Cold Facts

The Magazine of the Cryogenic Society of America, Inc.

INTERNATIONAL

Around the Labs | 26-32

Volume 33 Number 4

VNR Advances New Process to Ensure Reliability of Space-Flight-Critical Fasteners

In October 1989, while investigating the crash landing of United Flight 232 in Sioux City, the NTSB located the fan disk from the plane's number two engine in a cornfield near Alta, Iowa. It was in two pieces, ripped apart, the agency later determined, when an undetected metallurgical defect resulted in an explosive fracture that destroyed all three of the plane's hydraulic systems. The defect had not been discovered during required manufacturing inspections nor during six subsequent fluorescent penetrant inspections performed over the part's lifetime. In response, the FAA amended its regulations and implored industry to develop new and more efficient techniques to detect flaws in aircraft parts.

Such development continues today, and new advances in cryogenic methods hold great promise for preventing future disasters. Victor Aviation, Palo Alto CA, for example, has developed a process called Victor Noise Reduction (VNR). It builds on both established eddy current testing and the company's cryogenic non-destructive test (NDT), a process that uses electromagnetic acoustical transmission or ultrasound recognition technology to detect and even correct metallurgical material defects.

The aircraft and aerospace industries have come to rely on eddy current testing for incoming, finished and in-service inspection of materials. Inspectors use a probe to create an electromagnetic field on both the surface and subsurface of a material. A subsurface defect or flaw in the material will interrupt the lines of force in the magnetic field, resulting in change of conductivity reported to the operator. Such tests are reliable, but small defects can go undiscovered due to high residual stress, and thus high signal noise, often generated in parts due to improper heat treat quenching. Erring on the side of safety, inspectors will classify a part as uninspectable when high signal noise prevents testing.

The VNR process reduces high signal noise, allowing inspectors to examine previously untestable parts. Victor Sloan, President of Victor Aviation, says the company began working on the process to assist UniWest, a leader in the manufacturing of eddy current devices, with a batch of structure-critical shoulder bolts that were failing inspection. "We found that the aircraft bolts had such high residual stress, which is a force amongst the lattice structure in the crystal makeup of the metallic material, that the signal noise was elevated, giving the inspector too high of a noise signal which was masking the defect," says Sloan. "So we created VNR to reduce the residual stress and in doing so these bolts were then classified as inspectable because of the dramatic reduction in signal noise in the eddy current testing process."

In stainless-steel alloys, such as those used in the bolts tested for UniWest, if an improper heat treat quench occurs, the austenite phase transformation to martensite can be incomplete causing unwanted metallurgical properties and higher than normal residual stress. Sloan says the heat-treating industry

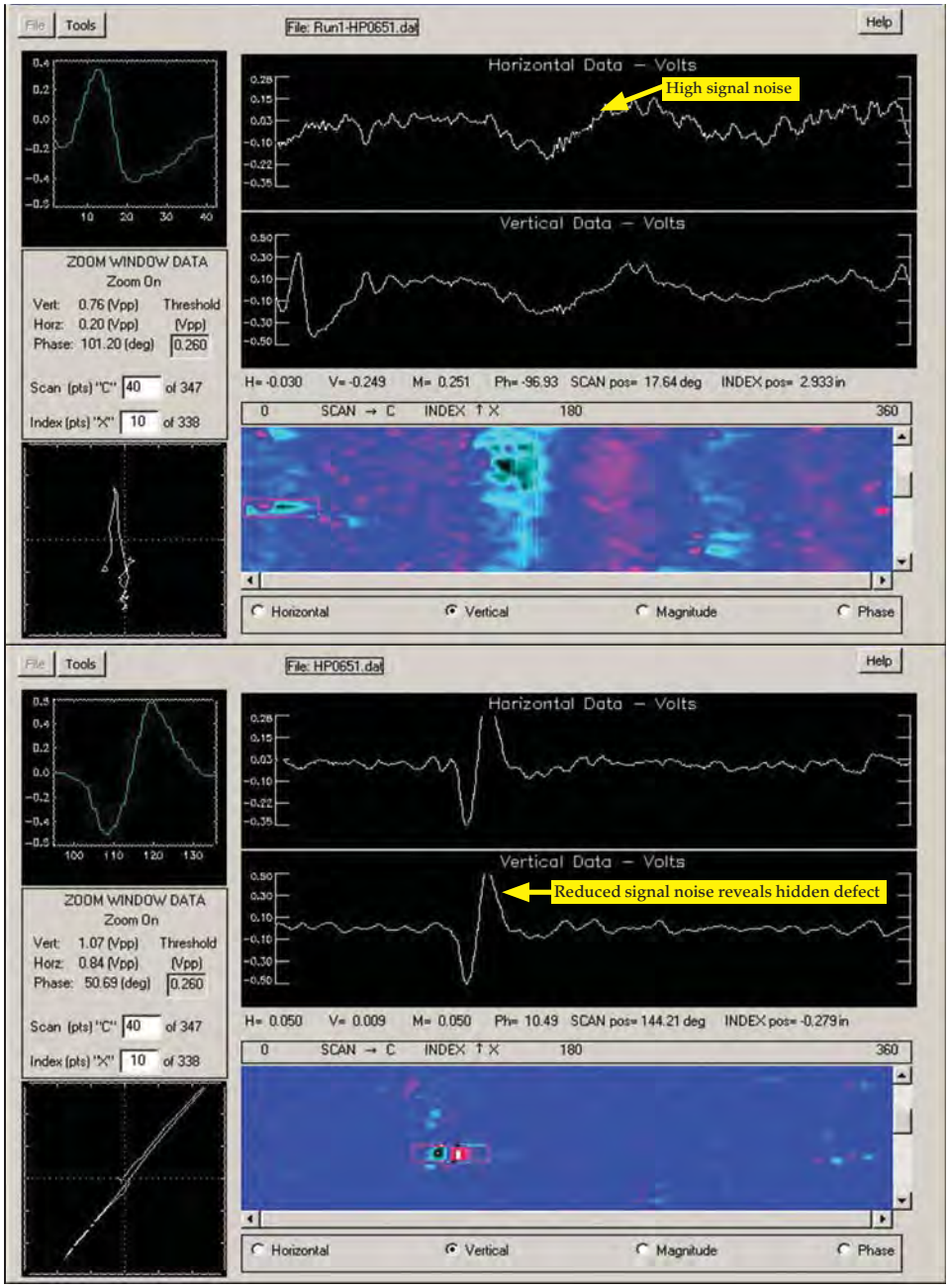

Figure 1. C-scan eddy current scans of bolt 1 before (top) and after (bottom) cryogenic treatment. *Image: UniWest*

doesn't have a real-time method to determine the time and temperature at which a phase change or stress component change occurs or completes, so his company developed a process of sending sound waves through a material in real time while it is going through both cryogenic cooling and heating. When a phase change or residual stress component occurs, it affects the speed of sound traveling through a material because the crystal lattice structure shifts, or changes, when the austenite converts to the martensitic phase. The VNR cryogenic system uses computers to analyze the slope and change in transit time to determine the time and temperature at which a phase change was actually completed. "And the thing that's really interesting," says Sloan, "is that we can not only identify an incomplete phase but in many cases, can also complete an uncompleted phase change simultaneously during the cryogenic heating and cooling cycle."

Figures 1 and 2 both show eddy current C-scans of the UniWest-supplied aircraft bolts before and after VNR cryogenic treatment. The process removed high levels of signal noise from both bolts, shown in the upper amplitude and lower SCAN—>C images. The line graphs show voltage levels along a horizontal location and vertical signal amplitude. With the noise reduced, inspectors were able to accurately examine the materials, accepting bolt two while rejecting bolt one for a previously undetectable flaw seen in the bottom, or after cryogenic treatment, chart in Figure 1. Prior to the treatment, both bolts were classified as uninspectable. "Basically," Sloan says, "we applied our cryogenic NDT phase transformation detection, one of our patented processes, and that is what caused the reduction in residual stress in the material and thereby reduced signal noise response from the material back to the eddy current instrumentation. Now the hidden defects in the material were made visible."

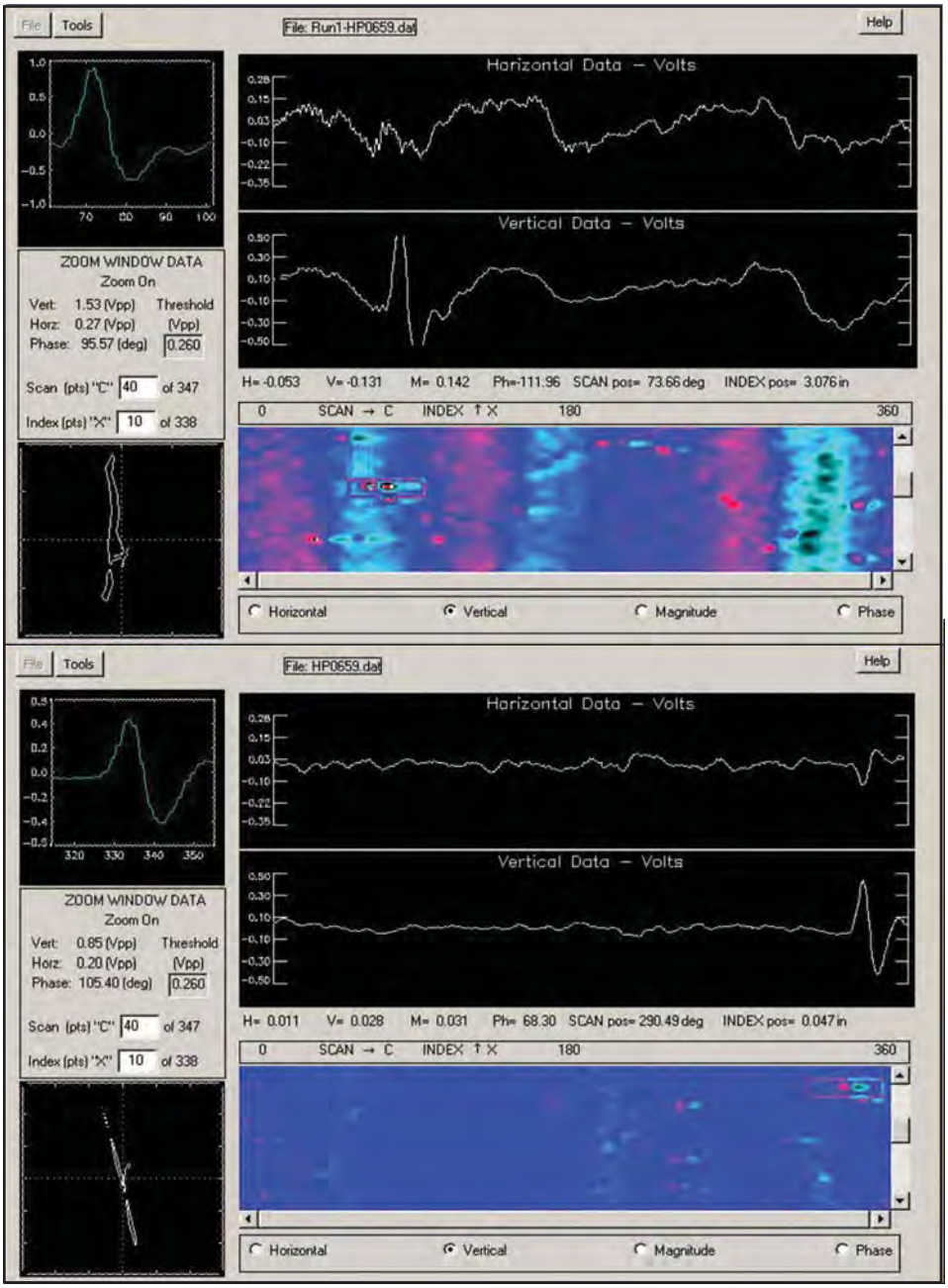

Figure 2. C-scan eddy current scans of bolt 2 before (top) and after (bottom) cryogenic treatment. *Image: UniWest*

Beyond aviation, the VNR process can help inspectors working with semiconductors, in the tooling or oil and pipeline industries, with ship manufacturers, the automotive and space industries and more. "Fact is, I should be calling Elon Musk," Sloan says. "Unknowingly, to space companies and airline manufacturers, as they're putting structural critical fasteners and materials up into the sub-zero temperatures of space or high altitude flight, a phase transformation in the material can be induced on improperly heat-treated parts. This can change materials to a brittle untempered metallurgical state leaving a high residual stress and would require heat tempering again. And then when, and if, an aerospace part was subjected to excessive force or vibration it could crack and it could fail."

Sloan was inspired to pursue cryogenic testing at the urging of his friend A. Scott Crossfield, the first naval test pilot to reach Mach 2 in the X-15 Rocket Plane and a strong advocate for aerospace education. "He kept pushing me to try to advance the technology of cryogenics, to produce a higher quality process for the aerospace industry," Sloan says. "We believe that we have now been able to enhance and raise the bar in the quality of inspection and material improved processes using cryogenics. If Victor Noise Reduction would have been invented earlier, things like the Sioux City crash most likely never would have happened, because the defect would have been detected." **www.victor-aviation.com** ■