Fluke instruments keep ferry electronics shipshape

Application Note

Testing Functions
Case Study

Measuring tools: Ti20 Thermal Imager, 68 IR Thermometer, 725 Process Calibrator, 771 4-20 mA Process Clamp Meter, 199C ScopeMeter, 125 ScopeMeter

Operator: Washington State Ferries Engineers: Doug Phillips, Mark Nitchman, Bryan Neufeldt

Tests conducted: Thermal inspections, temperature, pressure, electrical, bus health, 4-20 mA

Imagine two locomotive engines combined with the electrical system and electronic network of a factory and the plumbing and HVAC equipment of a hotel—all subject to continuous vibration and salt air, governed by stringent regulations, and expected to operate for sixty years.

The Washington State Ferries (WSF) system is the largest in the United States and the third largest in the world, transporting more than 25 million people per year on 29 vessels. The agency operates ten ferry routes and 20 ferry terminals throughout Puget Sound, with nearly 500 sailings per day.

WSF's largest vessels are a trio of Jumbo Mark II class auto/passenger ferries: the Puyallup, built in 1999, the Wenatchee, built in 1998, and the Tacoma, built in 1997. They are large as ferries go: 460 feet long and 90 feet wide, with a draft of 17 feet 3 inches. Each vessel can carry up to 2500 passengers and 202 vehicles (60 commercial vehicles).

As might be expected for commercial passenger vessels, safety standards are very strict and reliability is vital. The Coast Guard conducts annual certification inspections, and all personnel must be licensed or documented. "If we have problems that affect the maneuvering or safety equipment on the vessel, if we can't get it fixed right away then we have to take the vessel out of service, fix it, call the Coast Guard and have them come take a look and inspect it," says Doug Phillips, a graduate of the United States Coast Guard Academy and staff chief engineer (SCE) of the Wenatchee.

The Jumbo Mark IIs use diesel-electric propulsion; each ship has four 3300-hp EMD 710 16-cylinder diesel engines of the type used in railroad locomotives driving Kato 3.5 MW, 4160 V alternators. Output from the alternators goes through transformers that change it to 1100 V, then to Siemens SIMAR drive cycloconverters. Each cycloconverter feeds a pair of 6000 hp synchronous motors ganged together on each propeller shaft (one at each end) to drive the ship at speeds up to 18 knots. "It's like if you stripped all the sheet metal off a locomotive, that's what you'd see," explains Phillips.

A cycloconverter is an ac drive that has a variable output frequency that can reach about 30 percent of the input frequency. In this case the input is 60 Hz and the output is 0 to14 Hz. AC from the input goes to an SCR (silicon control rectifier/thyristor) bridge; the firing angles of the SCRs in the bridge vary continuously to construct the low-frequency output waveform. Cycloconverters are generally used in high power, low speed, high performance applications and are very efficient.

The SCRs in the cycloconverters cause severe distortion in the 4160 V ac waveform from the alternators—distortions that would wreak havoc with many loads, so each vessel also carries a pair of 500 kW motor-generator sets. These take the 4160 V from the alternators and turn it into clean 480 V power for the fluorescent lights and the on-board electronics.
SCR firing signals for the cycloconverters come from a Siemens SIMADYN system. Each vessel in the class is also equipped with a pair of Siemens S5 PLCs in each 4160 V switchboard, two more for monitoring and alarm systems, plus several hundred Siemens ET 200 remote I/O units.

Now, imagine the maintenance problems.

Early in 2007, three of the fleet engineers met with Fluke and talked about problems they'd always wondered whether they could solve, given the right set of tools. The engineers were Doug Phillips; Mark Nitchman, former Director of Maintenance and Senior Port Engineer and now Staff Chief Engineer (SCE) of the Puyallup; and Bryan Neufeldt, P.E., Digital Systems Port Engineer, Professional Electrical Engineer with a Masters in Physics, also assigned to the Puyallup.

Fluke offered to lend the four engineers some $15,000 worth of the company's newer test tools to try out—to their surprise and delight. "I left your e-mail on my screen a few days because I could not believe your last sentence, 'What sort of Fluke tools would you want to try out'? It was like some famous model asking me out for a date," said Nitchman. The instruments included a Ti20 Thermal Imager, a model 68 handheld Infrared Thermometer, a 725 Process Calibrator, a new Model 771 Milliamp Process Clamp Meter, a 199C ScopeMeter® Test Tool and a new 125 ScopeMeter® Test Tool.

The three divided up the instruments and tried them out over the summer. Six weeks later we asked them to describe their experiences.

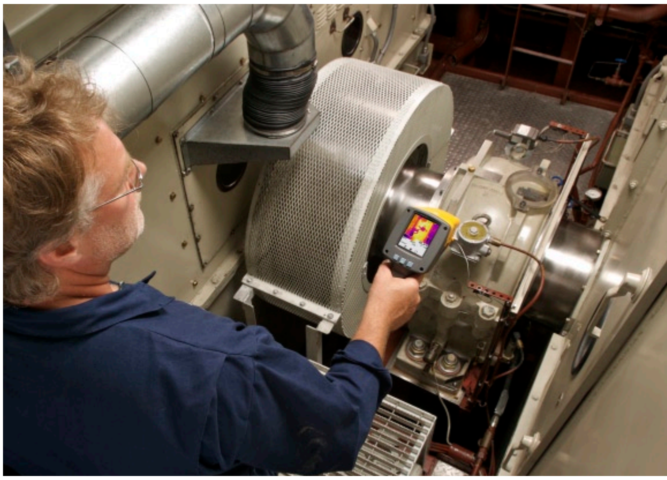
Ti20 Thermal Imager

The ability to "see" thermally what is normally invisible to our eyes can open up a vast range of possibilities, as the engineers discovered. It would be useful, for example, to look at a wiring panel and instantly pick out any loose or high-resistance connections without having to touch anything, and Phillips took full advantage of that. "We have several thousand connections on the boat," he says. "A thermal check for relative temperatures between wires," he explains, makes it easy to trace out things that are warmer than they should be, "or indicates that we've got loose connections, or whatever." With the Ti20 he could check all of them, from 24 V up to 4160 V.

He found this especially useful on the complex 24 V panels that hold the wiring from the instrumentation and sensors. "Either you've got to go through and test the torque on each one of the screw terminals or you can just look at it with the camera to see if you've got loose terminals there," He says. The former method, he goes on, risks damage to the terminals: "If you send somebody through with a screwdriver to test the torque," he explains, "everybody has a different idea of what's tight, and you end up over time overtightening the screws in the terminals, and you strip them after a while. Bad things happen then."

Mark Nitchman also used the imager for non-electrical things. Motor bearings are a good example. "A failing bearing has a heat signature that's different from one that's operating normally," he says. "The boat has probably 70 or 80 pumps on it, driven by electric motors, or fans." How do you tell if one of them has a bearing that's starting to fail? "Taking a look at the fan motor or the pump with the imager helps us determine whether or not there's a problem."

The thermal imager also helped to track down some overheating problems. The first had to do with the voltage regulators for the big generators that provide the electricity that runs the ship. "The voltage regulator for that system kept



failing," he says, "but it was an intermittent problem with no forewarning, and it's been very hard to troubleshoot." They'd tried sending the $1,500/each "failed" regulators back, but the manufacturer couldn't find any problems. Faced with the ongoing unreliability, the engineers were forced to run a third engine during every landing, at significant extra operating expense.

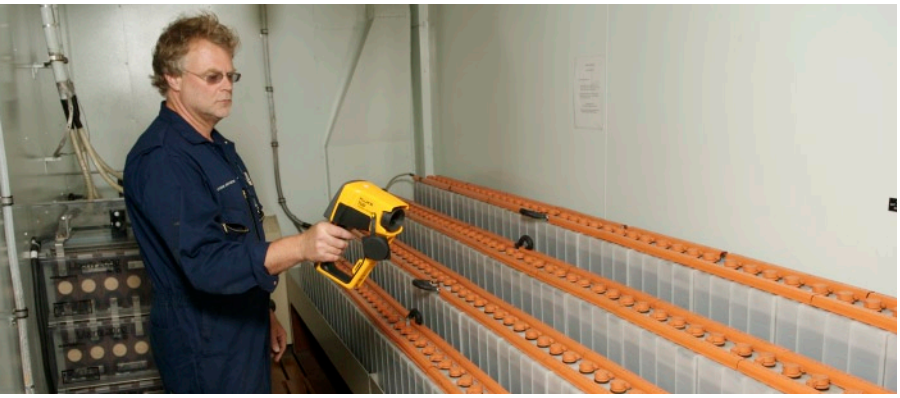
The voltage regulators are mounted in cabinets in the ship's engine room, where summertime temperatures can reach 110 °F. The regulators are rated to work in ambients up to 140 °F. There's a bank of resistors in each cabinet, and they're electrically live, "so you would never touch one in the course of looking through the cabinet while it's in operation," says Nitchman. A scan of the cabinet with the thermal imager showed that several resistors were operating at close to 300 °F, "and when the cabinet door gets closed you can only imagine that the temperatures inside that cabinet are going to go up as a result." So the problem turned out to be that the voltage regulator problem had an ambient temperature element to it that they had not previously considered.

Another problem revolved around the electronic governors for the ship's diesel engines. On hot summer days, the governors' speed regulation function would start to deteriorate. Meanwhile, the ventilation blowers were causing the compartment where the cabinets are located to get uncomfortably cool for the crew, and they would turn them off. "We hadn't really put two and two together with that until we . . . opened the cabinet and looked . . . through the thermal imager, and we saw how warm these things were getting." Half an hour after turning the fans back on, everything stabilized.

Model 68 IR Thermometer

Sometimes you need to measure the temperature of a specific object that's difficult to reach; this is where the FlukeModel 68 IR thermometer comes in handy. Phillips used it first off for checking sensors: "Every now and again we have sensors go south," he says, "and I'll go out and use the IR thermometer for a rationality check to see, we really don't have 1200 °F on an exhaust section or something like that." It's also handy, he adds, "when an RTD goes open and you get infinite temperature."

Philips also found a use for the 68 down in the bowels of the ship. The propeller shafts are enclosed by stern tubes—oil-filled tubes with double lip seals at each end—where they pass through the hull. At each end of the stern tube is a Babbitted bearing to carry the shaft, and there's no temperature sensor on those bearings. Phillips used the Model 68 to make periodic checks on the inboard bearing, just to make sure it was working properly.



725 Process Calibrator

Like most modern ships, the ferries are full of sensors and transducers: "pressure, temperature, magnetic pickups for rotational speed information, thermocouples in the engine exhaust, RTDs (temperature sensors) in various locations, all the different protection relays in the control cabinets for the alternators and the breakers," says Phillips. That's where the engineers found the Fluke 725 Multifunction Process Calibrator useful. The 725 can measure and source mA, volts, temperature (RTDs and thermocouples), frequency, ohms, and pressure, using optional pressure modules.

Bryan Neufeldt found it especially handy for checking RTDs. "I've used the calibrator for checking RTD signals to find out if the signal is good, and verifying whether a problem is with the RTD or the [transmitter]," he says. He also used it as an RTD simulator, to check if the transmitters are producing the correct output.

He even used it to identify an unknown RTD. On a ship, just as in an industrial plant, the record of what type of RTD was used in a particular location sometimes gets lost. The 725 made identification easy: "I hooked it up to the calibrator and read in the temperature," says Neufeldt, "and then I switched among the different setting where you choose what RTD you're reading . . . until I found one that gave the temperature that we thought the RTD was in, and so that told us what the RTD was."

771 4-20 mA Process Clamp Meter

A large percentage of the ships' pressure, temperature, and electrical sensors feed their signals back to the PLC via 4-20 mA loops. "A lot of maintenance surrounds whether the PLC is getting the right signal; then, if not, we need to know why: is it the sensor or is it after the sensor and before the PLC input," says Neufeldt.

In the past, the only way to check a 4-20 mA loop was to break it and insert a milliameter in series, which not only takes time but interrupts the signal. This is where Phillips appreciated the new Fluke 771 milliamp Process Clamp Meter. Just as an ac clamp meter can read the current in a power conductor without any physical connection, the 771 can measure the current in a 4-20 mA loop just by clamping around one of the wires.

"If we thought we had an issue with sensors," says Phillips, "we could just run out and check it real quick with that, and take a look at what's going on in a particular area." And it tells more than just if there's current in the loop, he continues. With an accuracy of ± 0.2 %, "it's accurate enough to calibrate everything, just using that alone."

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While Neufeldt wasn't experiencing any difficulty with the buses aboard the ferries, curiosity drove him to clip on the scope and see what was there. "It does a lot for you;" he says. "It checks both the physical layer by verifying the voltage levels are good, and that tells you if the wiring is OK, and it also checks the protocol in that Profibus is actually running on the bus."

The three engineers were delighted with the new instruments, and enjoyed using them; the only question remaining is how sad they were to have to give them back.

199C ScopeMeter

Some of the most important electronic devices in an electrically-propelled ship are SCRs. The voltage regulators for the alternators use SCRs to control the field current, and the cycloconverters use sets of big SCRs to turn the incoming 60 Hz power into the variable-frequency power that drives the motors. Ferry engineers have found the 199C ScopeMeter a useful way to check the waveforms associated with each of these functions, and more.

In the voltage regulators, says Neufeldt, "There are two SCRs on the circuit that converts ac into dc, and I wanted to make sure that both of those were working, not just one. If just one is working, it's possible that you'd get the correct field, but one is doing all the work. By putting the Fluke 199C ScopeMeter on, I could verify that the SCRs are firing." That happened once, and the scope spotted the problem right away.

Asked about checking the output waveforms from the cycloconverter, Neufeldt replies that he hasn't had occasion to do that for some time, "but definitely that would be a place where that could be used." It could also, he goes on, be used to check the gate voltage pulses to the SCRs in the cycloconverters. "If we had a problem with mis-firing in the cycloconverter we could use that to look at the ac waveform and then at the firing pulse and make sure that the firing pulse is coming at the right time."

125 ScopeMeter

The electronic equipment aboard the ferries is tied together with several different buses, including the Siemens H1 bus (an industrial Ethernet) and Profibus. The Fluke ScopeMeter 125 Test Tool features a Bus Health test that will check AS-I bus, CAN-bus, Profibus, FOUNDATION Fieldbus and Ethernet. The test quickly determines whether the bus is working, and if not, helps to identify the cause.

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