The cost effective alternative to heat treatment

Report on Vibratory Stress Relief

Prepared by Bruce B. Klauba
Product Group Manager

FRENCH OIL MILL MACHINERY CO
Picqua, Oh

FRENCH OIL MILL MACHINERY is a manufacturer of liquid-solid separation equipment used in, among others the Food and Chemical Processing Industries. This Report describes the successful use of the system on bi-metallic (stainless and mild steel) press frames which, because they are bi-metallic, could not be effectively treated with TSR.

Use of the VSR process after all welding had been completed enabled these workpieces to exhibit superb dimensional performance during final machining, assembly, transport and installation.

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7317 State Road, Philadelphia, PA 19136-4292

PH: 800.332.9770
FX: 888.964.3866

VSR TECHNOLOGY's Vibratory Stress Relief System was chosen by FRENCH OIL MILL MACHINERY (FOM) to stress relieve two feed oil processing Press Frames. FOM had previously authorized the use of this type of stress relief equipment on workpieces done by outside contractors, but this was the first time the VSR System was used in-house.

The workpiece weldments were L-Shaped and each was 250" L and weighed 6,000 Lbs. While the workpiece was primarily mild steel, the design did include a stainless steel liner and plumbing. Since the workpieces were bi-metallic, they were poor candidates for thermal stress relief.

In the past, stress relief of these workpieces had been performed in either of two ways:

(1) After the mild steel components of the workpiece had been completely fabricated and thermally stress relieved, the stainless components were added;

(2) The workpieces were made in halves. Both the low-carbon and the stainless materials were welded separately on each half. Each half was then vibration treated off-site by an outside firm. The two halves were then returned to FOM where they were welded together.

Both methods left a great deal of stress in the workpiece which interfered with final machining because of the dimensional instability. Using Vibratory Stress Relief *after* the workpiece was complete, however, resulted in a significant improvement in dimensional stability during machining. The VSR System is now an integral part of FOM's Quality Assurance Program.

VSR SETUP

There are five key aspects to the correct setup of a workpiece for Vibratory Stress Relief:

1. Locating and placing the load cushions under the workpiece:

   Load cushions are specifically located and placed beneath the workpiece to isolate it from the floor and to minimize workpiece dampening (allowing *resonance* to occur), and eliminate the cross-transfer of noise with surrounding shop equipment.

2. Locating, orienting, and clamping the Vibrator:

   Vibrator location and orientation are determined by how to most effectively promote the *resonance frequencies* of the workpiece. Generally, the Vibrator's axis of rotation should be parallel to the length of the workpiece, and the Vibrator located in the central 1/3rd of the part. The ideal Vibrator location is decided after response to vibration has been sampled.

3. Locating, orienting, and clamping the Accelerometer:

   Accelerometer location and orientation are selected to maximize *resonance frequency* detection. This acceleration sensor is best placed on a corner of the workpiece, and oriented so as to be most sensitive to either vertical deflections, or those that are horizontal but perpendicular to the workpiece's length.

4. Setting the Vibrator's eccentrics:

   Vibrator unbalance should be initially set at a low level to sample the workpiece's response to vibration. It is increased if the workpiece displays little resonance activity. The unbalance is adjustable over a range of 5–100% of the available unbalance.

5. Calibrating the Control Console and Plotter:

   The responsiveness of the workpiece to vibration, especially at *resonance frequency*, is an unknown. Therefore, the sensitivity input gain of the Plotter (which depicts workpiece acceleration) has to be adjusted, since different workpiece configurations have significantly different responses to vibration. The adjustment is easy to make, and after the Plotter adjustment is made, the setup is complete.

In order to perform effective vibration treatment, the workpiece must have the ability to respond to the most effective form of vibration – *resonance* – that will cause stress relieving. In order to stress relieve a workpiece, a great deal of load (force) within that workpiece is needed. This Vibrator imposed load combines with the residual stress within the workpiece to cause plastic flow at the granular level of the material being treated, *ie*, short-distance rearrangement of the material.

The most effective means of using vibration to produce maximum load within the workpiece is to tune upon the *resonances*.

To enable *resonance* to take place, the rubber isolation cushions must be placed far from the corners of the workpiece. If the cushions are placed underneath the corners, they only serve as shock absorbers, which minimizes the effect of vibration. Since only three points are needed to determine a plane, three cushions are usually all that are needed in a VSR System setup. In the case of these workpieces, one cushion was placed at the center of the workpiece along the left side major Axis on the outer-edge; the other two cushions were placed on the opposite side, also on the outer-edge of the workpiece, 18" either side of center.

The Vibrator was located on one of five "cross-bars" that spanned the trough and were equally spaced along the length of the workpiece. The Vibrator was clamped in place using the special Clamps (provided) which include machined bolt points which mate with the hardened steel inserts in the Vibrator's mounting feet.

Initially, the Vibrator's unbalance was set at the minimum 0.15 in-Lbs. (5% of the unit's 3.0 in.-Lbs adjustment), which was too low to resonate the workpiece. When the unbalance was increased to 0.45 in-Lbs (15%), the workpiece reached the levels of *resonance* which caused stress relief.

The Accelerometer was located on the corner of the workpiece (on the short leg of the "L"), and was oriented so as to be most sensitive to vertical deflections.

The XY Plotter required some gain adjustment of its Y-input (the vertical), so that the generated chart not only showed the workpiece's *resonance peaks*, but also allowed some room for peak growth.

At this point in the procedure, it was still not known whether the setup would be effective in stress relieving these workpieces. It is only after a VSR Treatment has begun, and a change in the *resonance pattern*, a classic response to treatment with the VSR Process, occurs that an operator knows that a setup is effective. It's important to note that with thermal treatment there is no feedback from the workpiece until machining, inspection, or assembly takes place, while with VSR Treatment, monitoring and documentation of the workpiece's response is real-time generated. The VSR System not only allows operator intervention, but also answers the questions of whether a particular workpiece needs stress relief, when to do the stress relief, and whether the workpiece would benefit from more than one treatment. Again, such questions can be raised but never answered when using the thermal treatment process.

VSR TREATMENT

VSR Treatment is accomplished by driving the workpiece hard enough to cause changes in the *resonance pattern*. Specifically, the *resonance peaks* either grow to higher amplitudes, shift to lower frequencies, or a combination of both. These changes are consistent with a change in the rigidity of the workpiece. A stress relieved Workpiece, whether relieved actively, via thermal or vibration treatment, or passively, via transport or long term storage, is less stiff than its stressed counterparts. Many machinists and fabricators are familiar with this fact because they've observed the difference while performing cold straightening operations.

During VSR Treatment the most effective Vibrator speed that relieves stress is centered at the *resonance frequency*. As stress is relieved, the charted peak either moves up, which means there is an increase in workpiece acceleration, or shifts to the left, which means there is a decrease in the workpiece *resonance frequency*. As mentioned previously, it's common that both changes occur.

After the first peak has been successfully treated, the second peak, and then the third peak can be tuned upon, held, and tracked as it changes. If more than three peaks are present, these too can be tuned upon, although rarely do fourth or additional peaks respond – the treatment of the initial peaks has done the job.

The *resonance pattern* starts out as being rather unstable. As the peaks are tracked and the changes occur, the pattern of peaks becomes more and increasingly stable, eventually showing no remaining change.

Similarly, the workpiece starts out as being, most likely, dimensionally unstable. As the *resonance pattern* becomes more stable, so do the dimensional stability characteristics of the workpiece, *ie,* workpiece stability results from *resonance pattern* stability.

The peak hold time required to cause these changes to take place is rather short. In the case of these workpieces, 10 to 12 minutes (per peak) for the first and second peaks was all that was needed. The dwell time on each peak doesn't vary much with the norm being 5 to 15 minutes. Treatments including before and after scan periods (which are automatically performed by the system) range from as little as 40 minutes, to 2 hours for massive workpieces (>75 Tons). The FOM workpieces took 75 minutes to stress relieve, using the VSR TECHNOLOGY System.

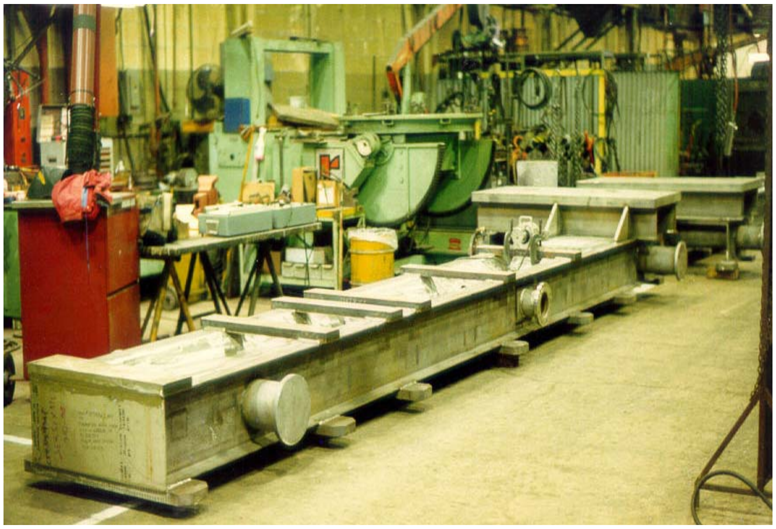
CONCLUSION

As evidenced by the clear change in the *resonance patterns* of these workpieces, they exhibited, as expected, good dimensional performance during machining, assembly, transport, and installation. Further, only the use of VSR Technology could assure good dimensional behavior, since attempts to thermal stress relieve bi-metallic workpieces regularly causes even greater problems. If VSR TECHNOLOGY's Vibratory Stress Relief System had not been utilized, the stresses would have complicated the machining process and assembly. Proper utilization of the VSR TECHNOLOGY System involves recognizing appropriate applications, executing a correct setup, and carrying out the procedures which enable the System to work.. As with many forms of applied technology, proper setup makes the job easy, quick and effective.

Bruce Klauba has a degree in Physics and a Level II Vibration Analysis Certification from the American Society of Non-Destructive Testing (ASNDT). 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:

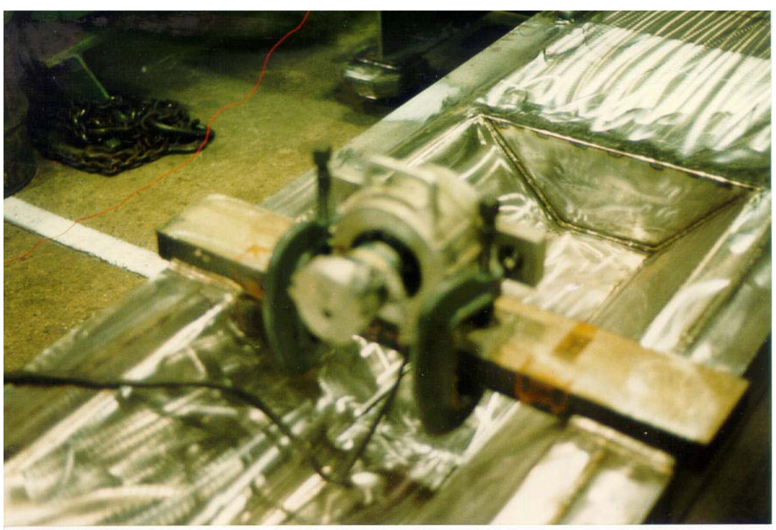
1. "Use and Understanding of Vibratory Stress Relief", *Productive Applications of Mechanical Vibration*, 1983, American Society of Mechanical Engineers.
2. "Vibratory Stress Relief: Methods used to Monitor and Document Effective Treatment, A Survey of Users, and Directions for Further Research", 2005,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



Workpiece set-up. Three Load Cushions were used to isolate the Workpiece, one beneath the pipe flange, the other two spaced 3' apart, on the opposite side.

Another view of setup. The Vibrator location shown, was the third one tried before the Vibrator's full speed range could be achieved (motor protection circuitry in the Console prevented full speed range at other locations). Pipe flange near midpoint was dividing line for weld seam which, previously, joined the two halves after stress relief.



The mounted MV2-3A-EC1 Vibrator during dwell time on a 4.2g peak (vibrator image is blurred due to oscillation). VSR Vibrators are designed to survive such usage. The Vibrator motor was barely warm during use.

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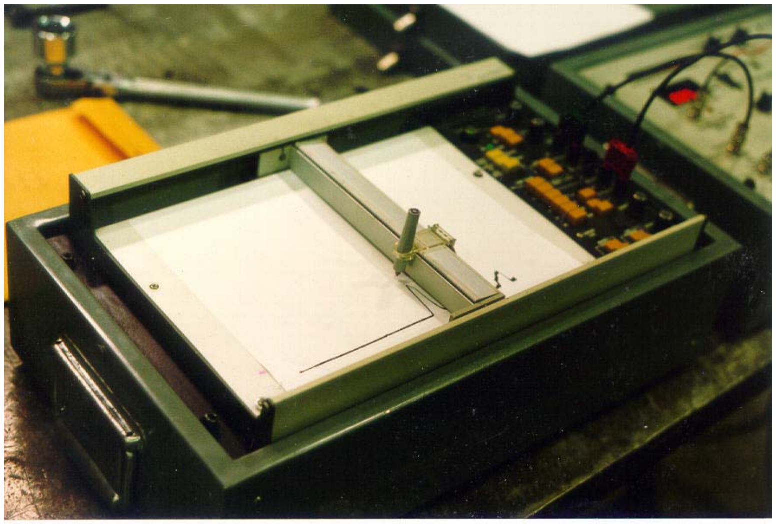
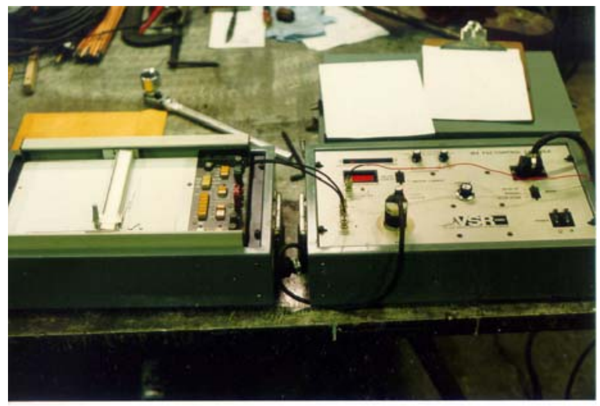
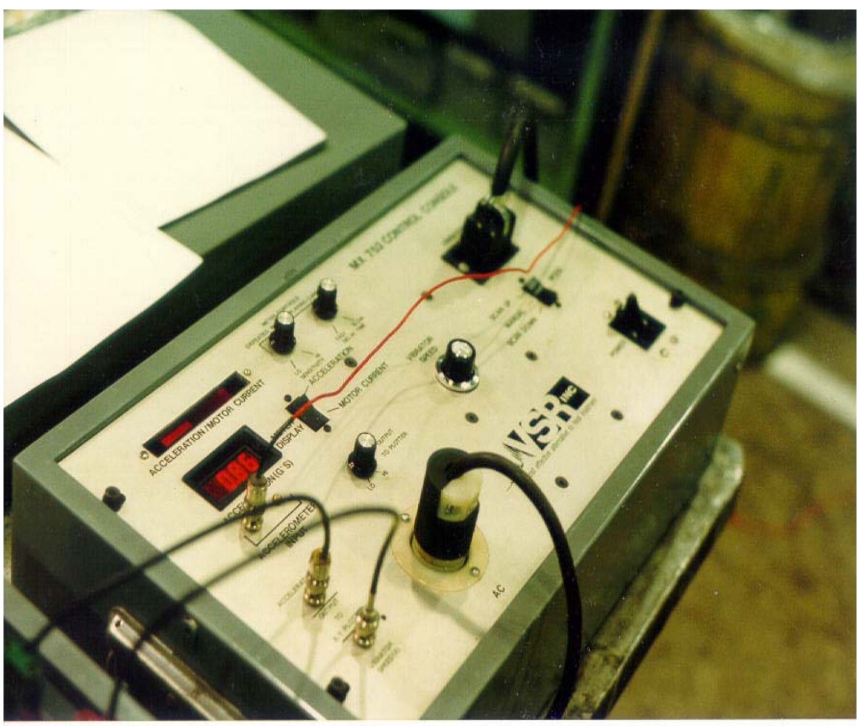


Close-up of the Plotter while Vibrator was tuned to the first peak. Some response has already taken place. Stress relief occurs rapidly at the beginning of the cycle due to the high levels of potential energy in Workpiece, which the Treatment then reduces by converting it to kinetic energy.

VSR-752 System Electronics; the Plotter is on the left, and the Console is on the right.





Close-up of VSR-752 Console. Note the digital readout shows 0.86g, which is the output of the Accelerometer in real engineering units. Calculations which compare the input force (*ie*, the output force of the Vibrator) into the Workpiece, to the force experienced by the Workpiece at *resonance*, indicate that the combination of Workpiece *resonance* and the set-up procedure used multiply the Vibrator's output 20 to 200 times. *NB*: Significantly higher multipliers often occur.

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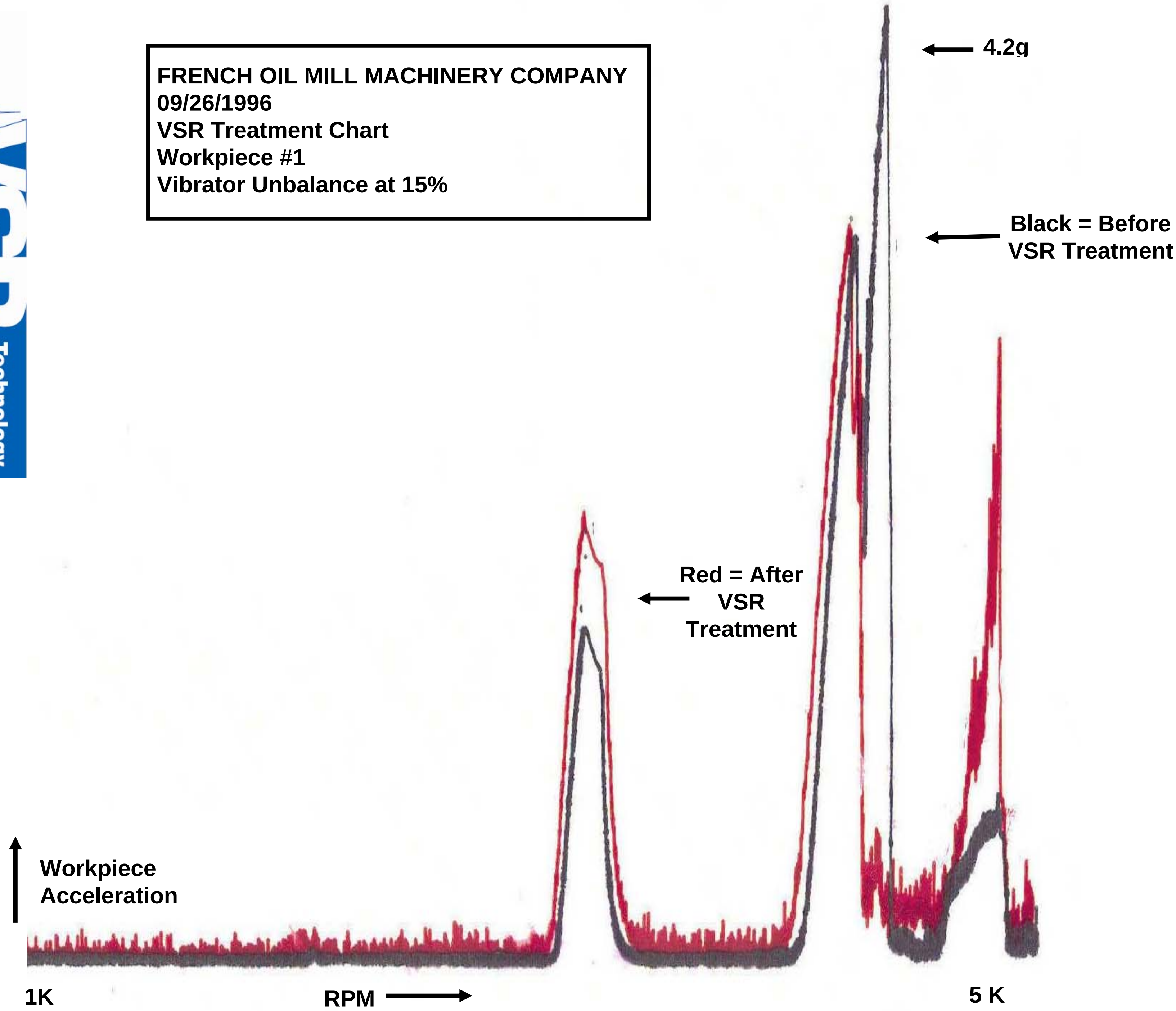

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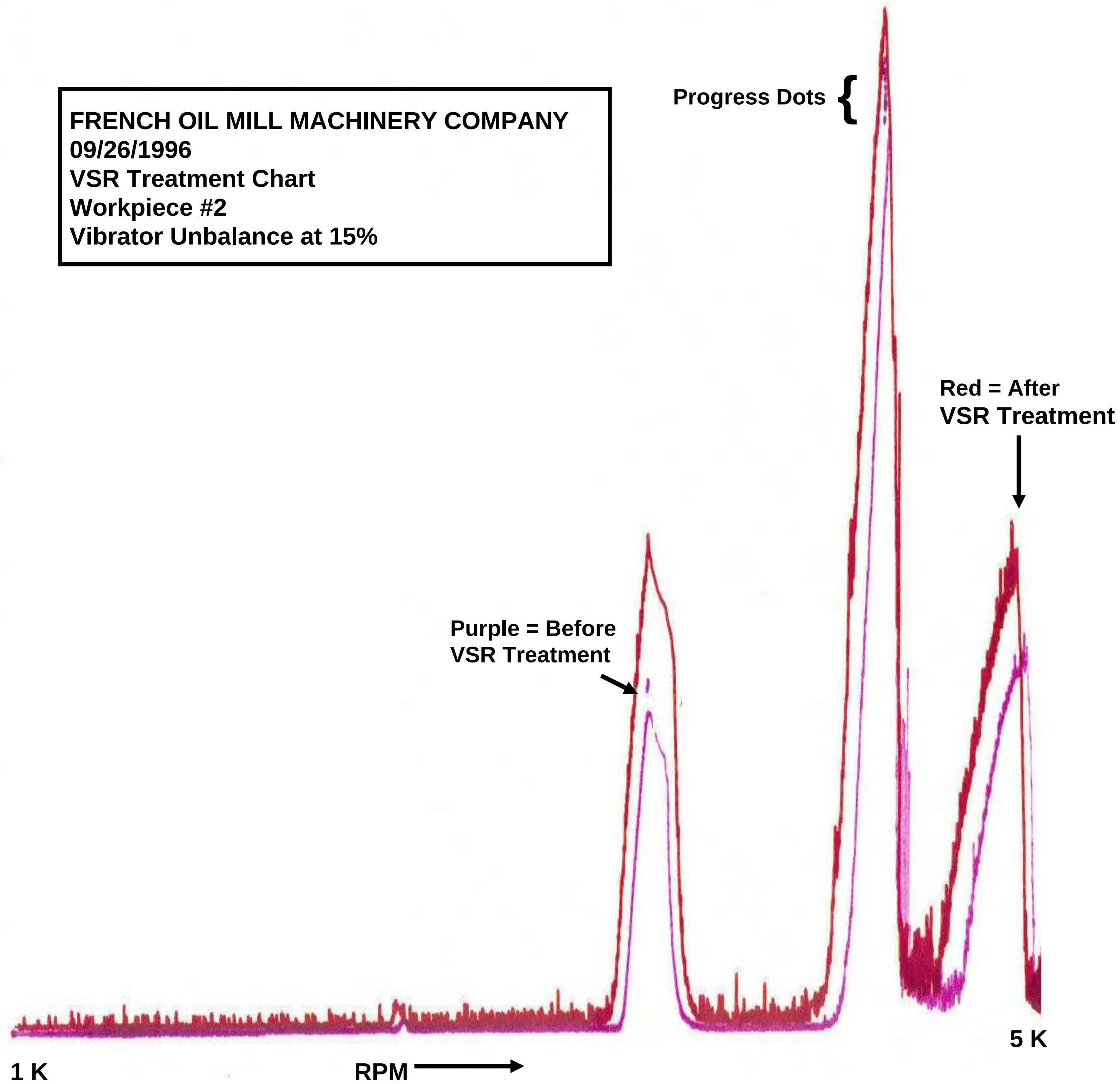
VSR Treatment Chart
Workpiece #2
Vibrator Unbalance at 15%



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