

Fluke 1587: Heavyweight testing on superlight motors

Application Note



Insulation Resistance Case Study

Measuring tools: Fluke 1587 Insulation Multimeter, Fluke 337 Clamp Meter

Operator: Ed Dempsey, Value Diamond Tool and Dempsey's World Record Associates

Inspections: Motor testing: Phase current draw, phase current balance, winding temperature, stator winding resistance, volts/amps

When five percent of the world's total commerce is waiting for you to cut 107 4 1/2-ton sections from the bottom of the Panama Canal, you had better be precise and quick. And if your goal is to build the world's fastest electric car then it goes without saying that speed is essential.

Ed Dempsey and the companies he founded achieved both of these goals using custom, lightweight 400 Hz electric motors. Meticulous electrical testing is critical for engineering and repair because, according to Dempsey, "We run these motors right up to their maximum capability." Last year Value Diamond Tool bought their first Fluke 1587 Insulation Multimeter and it quickly became the tool of choice around the shop.

The company, founded by Dempsey, designs, manufactures and repairs their own line of professional concrete cutting equipment. Light weight, powerful 400 Hz motors are at the heart



Ed Dempsey and the White Lightning, holder of the 1999 land speed record for an electrical car.

of the equipment. The technology has been used in thousands of cutting projects – nuclear plants, deep space tracking stations and the Panama Canal. After achieving success with 400 Hz motor technology in concrete cutting, Dempsey adapted the concept and led a successful effort to build the world's fastest electric vehicle. This profile describes VDT's distinctive motor technology, and how they use the Fluke 1587 for everyday design and repair.

Why 400 Hz?

Concrete saws and drills generally use diamond-impregnated circular blades, cylindrical coring bits or wire saws. The cutting speed of these tools is a function of the horsepower used to drive the cutting tools. According to Dempsey, "If you can cut 10 feet per minute with X horsepower, with 2X horsepower you can cut 20 feet per minute. The ability to cut quickly translates into labor savings and reduced volume of cooling water. Of course the motors have to be light enough to carry or roll so they can be easily transported around a job site. This requires motors capable of delivering high horsepower with the lowest possible weight.

The key to Dempsey's cutting technology is specially-designed motors running at 400 Hz. Aircraft use 400 Hz systems because 400 Hz generators require less copper and are lighter than 60 Hz units that generate the same power. The concrete cutting technology uses 400 Hz technology adapted from the aircraft industry for the same reasons. The weight savings are dramatic. A 20 hp, 60 Hz, 3-phase motor weighs about 275 pounds. This can hardly be considered portable! A 20 hp, 400 Hz, 3-phase motor used in one of VDT's cutting systems weighs just 30 pounds.

VDT also makes motor generators and inverters, to convert 60 Hz to 400 Hz, as well as gas and diesel engine generators that create 400 Hz electric power. The engine generator sets are used on construction sites that don't have existing power. On other sites, they use an inverter or a motor generator set to convert standard utility supply feeds to 400 Hz.

From Fast Cuts to Fast Cars

One cutting job really embodied the need for speed. The Panama Canal handles roughly 14,000 vessels per year, carrying about 850 millions tons of cargo. The canal includes three sets of locks. The Gatun Locks are made up of two sets of three chambers that lift vessels from the Atlantic Ocean to Lake Gatun which is 85 feet above sea level. Every ten years the canal is shut down for a short period to allow for major maintenance. During one such shutdown, the Panama Canal Commission was faced with drilling out 107 four-ton sections of concrete from the bottom of the Gatun Locks. Each section was "stitch-drilled" using 52 overlapping holes. This required drilling almost 33,000 linear feet in just 28 days. Dempsey's cutting equipment proved the key to success.

Fourteen professional concrete cutters worked in two teams around the clock. Three 62 kW, 400 Hz motor/generators powered highly-mobile 4 1/2 hp drills turning six-inch diamond impregnated bits at 750 RPM. Pumps worked constantly to provide cooling water for the bits.

Despite electrical outages, torrential rains and the unfortunate discovery of railroad tracks imbedded in the concrete the team finished the drilling in 21 days.

In addition to running a successful contracting and equipment businesses, Mr. Dempsey (who holds seven patents) has an impressive history of auto racing. When asked how he got from concrete cutting to racing of VDT, Dempsey said unequivocally, "Well, we used the concrete cutting to earn money so we could race!" Dempsey has been successful in many forms of racing, including AHRA drag racing, Formula One outboard motor racing, and the Tour de Sol High Mileage Challenge for hybrid vehicles.

One of Dempsey's objectives has been to fight the misconception that electric vehicles are sluggish and weak. He founded Dempsey's World Record Associates, and gathered a team of experts and sponsors with the goal of breaking the 215 mph world record for electric vehicles. Dempsey brought his experience with lightweight, high-powered motors to bear on the problem. He and his team developed a 2450 pound streamliner called White Lightning. It uses two 200 hp motors, driven by two 400 Hz inverters. The power source is 6040 rechargeable C-size cells! Everything about the car is custom-built – from the lightweight motors to its carbon fiber body.

In 1999 the consortium broke the Formula One Champions world's speed record for an electric vehicle. Driver Pat Rummerfield drove White Lightning at 245 mph at Bonneville Salt Flats. Rummerfield's story is also extraordinary. He had struggled back into racing and marathon running after an auto accident left him a quadriplegic 20 years before piloting White Lightning to the record.



Another favorite around the shop

The Fluke 337 AC/DC Clamp Meter is also a favorite tool. Technicians use it for checking current draw and balance on motors. Pat Husteth likes the fact that the 337 measures frequency: "It's good for checking the frequency stability on generators. It's especially handy if the generator doesn't have its own indicator. We have a couple of load banks and we load the generator up to see how the frequency changes." Because of its dc measurement capability, they can also use it to check battery systems.

Electrical Testing in Dempsey's Shop

The 1587 is a relatively new member of the VDT team, but it's a key contributor. The Fluke 1587 Insulation Multimeter combines dmm functions, insulation testing and temperature measurement in a single handheld measurement tool. According to Dempsey, "That one meter will do just about everything we need to do in this place. We've got a whole bunch of different odds and ends stuff around here but it's a very comprehensive device."

To get the most power per pound, VDT does more than just run standard motors at higher frequency. Their motors use custom fabricated rotors that use copper bars and end-rings instead of the more common cast aluminum rotors. This delivers better efficiency and temperature performance. And they also pay close attention to stator winding resistance and fan design. Every element of motor design is subject to modification.

Although the motors are distinctive, much of the testing is the same as for common 60 Hz induction motors. An in-house dynamometer helps them check out motors during engineering and prior to shipment. They perform most of their electrical and thermal tests with the 1587. Here are a few of the key tests:

- **Phase current draw.** They use the 1587 with a clamp accessory or the Fluke 337. The running current should not exceed the nameplate rating of the motor under test.
- **Phase current balance.** They look for current draw to be the same on each phase within 2 % or 3 %. Any more than that will cause excessive heating in one of the phases.
- **Winding temperature.** They use the thermocouple measurement capability of the 1587 to take temperature readings. Temperature is an important factor in any motor, since it can deteriorate the winding-to-winding insulation. Temperature is even more important to VDT since they run their motors hard. Experience has shown the hottest spot in their motors is at the copper end rings on the rotors. They evaluate a motor by running it at load then shutting it down and measuring the temperature of the rotor end ring after allowing it to stabilize for 10 – 15 seconds. They verify that the temperature does not exceed manufacturer's specifications for insulation breakdown (typically in the neighborhood of 200 °C).



Racing team manager Gus Fowlie taking a DC voltage measurement across one of the battery packs in White Lightning that hold multiple C size Nickel-Metal Hydride batteries.

- **Volt/Amp Curve.** To make sure new motor designs are delivering every RPM possible, they test the current characteristics at the motor's rated mechanical load. They vary the input voltage around the nominal operating voltage and measure the resulting current. By observing the way the current changes, they can determine whether the motor is optimally wound and drawing just the right current, whether it is drawing too much current and saturating it's core, or whether it can be adjusted to draw more current and maintain a stronger magnetic field.

They also troubleshoot and repair broken motors. They use the insulation testing capability of the 1587 to determine if the insulation failed in the field. The data from this testing helps them track failure modes and catch any engineering or process problems.

Whether they're paying the bills with new concrete cutting designs, or working towards their next speed record, the combination of DMM measurements, temperature and insulation tests make the Fluke 1587 the perfect tool for Dempsey's operation.

Fluke. *Keeping your world up and running.*

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