



EBCO / GL & V Twin Paper- Mill Vacuum Body

Richmond, BC Canada

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Report prepared by:

Bruce Klauba
Technical Director
Advanced VSR Technology
Philadelphia, PA

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The workpiece was an austenitic stainless steel weldment, measuring ~ 266" L X 43" W X 20" H, and weighed slightly more than 1 ton.

VSR SETUP

The work-piece was placed on 3 isolation load cushions. These were placed at the center of one of the 266" length sides, while the other two were spaced ~ 5' apart, on the opposite side. Workpiece resonance is used during the VSR Process to amplify dynamic loading, which, combined with the residual stresses trapped in the structure, causes plastic flow, the fundamental requirement of stress relieving activity.

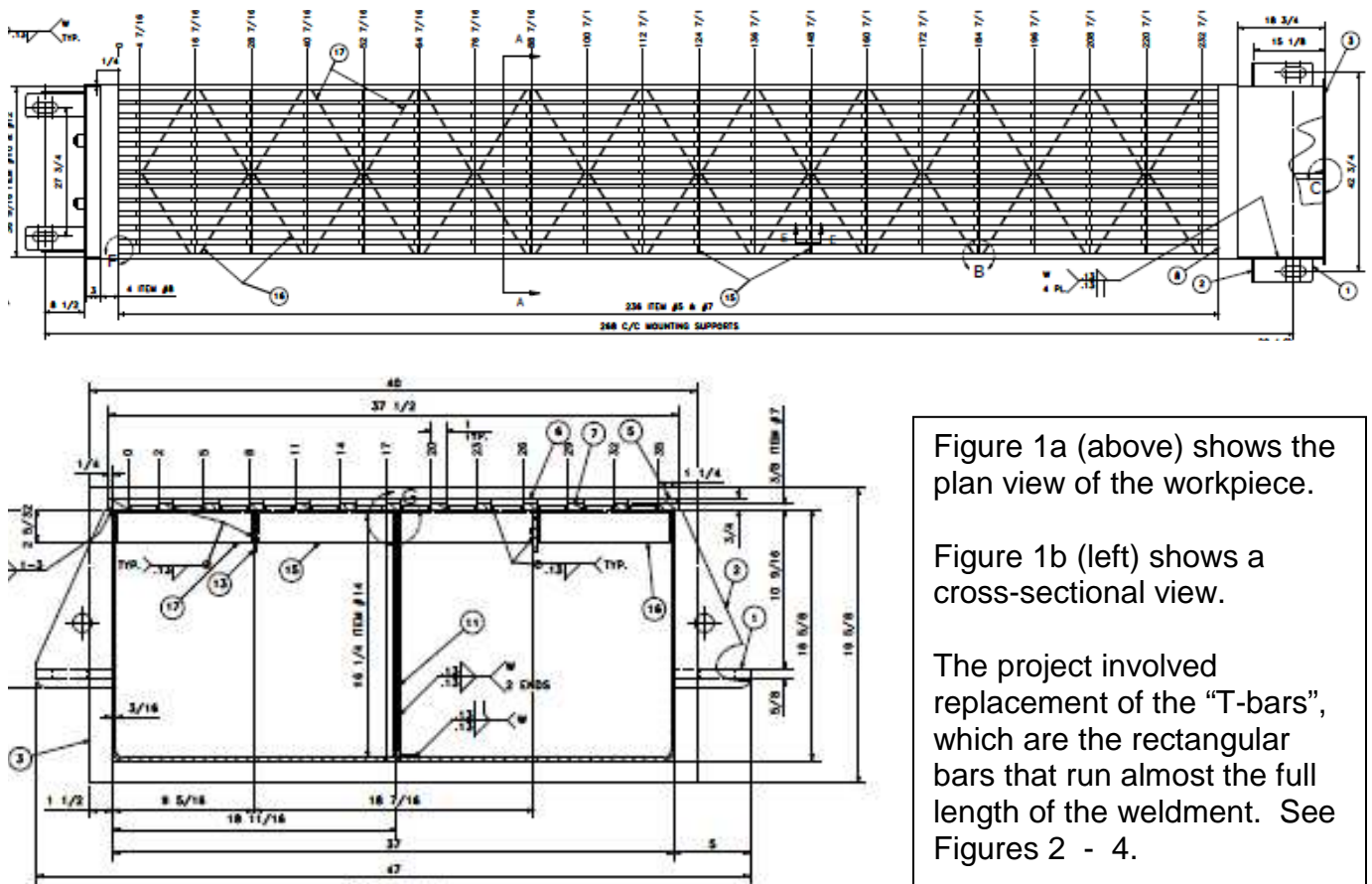


Figure 1a (above) shows the plan view of the workpiece.

Figure 1b (left) shows a cross-sectional view.

The project involved replacement of the "T-bars", which are the rectangular bars that run almost the full length of the weldment. See Figures 2 - 4.

Conventionally, VSR Vibrators are clamped on workpieces, using heavy-duty machinist's clamps. However, the grid of "T-bars", which were the only clamping surface to mount upon, disallowed this clamping method. Instead, a simple mounting plate with clamping bars was devised and prepared before the VSR work, and only required some minor fit-up trimming to permit proper fit and function.

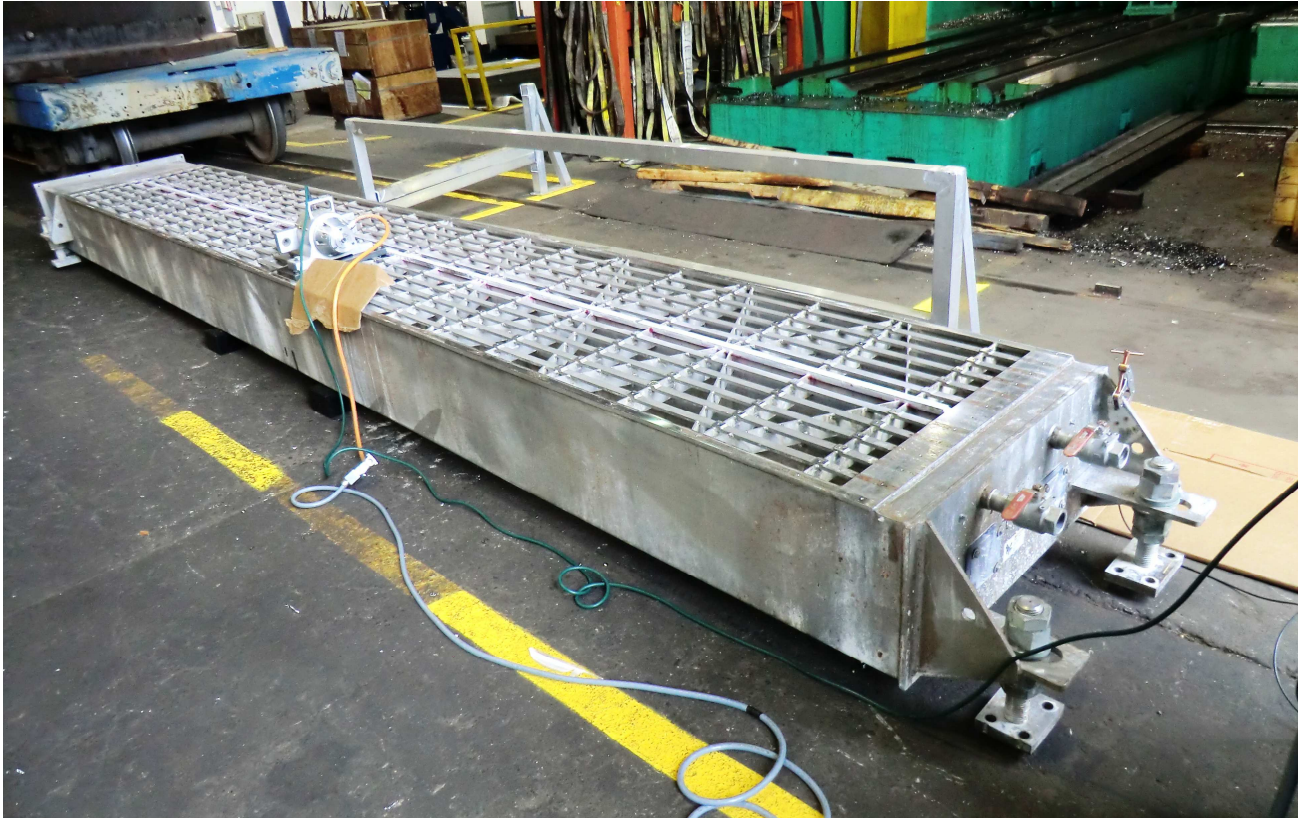


Figure 2: VSR Setup of vacuum chamber shows vibrator clamped on top, and two isolation cushions, spaced 5' apart, below it. The other cushion was on the opposite side, centered. This 3 point arrangement permits the greatest number of modes of resonance to occur during the VSR Process, and thus maximizes the flexure experience needed to render the structure dimensionally stable. The cardboard in front of the vibrator was used to protect the vibrator cables from rubbing on the edge of the workpiece, during vibration.

The accelerometer (a sensor whose output is proportional to acceleration) was placed on one of the corners (far right corner, in Fig 2, but not visible, but can be seen in Fig 3), and oriented to be most sensitive to vertical amplitude. Acceleration is used, rather than amplitude or velocity, due to its being proportional to force, the load the workpiece undergoes, based upon Newton's 2nd Law: $F = ma$ Both research and experience

implementing the VSR Process have consistently shown that acceleration is the best parameter to gauge workpiece response to vibration.

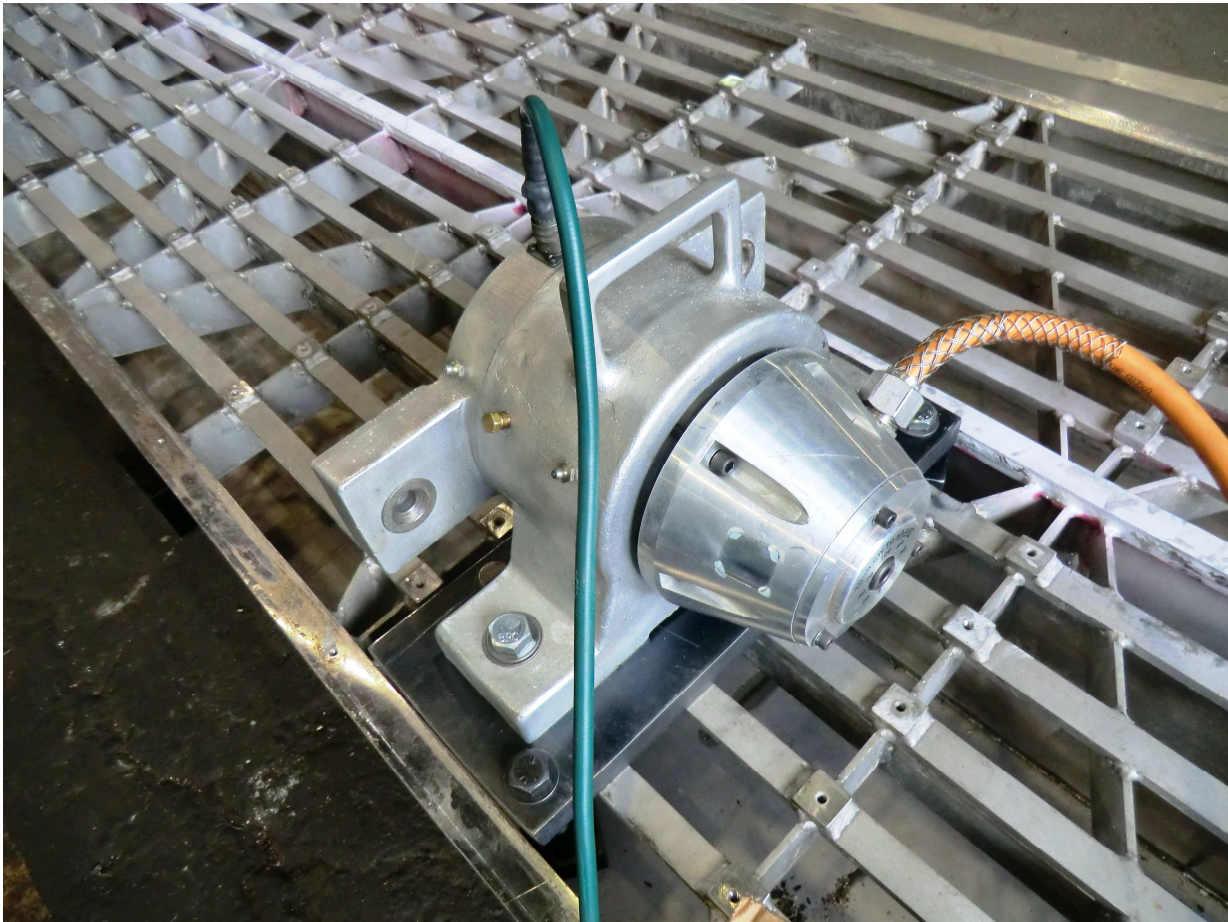


Figure 3: Closeup of vibrator mount shows detail of the length-wise “T-bars” and the mounting plate used to provide a secure, firm mount for the vibrator. Two 1” thick clamping bars, with drilled and tapped holes that “sandwiched” two of the T-bars, formed the lower portion of the clamping arrangement. The vibrator has an RPM max of 8000, and adjustable unbalance over a 20 : 1 range. Two VSR Treatments were done, using two different unbalance settings, to allow treatment of different groups of resonances.

The Vibrator's unbalance was initially adjusted to a low setting of 5% of the BL-8's available 4.0 in-lbs, i.e., 0.2 in-lbs. This unbalance setting was used to operate upon higher speed resonances of the workpiece, maxing out at 5000 RPM, which were focused upon during the first treatment.

A 2nd treatment was done, using the same setup, with the exception of the unbalance setting, which was increased to 20% (0.8 in-lbs.). This generated resonances in the low RPM, up to 3500. See Figures 5 – 8.



Figure 4: View from the end of the workpiece shows accelerometer in right-foreground, and single isolation cushion on the right, at the midpoint of the workpiece length.

VSR TREATMENT

The VSR-8000 System uses resonant frequency vibration to cause flexure of the work-piece, this mechanical flexure is the means of causing internal rearrangement of the material (i.e., plastic flow) thereby lowering the severity of residual stresses. Although other forms of vibration, and even randomly generated mechanical excitation, can cause stress relieving to occur, independent research has shown that resonant frequency vibration causes the greatest degree and fastest rate of stress relief.

Monitoring resonant frequency vibration data during stress relieving also provides the clearest indication of stress relief progress: The major change in resonance pattern that takes place, during the good majority of effective stress relief treatments, is growth of the resonance peaks.

A secondary response is the shifting of the resonance peaks, most often in the direction of lower frequency. Continuous monitoring of the tops of resonance peaks, along with the resonance frequencies, provides the most comprehensive real-time monitoring of the progress of a vibratory stress relief treatment.

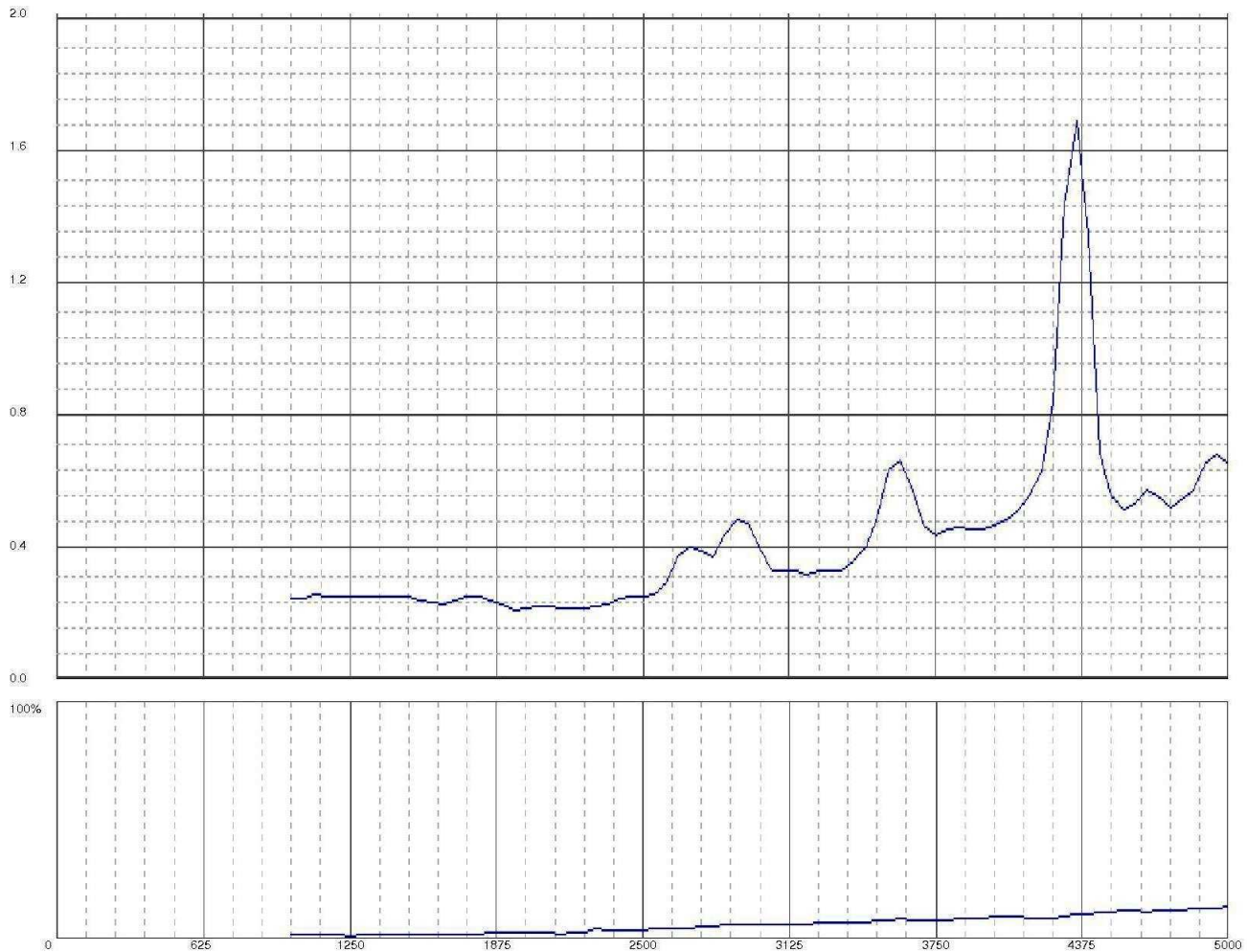


Figure 5: A Quick Scan is used to determine if there are resonances, and their intensity and frequency range. VSR Treatment Charts have two portions: An upper acceleration curve, and a lower vibrator power curve, each of these parameters plotted vertically, vs. a common horizontal axis of vibrator RPM (speed).

Quick Scans use a scan rate of 50 RPM / sec., five times faster (hence “quick”), than Pre-Treatment (base-line) or Post-Treatment (documentation) scans, which have the higher resolution needed to perform the VSR Process.

Full scales for this chart:

Acc = 2.0 g's	(adjustable from 1 – 50 g's)
Vibrator speed = 5000 RPM	(adjustable up to 8 KRPM)
Power = 2300 watts	(fixed)

Peaks in the acc curve are resonances of the structure.

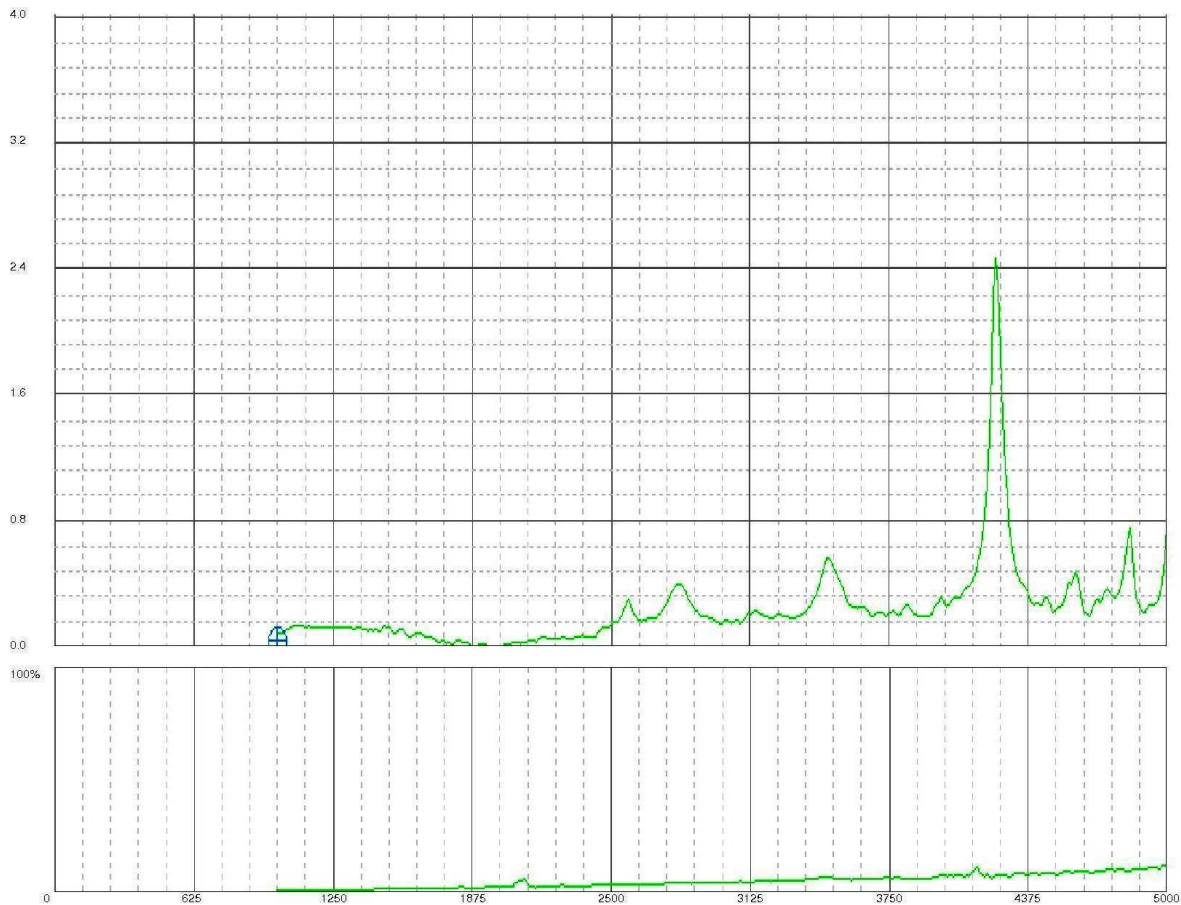


Figure 6: 1st Pre-Treatment Scan is made at a rate of 10 RPM / sec, and functions as a base-line for the remaining treatment. Full-scale (FS) acc is 4.0 g's, and RPM is 5000.

This chart shows one large peak at ~ 4200 RPM; the other peaks are much shorter. Treatment (dwelling upon and monitoring for change, in the form of either peak growth, peak shift, or the less frequent peak lowering, which can occur during workpiece change shape) was attempted on all peaks, but only treatment of the large peak resulted in peak growth. However, during the Post-Treatment Scan, all peaks showed growth, which was a result of the treatment of the 4200 RPM peak. See Fig. 7.

Total treatment time for the 1st treatment was roughly 20 minutes, while the scan took about 6 minutes.

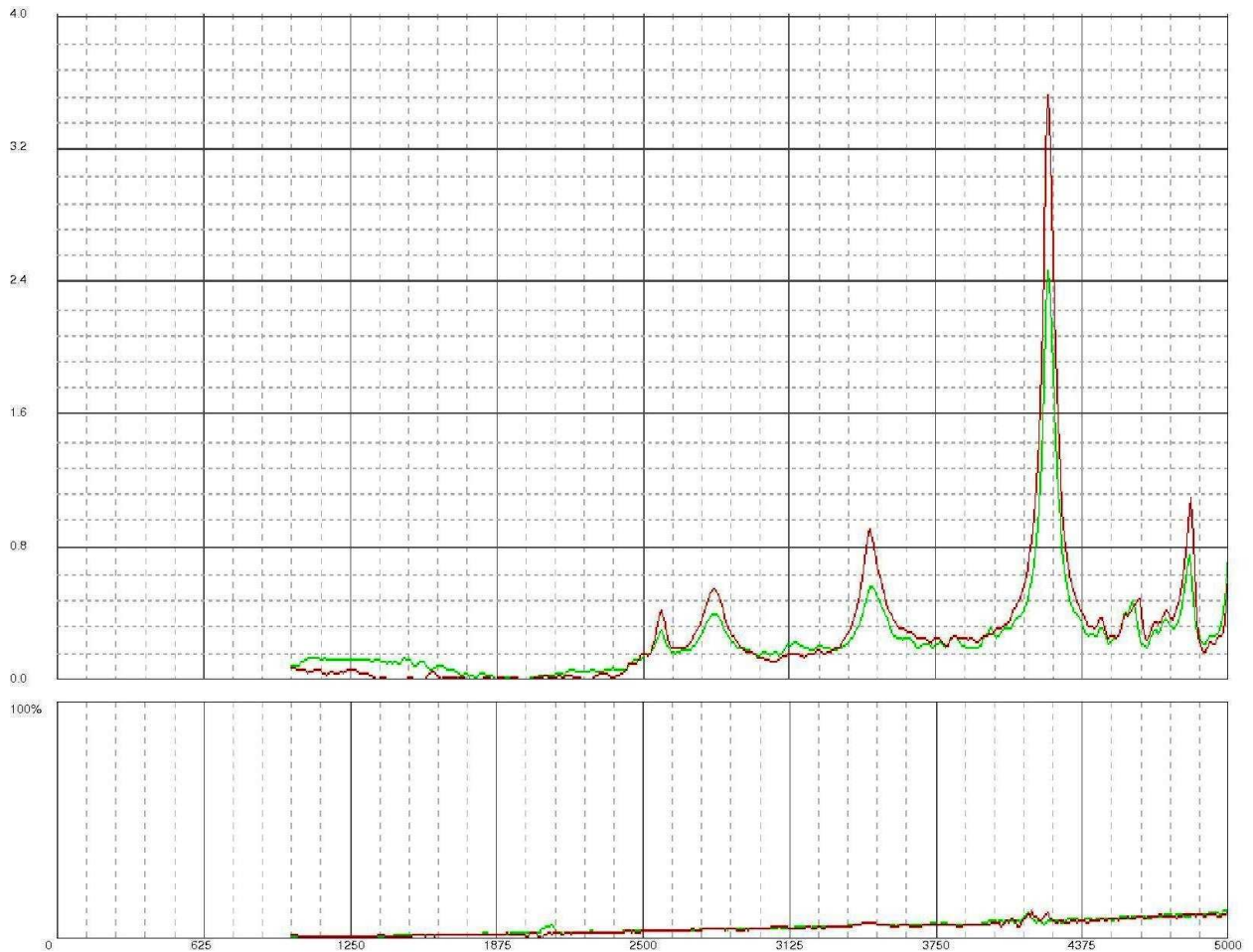


Figure 7: 1st VSR Treatment shows peak growth of all peaks, although only treatment at the large, 4200 RPM peak caused peak growth during treatment.

After the first treatment, the lower frequency peaks (those below 3500 RPM) were addressed by increasing the unbalance 4-fold, from 5% to 20% of the available 4.0 in-lbs, i.e., 0.8 in-lbs. The quick scan for this setting can be seen in Fig. 8

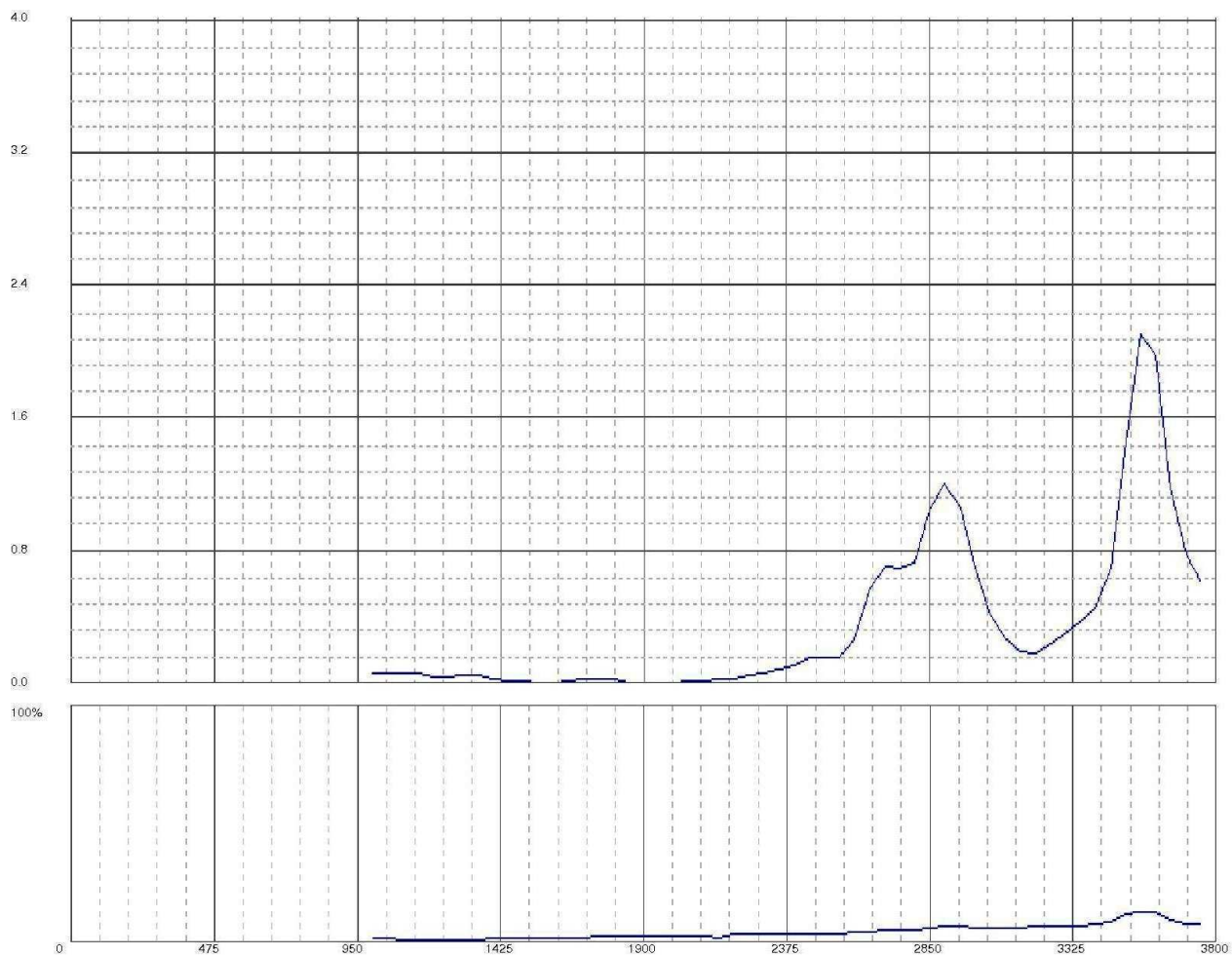


Figure 8: Peaks below 3500 RPM, that were very short in earlier scans, are now larger in this quick scan. Acc FS = 4.0 g's (same as the 1st treatment acc FS).

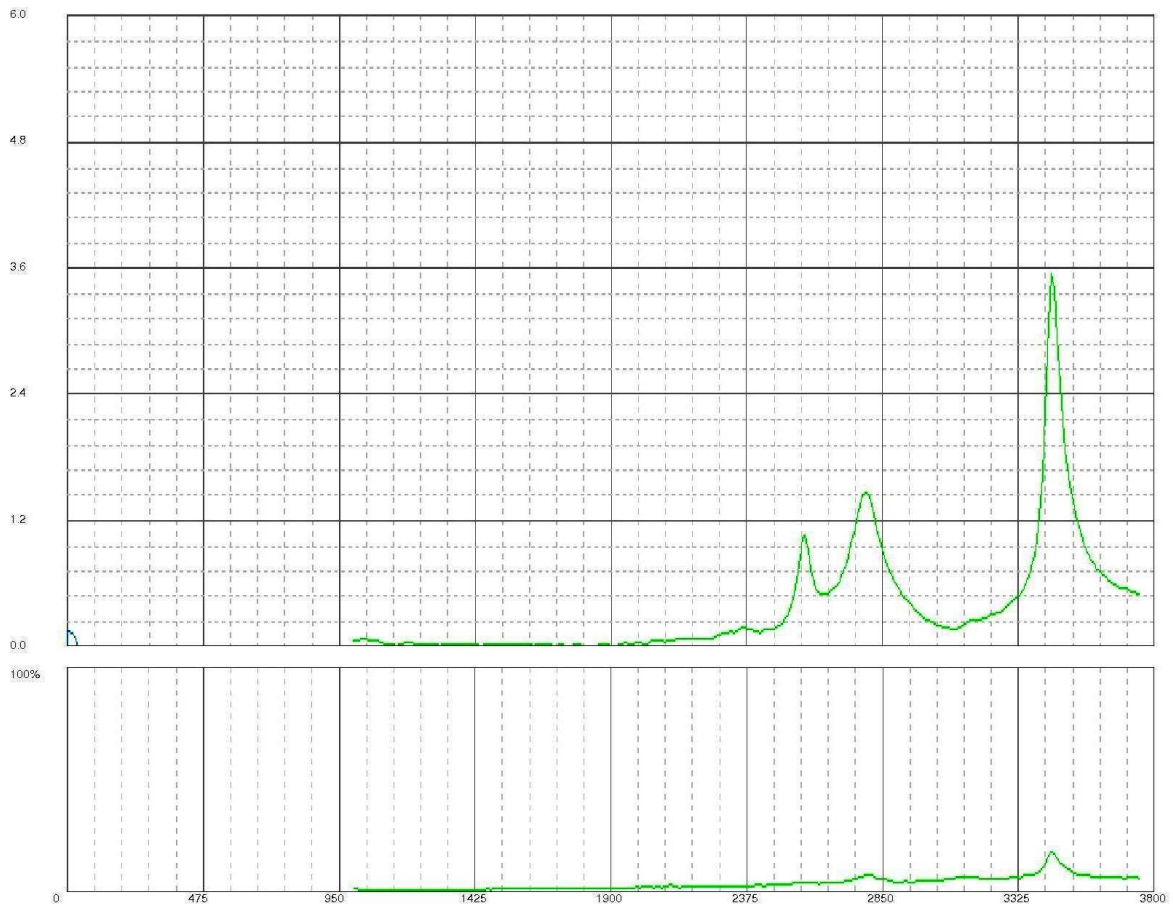


Figure 9: Pre-Scan shows high-resolution view of low frequency peaks. The acc FS has been raised to 5 g's, allowing “headroom” above the highest peak.

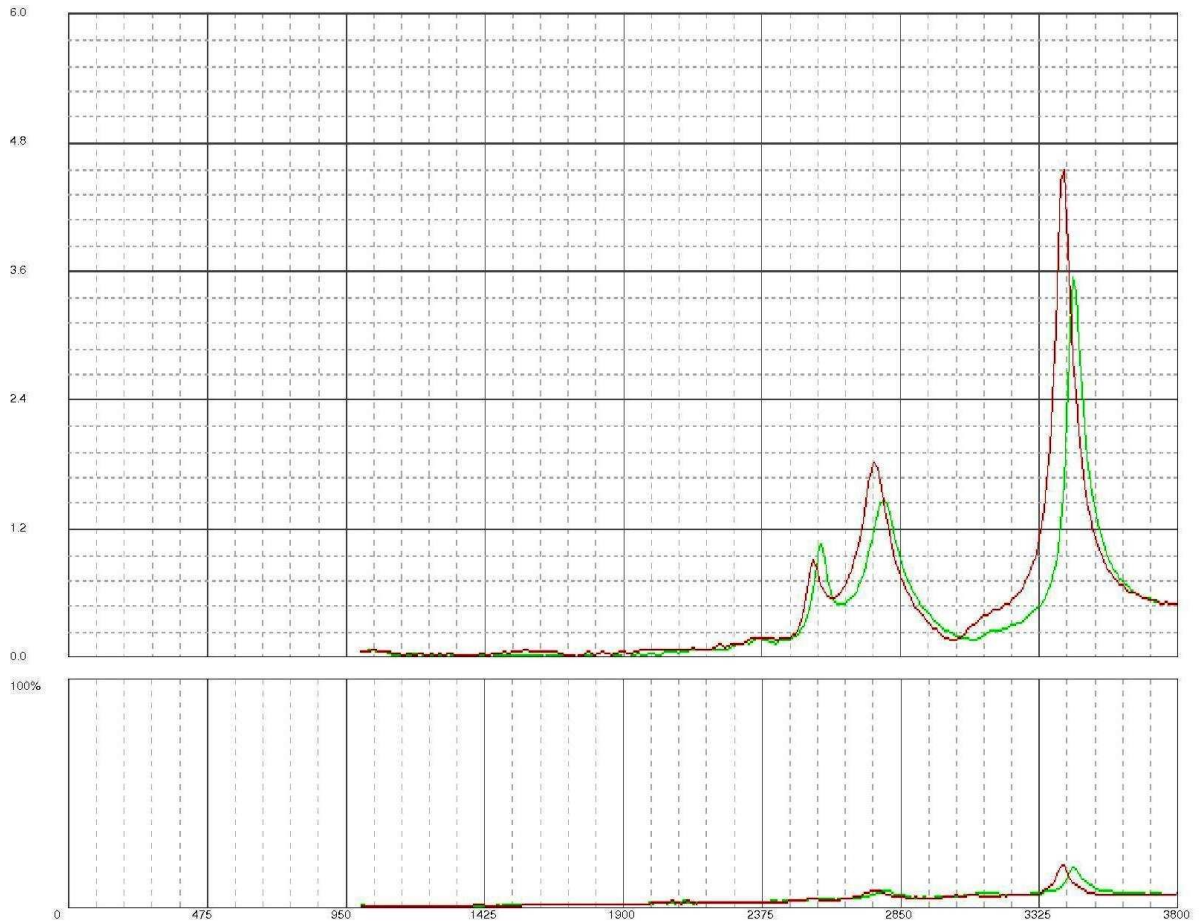


Figure 10: 2nd VSR Treatment reveals peak growth for two of the peaks, while the lowest frequency peak reduced slightly in height. All peaks show mild shifting to the left, but the greatest change percentage-wise, as is common, is peak growth, which was in the case of the largest peak, from 3.6 to 4.6 g's, a 27% increase.

Treatment time was approximately 15 minutes for each peak.

CONCLUSION BASED UPON VIBRATION DATA

Based upon two clear VSR Treatment Charts showing chiefly peak growth, but then resulting in stable peak data, this structure should demonstrate good dimensional and mechanical integrity during subsequent manufacturing operations, transport and field usage.

MACHINING & INSTALLATION RESULTS

The following information was provided by EBCO approximately one week after the VSR Treatments were performed:

“As far as the machining is concerned, we supported the ends of the vacuum box as called for on the drawing and let the middle section deflect naturally. After the set-up, we had a variation of .135” from the low point to the high point on the top of the vacuum box. My customer wanted to minimize metal removal and achieve a flatness within +/- .010”. Consequently, we removed up to .115” of material and met the customer’s requirement.”

When a metal structure behaves like a perfect spring, i.e., when natural deflection or loading within its design / operational limits, followed by its return to zero or very-near zero when the deflection load is released, that is a true indication of dimensional stability. Such parts (an engineer’s dream) are predictable during subsequent machining, handling, transport, erection and assembly procedures.

“Late last week, we installed the T-bars again, the vacuum box was sent to the pulp mill and the installation was completed on June 22. The pulp table was re-started on June 23 and everything appears to be working well.”

It is not unusual that some distortion take place during stress relieving, whether thermal or vibratory. With thermal, this can be due to unequal cool-down or gravitational sagging while in-furnace, i.e., activities not directly linked to the stress relieving, *per se*.

With vibratory, such distortion should thought of as inevitable, and best to occur prior to final machining, when the opportunity to account / correct the distortion is easy, indeed, planned. Such release of the potential energy that threatens the dimensional or mechanical integrity of a structure is required, and much preferred to release of this energy post-machining. Such distortion can occur during assembly or transport, the famous “fahrtbehandlung” effect, which was used during WWII by German engineers and project managers, when virtually all their heat-treating facilities had been eliminated by Allied bombing.