BETA
Machinery Analysis

THE BETA BULLETIN

VOLUME 11 #1

A Major Wreck Prevented

Probably most of our readers are aware that Beta Machinery Analysis has a unique tool called the "B-Probe" which is used to measure critical engine internal clearances without the need for disassembly. During the second half of 2001 we were involved in a pilot program for a major US oil & gas company. The customer wanted to evaluate the benefits of Beta's approach to managing these assets.

Comprehensive analyses were performed at a number of the customer sites. A number of deficiencies were found and corrected. More significantly, planned major maintenance was deferred based on reliable information about engine condition, thus saving a substantial amount.

Then came the "show stopper", as the customer representative described it. A rod bearing clearance on a large integral unit was measured at 0.017". This is two to three times a normal and reasonable clearance for this particular situation. The Beta analyst immediately informed the facility manager. The manager deployed a maintenance crew to remove and inspect the bearing.

What they found is shown in the pictures below. Customer personnel were, in their own words, "amazed". They are sure that if this unit had run much longer in this condition there would have been a severe crash causing major crankshaft and frame damage. A Company specialist estimated that the repair cost could easily have run $500,000 to $1,000,000. Lost production revenue would likely have been even greater since this unit is critical to production.

Detecting incipient failures and preventing wrecks is not the only reason for an analysis program. More often than not the major saving is from doing less maintenance. But sometimes, as in this case, preventing a failure has a huge economic benefit.

News & Notes

A two day course entitled "Improving the Reliability and Performance of Reciprocating Compressors" and sponsored by the Gas Machinery Research Council was held in Houston late in 2001. The instructors were Bryan Long, Frank Fifer and John Harvey of Beta Machinery Analysis. Participants gave the course very good reviews. It will be held again this coming September 10th and 11th.

At the same Houston facility that week, a course entitled "Fundamentals of Gas Compressor Foundation Repair and Maintenance" was put on by the GMRC and taught by Bob Rowan. BMA personnel sat in on this course and were very impressed. It is scheduled again for the GMRC Field Maintenance Workshop April 30 to May 2 in Oklahoma City.

Beta's Pulsation/Vibration, Torque Talk, and Balancing Compressor Design with Risk seminars will be held in the Calgary office during the first quarter. If you have staff interested in attending please contact us.

This years Condition Monitoring Educational Conference and Exhibition, hosted by the Society of Tribologists and Lubrication Engineers (STLE), will be held in Dallas, TX, Feb. 18-20. The theme is “Monitoring Your Way to Profitability.” Beta’s Mike Lubich is scheduled as a keynote speaker.

INSIDE:

"PROFILING" OF PULSATION AND VIBRATION IN COMPLEX RECIPROCATING COMPRESSOR FACILITIES

ABSTRACT

Eleven integral reciprocating engine and compressor packages are operating in one natural gas storage and transmission application. Together the units comprise more than 50,000 hp on a common header system. Sorting out pulsation and vibration problems by reviewing multiple spectra is a daunting task if viewed one test point at a time. Crucial information can be missed. The shear volume of data can overwhelm an analyst.

Presented is a method of "profiling" data in which unit pulsation and vibration can quickly, easily, and accurately be evaluated. A thorough comparison of units operating under different loads, speeds, and conditions was made in a fraction of the time normally required. "Profiling" saves time and money, offers a deeper understanding of pulsation and vibration concerns, and shows clearly the benefits to be expected by resolving those concerns.

1. INTRODUCTION

A pulsation and vibration analysis was conducted on a large natural gas storage and transmission facility. The purpose of the analysis was to determine the cause of, and possible solutions to, ongoing vibration concerns on the integral compressors. The station consists of eleven units that were installed over a period of approximately 30 years. The study was to determine if a particular unit was contributing more to the problem than the other units. Operations staff felt that Unit K705 historically exhibited higher vibrations than did their other 10 similar units. Reported symptoms of the vibration problem on Unit K705 included, excessive shaking of the catwalks, cracked compressor base grouting, and broken pipe supports and pipe nipples at the unit block valves. Unit K705 was the fifth installed and the first with infinite step unloaders. On initial installation in the early 1970's, Unit K705 was determined to have a pulsation problem and a new discharge dampener was designed and installed. In later years Units K706 through K711 were installed on substantially larger foundations.

2. THE EVALUATION

Vibration and pulsation was evaluated on three of the eleven integral engine compressor packages under various loads and combinations of units on line. To facilitate a thorough understanding of a complicated system, vibrations and pulsations were *profiled*. The profiling technique compares multiple test points and allows for a complete understanding of how units compare to each other and behave at various loads and speeds. Without profiling, visual comparison of more than 100 plots would have to be made.

Vibration profile introduction:

Measurement points were:
C1 to C4 head ends of the compressor cylinders.
EOF, E2 to E9, and EFE engine anchors and engine main bearing.
DF, D1 to D4, DB, DH discharge bottle front, discharge bottle at cylinders 1 to 4, discharge bottle back end, discharge header test points respectively.
SF, S1 to S4, SB, SH suction bottle front, suction bottle at cylinders 1 to 4, suction bottle back end, suction header test points respectively.

For each test point the bar hatching refers to the direction of vibration as follows:

Horizontal hatch refers to the direction parallel to compressor piston motion.
Vertical hatch refers to the vertical direction.
Diagonal hatch refers to the axial direction or perpendicular to compressor piston motion in the horizontal plane.

- Overall profiles display the overall vibration from all sources at each measurement point.
- The Rotational Dominant Profile searches the orders of unit run speed and profiles the highest level. It annotates a number above the bar if the largest level displayed is other than the fundamental 1x rotation.
- The Rotational Profile compares vibration levels at specific harmonics of run speed.
- The Remainder Profile displays the highest vibration levels not identified in the Rotational Profiles, (usually energy from a unit running at a different speed).

Profiles were taken for the following tests and are discussed in detail on the following pages.

Test 1, 20-Feb-01 08:38:30, Unit K707 running in the range of 331 to 334 rpm.
Test 2, 20-Feb-01 13:40:56, Unit K705 running in the range of 341 to 344 rpm.
Test 3, 21-Feb-01 08:09:13, Unit K705 running at 350 rpm.
Test 4, 21-Feb-01 11:42:05, Unit K707 running at 350 rpm.
Test 5, 22-Feb-01 06:15:40, Unit K711 running at 350 rpm.

Fig. 2.1: Cylinder vibration.

2.1 In Figure 2.1 the plots from top to bottom are test 4 - K707, Test 3 - K705, Test 2 - K705, and Test 1 - K707. K705 in test 2 exhibits slightly higher cylinder vibration than does K707 in test 1 however K705 was running about 10 rpm faster. With both units running full speed at 350 rpm in tests 3 and 4, overall vibration increases on both units with the maximum vibration level measured to be about 0.7 inches per second peak in the vertical direction. The maximum vibration occurs in the vertical direction on both units but at opposite ends of the machine. The levels measured are not considered to be excessive.

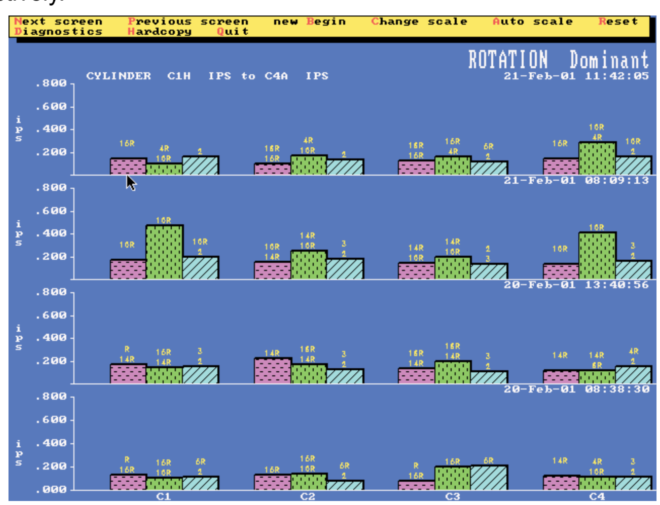

Fig. 2.2: Cylinder vibration Rotational Dominant.

2.2 Rotational dominant profiles in Figure 2.2 indicate that the majority of the vibration on the cylinders is at higher harmonics (10R being the most prominent). The 10R component corresponds to 58 Hz. Pulsation levels were found to be highest at 58 Hz and in the case of K705 the mechanical natural frequency of the suction bottle was measured to be in this range.

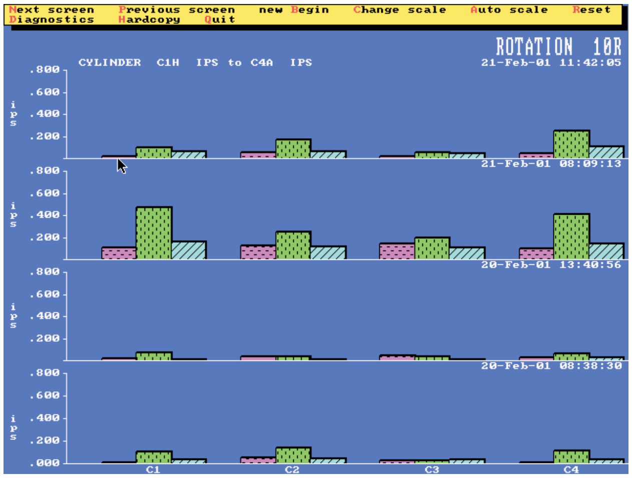

Fig. 2.3: Cylinder vibration rotation 10R.

2.3 In the rotational 10R profile it becomes obvious that both Unit K705 and K707 experience an increase in the 10R component but for Unit K705 the increase is more pronounced because of the mechanical resonance.

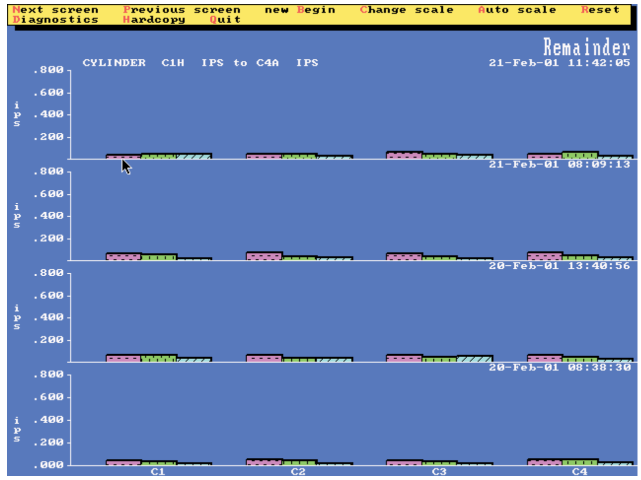

Fig. 2.4: Cylinder vibration remainder profile.

2.4 The remainder profile indicates less than 1/10 of the overall vibration levels can be attributed to energy at frequencies other than multiples of the run speed on each unit.

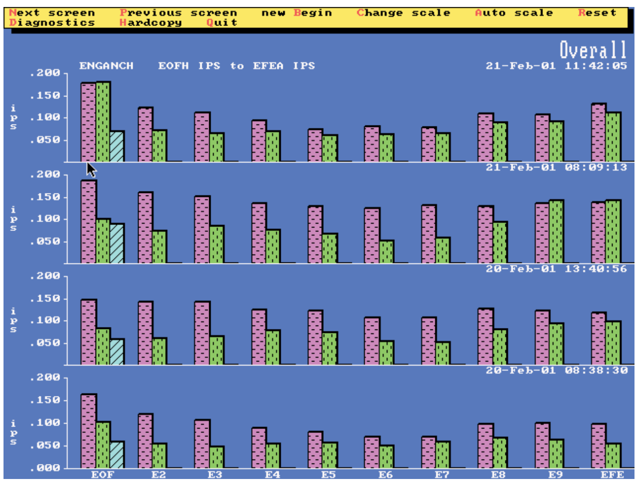

Fig. 2.5: Engine Anchor Overall Vibration.

2.5 Unit K705 has slightly higher overall vibration across the machine as compared to K707. Both units show an increase in vibration levels with the increase in speed to 350 RPM. Unit K707 shows an increase in vertical vibration at the opposite the flywheel end anchor location. Rotational dominate, discrete, and remainder profiles weren't significant and aren't included.

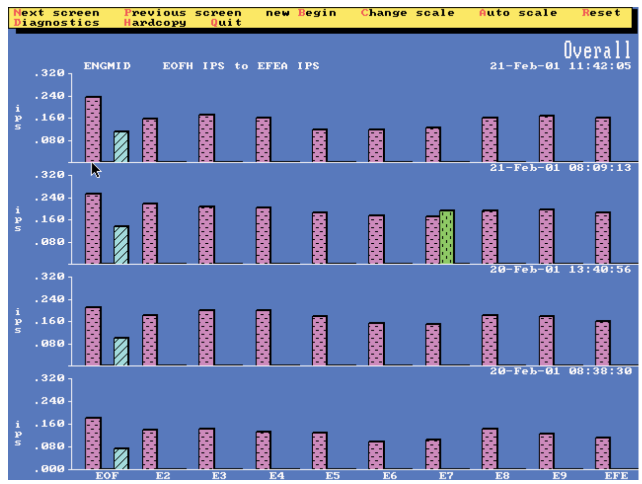

Fig. 2.6: Engine at main bearing height rotational dominant.

2.6 No problem here at the engine mid height. Similar to the vibration at the anchors in item 2.5, there was an increase in amplitude with speed and K705 has slightly higher vibrations at some locations.

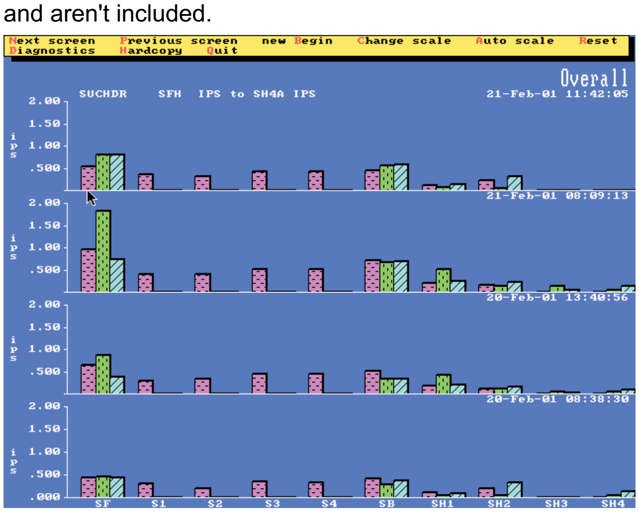

Fig. 2.7: Suction system vibration overall.

2.7 A significant increase in vertical vibration on the inlet end of the suction bottle is evident for Unit K705 with the increased speed of Test 3.

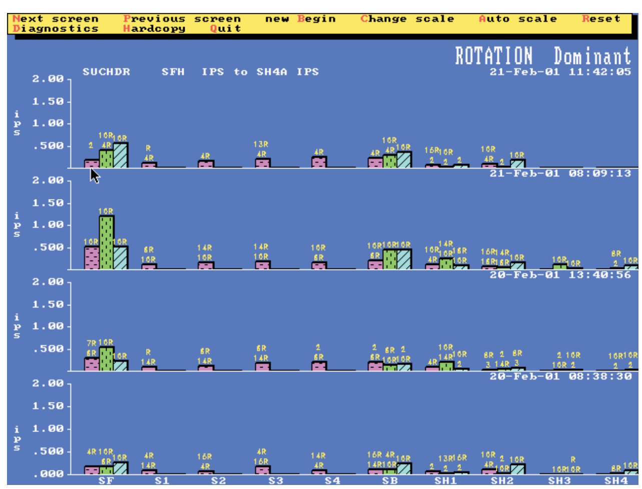

Fig. 2.8: Suction system vibration rotational dominant profile.

2.8 The rotational dominant profile shows that the significant increase in vibration at the front end of the suction bottle is due to the 10R component.

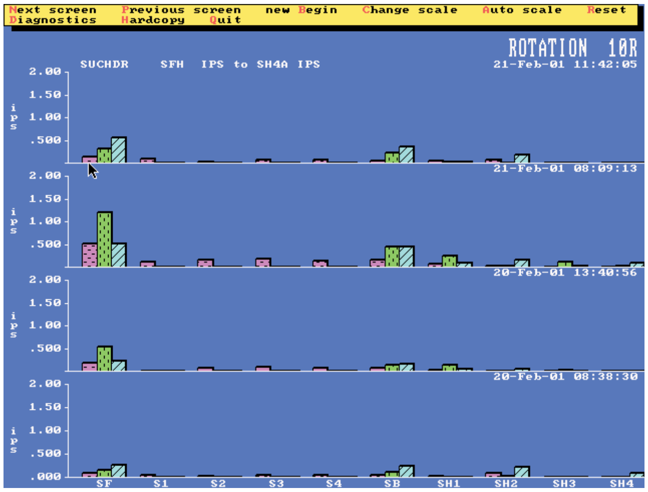

Fig. 2.9: Suction system vibration 10R

2.9 The 10R or 58Hz component increases dramatically at the front end of the suction bottle but is not as significant elsewhere on the suction system. The increase is clear evidence of the mechanical resonance at this frequency.

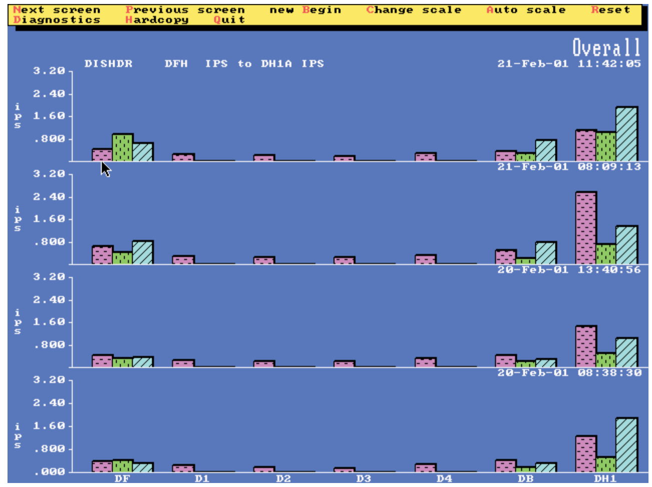

Fig. 2.10: Discharge system overall vibrations.

2.10 The K705 discharge pressure safety valve has excessive vibration in the horizontal direction at 350 rpm. This safety valve is mounted in an elevated position next to the outside wall of the compressor buildings. Unit K707 has moderately high vibrations at this location.

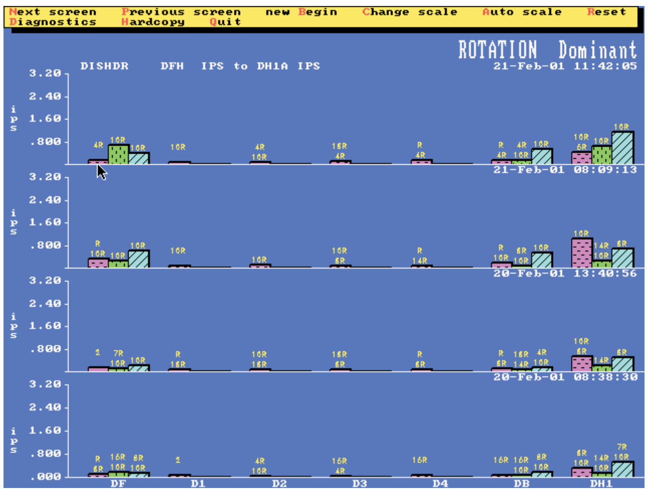

Fig. 2.11: Rotational dominant profile of the discharge system vibrations.

2.11 The 10R component again shows up as the dominant order at the location of high vibration. The motion of the pipe below will significantly affect vibration on the pressure safety valve. The high vibration on the K705 suction bottle will be the major contributor to the vibration on the pressure safety valve.

3. FINDINGS

On Unit K705, high vibrations were observed on the unit block valves, on the inlet end of the suction bottle and on the discharge pressure relief valve. The high vibration in these areas is resulting from a coincidence of a structural natural frequency with pulsation induced unbalanced forces. Enhancing the support at the unit block valves should sufficiently raise the mechanical natural frequency in this area to reduce vibrations to acceptable levels. The header catwalk is not supported as well at Unit K705 as it is at the other units. Adding more support in this area will reduce vibration on the catwalk. Cracks in the grout at the engine anchors are developing on Unit K705 and winking between the feet and sole plates was evident. Ensuring adequate bolt stretch, and monitoring vibrations and web deflections will allow for continued operation without major reworking at this time. With the significant horsepower of this facility a substantial degree of vibration will be expected. This analysis did not determine that a major rework of the pulsation control is in order. Differences in the foundations and floor support beams between Unit K705 and the newer units, accounts for the greater perception of vibration around Unit K705.

4. CONCLUSIONS

For this analysis profiling offered a thorough understanding of how multiple units on the same service compared to each other at various operating conditions. Doing this evaluation manually would have required looking over and understanding hundreds of spectra. Profiling reduced the process to minutes and proved an excellent tool for defining the problem areas.

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