

Welding Cable ACID Test



Drake Chamberlin

©2000 Drake Chamberlin

Cable specimens soaking in battery acid.

The Renewable Energy Test Lab has conducted its first experiment. The lab is dedicated to defining and promoting safe and cost effective methods for the construction of renewable energy electrical systems. We believe that system costs can be significantly reduced by using only what is truly necessary for system safety and efficiency.

In recent years, inspection agencies have become interested in photovoltaic and other renewable energy (RE) installations. An effort has been made by the *National Electrical Code* to define requirements for these systems. Manufacturers and Underwriters Laboratories also specify conditions for certain system components.

Safety & Common Sense

Solar and other RE systems were being installed for at least a decade before code compliance became an issue. (Wind systems go back many decades.) During this period, many pioneers in the field developed safe and effective methods of constructing systems. There were remarkably few safety problems with these early systems.

When code enforcement began, it was welcomed by many. Some early systems did not use fuses or follow other basics of good electrical design. But as code enforcement developed, it quickly became apparent that the experience of RE pioneers had not been taken into account when drafting the new regulations. Requirements were added that drove up system costs, without benefit to safety or performance. Bob-O Schultze's early *Wrench Realities* columns in *Home Power* documented many of the concerns.

Welding Cable

One area where new requirements ignored the experience of RE pioneers was in the banning of

Ideal Sperry 61-780 Insulation Tester Results for Cable Insulation Test

Tested Cable Insulation	Date In	Date Out	Visible Change	Meter Reading
#2/0 AWG THW or Oil Resistant I	4 Mar	7 Aug	none	OL**
#2/0 Essex Excelene welding cable	5 Mar	7 Aug	none	OL
#4/0 Cobra Wire & Cable X-Flex (Trace cable)	4 Mar	7 Aug	none	OL
#4/0 Carol Prene welding cable, 600 V	4 Mar	7 Aug	none	OL
#4/0 Carol Super Vu-Tron type W RHH or RHW	4 Mar	7 Aug	none	OL
#2/0 Hypalon diesel locomotive cable	25 Feb	27 Aug	none	OL
#2/0 Essex THHN or THWN*	4 Mar	21 Apr	loss of mass	OL

* This specimen spilled on 21-Apr, but remained in a puddle of acid until 06-Aug.

** The "OL" reading means resistance is beyond the range of the meter.

welding cable from use in battery boxes. Welding cable has proven to be an effective material to use for connecting batteries to each other, as well as to disconnects and inverters. Welding cable is readily available, very durable, and relatively inexpensive. Many national suppliers of RE equipment still use welding cable for battery interconnects.

The banning of welding cables from battery enclosures is a perfect example of an institutional barrier. Although welding cable has been used successfully for years in battery boxes, it is not listed for this purpose. Its use has been actively suppressed by regulatory agencies.

Several years ago, inspectors in many areas began to reject systems where welding cable was used. They required cable types that were more expensive, and often hard to get. System rejection has caused many RE electricians to be humiliated in front of their customers. It is often necessary to have exotic cables shipped in, sometimes causing stressful delays in system approval.

RE electricians are happy to do whatever is necessary to construct safe systems. But few electricians believe that the zealous suppression of welding cable is in any way justified to obtain that safety.

What to Test

We first needed to determine what the differences are between welding cable and the cables approved by the NEC. Most of the popular, acceptable battery cables have conductors composed of finely stranded copper wire. Welding cable conductors are also made from finely stranded copper wire. The difference between the cable types is in the insulation. The concern is the presence of battery acid in the cable's environment.

The issue to be determined was whether or not welding cable insulation is sufficiently resistant to battery acid to justify its use in battery boxes. Would there be any catastrophic reaction if welding cable was subjected to contact with battery acid? Would the insulation dissolve or lose its resistance to electrical potential?

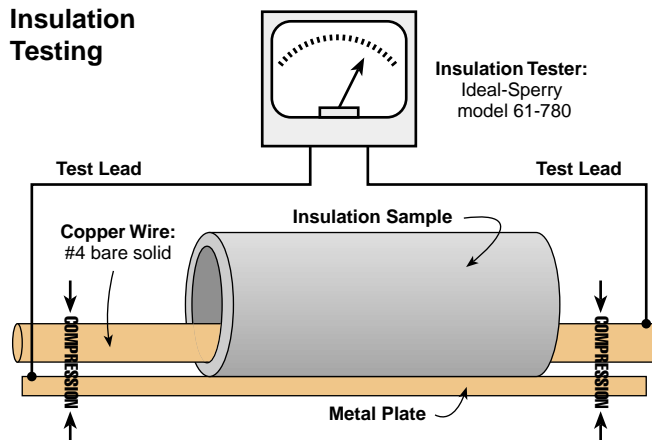
The Acid Test

Several samples of cable sheath were removed from their copper cores. The cables ranged from welding cable to various cable types currently deemed acceptable for use in battery enclosures. The cable samples were all roughly 2 inches (5 cm) in length.

Ideal-Sperry 61-780 Insulation Tester on the 1,000 Megaohm Test

	Megaohms	Deviation
High reading	940	6.0%
Low reading	928	7.2%

Insulation Testing



All of the samples were submerged in standard strength battery acid by March 5, 2000. Each specimen went into an individual glass jar. One sample jar was tipped over and mostly emptied of its acid by a squirrel on April 21st. This was a specimen of cable that is not approved for use in battery boxes, and not commonly used—type THHN-THWN.

All of the specimens were removed from the acid on August 6, 2000. They were then dipped in a solution of water and baking soda. All samples, including the spilled specimen, fizzed dramatically when doused in the soda solution. All specimens were then thoroughly rinsed in cold water, dried, and stored in labeled envelopes. Later, they were examined and tested for electrical resistance.

The Results

The only specimen to show any visible deterioration was the THHN-THWN. Within a day or so of being immersed in the acid, it began to darken the solution. Within a week, the solution was black. The insulation was apparently losing mass.

Measured Resistance of Individual Resistors

Resistor Number	Test Instrument		
	Ideal-Sperry 61-780 Insulation Tester (Megaohms)	UEI DM 383 Digital Multimeter (Megaohms)	Soar 3200 Digital Multimeter (Megaohms)
R-1	9.99	10.03	10.04
R-2	9.70	9.72	9.78
R-3	9.82	9.88	9.93
R-4	9.82	9.80	9.90
R-5	9.57	9.63	9.70
Average	9.78	9.81	9.87
Deviation	2.2%	1.9%	1.3%

To determine accuracy of the insulation test meter, resistors rated at 10 megaohms were tested.



Author Drake Chamberlin, testing a sample of welding cable insulation.

After more than five months of soaking in acid, all the other specimens came out of the solution with no signs of degradation. The two samples of welding cable remained flexible. They maintained mechanical integrity, as evidenced by the inability to damage the sheath by twisting and pulling.

The electrical resistance of the samples was tested with an Ideal-Sperry 61-780 insulation tester. This device applies 1,000 VDC to the material being tested. It will test for resistance values up to 2,000 megohms, or 2 billion ohms.

The accuracy of the meter was investigated by testing 10 megohm resistors, individually and wired in series groups. One test involved one hundred 10 megohm resistors wired in series. That adds up to 1 billion ohms, or a gigaohm! The tests demonstrated that the accuracy of the meter was adequate.

The meter readings showed less resistance than the theoretical value of the resistors. The resistors were rated for a 5 percent variation. If the insulation tester was off, it appears that its readings were conservative, showing less resistance than the material being tested. The total variation is insignificant to the hypothesis under investigation.

The samples were tested by inserting a bare #4 (21 mm²) copper wire through each empty tube of insulation. The sample wall was squeezed between the bare copper wire and a metal plate. One electrode of the tester was attached to the wire, and the other to the plate. Each piece of insulation was tested repeatedly. A

short circuit connection was made between the plate and the #4 copper wire after each test to verify the connections.

The bottom line is that none of the insulation specimens registered any conductance whatsoever. Even the sample of THHN, which partially melted in the acid, showed resistance beyond the range of the meter.

Conclusions

The insulation specimens had hundreds of times more exposure to battery acid than cables would in real systems. The welding cable, which we are forbidden to use, showed no signs of being damaged by prolonged submersion in battery acid. The welding cables tested are excellent products for use in battery enclosures, and their use should certainly be permitted.

A Note on the RE Lab

There are many other issues about regulations that affect RE installations. Many of these issues have a far greater impact on system cost than the banning of welding cable from battery boxes. The welding cable experiment was chosen as the first because it was relatively inexpensive. The RE Lab would like to address other issues that are important to RE system installers.

At present, the RE Lab is operating with no formal budget. We are looking for sources of funding, and for volunteers with grant writing skills. With adequate financial backing, we would perform a series of experiments dealing with other controversial areas of RE installation.

RE Lab volunteers would like to become involved in the code writing process. Our goal is to evolve clear guidelines—based on testing—that allow for safe, economical, and effective renewable energy installations.

Access

Drake Chamberlin, Electrical Energy Contracting and Consulting, 3138 Lyle Ct., Denver, CO 80211
303-477-4739 • solar@eagle-access.net
www.eagle-access.net/solar

National Electrical Code® and *NEC*® are registered trademarks of the National Fire Protection Association. The 1999 *NEC* and the *NEC Handbook* are available from the NFPA, 11 Tracy Dr., Avon, MA 02322
800-344-3555 or 508-895-8300 • Fax: 800-593-6372 or 508-895-8301 • custserv@nfpa.org • www.nfpa.org

Other Lab Members:

Don Wallingford, Quicksilver Electrical Service, PO Box 766, Frederick, CO 80530 • Phone/Fax: 303-833-4214
quicksilver@eagle-access.net

Sarah Wallingford, Alpine Art & Graphics, PO Box 766,
Frederick, CO 80530-0766 • Phone/Fax: 303-833-4224
alpartgraph@eagle-access.net

RE Lab Web Master: Willy Wallingford,
neophoenixte@eagle-access.net
www.eagle-access.net/solar

Rob Savoye, Seneca Software & Solar, 60 Bigbee High
Rd., Ward, CO 80481 • 303-258-0506
rob@welcomehome.org • www.senecass.com

Dr. M Tariq Iqbal, Associate Professor, Pakistan Institute
of Engineering and Applied Sciences, Nilore,
Islamabad, Pakistan • +92-51-583596
Fax: 14358085827 • m_tariq_iqbal@yahoo.com
www.geocities.com/m_tariq_iqbal

Phoenix Composting Toilet System

Odorless • Waterless • Large Capacity
Low Energy Requirements • Owner-Friendly

Advanced Composting Systems
195 Meadows RD
Whitefish, MT 59937
Voice: 406-862-3854
Fax: 406-862-3855
phoenix@compostingtoilet.com
www.compostingtoilet.com

Sunergy Systems, LTD
Box 70, Cremona AB T0M 0R0
Voice/fax: 403-637-3973
sunergy@telusplanet.net
In British Columbia:
Voice: 250-751-0053
Fax: 250-751-0063

AUTOMAGIC BATTERY WATERING



WE MAKE WATER FROM YOUR GAS

Hydrogen and oxygen battery gas catalytically recombined into pure water and returned to each battery cell. Keeps battery topped off for extended periods of time and reduces maintenance costs. Explosive hydrogen gas is virtually eliminated from the battery area. Corrosive spray and fumes are contained and washed back into each battery cell. Electrolyte kept strong longer, extending the useful power and life of the battery. HYDROCAP Vents simply replace the battery's caps. Battery maintenance is greatly reduced. Write or call for more information.



Hydrocap
BATTERY VENTS

305-696-2504
975 NW 95 St.
Miami, FL 33150

SOLAR ON SALE

Congratulations to Our Latest Contest Winners !



Mark Boden of AL
1st Prize,
BP-585 Solar Module



Francis McClausan of WA
2nd Prize,
Trace TS-512 Inverter



Brad Stanton of TN
3rd Prize,
Vector 600 Inverter

Be sure to enter our next contest which began September 1st
We'll be giving away another BP-585, a Trace inverter and much more !

Kyocera KC120 \$529.00
BP 585 Laser Grooved PV \$415.00
BP 75 Watt PV \$349.00

Photowatt 100 Watt PV \$375.00
PowerStar 1300 Watt Inverter \$269.00
Photowatt 75 Watt PV \$290.00

Nationwide financing now available for alternative energy systems !
Trace prices so low that we can't even quote them here !

Sales & Repair

Trace Authorized Service Center

Toll Free 1-888-64-SOLAR (647-6527)

<http://www.solaronsale.com>

19059 Valley Blvd Suite 219 Bloomington California 92316-2219

