BETA
Machinery Analysis

# THE BETA BULLETIN

VOLUME 12 #3

# Optimized Machinery Management

Somewhere, someone responsible for the safe, reliable, and efficient operation of his machines is mulling over a machine problem. He needs to make a decision but really needs more information. As it stands, either he goes on what his resources are able to provide or he decides that it is worth the extra time and cost required to call in the appropriate experts. After all, it's the bottom line that counts...

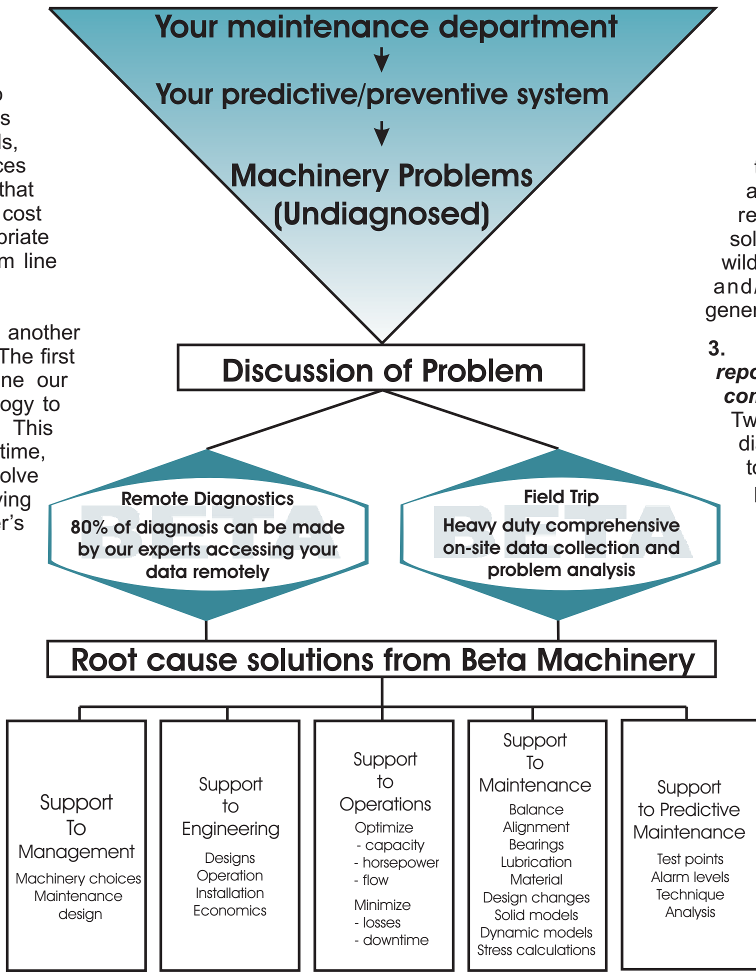
Beta Machinery is able to offer another choice - Remote Diagnostics. The first move would then be to combine our mutual experiences and technology to optimize the diagnostic effort. This would allow the balancing of time, accuracy and costs required to solve the machinery problem while having the best impact on the customer's bottom line.

What is Remote Diagnostics?

- A cost-effective alternative to traditional field diagnosis for a wide range of machinery performance, reliability and vibration problems.

What makes Remote Diagnostics an attractive alternative?

- Loss of frontline machinery experience through staff cuts, retirement, etc.
- Increased emphasis on bottom line accountability of all machinery.
- Increased capabilities in data collection equipment, either already in the hands of the machinery owner or rapidly deployed to site.
- Internet connectivity for data and imaging transfer.
- Beta staff has a combined 150 years of field experience with immediate access to computer modelling for rapid problem verifications and cost effective evaluation of potential modifications.




**Examples:**

**1.** ***Remote troubleshooting a reciprocating compressor vibration problem in China***
A vibration data collector was dispatched to China with the scheduled start up mechanic. Data collected upon arrival was e-mailed to Beta engineers who quickly verified the problem; the data also calibrated a mechanical model allowing our engineers to present an appropriate solution. Once implemented, the behavior of the modified system was quickly evaluated in the same manner. A small change was made to optimize performance, again verified. As a bonus, an engine misfire was identified, investigated and resolved.

**2.** ***Remote troubleshooting generator problems in remote northern Canada***
A vibration data collector was dispatched to site with detailed operation and test instructions. The site mechanic, with no previous experience, rapidly collected excellent initial data and e-mailed it to Beta engineers who identified a high

**Examples** (continued)
likelihood of a serious structural resonance. Additional tests, including mechanical natural frequency tests, were communicated to the site mechanic who again proceeded to collect and transmit excellent data for remote analysis. The skid structural resonance was confirmed. The solution provided prevented a costly wild goose chase into an investigation and/or replacement of unrelated generator parts.

**3.** ***Remote assistance and in-field reporting of multi-unit reciprocating compressor vibration assessment***
Two rewarding efforts utilized remote diagnostics to involve an off-site expert to review initial field data and produce preliminary field reports. The off-site analysis was conducted while the field data collection on subsequent units was still underway. This approach allowed the site engineer the ability to immediately involve the customer in the analysis and direct the on-site activities appropriately to avoid the necessity of a return visit. The success of this approach, which included a thorough consideration of a great deal of small bore piping vibration, can be largely attributed to an insightful graphical presentation of the vibration results that can be easily understood by all field personnel.

**4.** ***Remote assistance and in-field reporting during troubleshooting cement plant ball mill drive train vibration problems***
Initial vibration data was collected by a field engineer

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# "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

*- Bryan P. Fofonoff, BMA and Abnil Dejarme, Dow Chemical*

Beta Machinery Analysis wishes to thank Dow Chemical Canada for their permission to present this case.

### Abstract

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

The unit had exhibited high vibration for many years and experienced a number of failures. The 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 was 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.

### Introduction and History

In June of 2002, Beta Machinery Analysis conducted a field vibration analysis on a refrigeration screw compressor unit 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 had 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 compressor discharge. Shutdown time on this unit was rare and installing the orifice plate was not an option immediately available.

### Observations

The predominant frequency of the high vibration on this unit was 119 Hz (lobe passing frequency on the screw compressor). This was evident in a number of locations. Figure 1 is a plot of the typical vibration spectra encountered on the unit.

**Compressor Discharge Separator**

One of the areas where high vibration had been a major concern was the compressor discharge separator (vessel D118). At these frequencies (119 Hz) the vessel shell modes were a main concern. The thought process prior to beginning the field de-tuning was to affect the vibration modes by adding mass to the shell of the vessel.

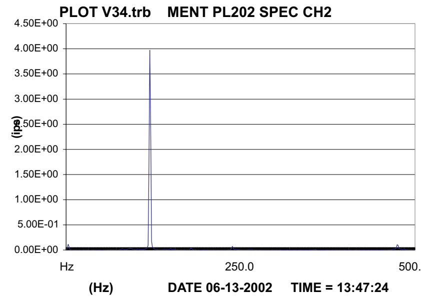


Figure 1 3.9 inches per second peak at 119 Hz on discharge line

Four band clamps that would fit around the outside of the D118 discharge separator to attach trial weights were constructed. The clamps were made of 1/4″ thick 4″ wide plate 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 2.

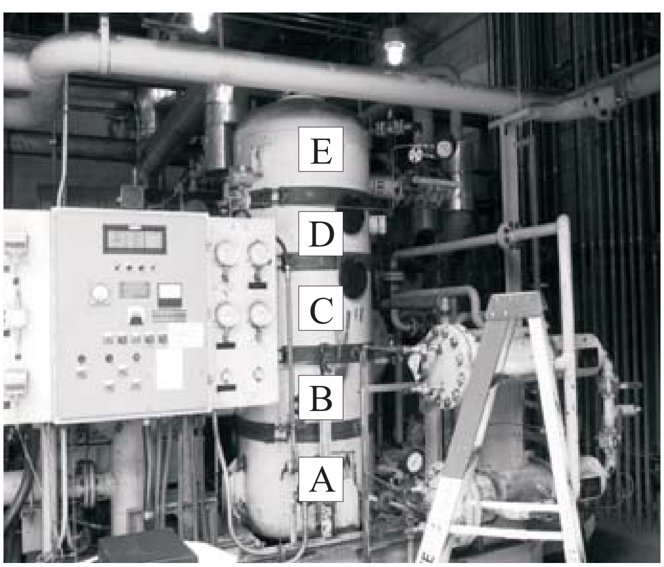


Figure 2 Discharge separator vessel D118 test point locations

Figure 3 Discharge piping from vessel D118 with de-tuning weights secured

Final vibration readings on the compressor discharge separator were 0.19 ips peak at 119 Hz as compared to the 1.65 ips initially encountered.

**Separator Discharge Piping** Very high vibration was also 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 3.

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.

Adding 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.

**Vessel Pressure Gauge** 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 1/2" blind flanges, as shown in Figure 4, eliminated the high vibration on the tubing line and pressure gauge.

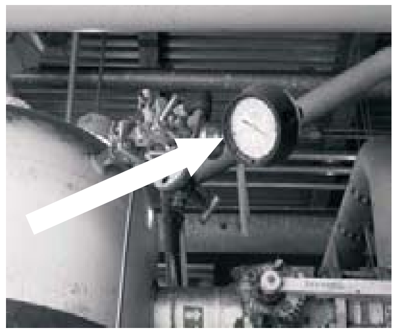

Figure 4 Vessel D118 pressure gauge and tubing line de-tuning weights

**Discharge Line** 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 5 and 6.

## 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.

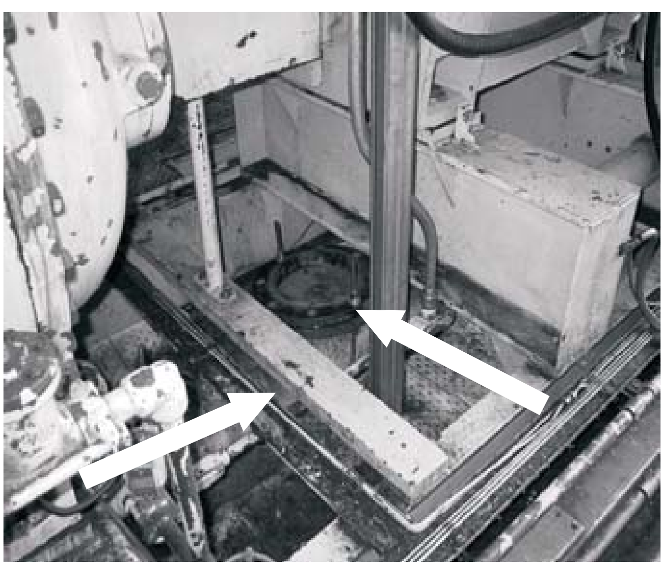

Figure 5 Discharge line de-tuning weight located under compressor/motor coupling

Figure 6 Discharge line de-tuning weight located at lower elbow before D118

continued from page 1...

and sent off-site for analysis by experts with wide ranging experience. A concise preliminary report with a graphical presentation of the supporting vibration data was available to the field engineer by e-mail next morning for a conference call presentation to plant engineers.

5. ***Remote performance analysis of reciprocating compressor***
The operation of an engine driven reciprocating compressor was improved by the implementation of recommendations derived solely from the off-site examination of log sheet data and operator phone interviews. This case very much highlights the importance of a partnership approach...neither entity is capable of achieving the same result without significant additional cost.

*It is our Wish*
*That you have a*
*Happy Holiday Season*
*and that your New Year*
*is healthy and prosperous.*

In lieu of sending cards, Beta has chosen to support local food banks.

## Rotating Machinery Services From Beta Machinery Analysis

Beta Machinery Analysis is widely recognized as a leader in engineering services for reciprocating machinery. But the Company also has a long and successful history of providing field and design services for rotating machinery. A few examples follow.

**Troubleshooting** - solutions to vibration, performance and reliability problems in industrial rotating machinery; diagnostic analysis leads to in-depth understanding of the problem and leads to cost effective solutions:

- Structural analysis encompasses mechanical natural frequencies, mode shapes, operating deflected shapes and damping evaluations
- Skid and foundation analysis determines dynamic characteristics of the support system
- Torsional analysis measures torsional vibrations, torsional natural frequencies
- Failure analysis determines the root cause of machinery failures and leads to cost effective correction

**Field balancing** - provides in-place balancing of rotor systems; notably multi-plane, flexible shaft balancing of turbogenerator rotor systems; "one shot" balancing of paper machine dryer cans.

**Alignment** - measurement of running alignment; guidance for correction where required; assessment of hot growth and soft foot conditions.

**Piping pulsation vibration analysis** - solves vibration problems in process piping and ducts; leads to practical, cost effective solutions; centrifugal compressors, screw compressors, centrifugal pumps.

**Condition audit** - evaluates mechanical condition and performance during normal operation; provides information for condition based maintenance and for improved operation; identifies conditions posing reliability threats; predictive maintenance audits evaluate in-house predictive maintenance programs and identify how to achieve improved results. Vibration Profiling for paper machines.

**Design audits** - computer simulation of proposed design to ensure reliability. Can involve critical speeds of shaft/bearing systems, transient torsional response with synchronous motor drives, balance sensitivity studies.

**Remote monitoring and diagnostics** - from data supplied by customer over internet; evaluates mechanical condition, performance; provides troubleshooting guidance; fast and cost effective.

**Training** - covering a range of machinery topics including vibration, pulsation, predictive maintenance. Training is customized to customer requirements.

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|---|---|---|
| > centrifugal compressors | > screw compressors | > gas turbines |
| > steam turbines | > turboexpanders | > electric motors |
| > centrifugal pumps | > fans & blowers | > paper machines |
| > turbochargers | > piping | > frames and foundations |
| > structures | > gearboxes | > pulp refiners |

## News & Notes

The CMVA Annual Meeting and Trade Show was held in Halifax, Nova Scotia from October 27 to 31, 2003. Beta's Brian Howes, Bryan Fofonoff, and Bill Eckert presented papers.

Beta's "Improving the Reliability & Performance of Reciprocating Compressors" seminar was presented at the GMRC Workshop in Houston.

Beta was at the annual Gas Machinery Conference in Salt Lake City. The following papers were presented:
- "Restoring Crankshaft Alignment: A Case History" - Mark Deutscher and Brian Howes
- "Vibration Related Failures of Small Bore Attachments" - Brian Howes and Chris Harper
- "Torsional Vibration Modelling and Analysis" - Rodney Varty and John Harvey

The GMRC held the Engine Analyzer & Reliability Workshop in Nashville, Tennessee. Mark Deutscher presented "Troubleshooting Vibration & Pulsation Problems".

Our website is still a work in progress. Hopefully you will be seeing changes over the next few months. We would love to hear from you with your comments and suggestions on what you might like to see. Contact us at info@betamachinery.com.

Our regular seminars, Torque Talk, Pulsation Vibration, and Field Troubleshooting, will be offered in our Calgary office in the coming months. Onsite training may be arranged. E-mail us at info@betamachinery.com or call Sarah at 1-800-561-2382 to register or obtain further information on our training opportunities.

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