Motor Guarantee Corporation

Tech Talk

by L. Y. Wagner, Ph.D.

#4: Normal Insulation Wear vs. Contamination-Accelerated Failure

("Insulation performance is supposed to drop slowly & steadily. ...So how come my motor failures are always a surprise??")

Brief: Insulation degrades as it ages in a slow, consistent & predictable fashion. Most low resistance failures occur, however, ***when an otherwise healthy insulation system is compromised*** *by external contaminants such as moisture, dirt & oil. Methods to recognize & combat this problem are discussed.*

Motor windings can fail either from old age or from contamination. From a practical standpoint, though, old age is a rare cause of motor demise; it's much more common to dissect a failed motor & find evidence of serious contamination, leading to burnout.

Contamination kills motors. Such a death can be slow or sudden, but is invariably due to a drop in the effectiveness of the insulation system sufficient to allow a direct path to ground. Contamination comes in many forms—some obvious, some subtle & surprising. The good news is that while we can't do much to fend off old age, we can prevent contamination-related failures.

Normal Degradation (Heat)

Consider this: if you could operate your motors in a *clean room*—the ultra-controlled environment used for semiconductor chip manufacturing—the insulation would *still* eventually fail.

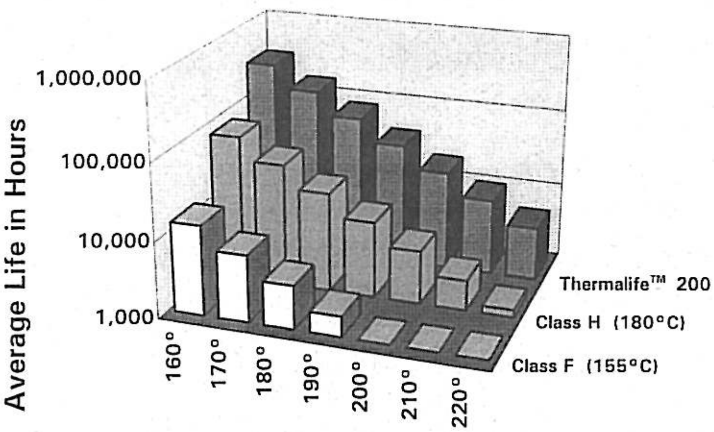
Think of insulation as a hose carrying a stream of water. If it's properly specified for the application —& if it's not cut, run over, kinked or abraded—it will last a long time. Ultimately, though, due to constant pressure, ultraviolet exposure, & other factors, it will simply wear out & need replacing. Actual failure is caused by the drying out of the rubber compounds, making the hose brittle & prone to cracking...& therefore leaks.

Insulation performance is similarly affected by a number of environmental factors, but by far the most significant is heat. Heat dries out the resins which are the primary insulation components. As resins dry, they become brittle & crack due to thermal shock & mechanical stress. This means that even the heating/cooling cycle that accompanies every start-up & shut-down "wears out" insulation by causing it to expand & contract.

There are 3 main components of heat which affect all motors: *Core Loss* [the "baseline" motor heat generated by running with no load]; *Winding Rise* [the full load component, generally peaking at 3 to 4 times Core Loss]; & *Ambient Temperature* [not "room temperature," but measured at the motor intake].

If a motor is consistently run at a temperature greater than its rating, it can fail catastrophically. This happens because increasing temperatures cause winding resistance to increase, thereby increasing loss...which boosts temperatures still further. If this cycle continues beyond a motor's cooling capacity, temperatures will keep rising until the insulation system fails.

It's important to remember that—even when operating within rated limits—heat still causes insulation to degrade by reducing its dielectric effectiveness. Heat actually causes insulation to become a better conductor...which is exactly what we don't want it to be. The more heat, the faster this happens. The chart below shows how insulation is typically affected by heat & time:



Ask your motor manufacturer or your rewind shop—they'll both provide the same statistics on the expected useful life of insulation. Service life is greatly affected by the environment in which your motor operates. When your motor is new—or newly rewound—you can usually expect 10 or more years of service.

Note that high quality rewinds provide a motor insulation system as good—& often better—than the factory insulation supplied by the motor manufacturer. Remember to ask for the highest insulation grade available; big performance improvements can be had for a very small premium. Eg: Upgrading from Class F [155 °C] to Class H [180 °C] insulation on a rewind will typically increase material costs by 10-15%. Because the incremental material cost is a small fraction of the job, total cost will increase by just 3-5%...but insulation life will generally quadruple as a result!

Contamination

Studies show that 1st wave infantry making a beach assault tend not to worry about high cholesterol. Similarly, it makes little sense to worry on a daily basis about normal insulation degradation. If you test insulation resistance regularly & watch for trends, you'll spot trouble in plenty of time to schedule a recondition, rather than a much more costly rewind.

The tougher job is keeping track—& staying a step ahead—of the many enemies around the plant. Oil & grease, carbon, dust & dirt, & worst of all—water; these things routinely find their way inside motor housings, building up damaging deposits.

With DC motors, these contaminants can come into direct contact with brushes & brushholders & create a parallel path to ground. Your insulation can be in *great* condition, testing at hundreds of megohms... yet the contaminants will cause the current to bypass it entirely, going straight to ground.

With AC motors, contamination problems can be equally severe, but they're generally more subtle. Anything airborne can find its way into your motor & cause problems where you can't see. And two of the worst offenders—oil & humidity—are always present inside the motor & can cause trouble with no clues evident. Once your winding integrity is thus compromised, failure can be sudden.

Water...need not be present in an obvious way. Enough moisture to do serious damage by causing a short to ground is always in the air as humidity. Temperature changes often cause this moisture to condense on cooler surfaces. This means motor components are susceptible when they're not operating & cold; that's why this kind of contamination is a common cause of "start-up failure." Warm air circulating through idle armatures can deposit moisture invisibly on interior surfaces. On brushless motors, modest dampness from condensation generally has little impact if the insulation is sound. If even minute cracks are present, however—allowing penetration—it can be deadly. In larger quantities, water is always dangerous.

Oil...without it, rotating equipment wouldn't work very long at all. Yet just a small amount—in the wrong place—can compromise insulation integrity & create a parallel conductive path to ground. Oil & grease tend to become impregnated in the insulation, reducing its dielectric coefficient. And while water will predictably seek its own level &

collect at low spots, oil & grease are viscous & adhesive...& tend to spread *everywhere* once introduced into a motor.

Dirt & Dust...can readily penetrate between windings, but are actually very poor conductors. The problem is that what we call "dirt" or "dust" in an industrial environment almost always includes plant or process particulates, such as metal dust in a foundry, shavings or turnings from machining operations, etc. These are highly conductive, & can dangerously reduce insulation between turns, thereby causing arcing that in turn causes more widespread & severe damage.

Prevention

How, then, can I keep my insulation free of contaminants to avoid these problems?

Every application is different, & it's a good idea to have an expert—like the guy who rewinds your motors—visit your site & give you specific pointers. These rules of thumb, though, apply to nearly all situations:

1. Make sure your motors breathe plenty of clean air.

Cooling air must be clean to minimize contamination. It seems so obvious...yet this most basic technique is often ignored. There are two ways to prevent external, airborne contamination: A] use direct outside air feed; B] use high quality filters... & change or clean them often.

Always be sure that fans & filters are correctly oriented: air should be filtered at the *intake*, on its way *into* the motor. [You'd be surprised how frequently—especially on DC installations—the hardware is arranged so that the air *leaving* the motor is nice & clean!]

Be sure airflow is sufficient, too. Inadequate circulation—whether caused by dirty filters or excessive baffles—can increase winding temperature by 1/3, greatly reducing service life.

2. Use internal heaters.

The object is to keep water out of the windings. Remember that when water condenses inside from airborne moisture, you won't see it. Heaters are a simple, inexpensive & nearly foolproof way to make sure motors are dry at start-up.

You must still remember to exercise care when cleaning motor housings & doing "routine environmental maintenance" [yes—that means mopping the floor]. Liquids splashed with abandon can easily find their way inside; even when evaporated by heaters, they'll leave minerals, dirt & other residues on the windings. Baffles can help, but be sure they don't reduce airflow.

3. Watch for increased brush wear.

On DC motors, slip-ring, & other brush-type apparatus, brushes may need replacing as often as once or twice per year. Whatever your equipment & experience, you should have a definite, well-established pattern for each motor. It's a *change* from that pattern that you should watch for: if you're suddenly replacing brushes twice as often, it's a sure sign of trouble, in the form of carbon dust & a possible parallel path to ground. When you notice this frequency change, make an immediate visual inspection of the windings, & test the resistance. Odds are high a professional cleaning or re-insulation will be needed.

If contamination is causing increased brush wear, it can feed on itself...worn brushes cause arcing, which further wears the brushes, which increases contamination, which causes more arcing. Deal with it promptly.

Remember to also check for these other common causes of increased brush wear:

- brushes used are the wrong grade
- brushes are not seated properly
- spring tension is too high [or too low]
- running with too few or unequal brushes [always replace all brushes together]
- uneven commutator film & wear

4. Watch for oil leakage.

If oil is dripping—particularly from the bottom of the endbells—it's highly probable that you have an internal seal failure. This is a telltale sign of serious trouble, which will not be remedied simply by putting more oil or grease into the reservoir. Letting the motor run dry can obviously cause catastrophic failure...but letting leaking oil contaminate the windings can cause equally severe damage. Find the source of the leak & fix it—then check insulation resistance—before continuing operation.

5. Test your motors often.

It's the simplest, easiest & cheapest thing you can do to make sure your motors are electrically healthy...& it's the one chore easiest to put off. Just taking a daily reading of your insulation resistance will likely prevent most insulation-related failures. [Periodic Polarization Index tests—perhaps once each quarter—are also extremely useful in determining insulation condition & performance.] It will also give you great predictive maintenance information, allowing you to schedule reconditioning at appropriate & convenient times. Even weekly megohm readings can help—but much longer intervals between checks & the odds of unexpected catastrophic failure soar.

6. Stop & think.

Remember the old saw: "Common sense is anything but common." Don't act on a reflex!

- Water visible on the windings—better start the motor up & spin it off. ***Wrong!***
- Oil dripping from the housing—better top off the reservoir so it doesn't run dry. ***Wrong!***
- "It's already scheduled for service during our annual shutdown—no need to pull it now."

  "I've run it with readings that low before!"

  "We just can't worry about it now..."

Wrong! Wrong! Wrong!

Failsafe

Finally—consider installation of a failsafe system. Few of us can be troubled to perform a megohmmeter test daily on every motor. The meter isn't always available, test leads are hard to connect, & it takes too much time. And—catastrophic failure is still possible unless you test at every start. A "failsafe" such as the Tru-Meg™ system can provide the assurance of a positive test of insulation integrity each time the motor is started, before current is applied. The added benefit of daily performance information—without the nuisance of taking manual readings—is a significant bonus.

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For more information:

...on *keeping windings clean,* we recommend "The Motor & Its Environment," a chapter in Managing Motors by R.L. Nailen, P.E. [Barks Publications, Chicago, 1991]

...on electrical *types of motor failure* & *why insulation resistance testing is critical,* see Tech Talk #1: "Electric Motor Failure Modes."

...on various types of *systems & methods for insulation resistance testing,* see Tech Talk #2: "Safety & Effectiveness in Resistance Testing."

...on *how insulation systems fail,* see Tech Talk #3: "Testing the Insulation System...Why & How."

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