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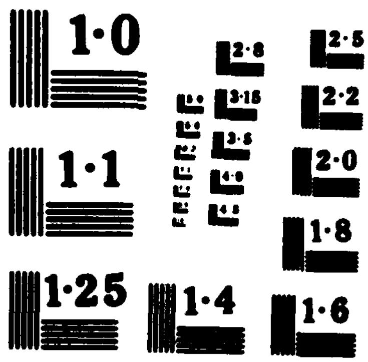
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USA Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire 03755

Using electronic measurement equipment in winter

Ronald T. Atkins

Introduction

It is well known that heat is the enemy of electronic semiconductor devices because it causes high noise voltages and large leakage currents. But low temperatures can also present problems—for example, high junction voltages, loss of hermetic seals, and breaks in input/output lead wires.

Today, electronic instrumentation and measurement equipment can be successfully operated in a winter field environment much more readily than 10 or even 5 years ago. Semiconductor devices like transistors, diodes, silicon control rectifiers (SCR's), and operational amplifiers will work at temperatures down to −40°C. With modern integrated circuit technology it is much easier to obtain excellent thermal performance from a circuit since the entire circuit is concentrated on a small chip, guaranteeing that all its components will have a uniform temperature. Better design strategies are constantly being developed to keep electronic devices well behaved over wide temperature ranges.

Still, there are pitfalls to be avoided when using electronic equipment in a winter field environment. Before potential problem areas and ways to avoid them are discussed, a definition of "winter field environment" is necessary. For the purpose of this article it means:

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- Nighttime temperatures around -12° to -18 °C but occasionally as low as -30° or -40 °C.
- Daytime temperatures around -5 °C but occasionally as high as +5 °C.
- Low relative humidity.
- Some days with bright sunshine and some dark days with low visibility.
- A foot or two of relatively dense snow on the ground, periodically topped off by a snowfall of lighter, fluffy snow.
- Occasional blowing snow, usually fine and powdery.
- Occasional thaw periods with above-freezing temperatures, thick ground fog, and rain.

The discussion of how these winter conditions can cause problems will be broken into three categories: 1) commercial equipment, 2) individual components, and 3) installation techniques. The examples cited are not meant to be all-inclusive, but merely representative of the types of problems that occur. Obviously there will be some overlapping, since certain problems are common to all categories.

Commercial equipment

Electronic measurement equipment that is large and complex will be kept in heated instrumentation vans and therefore will probably never be exposed to cold. Nevertheless, electric power and heaters have been known to fail, so it is a good idea to check to see what the equipment's storage temperature is. If it can't be stored at -30 °C or so, a back-up heating system might be considered—kerosene or propane space heaters, for instance. Examples of equipment that can be damaged at -30 °C include any device that uses a liquid crystal display as well as some meters, especially those with taut-band suspensions. Some instruments contain these devices as "specials" which have been designed to withstand the cold. Check the equipment manual. There may or may not be a problem.

A second group of commercial instruments that may have problems is the test equipment used to support the main instrumentation system. Examples of this equipment are digital volt–ohm meters, oscilloscopes, thermocouple readers, multimeters and counters. Very often equipment of this type is battery-operated. It may be used to install, monitor, align, calibrate or repair outside equipment, and may therefore be exposed to winter conditions for up to several hours. If test equipment is to be used in this manner, the following points should be considered.

Even though a piece of equipment appears to operate correctly at low temperature, it is always a good idea to have some means of checking it, even if only at a single point. For example, a digital multimeter can always be checked by shorting its leads on its lowest "volts" range to be sure it reads zero. Another check is to keep a precise resistor with a low temperature coefficient (10 ppm or less per degree Celsius) on hand and occasionally check the "ohms" range. For a thermocouple reader a short piece of thermocouple wire can be put under the tongue to read a "known" temperature. If this is done, the thermocouple wire should be held tightly with both hands where it exits from the mouth to prevent an erroneous reading due to heat conduction along the wire. It is also possible to carry an ice bath as a temperature reference, but this thermal system must be kept above 0°C to work properly. For volt–ohm meters, a couple of small batteries can be kept in the pocket to check "volt" scales.

Some hand-held instruments have low-temperature "specs" down to −40°C. However, they may give inaccurate readings during the transition from one temperature to another. The reason for this is that during the transition compensation circuits may not all be at the same temperature. This problem becomes especially severe if the instrument is repeatedly taken from a heated vehicle into the cold and back again. If thermal gradients cause problems, the easiest solution is to keep the instrument inside your coat while it is in the cold, or else keep it in a small Styrofoam box so that temperature cycling is minimized. Another point is that testing of equipment at low temperatures should include a test *during* temperature transition.

Instruments with LED (light emitting diode) readouts may be a problem on bright, sunny days with strong reflection from the snow cover. Dark glasses help some, but it may be necessary to put the instrument under your coat or in a box to keep the display from "washing out."

Instruments that have been left in the cold long enough to become thoroughly chilled should be wrapped in air-tight plastic before being brought into a warm environment. This is to prevent the warm air from coming in contact with the cold circuit boards. If this should occur, the air will be chilled below its dewpoint temperature, and moisture will "condense" onto the circuit. Since the volume resistivity of this moisture is about 20,000 ohms or so, it will almost certainly cause problems in today's high resistance circuits. Of course the instrument won't be permanently damaged, but it will be useless until it dries out.

As a rule, strip chart recorders must be kept warm in the field. Otherwise, the ink freezes and the lubrication on the chart drive and/or slide wire causes sluggish, unreliable operation. There are some recorders that were designed for winter field operations. They have alcohol-based inks and Teflon gears. They cost more, but may be worth it.

Individual components

Many field instrumentation systems involve some sort of non-commercial interface or control circuit which was designed and built by the users. The components that go into these circuits deserve some consideration.

Semiconductor devices can generally be purchased as military grade, industrial grade, or commercial (consumer) grade. The low temperature "spec" for *full performance* on military grade devices is −40°C or lower, while on industrial grade devices it is generally 0°C. For winter operations it is worth spending the extra money for the military grade, especially for integrated circuit devices, both analog and digital.

Small components all have their peculiar problems at low temperatures. For instance, carbon resistors and some capacitors have exceedingly high temperature coefficients (1000 ppm per degree Celsius and even higher). Some electrolytic capacitors will fail below 0°C; variable resistors become stiff and difficult to turn; liquid crystal displays get sluggish and difficult to read; and rotary switches become stiff and hard to turn. The solution is to use mil-spec components whenever possible. It is also a good idea to test completed circuits in a freezer, just to be sure.

Batteries are especially troublesome at low temperatures. All commercially available batteries lose some of their capacity as the temperature drops. However, lead–acid cells (including sealed cells) will probably give the best low temperature performance. Ni-cad batteries also do well in the cold. Mercury cells in general will perform poorly except at very light loads. Carbon–zinc batteries are somewhat better than mercury cells, but for prolonged operation it is probably a good idea to run a second set of batteries in parallel in order to double the normal capacity.

Connectors can be particularly troublesome in a winter environment. Low temperatures normally do not bother connectors, but blowing snow will, unless the connectors are hermetically sealed. Also, snowpacks normally have some liquid water in them, especially on bright, sunny days. If a connector is lying on or in the snow it will almost certainly get water in it unless it is hermetically sealed. If connectors are to be left out for any period of time, it is probably worth while to wrap them with a plastic sheet and seal both ends with rubber bands or tape.

Cables and wires are normally not troublesome in the winter, but their insulation can be. The polyvinylchloride (PVC) insulation used on most standard wire and cables becomes stiff and difficult to work at temperatures much below -8 °C, and at very low temperatures (-20 °C and below) it becomes brittle and cracks if flexed at too small a diameter. Nevertheless, it is possible to use PVC at low temperatures if it is positioned in the field while relatively warm and then not unduly flexed. Polyethylene insulation doesn't crack at low temperatures but it becomes so stiff it is almost impossible to work with. One particularly irritating characteristic of polyethylene is its tendency to coil back up on itself if spooled out at low temperatures.

Teflon and nylon both perform well in the cold, remaining reasonably flexible. Most rubber insulations also will cause no problems but should be checked for low temperature use.

Coaxial cable sometimes becomes noisy at low temperature due to charge generation caused by thermal expansion of the wire, insulation, and shield. Special low-noise coaxial cables are available but are generally quite expensive. However, they may be the only answer in circuits with low level signals. Testing cable for this problem is easy: a coil can be placed in a freezer and checked for normal system performance while it is cooling.

Panel meters also have problems in winter environments. The low temperatures cause sluggish response in meters with jewel-bearing suspensions; and taut-band meters may be permanently damaged by thermal contraction at low temperatures. Fortunately, both types of meter movements are available in low temperature versions and the use of one of these "specials" may be advisable.

Some panel meters have plastic face covers which will retain electrostatic charge to the point where the meter movement can be pulled from its "correct" position and held there. A quick check for this condition is to draw a finger across the plastic face of the meter just above the needle and see if the needle moves. If it does, the meter's reading is suspect. This problem is really not peculiar to cold environments but it is definitely intensified by the low humidity found in the winter environment. A temporary solution to this problem is to wet a finger and rub it on the meter's face cover. This process will eliminate the static charge long enough to insure a correct reading. Anti-static sprays are also useful in solving this problem.

Installation techniques

When an instrumentation system that will be operated in a winter environment is being planned, there are certain points that need to be considered:

It is almost impossible to solder leads in the typical winter environment because of the difficulty in heating the wire enough for the solder to flow. Therefore, if cables need to be permanently made up in the field, crimping leads together or using "poke-home" connectors is advisable.

If a junction box is to be installed in the field, spade lugs and barrier strips are the easiest way to make connections. If possible the spade lugs should be put on the cable leads before the field work begins. In fact, all possible installations should be completed ahead of time.

Junction boxes have to be sealed against blowing snow and meltwater in the snowpack. If snow gets in, it will almost certainly melt due to solar radiation, and the meltwater could very well provide a low impedance path between circuits.

Many of today's digital multimeters (DMM) use push buttons to change ranges and functions. A check should be made to see if they can be operated with gloves on. If not, a small wooden dowel can be used as a range change "tool."

Field personnel can protect instruments by keeping them under their coats. A coat that's a little oversize helps.

If a connector or similar type equipment is dropped in the snow, *it should not be blown on* to get the snow out of it. The human breath has a lot of moisture in it and it will freeze onto the connector's pins or sockets, creating "open circuits" in some of the connector leads.

If electrical power is available, a Styrofoam box can make a cheap heated shelter for small instruments. For example, a 1-meter cube made with 7-cm-thick Styrofoam can be easily heated by a 40-watt lightbulb. This will keep the instrument above freezing down to ambient temperatures as low as -30°C. A cheap thermostat (on–off controller) can be used to keep the box from overheating. In extremely cold weather a 60-watt bulb can be used.

References

The open literature contains very little information on the specific problems encountered when using electronic measurement equipment under winter field conditions. This type of information is more often found in journal articles and reports written primarily to describe data obtained and the conclusions drawn from it.

The more general topics of winter environments, component testing and equipment performance are contained in a variety of handbooks, catalogs, manuals and compilations. A representative sample is listed below.

Atkins, R.T. (1971) Use of instrumentation under arctic conditions. In *Proceedings of the Arctic Logistics Support Technology Symposium,* November 1–4, 1971, Hershey, Pennsylvania, p. 183-188.

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