"COMPRESSOR HASN'T RUN THIS QUIETLY OR SMOOTHLY IN 18 YEARS OF OPERATION" A CASE STUDY ABOUT FIELD DE-TUNING OF MECHANICAL RESONANCE ON FIXED SPEED SCREW COMPRESSOR PACKAGES

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ABSTRACT

A field vibration analysis was conducted on a refrigeration screw compressor unit. The purpose of the analysis was to field de-tune high vibration on the compressor package.

The unit had exhibited high vibration for many years and vibration related failures have occurred. The high vibration was at a frequency equal to four times compressor run speed (lobe passing frequency). Acoustical unbalanced forces caused by pulsation in the compressor discharge system were exciting structural natural frequencies (mechanical resonance). This compressor is rarely shut down making it impractical to implement modifications to reduce the pulsation in the gas stream.

When the unit was running under normal conditions, piping that was exhibiting high vibration was de-tuned by solidly attaching additional mass. This de-tuning exercise proved very successful with vibration levels dropping by 10 fold at many locations.

1. INTRODUCTION AND HISTORY

On June 13, 2002 Beta Machinery Analysis conducted a field vibration analysis on the refrigeration screw compressor in the Dow plant at Fort Saskatchewan. The analysis was conducted to determine if field de-tuning of high vibration areas could be successfully carried out. High vibration has been an issue on this compressor for many years. Previous field assessments conducted by Beta determined that the high vibration was the result of pulsation induced unbalanced acoustical forces in the discharge system. Initial recommendations to resolve the high vibration problems included installing an orifice plate at the discharge of the compressor. Shutdown time on this unit is rare and installing the orifice plate was not an option immediately available.

2. OBSERVATIONS

2.1 One of the areas that high vibration had been a major concern was the compressor discharge separator (vessel D118). The predominant frequency of the high vibration on this unit was 119 Hz (lobe passing frequency on the screw compressor). At these frequencies the vessel shell modes were a main concern. The thought process prior to beginning the field detuning was to affect the vibration modes by adding mass to the shell of the vessel. For attaching trial weights, four band clamps were constructed that would fit around the outside of the D118 discharge separator. The clamps were made of ¼" thick plate 4" wide with four studs welded to them to facilitate hanging 4" 150# blind flanges from the band clamps. The band clamp material size was chosen for ease of construction and handling. The 4" 150# flanges were specified because they offered a reasonable weight increment (15 lbs), were easy to handle, and were a common stock item at the plant. Vibration levels were measured on the vessel at five locations along the height of the weld seam. At the start of the testing the peak vibration measured on the vessel was at location B shown in Figure 1. The maximum as-found amplitude at location B was 1.65 inches per second peak at a frequency of 119 Hz.

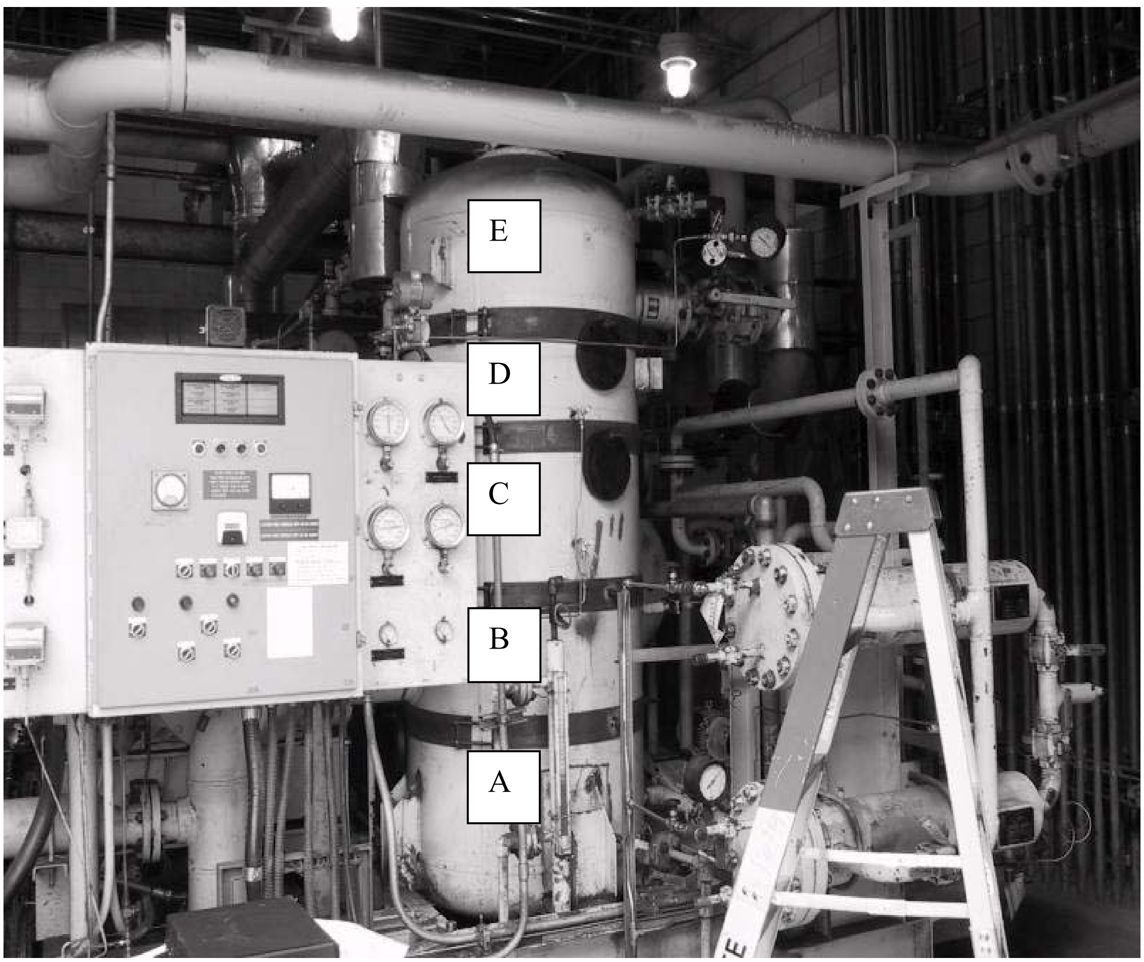


Figure 1: Discharge separator vessel D118 test point locations.

Example plots of vibration data recorded on June 13, 2002 are presented later in this paper. All four band clamps were installed with eight 4" 150# blind flanges secured to the bands at various locations around the vessel. At the conclusion of the project the maximum vibration recorded on the vessel was at location B with a peak of 0.19 inches per second.

2.2 Very high vibration was observed on the separator discharge piping. Vibration levels greater than 4.0 inches per second peak were observed at a frequency of 119 Hz on the lower elbows of the discharge line. The vibration on the discharge line drain valve was extreme, measuring greater than 9.0 inches per second peak. 4" 150# blind flanges were u-bolted one at a time to the discharge piping as shown in Figure 2. Vibration levels were checked after each flange was secured in place. With four blind flanges secured, the vibration on the discharge line dropped to a peak of 0.8 inches per second. Vibration on the drain line was still marginally high at a peak of 2.0 inches per second. At this point there was a noticeable decrease in the noise level around the C118 compressor.

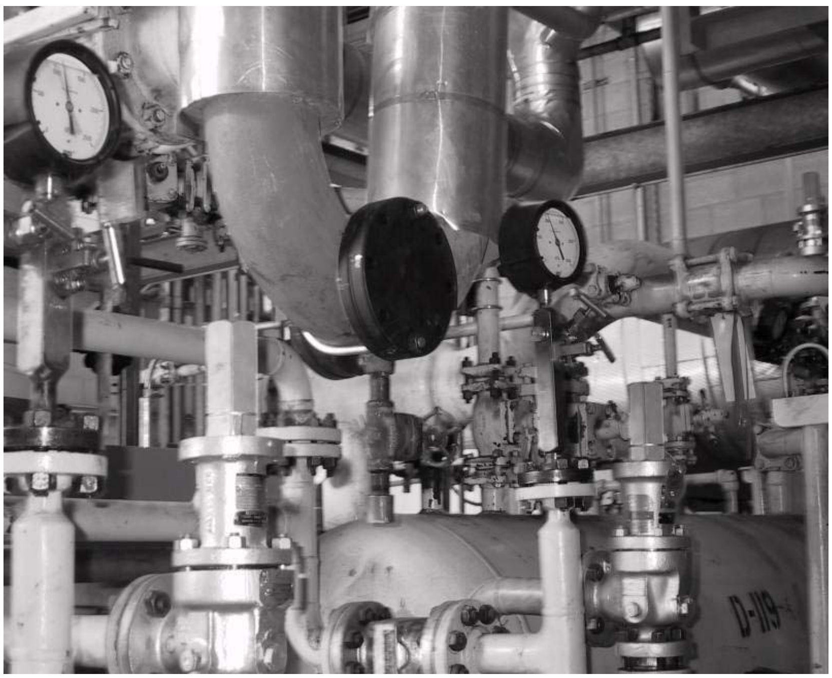


Figure 2: Discharge piping from vessel D118 with de-tuning weights secured.

Adding this de-tuning weight resulted in a considerable reduction in the vibration levels. At the conclusion of the project with all the de-tuning weights installed, an even more dramatic reduction in levels was observed. Final readings on the discharge line were measured to be 0.42 inches per second peak at 119 Hz and the level on the drain line dropped to 0.115 inches per second peak at this same frequency.

2.3 High vibration was observed on the vessel pressure gauge and tubing line located at the top of D118. The 119 Hz buzz was considerable on the stainless valve and tubing line. The gauge needle was vibrating to the point where it could not be read. Adding two ½" blind flanges as shown in Figure 3, eliminated the high vibration on the tubing line and pressure gauge.

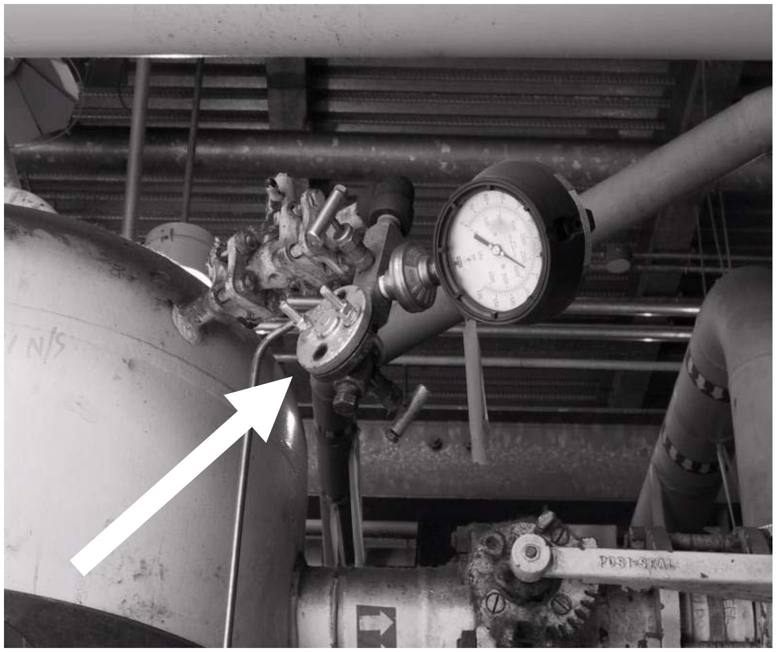


Figure 3: Vessel D118 pressure gauge and tubing line de-tuning weights.

2.4 The discharge line between the compressor and the separator D118 exhibited high vibration. Initially vibration levels on the pipe in the vertical direction measured 3.4 inches per second peak at a frequency of 119 Hz. Several tests were conducted to determine the effect of the pipe clamp located under the coupling end of the motor. The greatest reduction in vibration levels on the discharge piping was achieved with the pipe clamp removed and two sets of de-tuning weights clamped to the discharge line. A set of weights was located on the discharge line directly under the compressor / motor coupling and another was installed at the lower elbow of the discharge line into the D118 vessel. Both sets of weights were secured with a bent length of ready rod and were made up of 8" 150# blind flanges and rings. Final vibration levels on the discharge line under the coupling were measured to be 0.21 inches per second peak in the horizontal direction and 0.85 inches per second peak in the vertical direction, both peaks were at 119 Hz. Vibration levels on the discharge pipe, just before the elbow rising up to the vessel, saw reductions at 119 Hz from 1.3 inches per second peak to 0.15 inches per second peak in the horizontal direction. At the same location and frequency, vertical vibration dropped from 2.8 inches per second peak to 0.58 inches per second peak. The de-tuning weights installed on the discharge line are shown in Figures 4 and 5.

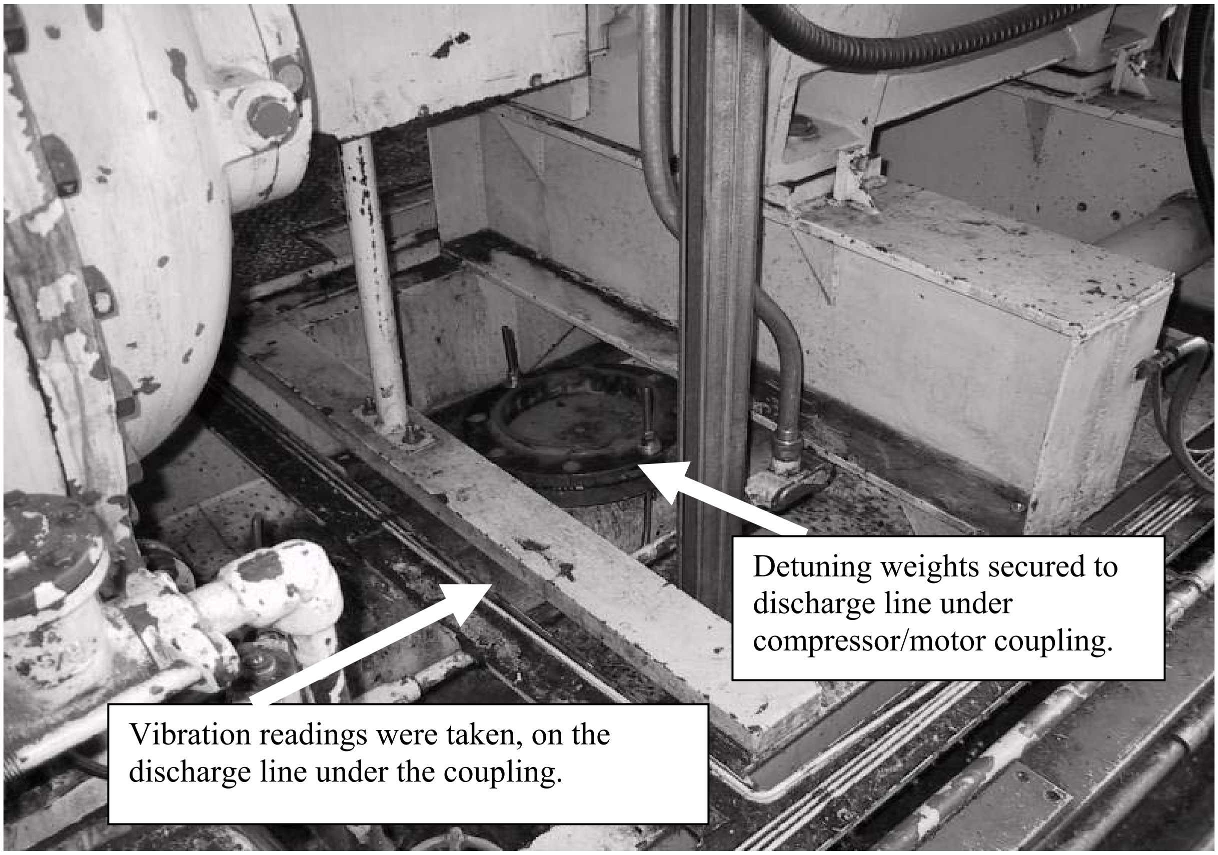


Figure 4: Discharge line de-tuning weight located under compressor/motor coupling.

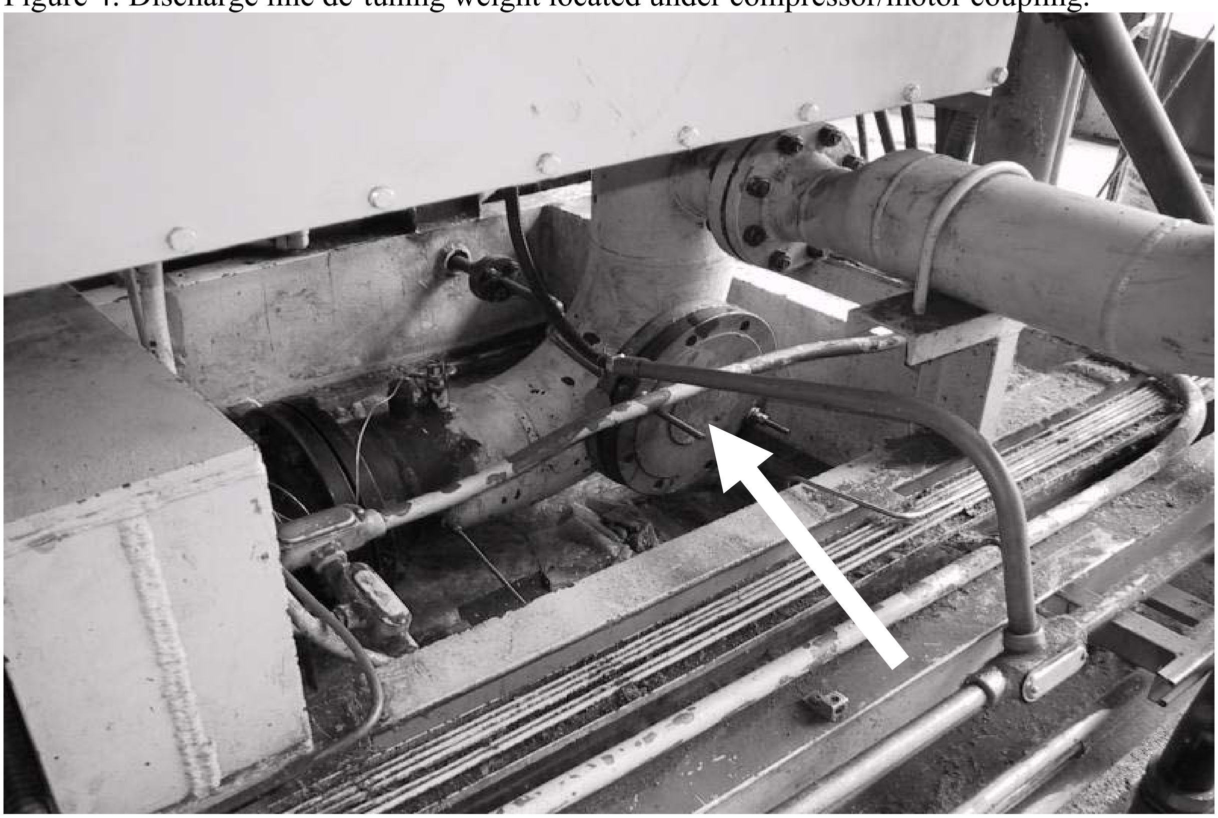
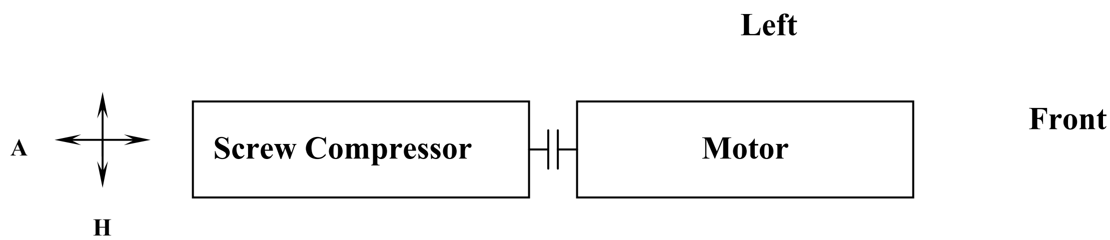


Figure 5: Discharge line de-tuning weight located at lower elbow before D118.

Unit Layout Top View



Instrumentation Used: DI Spectrum Analyzer Model DI 2200

Test Point Description: V01: where
V - Vibration reading in velocity inches per second peak.
01 - Test point

Directions:

Axial Direction (A) — direction parallel to the machine shaft.

Horizontal Direction (H) — direction perpendicular to machine shaft in a horizontal plane.

Vertical Direction (V) — direction perpendicular to a horizontal plane.

Job: Dow C118				**Date: 06/13/02**		
Test Pt.	**CH**	**Description**	**HVA**	**ips peak @ 118.75 Hz unless noted**	**Test #**	**Note**
V02	A	Vessel D118 ¼ up from base, location B	HA	1.65	1	
V17	A	Vessel D118 ¼ up from base, location B	HA	1.36	4	
V28	A	Discharge line under coupling	H	1.4	6	
V28	B	Discharge line under coupling	V	3.4	6	
V31	A	Discharge line, lower elbow before D118	H	1.3	6	
V31	B	Discharge line, lower elbow before D118	V	2.8	6	
V37	A	Discharge line, lower elbow before D118	H	0.15	12	
V37	B	Discharge line, lower elbow before D118	V	0.58	12	
V38	A	Discharge pipe near drain line	V	0.54	12	
V38	B	Discharge drain line flange	V	0.60	12	
V40	A	Vessel D118 ¼ up from base, location B	HA	0.19	13	

Test # and description:

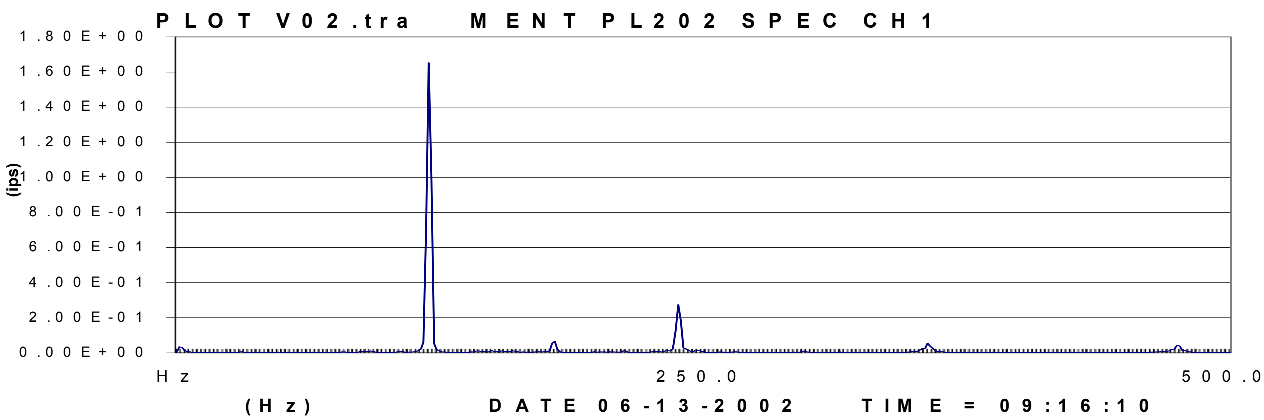
1 Vibration on discharge separator D118 with the bottom band clamp tight around vessel.

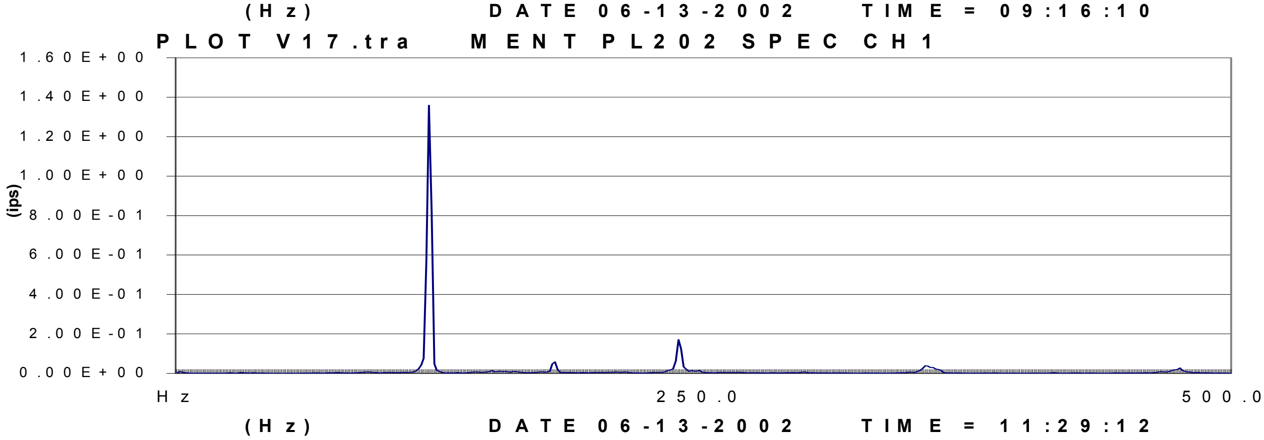
4 Vibration with four vessel bands on and four 4" 150# flanges hanging from the D118 discharge line. Vibration @ 118 Hz was 4.0 ips in the horizontal @ this location down to 0.6 ips peak on the bottom two 90-degree elbows. Vibration at 118 Hz in the horizontal was greater than 9 ips peak on the drain line under these elbows before the weights, now down to 2.0 ips peak.

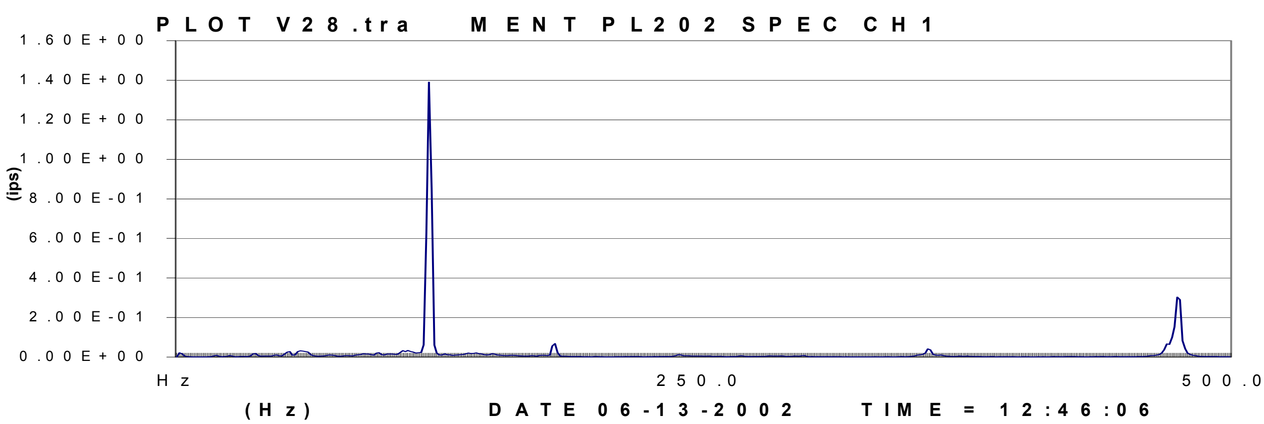
6 Vibration on the compressor discharge line with the clamp under the coupling end of the motor tight but not shimmed.

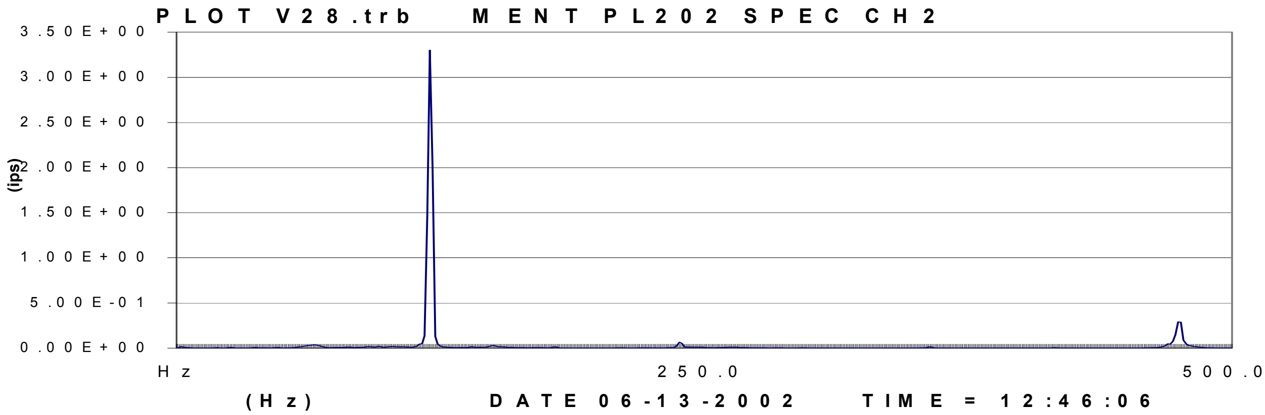
12 Vibration on the discharge line with two 8" 150 # flanges added as a de-tuning mass to the lower elbow of the discharge line before the cooler.

13 Vibration on discharge separator D118 with the as-left de-tuning weights in place.





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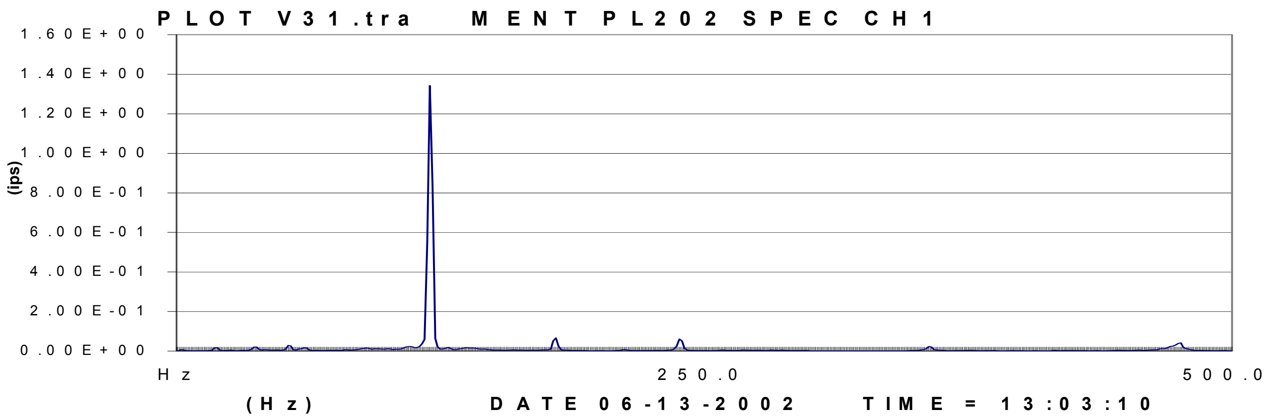
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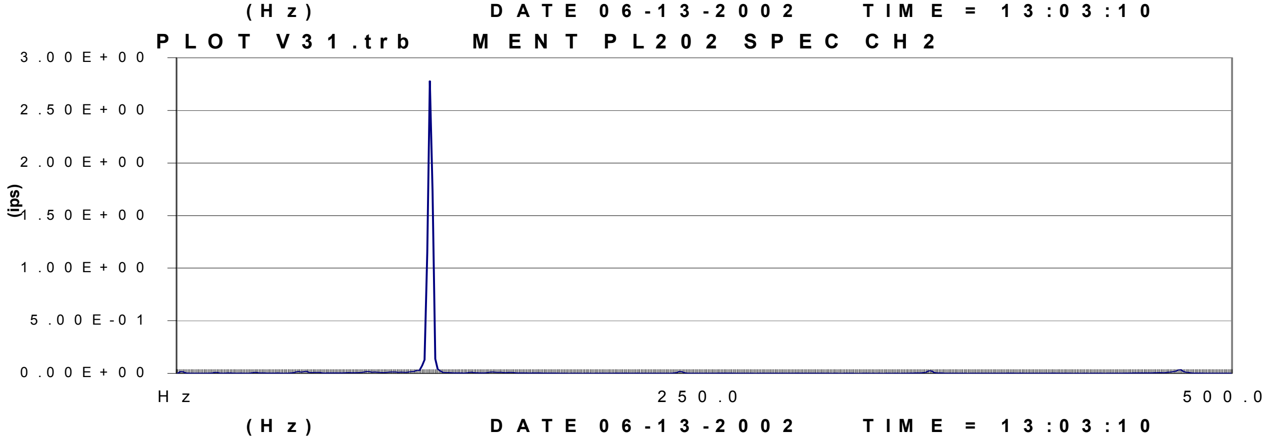
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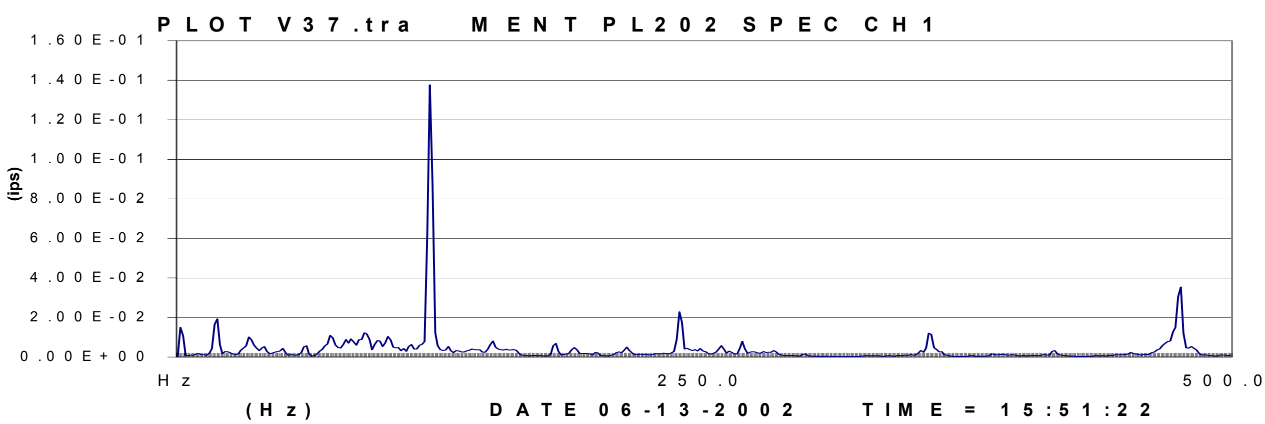
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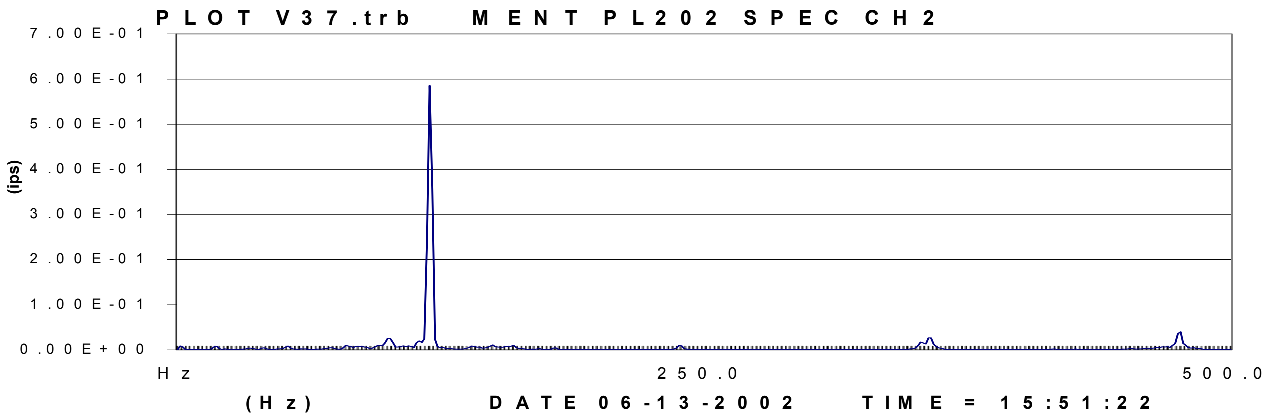
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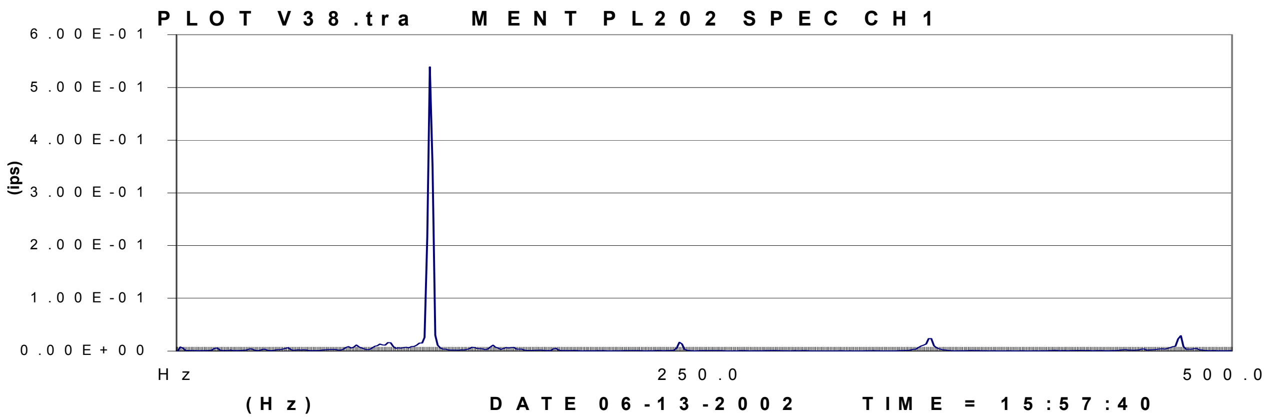
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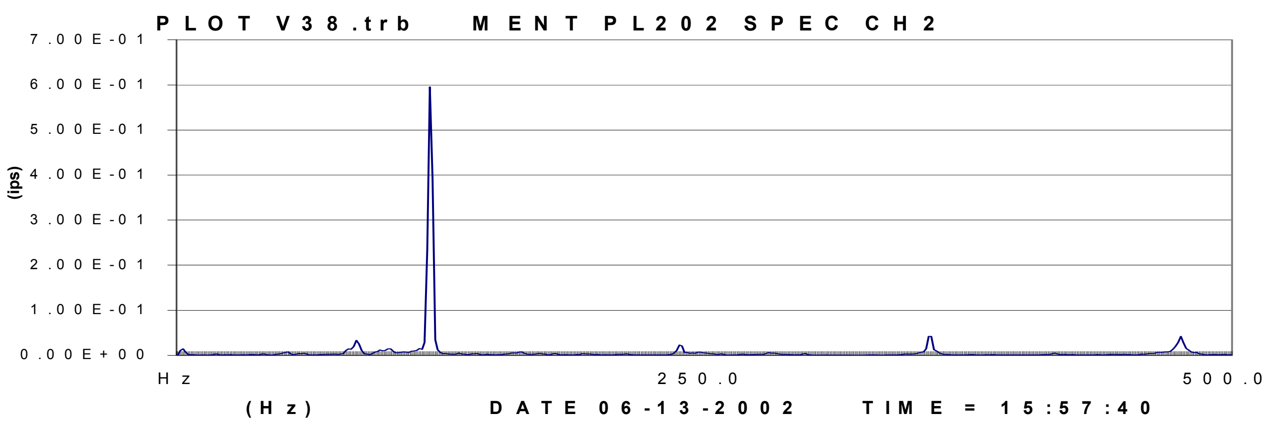
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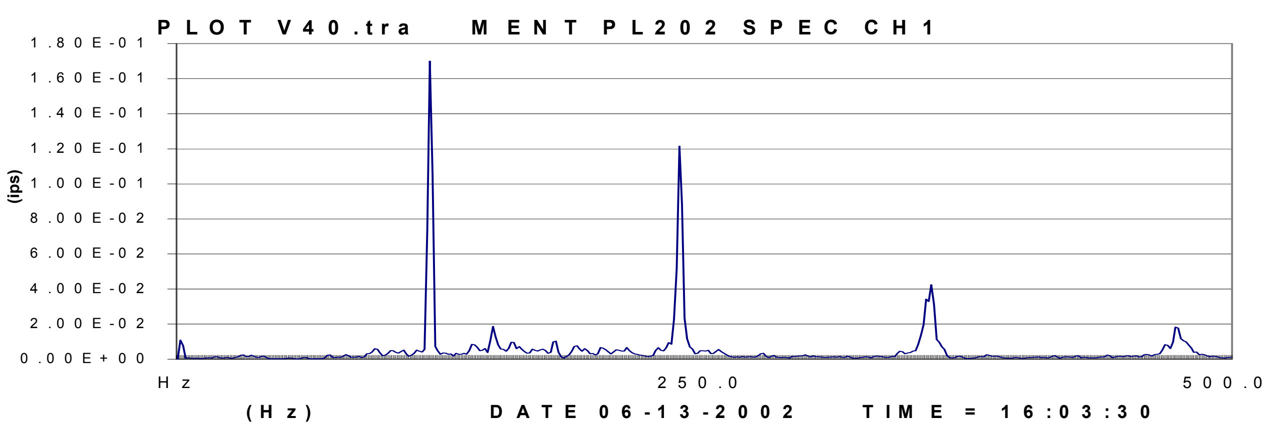
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3. CONCLUSIONS

Field de-tuning was very successful with vibration levels throughout the compressor package substantially lower as a result. Vibration reductions in the order of 10 fold were achieved. With the exception of periodically checking that the de-tuning weights remain securely attached no further action should be required.

4. ACKNOWLEDGEMENTS

The authors wish to thank Dow Chemical Canada for their permission to present this case.

5. AUTHOR BIOGRAPHY

Bryan Fofonoff obtained his Bachelor of Science degree in mechanical engineering from the University of Saskatchewan in Saskatoon in 1991. Bryan's first five years with Beta were spent doing computer simulations designing pulsation control on reciprocating compressor packages. For the last seven years Bryan has been full time troubleshooting pulsation and vibration issues on existing compressor installations.

Abnil Dejarme has been involved with Rotating Equipment and Vibration Analysis and Oil Analysis at Dow Chemical Canada for over 13 years. A graduate of Mechanical Engineering from The University of San Jose Recoletos (Phillippines), Abnil is a Certified Vibration Specialist, Certified Journeyman Millwright and has a Certificate in Construction Administration from the University of Alberta. He is a member of the Society of Tribologists and Lubrication Engineers.