930s. Most streetcars relied on direct current (DC) for their traction, and the rails not only supported the cars but also served as one leg of the electric circuit—the return path for the large amounts of DC (many hundreds of amperes) required to operate the system. Rail sections were connected with mechanical bonds (metal straps or cables) to establish long lengths of electrically continuous track. If a rail lost its electrical continuity, from faulty or missing rail bonds, the current would enter the ground and force its way back to the source (the substation) by taking whatever path it could. This often included water mains, gas lines, and other linear metallic utilities that were buried just beneath the city streets.

Where the current left the pipe, it took metal with it, which led to rapid failure of buried water and gas pipelines. This phenomenon was referred to as electrolysis and was considered to be caused by "vagrant" or "vagabond" current, which is known presently as electrical interference or stray current. At the time, all corrosion of buried utilities was blamed on electrolysis, and many electrolysis departments, committees, and engineers came into existence as a result.

The East Bay Municipal Utility District (EBMUD) (Oakland, California), organized in 1923 to provide reliable, high-quality water for the people of San Francisco's East Bay area, employed a corrosion engineering staff early on to help mitigate corrosion of its buried water pipe infrastructure. Known originally as the Electrolysis Department of the East Bay Water Co., this group helped pioneer the implementation of corrosion-control techniques for EBMUD, including the use of cathodic protection (CP) on large water transmission mains, which was groundbreaking at the time. Their corrosion laboratory was housed on the second floor of the District's Claremont Center building, a critical pump station in Berkeley, California.

The Electrolysis Department used a variety of equipment to conduct comprehensive surveys to track the flow of the electrical current. Results of the surveys were recorded by hand, compiled, and mapped. Before the pump station building was demolished and reconfigured in 1996, a collection of historic instruments used by the District was discovered—antique tools that date from about 1893 through 1950.

The tools span the period from the beginnings of commercialization of electricity in the 1880s to the development of CP in the 1930s, and beyond. Aside from the fact that these antique instruments are beautifully and artfully crafted of fine materials such as black walnut, cherry, mahogany, oak, and polished nickel and brass, they represent what might be called the golden age of electrical instrumentation. Also retrieved from the building were historical records of the Joint Committee for the Protection of Underground Structures in the East Bay Cities, a group formed in 1922 that was dedicated to the preservation of underground utilities.

The instruments in this collection were used not only in the early studies of electrolysis, but were also witness to the emergence of electrical bonds as a method of corrosion mitigation. The electrolysis engineers recognized that bonding the rail to buried pipelines was one method of mitigating stray current. Where

FIGURE 1. The Weston Mil-Ammeter Model 264 was first patented in 1888.

FIGURE 2. General Electric Thomson Alternating Ammeter.

FIGURE 3. Western Electro-Mechanical Co. Portable AC Ammeter.

FIGURE 4. Weston DC Ammeter Model 45.

FIGURE 5. Rhodes Potentiometer Voltmeter Model P.

FIGURE 6. Weston DC Millivoltmeter Model 622.

current flow was determined to be detrimental, they installed drainage bonds between the pipe and the rail itself, or at railway substations, to drain excessive current from the affected structure. In its simplest form, a bond was a wire that connected a rail to a buried pipe. To monitor and manage this current exchange, amperage and voltage measurements were taken at bond stations using ammeters, voltmeters, and shunts. Ammeters measured the amount of electric current in amperes in a circuit. Voltmeters measured the electrical potential difference between two points in an electrical circuit. Shunts were used to measure current. When a shunt was placed in the wire or bond that connected the rail and the pipe, current passing through the drainage bond could be measured. By knowing the resistance of the shunt and measuring the voltage with a millivoltmeter, the amount of current passing through the shunt could be calculated using Ohm's Law (I=V/R, where I is current, V is voltage, and R is resistance).

Ammeters in the EBMUD collection include the Weston Mil-Ammeter Model 264 (Figure 1), manufactured by the Weston Electrical Instrument Corp. and first patented in 1888, and the General Electric Thomson Alternating Ammeter (Figure 2), first patented in 1895 and standardized at the Lynn Laboratory in 1905. According to General Electric, "This instrument is intended to be used in a horizontal position. It is practically correct for alternating currents of any frequency or wave form." A 200-A capacity Portable AC Ammeter (Figure 3), manufactured by the Western Electro-Mechanical Co., Inc., is also part of the collection, as well as a Weston DC Ammeter Model 45 (Figure 4), manufactured in 1948 by the Weston Electrical Instrument Corp. and used in conjunction with an external 50-mV shunt. This popular ammeter was extremely accurate for measurements between 0.01 and 20 A.

The collection also includes several voltmeters. The 1941 Rhodes Potentiometer Voltmeter Model P (Figure 5), manufactured by the Sensitive Research Instrument Corp., was designed particularly for measuring the voltages encountered in electrolysis and was probably used in the field to measure stray current at rail bonds. This very versatile instrument could also measure electric potential. The original cost was $258. The Weston DC Millivoltmeter Model 622 (Figure 6), manufactured by the Weston Electromechanical Corp., features a Bakelite plastic case. This model was standardized in 1936. The Westinghouse Electric 600-V capacity AC Voltmeter (Figure 7) also has a Bakelite case. Bakelite was the first synthetic thermoset plastic and was known for its electrical nonconductivity, although it was also used in costume jewelry and kitchenware.

Various shunts used by the Electrolysis Department that are part of the collection include a DC shunt (Figure 8) manufactured by the Weston Electrical Instrument Co. Constructed of a ventilated cherry wood box that houses a long, accordioned ribbon of resistance wire, this 150-A device likely predates the present-day shunt design patented in 1893. Other antique shunts include a 50-A shunt on an oak base (Figure 9) and a 150-A shunt on a wood base (Figure 10), both developed after 1893, that feature resistance ribbons made from an 86% copper, 12% manganese, and 2% nickel alloy known as Manganin; a 10-A shunt with a Bakelite base and a delicate resistance element that is covered with a non-metallic shield (Figure 11); a 10-A shunt with an oak base and oak-covered resistance wire (Figure 12); and a 600-A shunt (Figure 13) that was used in electrical bonds between water mains and the electric street car rails. Some shunts were designed to be mounted permanently and some were portable. Shunts such as these are still commonly used in CP rectifiers and anode junction boxes. The shunts in this collection were primarily used in trolley drainage bonds.

Another piece of equipment used in conjunction with drainage bonds was the recording voltmeter. A pair of wires led from the shunt to the recorders so voltage could be measured continuously. The early units were called smoked-chart recorders. These devices used rotating circular chart paper that had been blackened with smoke residue. As the disc rotated, a stylus would scratch off the residue, which left a trace that corresponded to the voltage being measured vs. time. In San Francisco's East Bay, numerous smoked-chart recorders were assembled in one central location to monitor bonds throughout the area

(Figure 14). This system, which used the recording voltmeters to remotely monitor the voltage drop across shunts installed at a variety of locations around the railway network, is probably the earliest example of remote monitoring of corrosion control equipment. Chart recorders are still used today, but data loggers, supervisory control and data acquisition (SCADA) systems, and satellite monitoring have taken their place for many applications.

Early investigators measured DC current flow in the soil by exposing buried pipe and measuring the flow of current onto a pipe using instruments such as the McCollum Earth Current Meter (Figure 15). This rare, unusual instrument, developed by the U.S. Bureau of Standards' physicist Burton McCollum, required an equal amount of current to be supplied in order to accurately measure current in the soil. The set featured a built-in galvanometer with a hand-cranked commutating vibrator in a walnut enclosure (Figure 16), a trench contacting electrode (Figure 17), or a cantilevered electrode (Figure 18). The complete set originally sold for $790. The instrument is now obsolete, most likely because its use required the environment around the pipe to be disturbed, which could affect the accuracy of the data being collected.

During the early twentieth century it became increasingly clear that soil itself could cause corrosion of underground utilities, even in the absence of DC railways. The conductivity of a given soil was discovered to be directly related to its corrosivity. The recognition that soil characteristics could influence the rate of corrosion of buried utilities led to widespread soil studies. With these studies came a variety of innovative test instruments.

The Shepard Earth Resistivity Meter (Figure 19), first described in 1930s literature as an instrument for conducting soil corrosivity testing, measured the resistance of soil between two steel probes. The meter set, which originally cost $95, featured steel rods sheathed in Bakelite and a cast aluminum handle that contained two dry-cell batteries.

One particularly ambitious study authorized in 1931 by the Electrolysis Committee—part of the Joint Committee for the Protection of Underground Structures in the East Bay Cities—conducted a soil

FIGURE 7. Westinghouse Electric 600-V AC Voltmeter.

FIGURE 8. A nineteenth-century 150-A DC shunt.

FIGURE 9. A 50-A shunt on an oak base.

FIGURE 10. A 150-A shunt on a wood base.

FIGURE 11. A 10-A shunt with a Bakelite base.

FIGURE 12. A 10-A shunt with an oak base and oak-covered resistance wire.

FIGURE 13. A 600-A shunt shown on a trolley map.

FIGURE 14. A centralized bank of smoked-chart recorders allowed the Electrolysis Department to remotely monitor each bond.

FIGURE 15. An electrolysis surveyor uses a McCollum Earth Current Meter to measure current flow on a buried cast iron pipeline adjacent to a rail line.

FIGURE 16. The McCollum Earth Current Meter.

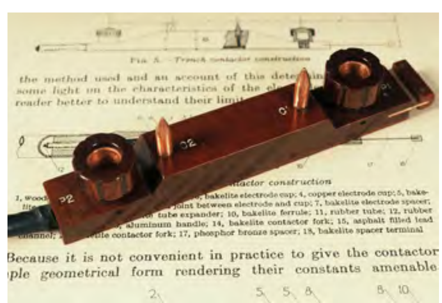

FIGURE 17. A trench contacting electrode used with the McCollum Earth Current Meter.

FIGURE 18. A cantilevered electrode used with the McCollum Earth Current Meter.

FIGURE 19. Shepard Earth Resistivity Meter.

survey for the entire East Bay Cities area. At every soil excavation, each of the committee's member utilities used the Leeds & Northrop Potentiometer (Figure 20), an instrument used with EBMUD-designed soil electrodes to measure soil resistivity. Each member agency filled out a test card for each excavation (Figure 21), and comprehensive soil corrosivity maps were then generated from the data. Areas where soil resistivity measurements were <2,500 Ω-cm were marked as corrosive with colored pencils. These maps can be seen in the background of Figures 1, 7, and 11.

Soil resistivity continued to be a primary parameter in determining the corrosivity of soil. By 1950, ground resistance meters had evolved into what the sales literature referred to as the "smooth and modern appearance" of the "jet black" Megger Ground Resistance Meter Model CVM (Figure 22). This 1950 instrument features a Bakelite case and a hand-cranked AC generator. It was manufactured in England by the James G. Biddle Co. and the original cost was $135.

Antique instruments used by the District for applications other than corrosion control were also found in the collection. The Westinghouse Polyphase Wattmeter (Figure 23) is an exquisite example of early instrumentation used to measure electric power. First patented in 1902, this device surely measured some of the very first watts ever generated. The 500-W General Electric Field Rheostat (Figure 24), with a dial-in steel case and multiple knife switches, is a piece of test equipment that controlled the electrical resistance of a circuit without interrupting the current flow. Two potential transformers housed in walnut cases (Figure 25), manufactured by Weston Electrical Instrument Corp. and calibrated in 1930, converted high voltages to low voltages so they could be measured with meters, and were most likely used alongside the wattmeter.

Most of these instruments, stored in boxes intended for vehicle transportation, were designed to be used in the field by electrolysis professionals, and the tools required to conduct field surveys could easily fill a station wagon (Figure 26). Over the years, testing and remote monitoring techniques have advanced significantly; and these antique meters have been replaced with smaller, lighter, more accurate digital versions, with some digital meters combining many functions in one tool. For the early electrolysis engineers who were mitigating corrosion 80 to 100 years ago, today's range of corrosion-control equipment available for the modern corrosion professional surely would have been unimaginable.

Editor's Note: Mark Lewis is the unofficial curator of EBMUD's antique corrosion test equipment and instrumentation collection, which was on display during CORROSION 2013 in Orlando, Florida, USA from March 18 to 21 in the Exhibit Hall. The collection, generously on loan from EBMUD, is currently on display at NACE International's Elcometer Building in Houston, Texas, USA.

Bibliography

Lewis, M. "How 'Vagrant Current' Became Impressed Current Cathodic Protection—Part 1." *MP* 64, 11 (2008): p. 36.

Lewis, M. "How 'Vagrant Current' Became Impressed Current Cathodic Protection—Part 2." *MP* 64, 12 (2008): p. 34.

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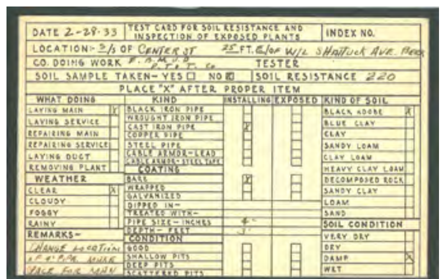
FIGURE 20. Leeds & Northrop Potentiometer.



DATE 2-28-33
TEST CARD FOR SOIL RESISTANCE AND INSPECTION OF EXPOSED PLANTS
INDEX NO.
LOCATION:- S/s OF CENTER ST 25 FT. E/of W/L SHATTUCK AVE. Berk
CO. DOING WORK E.B.M.U.D. P.T.&T. Co
TESTER
SOIL SAMPLE TAKEN—YES ☐ NO ☒
SOIL RESISTANCE 220
PLACE "X" AFTER PROPER ITEM

WHAT DOING: LAYING MAIN X; LAYING SERVICE; REPAIRING MAIN; REPAIRING SERVICE; LAYING DUCT; REMOVING PLANT
WEATHER: CLEAR X; CLOUDY; FOGGY; RAINY
REMARKS— CHANGE LOCATION OF 4" PIPE MAKE PLACE FOR MAIN
KIND (INSTALLING / EXPOSED): BLACK IRON PIPE; WROUGHT IRON PIPE; CAST IRON PIPE X; COPPER PIPE; STEEL PIPE; CABLE ARMOR—LEAD; CABLE ARMOR—STEEL TAPE
COATING: BARE X; WRAPPED; GALVANIZED; DIPPED IN—; TREATED WITH—
PIPE SIZE—INCHES 4"
DEPTH—FEET 3'
CONDITION: GOOD; SHALLOW PITS; DEEP PITS; SCATTERED PITS
KIND OF SOIL: BLACK ADOBE X; BLUE CLAY; CLAY; SANDY LOAM; CLAY LOAM; HEAVY CLAY LOAM; DECOMPOSED ROCK; SANDY CLAY; LOAM; SAND
SOIL CONDITION: VERY DRY; DRY; DAMP X; WET

FIGURE 21. A test card completed for the East Bay Cities soil survey.

FIGURE 22. Megger Ground Resistance Meter Model CVM.

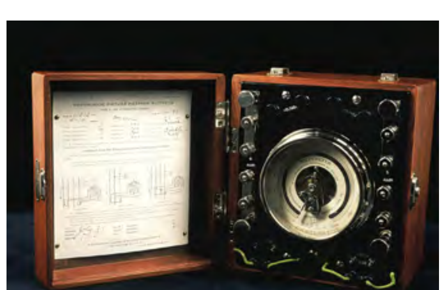


FIGURE 23. Westinghouse Polyphase Wattmeter.

FIGURE 24. 500-W General Electric Field Rheostat.

FIGURE 25. Weston potential transformers housed in walnut cases.

FIGURE 26. Corrosion test equipment ready for loading at the Adeline Maintenance Center in Oakland, California in 1957.