



Report on Vibratory Stress Relief

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INGERSOLL MACHINE TOOLS COMPANY Rockford, IL

INGERSOLL MACHINE TOOLS is a manufacturer of some of the world's largest milling machines. During machining of two (2) 28' X 8' X 8' fabrications, defective welding was found and replaced. This repair raised concerns among INGERSOLL's Engineers about the dimensional stability of the Workpieces. AIRMATIC's VSR Technology Group was summoned to treat the Workpieces in preparation for machining, so that dimensional accuracy and stability would be assured.

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INGERSOLL MACHINE TOOLS is a manufacturer of machine tools located in Rockford, IL. INGERSOLL contacted the VSR Technology Group of AIRMATIC INC to perform VSR Treatments on two (2) mild steel fabrications, measuring 28' L x 8' W x 8' D. During machining it was discovered that these fabrications contained faulty welds. The VSR Process was chosen to stabilize these parts after these welds were replaced.

VSR SET-UP

The set-up and procedure used to treat each Workpiece was identical. A Workpiece was placed on three (3) Isolation Load Cushions. One Cushion was placed at the center of one long side of the Workpiece (*as shown in Photo 1*), and the other two Cushions were placed under the opposite side, and spaced six feet apart. This three (3) point arrangement minimizes the damping of the Workpiece, enabling flexure during VSR Treatment, which maximizes the benefits of the Treatment.

The VSR-8000 System's Model BL-8 Vibrator was mounted on a plate near on top of the long side of the Workpiece where the two Load Cushions were located (*see Photo 2*). The Vibrator was oriented so its Axis of Rotation was horizontal, and the Vibrator's unbalance was adjusted 20% of the four in-lbs available. The Vibrator can be seen at the top of Photo 2.

The VSR Process uses an Accelerometer (an electronic sensor whose output is proportional to acceleration), to measure and record the intensity of the Workpiece vibration. This is because acceleration is proportional to force ($F = ma$, Newton's 2nd Law), and VSR Technology has standardized on relative force measurement as most indicative parameter of a Workpiece's response to Vibration Treatment. The Accelerometer was clamped on the corner of the Workpiece, opposite the Vibrator, and oriented so as to be most sensitive to vertical deflection. The Accelerometer, and the black cable bringing its signal to the MX-8000 Console, is visible in Photo 1, in the upper, left corner of the Workpiece.

PRE-TREATMENT SCAN

The MX-8000 Console, shown in Photo 3, was calibrated to provide a maximum Vibrator speed of 6800 RPM for a trial scan. This top speed, combined with the set-up details described earlier, produced a Pre-Treatment Scan which displayed several distinct peaks in the acceleration curve, which is the upper of the two curves shown in Photo 4 (Workpiece # 1). The Pre-Treatment Scan was performed at the slow rate of 10 RPM / second, so as to produce the high-resolution required to effectively perform the VSR Process. The recorded Pre-Treatment Scan curves are displayed in green tint. Photo 5 shows the Pre-Treatment Scan for Workpiece # 2.

VSR Treatment

VSR Treatment was performed by tuning upon each Peak. The Treatment was monitored and verified by following both peak growth and shifting, which are the classic responses seen during the Treatment. Even though the peaks were relatively narrow, they were tuned upon and tracked.

Peak growth ranging from 5 – 30% of the original peak height was observed during this period. Compared to what is typically seen during VSR Treatment on an as-welded Workpiece, this was a mild response. Because these Workpieces had undergone PWHT prior to machining, and then had only a small percentage of their total welding replaced prior to VSR Treatment, this mild response was expected.

Each peak was tuned upon and monitored for a minimum of five minutes. The two (2) large peaks which had displayed the greatest amount of peak growth were tuned upon for 15 minutes each.

POST-TREATMENT SCAN

After the subtle growth and shifting of the peaks had stopped, *ie*, the peak heights and locations became stable, a Post-Treatment Scan was performed, and superimposed upon the Pre-Treatment Scan. The recorded Post-Treatment Scan curves are displayed in red tint. Photo 6 shows the superimposed Pre- and Post-Treatment Scans for Workpiece # 1. A small vertical offset, likely caused by some shifting of the plant's electrical service ground potential, accounts for the red curve being lower than the green curve. When this offset is taken into account, some of the growth that occurred during Treatment can be seen by comparing the Pre- and Post-Treatment Scans.

The change in resonance pattern, although mild, demonstrated that stress relieving activity had taken place during this Treatment. There were, in all likelihood, two different sources of residual stress:

1. Stresses induced during the corrective welding.
2. Stresses induced during the cool-down period of PWHT. These stresses are more severe in weldments with large variations in wall thickness, of which these two Workpieces are good examples.

The superimposed Pre- and Post-Treatment Scans for Workpiece # 2 are shown in Photo 7. Also visible in this photo are two sets of circles:

- a. The large circles, centered on peaks, indicate the peaks chosen for Treatment in the Automatic Operation Mode, using software in the MX-8000 Console. (For comparison purposes, Workpiece # 1 was treated using Manual Operation Mode to perform Treatment.)
- b. The small circles, called "progress dots", are record of the Treatment pattern. By producing a progress dot every 15 seconds, the path or pattern of Vibrator speeds and Workpiece acceleration levels during Treatment can be shown. For clarity purposes, the density of small circles can be adjusted. This is done by clicking on different time periods (or none, for no circles) on the icon just above the acceleration curve.

CONCLUSION

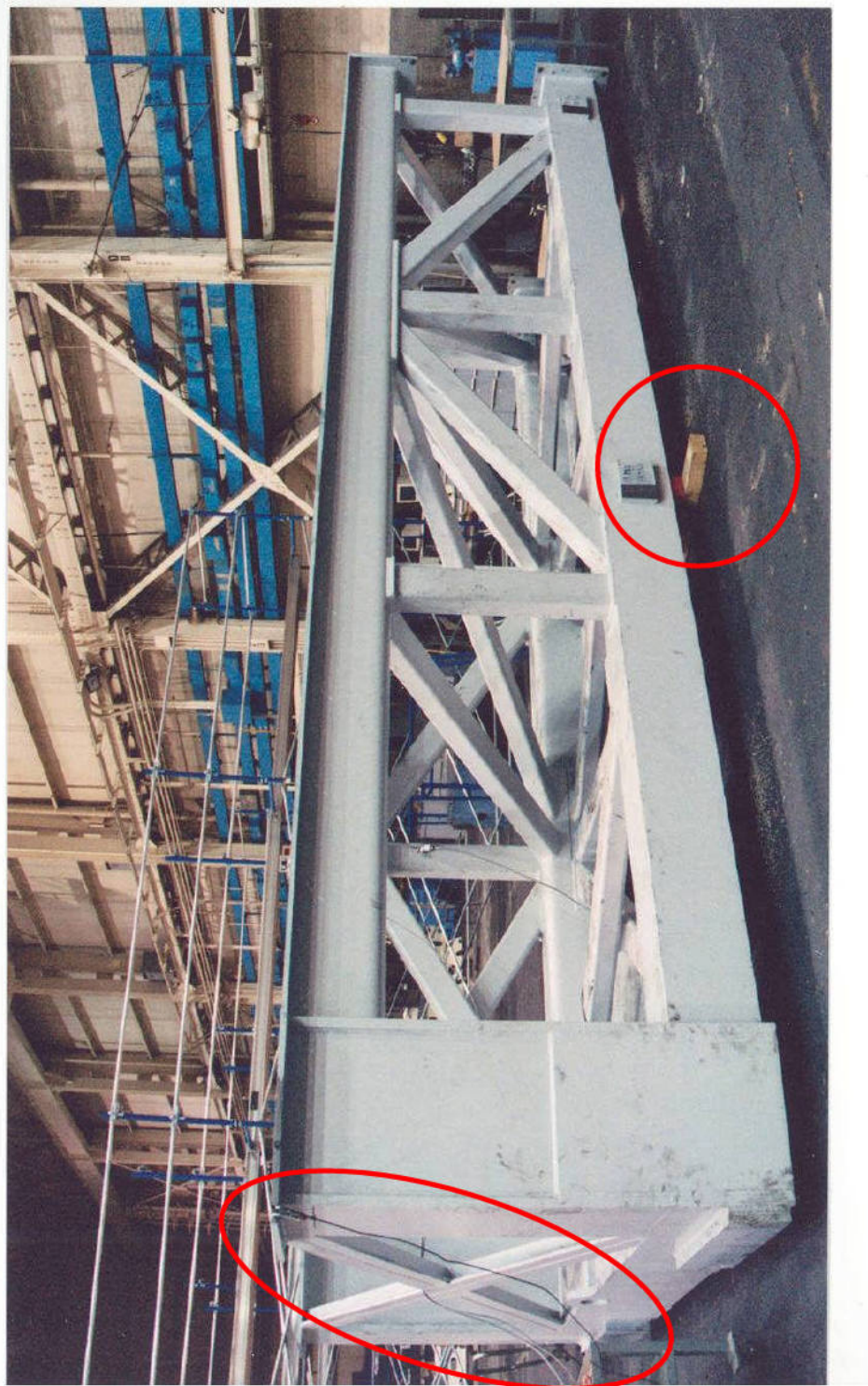
Based on the changes seen in the resonance patterns during Treatment, these Workpieces will be more stable than they would have been without stress relief, and will show good dimensional stability during subsequent machining, assembly, and transport.

Bruce Klauba has a degree in Physics and a Level II Vibration Analysis Certification from the American Society of Non-Destructive Testing (ASNT). As a pioneer in the cause and effect of Vibratory Stress Relief, Mr. Klauba was named chief inventor (*Klauba et al.*) in U.S. Patent 4,381,673, which is both an equipment and process patent describing advances in the technology. He has authored numerous articles and original research papers on the subject, which have been published in leading magazines and periodicals. Published papers include:

1. "Use and Understanding of Vibratory Stress Relief", *Productive Applications of Mechanical Vibration*, 1983, American Society of Mechanical Engineers.
2. "Vibratory Stress Relief: Methods used to Monitor and Document Effective Treatment, A Survey of Users, and Directions for Further Research", 2005, *Trends in Welding Research*, ASM International.

A co-author in both papers, Dr. C. Mel Adams, is a leading authority in metallurgy and co-founder of MIT's Welding Research Department. In addition, Mr. Klauba has extensive experience in designing, building, and troubleshooting Industrial and Commercial Electrical Controls with a focus on extending the performance and reliability of Electric Motors and the systems they power.

**Photo 1: Isolation Load Cushion placed at center of Workpiece;
Accelerometer clamped to upper left corner (Black
Accelerometer Cable visible.)**



**Photo 2: BL-8 Vibrator mounted to top of Workpiece;
Placement of other two Load Cushions.**

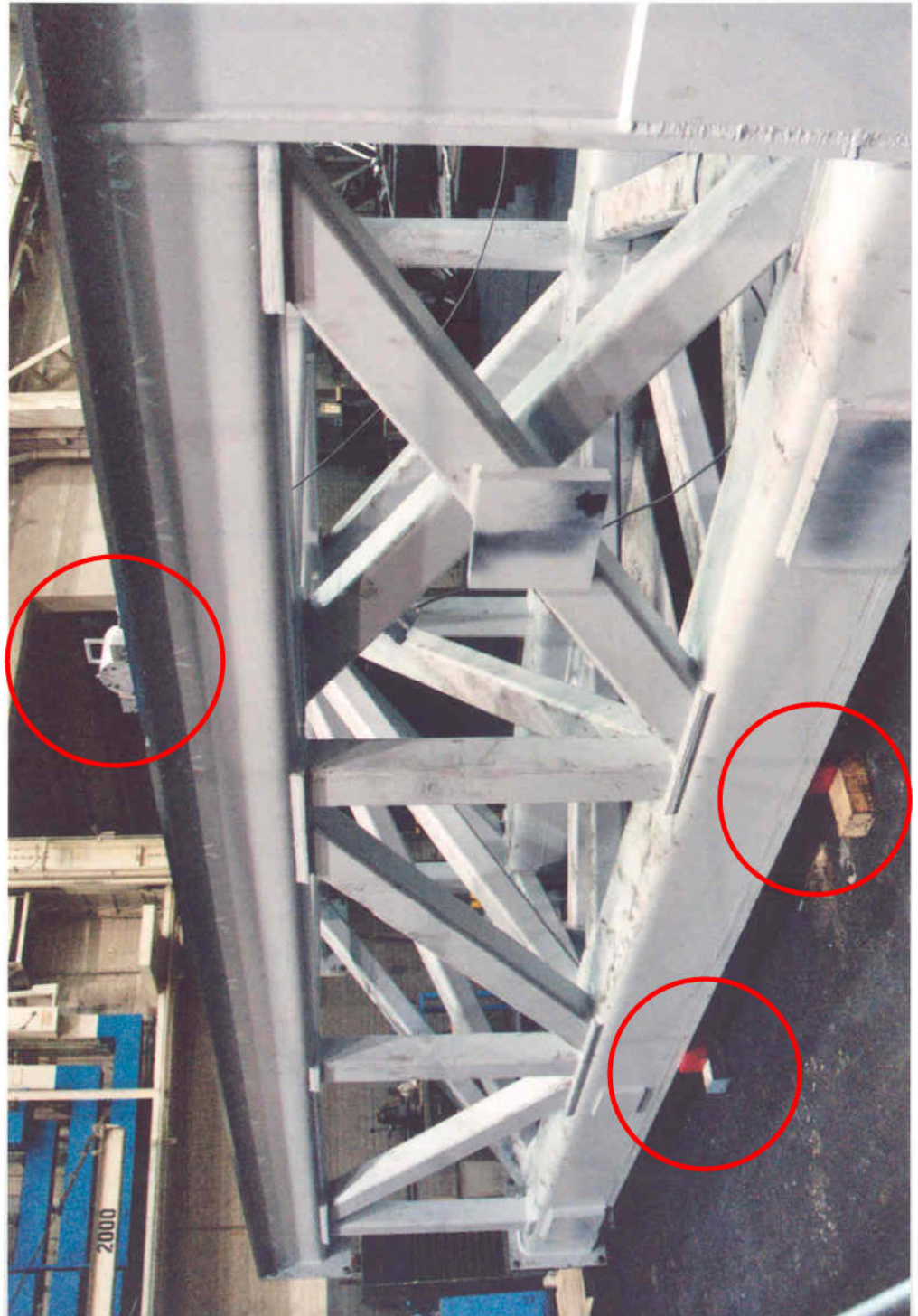


Photo 3: MX-8000 Control Console.

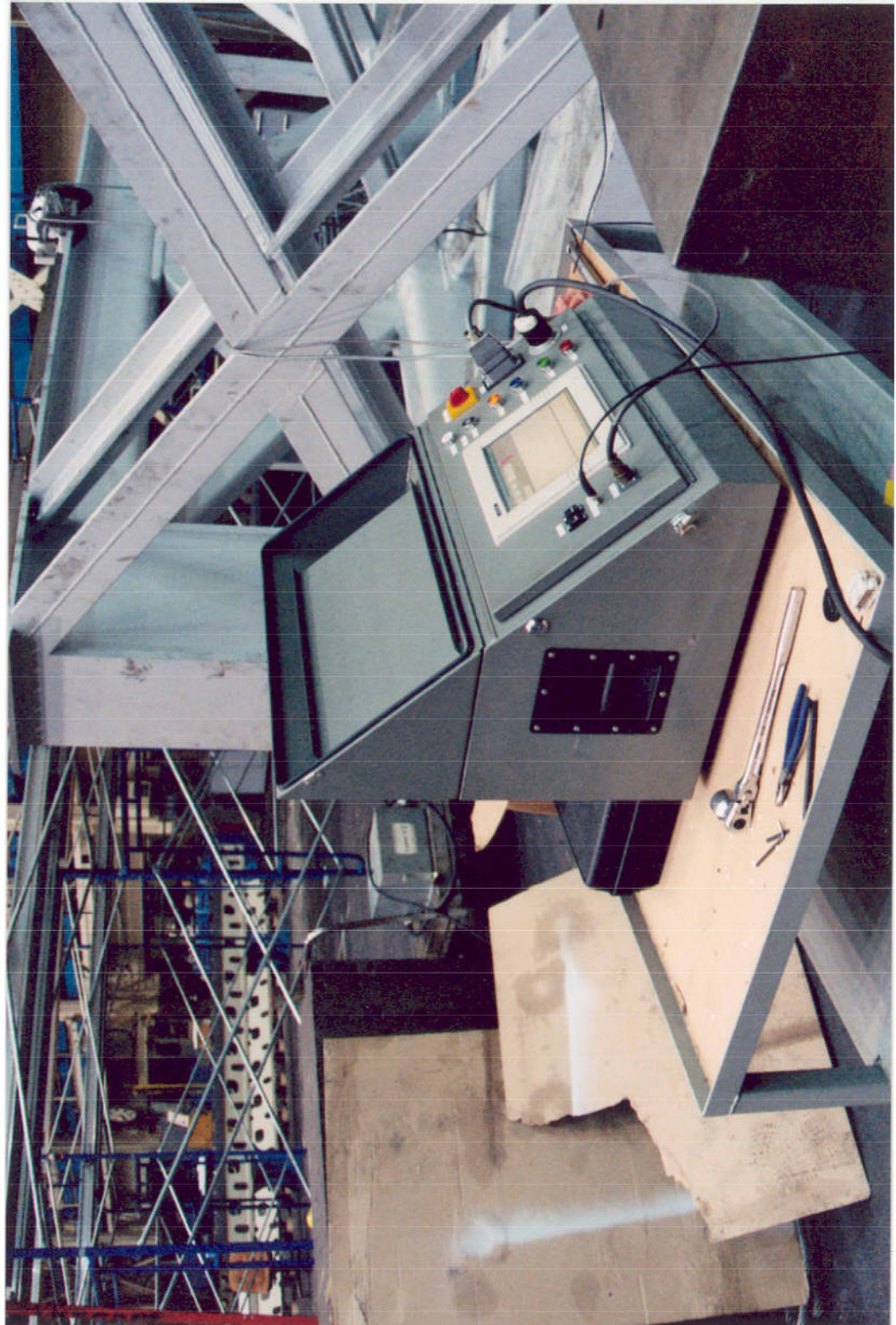


Photo 4: Pre-Treatment Scan of Workpiece #1.

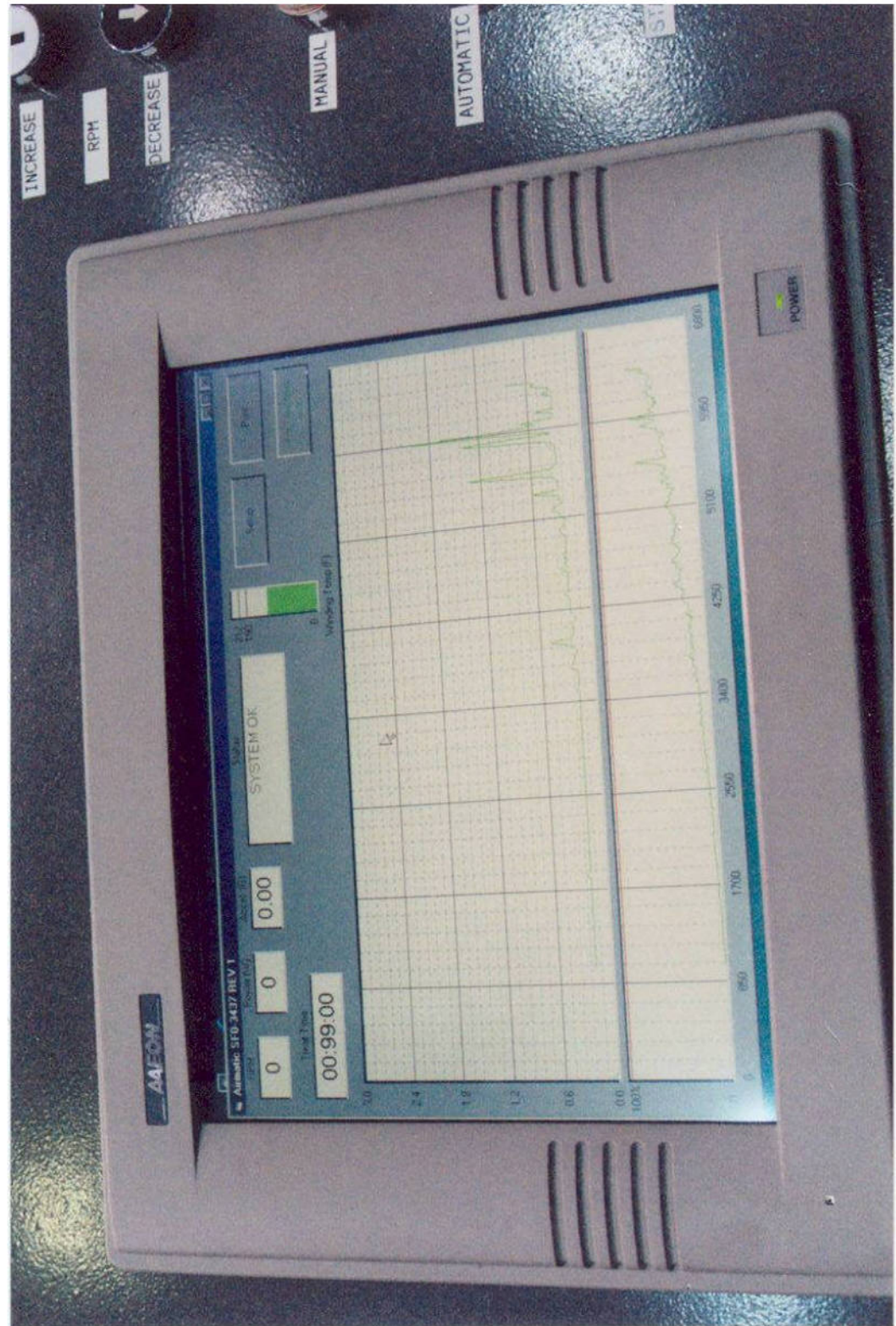


Photo 5: Completed VSR Treatment Chart, Workpiece #1.

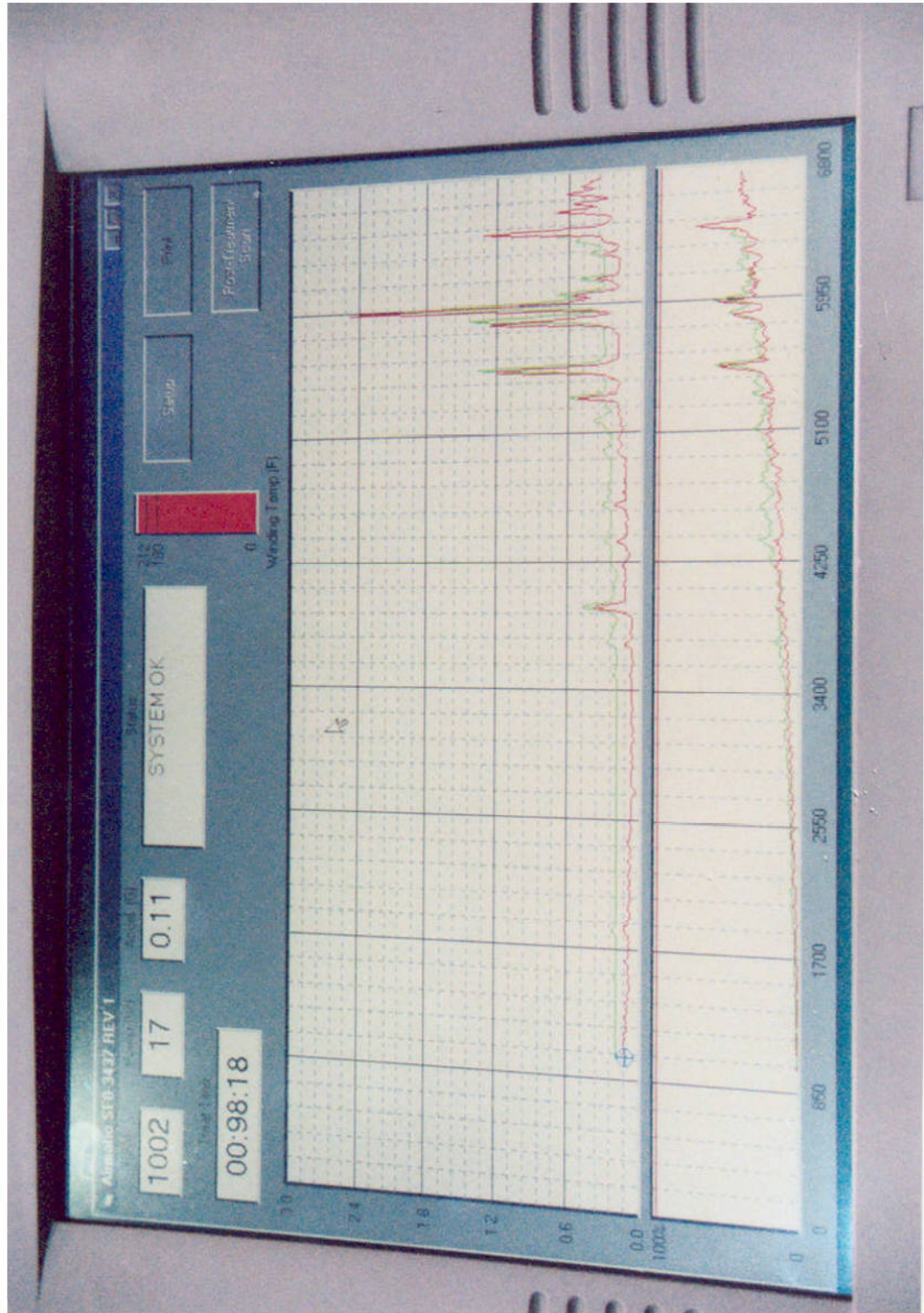


Photo 6: Pre-Treatment Scan of Workpiece #2.

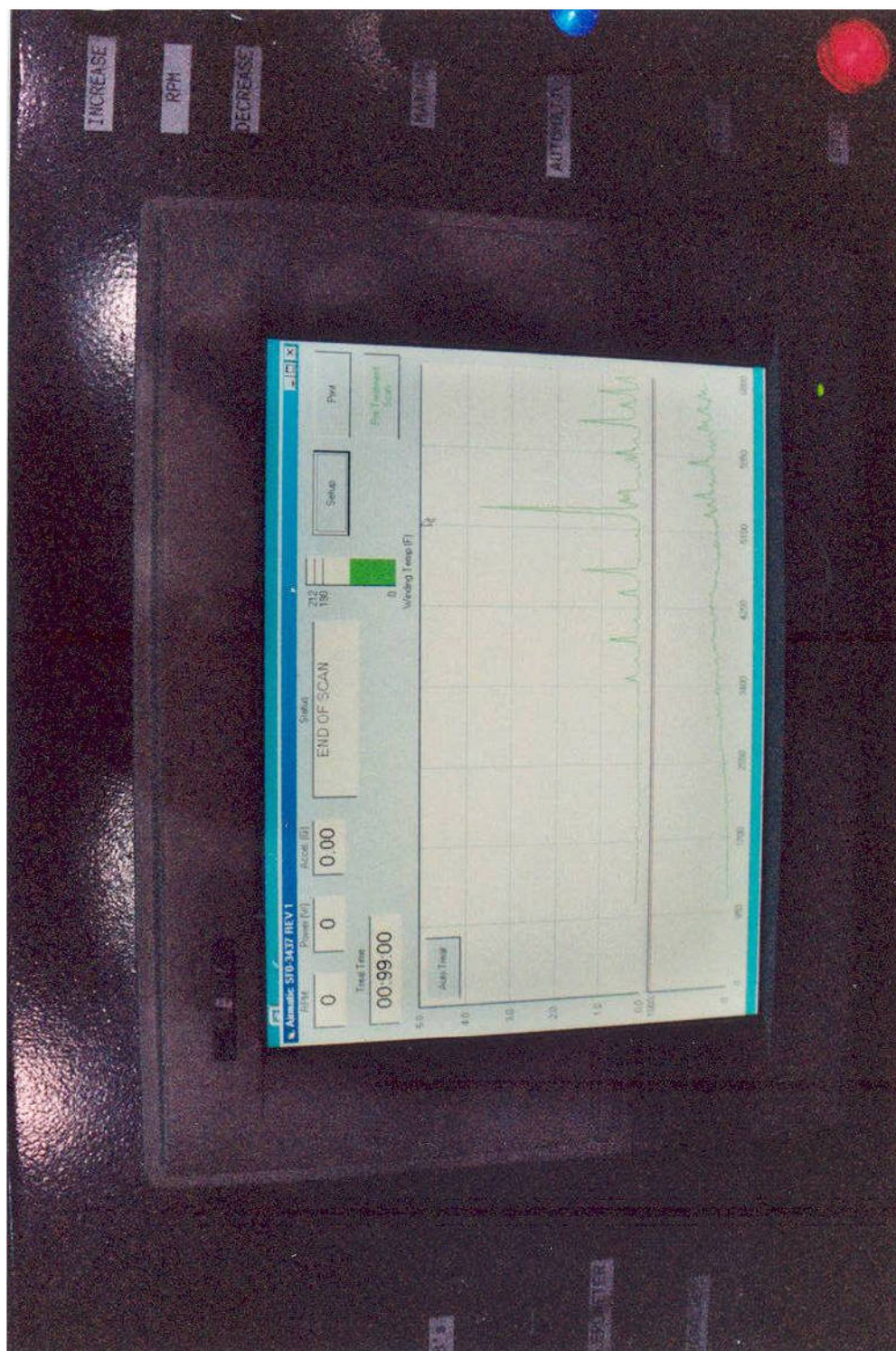
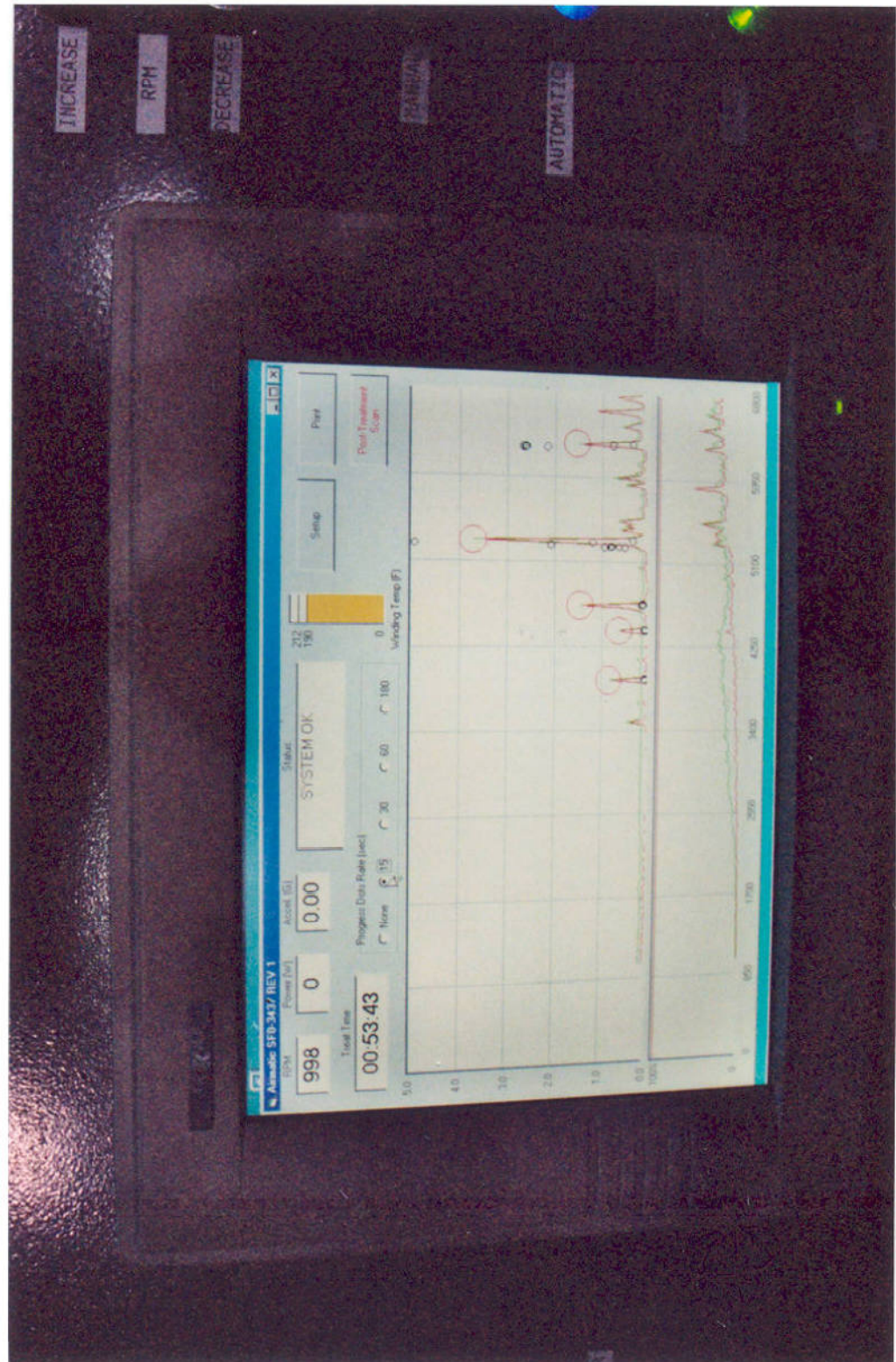


Photo 7: Completed VSR Treatment Chart, Workpiece #2.





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