

MACHINE VIBRATION STANDARDS: OK, GOOD, BETTER & BEST

Part 4 – Comparative & Historical Standards

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Different Types Of Vibration Standards

- 1) ABSOLUTE, GENERAL (OK)
- 2) ABSOLUTE, MACHINE SPECIFIC (GOOD)
- 3) COMPARATIVE (BETTER)
- 4) HISTORICAL (BEST)

Comparative Vibration Standards (Better)^[18 & 19]

- Both comparative & historical vibration standards differ from absolute standards in that they don't begin with assumptions of what a machine's vibration levels should be. They instead essentially let either the history from a group of similar machines or an individual machine's history "decide" what the levels should be.
- Comparative vibration standards involve the following:
 - 1) How one machine's vibration levels at a specific measurement point compare to that at a very similar machine (families of machines).
 - 2) How the vibration level
 - 3) Statistical standards can be applied in at least two different ways:
 - 4) Using the history from a specific measurement point on an individual machine.
 - 5) Using the combined histories from specific measurement points from similar machines.
- The current vibration level is compared to either a multiple of the baseline level (usually 50-100% of baseline) or the average level plus a multiple of standard deviations from that average (usually 1, 2 or 3 standard deviations).
- If both no machine history and no similar machines are available for comparison, one can begin with baseline levels and observe for changes (usually 50-100%) from them.
- Statistical standards generated from historical data become more and more meaningful when either longer histories or a greater number of similar machines are used.

Comparative Vibration Standards (Better)

- ◆ PROS:
 - a) Can be applied immediately if either a baseline approach is taken or if a number of similar machines exist in the plant.
 - b) Accounts for most (similar machines) if not all (individual machine history) of the unique characteristics that determine a machine's final vibration level such as machine type, mounting, speed, loading, etc.
 - c) Gives a unique perspective to determining the severity of similar problems on different machines. Quite often makes the job of picking which of the bad machines to work on during the upcoming outage more easy than it would be otherwise.
 - d) Once substantial historical data are acquired from either an individual machine or a group of similar machines, these standards become quite powerful in detecting problems.

- ◆ CONS: If using calculated average + standard deviation values, either a large amount of historical data from an individual machine or a good number of similar machinery in the plant are required to generate meaningful standards.

Historical Vibration Standards (Best)

- Historical or Baseline data from the exact machine & point in question (BEST)
- Historical data from the exact machine & measurement point in question will almost always be superior to all other types of standards or specifications. This is because it takes into account all the pertinent factors effecting machine vibration such as:
 - 1) The specific dynamic forces present
 - 2) The specific machine's & base's combination of mass, stiffness & damping
 - 3) Loading
 - 4) Speed
 - 5) Unique process conditions
 - 6) Transmission of vibration from nearby machinery
- PROS: a) Provided enough historical data exists, this technique arguably provides the most accurate indication of changing machine conditions as it is based specifically on the machine in question with all its unique characteristics.
- CONS: a) Requires historical data on the machine in question to be effective, and the more historical data available, the more meaningful the technique becomes, b) If a machine begins its service with problems, there is a chance these problems could be overlooked for some time as this technique by definition watches for changes from the long-term historical trend (perspective - can't see the forest for the trees,etc).

Common Vibration Parameters

- ◆ Below is a list of common vibration parameters used by the author to determine a machine's condition. Not all parameters are created equal. Each has their own strength's & weaknesses. **The best parameter is the one most sensitive to the problem's you experience most often on your machine.**
 - 1) **Overall levels** (ips-pk, ips-rms, etc)
 - 2) **Waveform levels** (g's-pk, g's-pk-pk, etc)
 - 3) **1x RPM levels**
 - 4) 2x RPM levels
 - 5) Subsynchronous levels (below 1x rpm)
 - 6) Electrical frequency levels (ie: LF, 2x LF or 6x LF, etc)
 - 7) Vanepass levels and multiples thereof
 - 8) Gearmesh levels and multiples thereof
 - 9) Bearing fault frequencies or band levels
 - 10) High frequency energy bands such as HFD, Spike Energy, etc
 - 11) Levels from acceleration enveloped or "Peakvue" data.
- ◆ Meaningful parameters should be chosen based on the forcing frequencies generated by the unique machine in question.
- ◆ All the examples of parameters mentioned above are valid for particular machinery, but the first three parameters **underlined** and in **bold** above are in the opinion of the author the three most important to be monitored for nearly all machinery.

Normal Distribution Curve – Statistical Standards^[19 & 20]

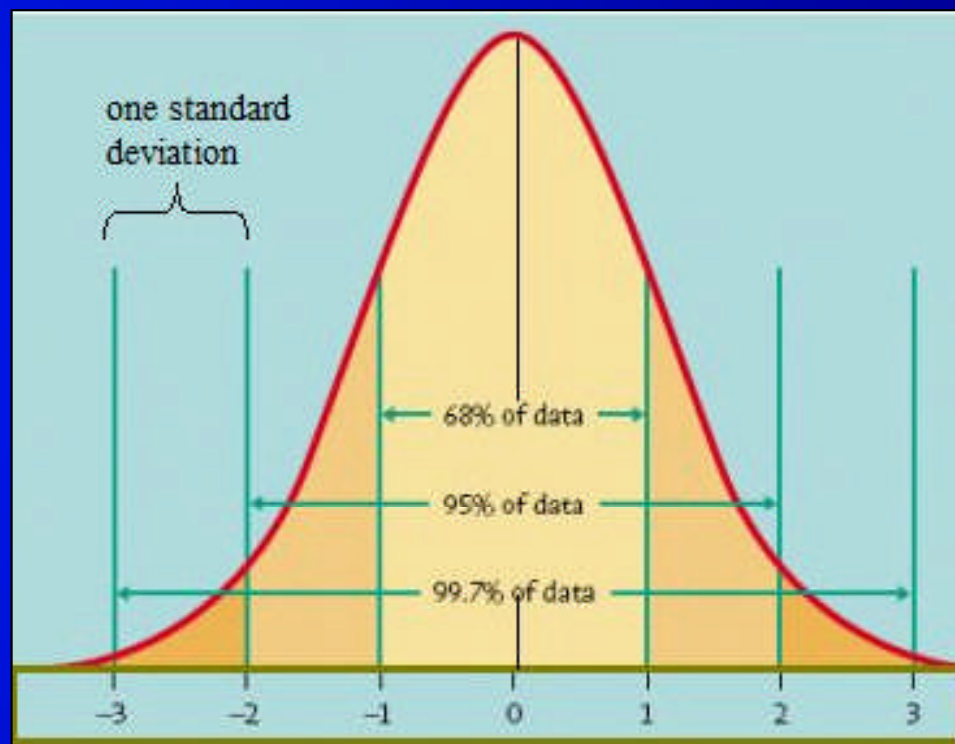
A normal distribution curve or histogram as shown at right represents the theoretical limits your historical data should fit within if no significant problems exist.

The more historical data used to calculate the average & standard deviation, the more meaningful these limits become.

Your chance of achieving anything like a normal distribution curve from your historical vibration data improves if done on the same machine, same measurement point as opposed to similar machines.

In general, those data that don't fit within 2 or 3 SD from the average increasingly indicate that either a problem exists or that they are "outliers" (bad data). In either case, they should be further investigated.

These calculations of average values & standard deviations, etc can be made either by the vibration database software itself or by a spreadsheet software such as Excel once the data is exported.



Real world historical data versus the normal distribution curve

- Real historical vibration data will many times not conform perfectly to this normal distribution curve due to factors such as:
 - 1) Changes in the process such as load, pressure, speed, etc.
 - 2) Different personnel collecting vibration data.
 - 3) Different transducer used.
 - 4) Different transducer mounting used.
 - 5) Differences in surface quality that transducer is mounted on (dirty, not level, etc).
 - 6) Changes in the amount of vibration transmitted from nearby machines.
- To the degree to which these factors and others not mentioned can be controlled, your historical vibration data should conform better to the normal distribution curve.
- It is thought by the author that much can be learned going forward by the study of histograms of historical vibration data.

Tight grouping is better Consistency → tight grouping

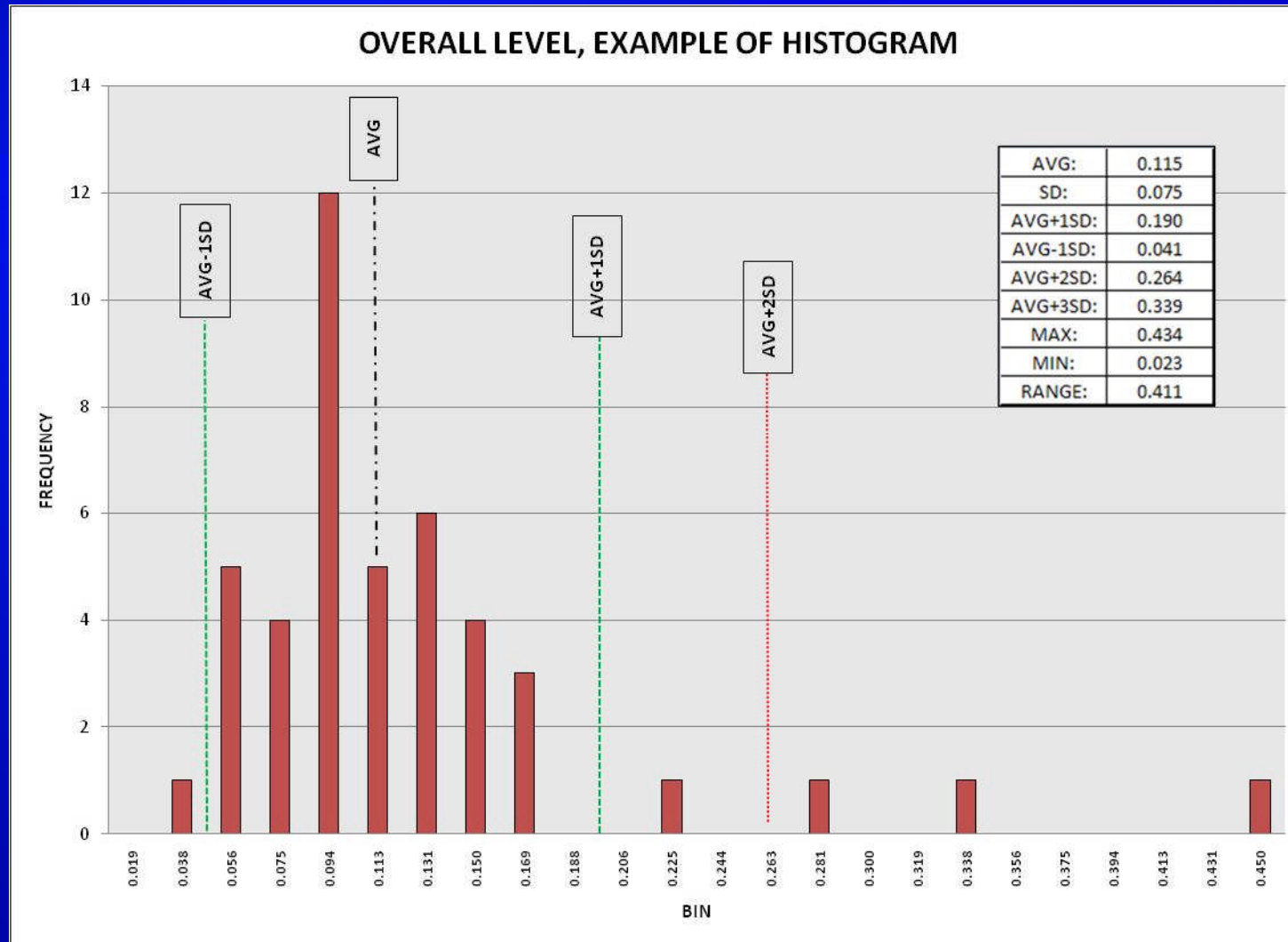
Tight Grouping



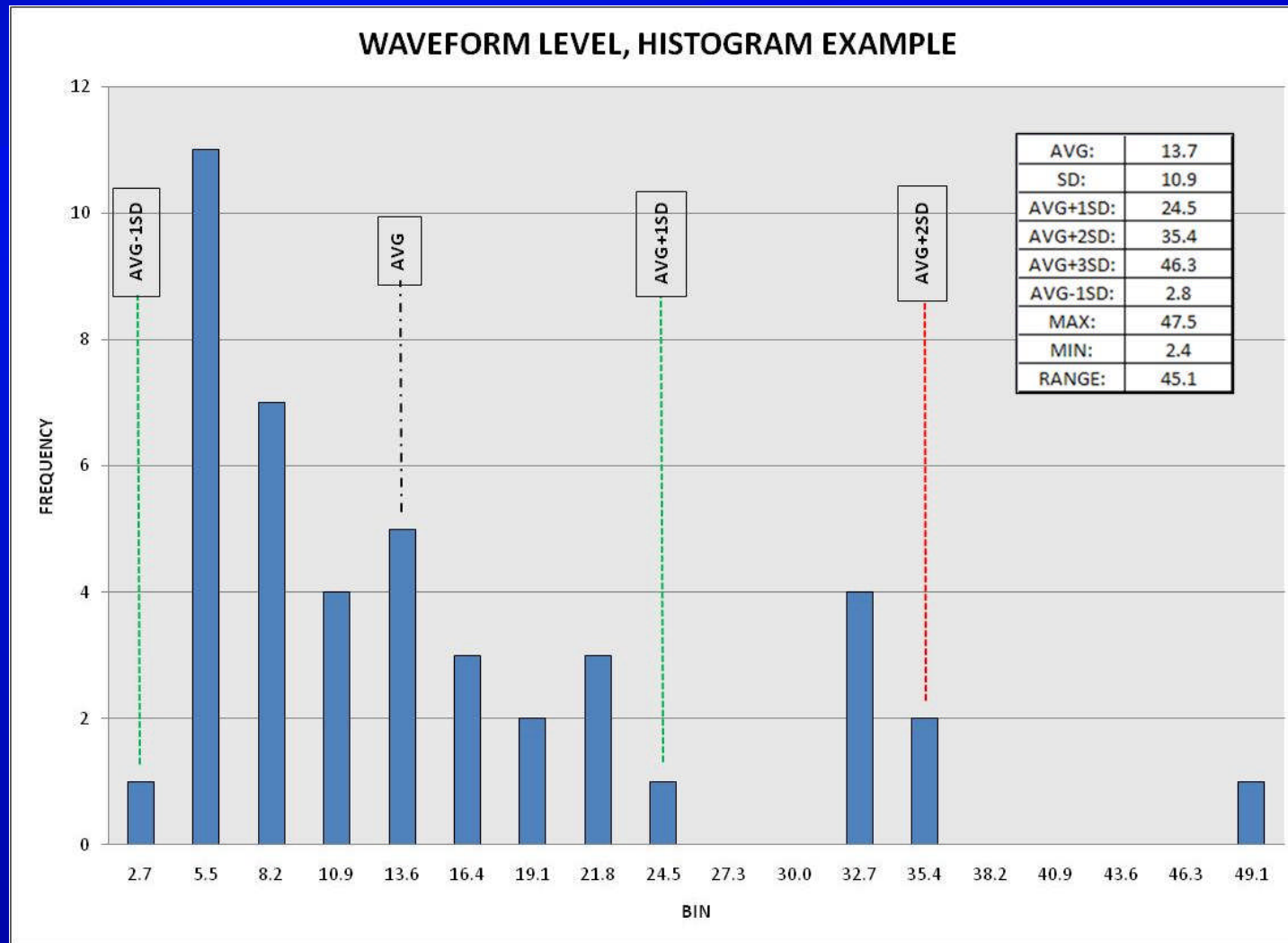
Not So Tight Grouping



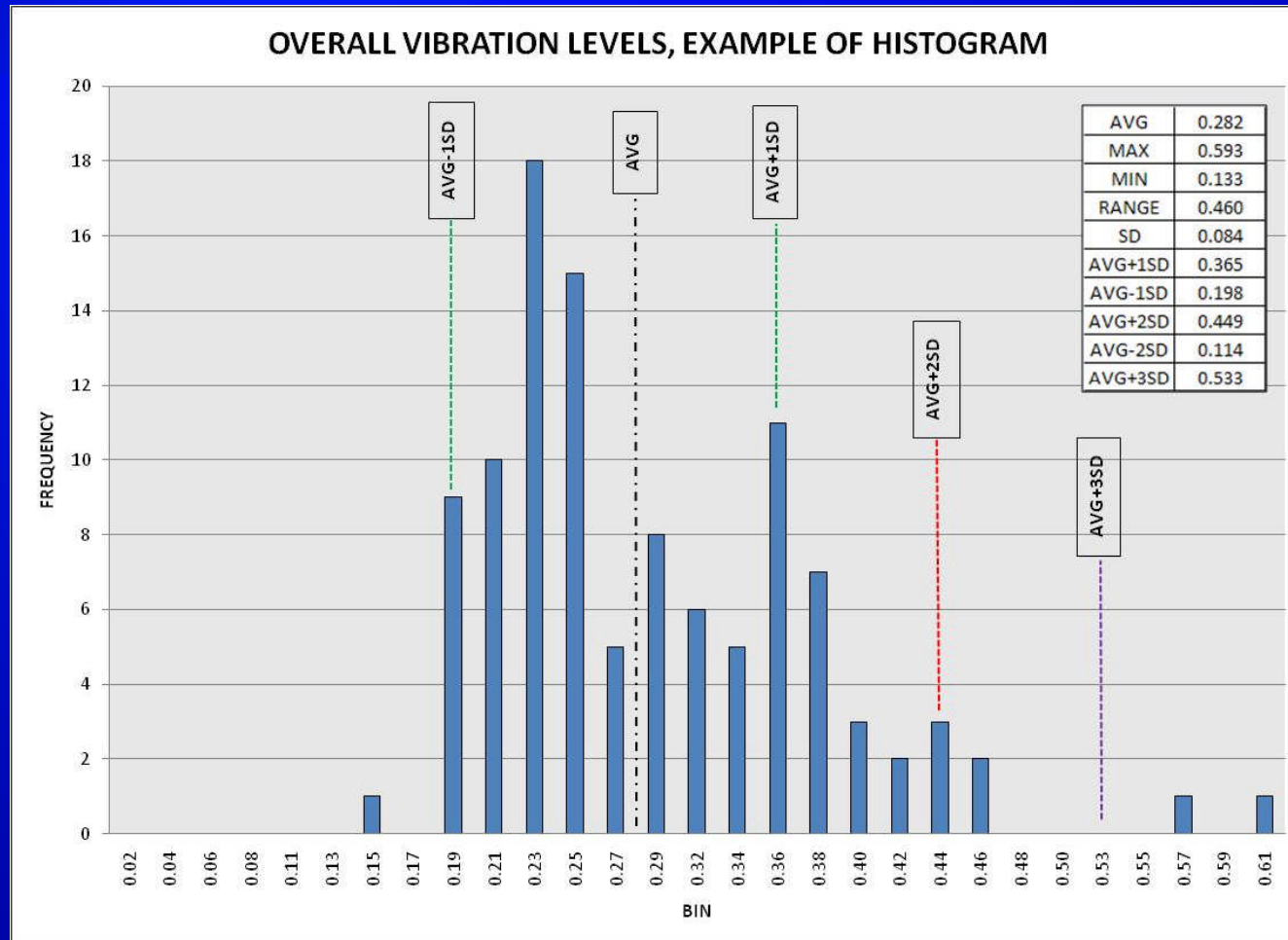
Histogram of overall vibration levels on a family of similar motors



Histogram of waveform levels on a family of similar motors



Histogram of overall vibration levels on a family of similar rotary screw compressors



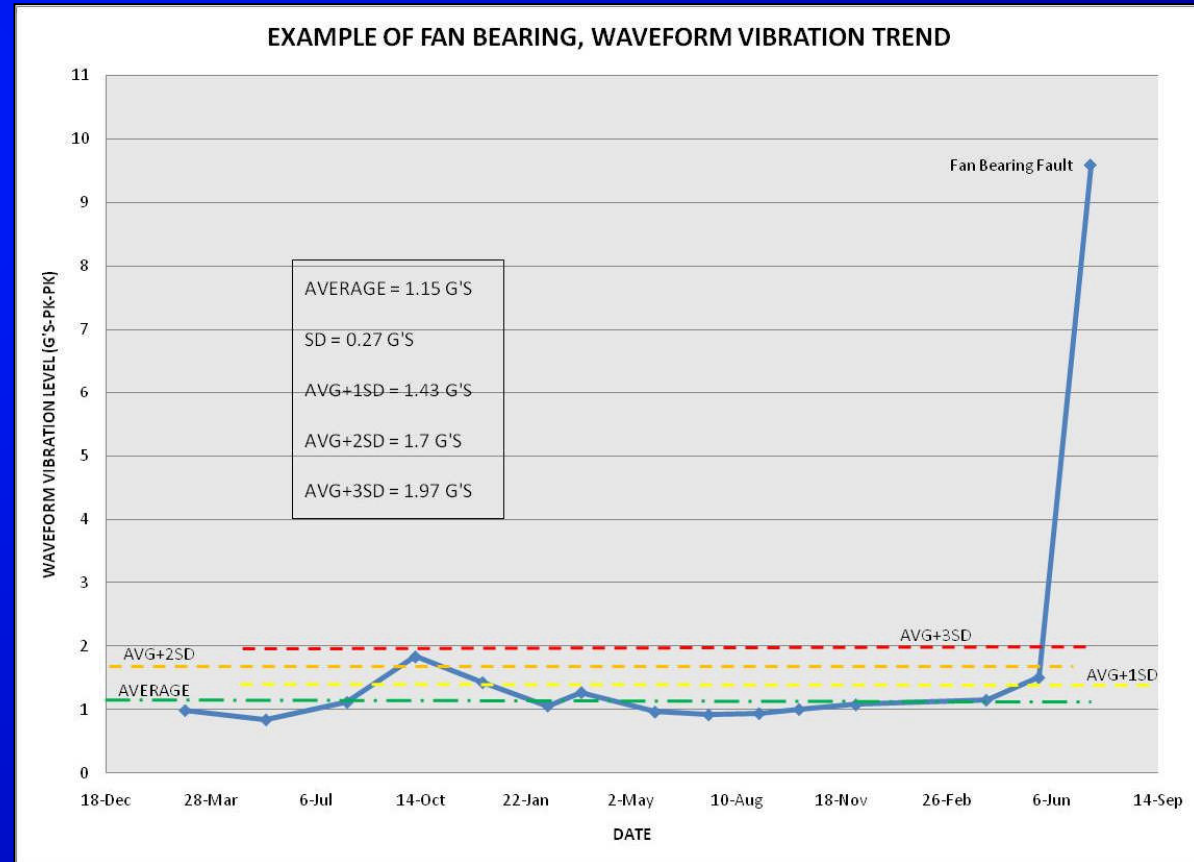
Suggestions on how to improve consistency in vibration measurements (tight grouping)^[19 & 20]

- ◆ Data collected by the same person during every survey.
- ◆ Mark exact points where data is to be collected everytime.
- ◆ Use the same transducer & analyzer during every survey.
- ◆ Wait 2 to 3 seconds or more after placing sensor in position before collecting data .
- ◆ As much as possible, try to collect data when the load, speed, and other conditions are identical.
- ◆ As much as possible, collect data from a clean, flat surface.
- ◆ Collect more data and/or identify similar machines to bring into the calculations.
- ◆ Identify outliers quickly (in the field if possible) to determine whether they represent simply bad data (discarded or new data collected) or a significant change in the machine's condition that should be flagged.

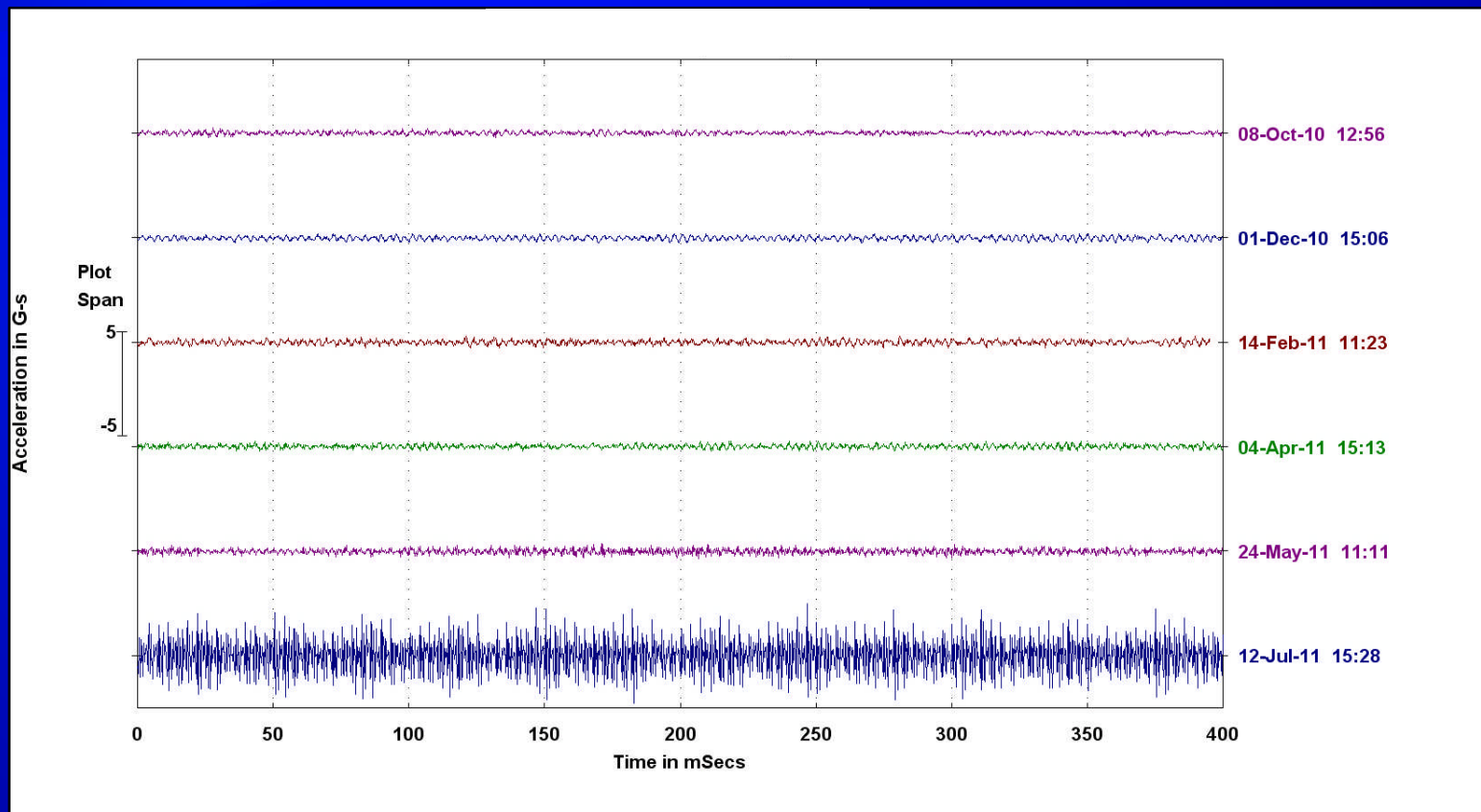
Historical Standards:

Example of simple statistical standards applied to historical waveform data from a fan bearing

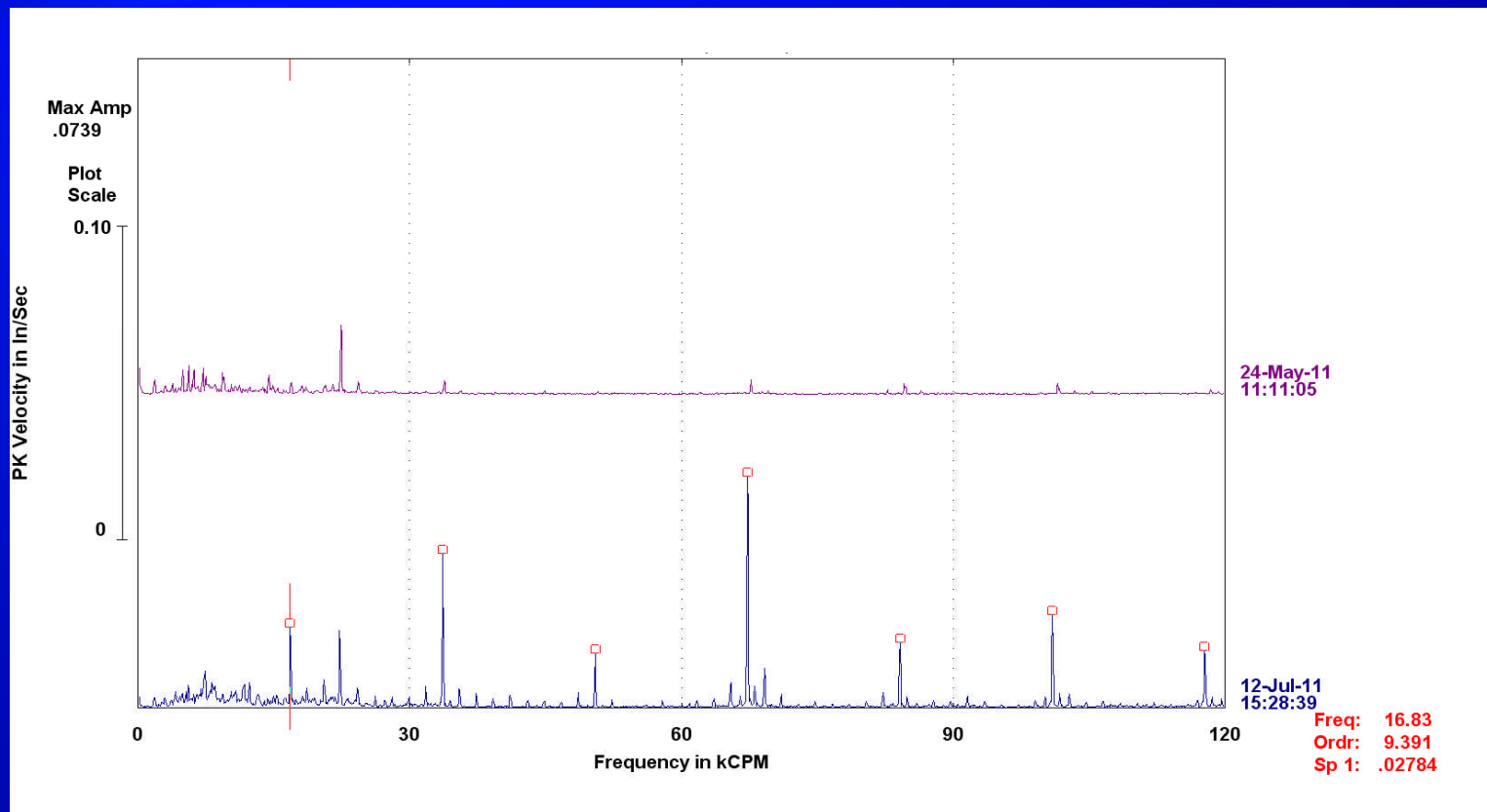
- Given the long historical trend data available, it wasn't hard to see that something big was happening here!
- In this example, 14-ea historical data points from an individual machine and an individual measurement point were used to calculate the average & standard deviation values applied.
- Either the AVG+2SD or the AVG+3SD alarms worked well in this case.



Fan bearing waveform data before & after alarm violation



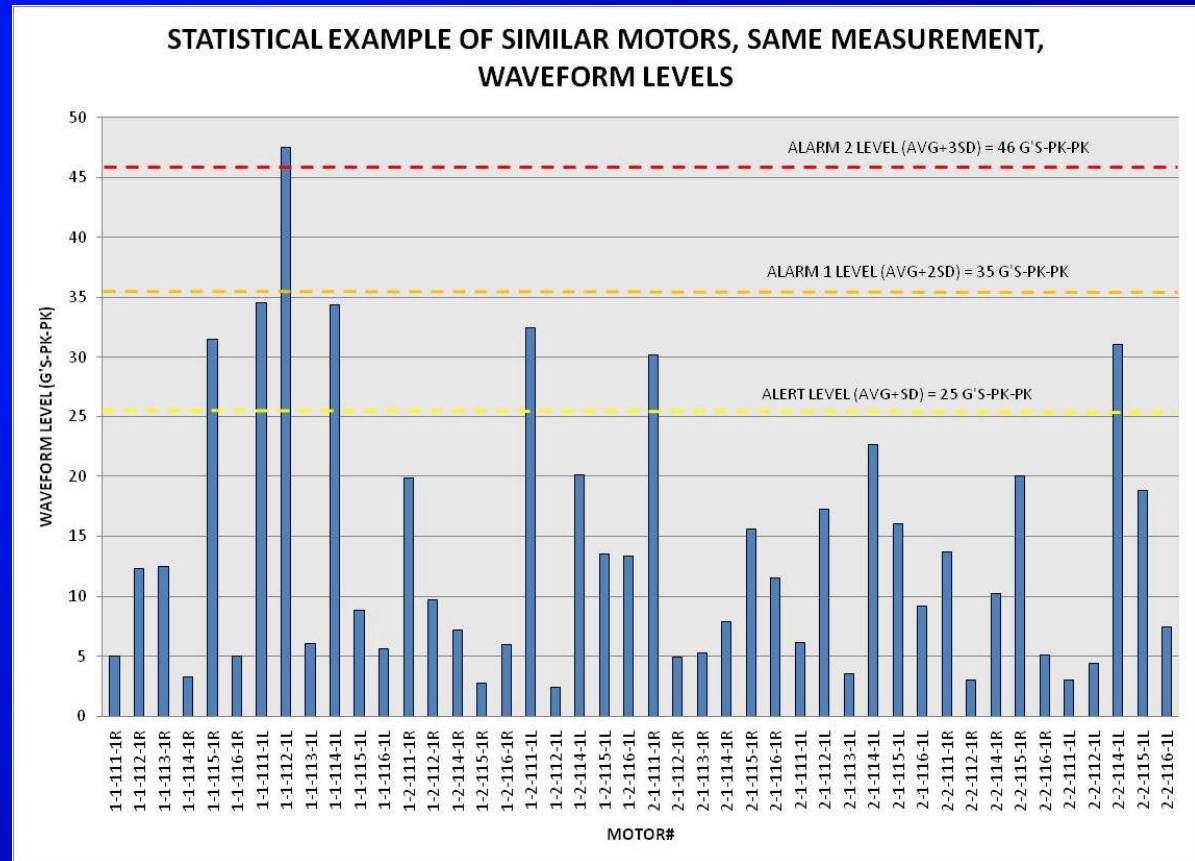
Fan bearing spectral data before & after alarm violation



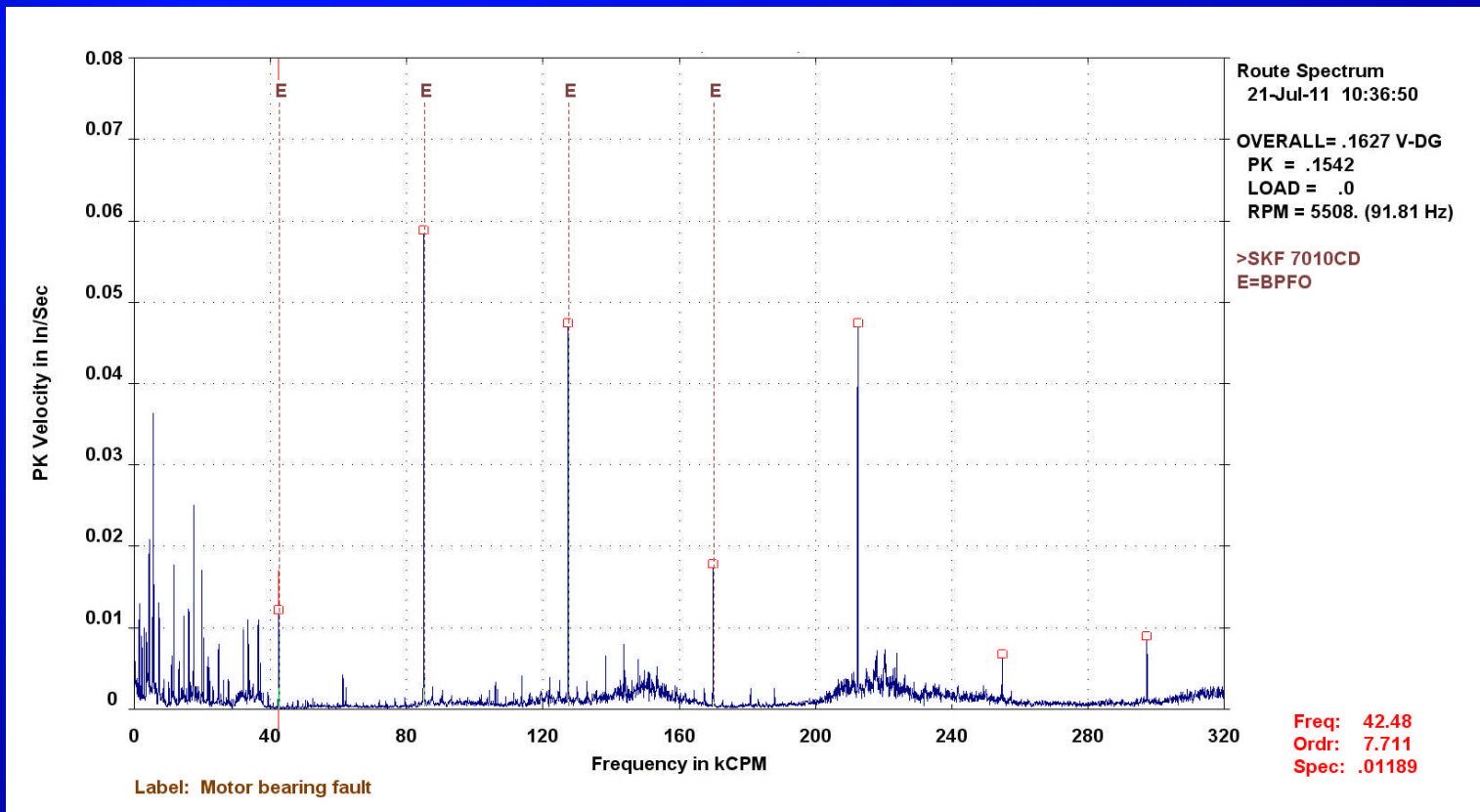
Comparative Standards:

Example of statistical standards applied across similar machines, identical measurement points

- In the example at right, statistical standards were calculated from very similar motors & identical measurement points.
- Each column represents the waveform level in g's-pk-pk from a specific motor.
- The motors were of the same size, speed, loading & operation.
- In this case, all those motors violating the yellow ALERT LEVEL of $AVG+1SD$ were observed to have bearing faults of differing severity and type in the vibration spectral data.



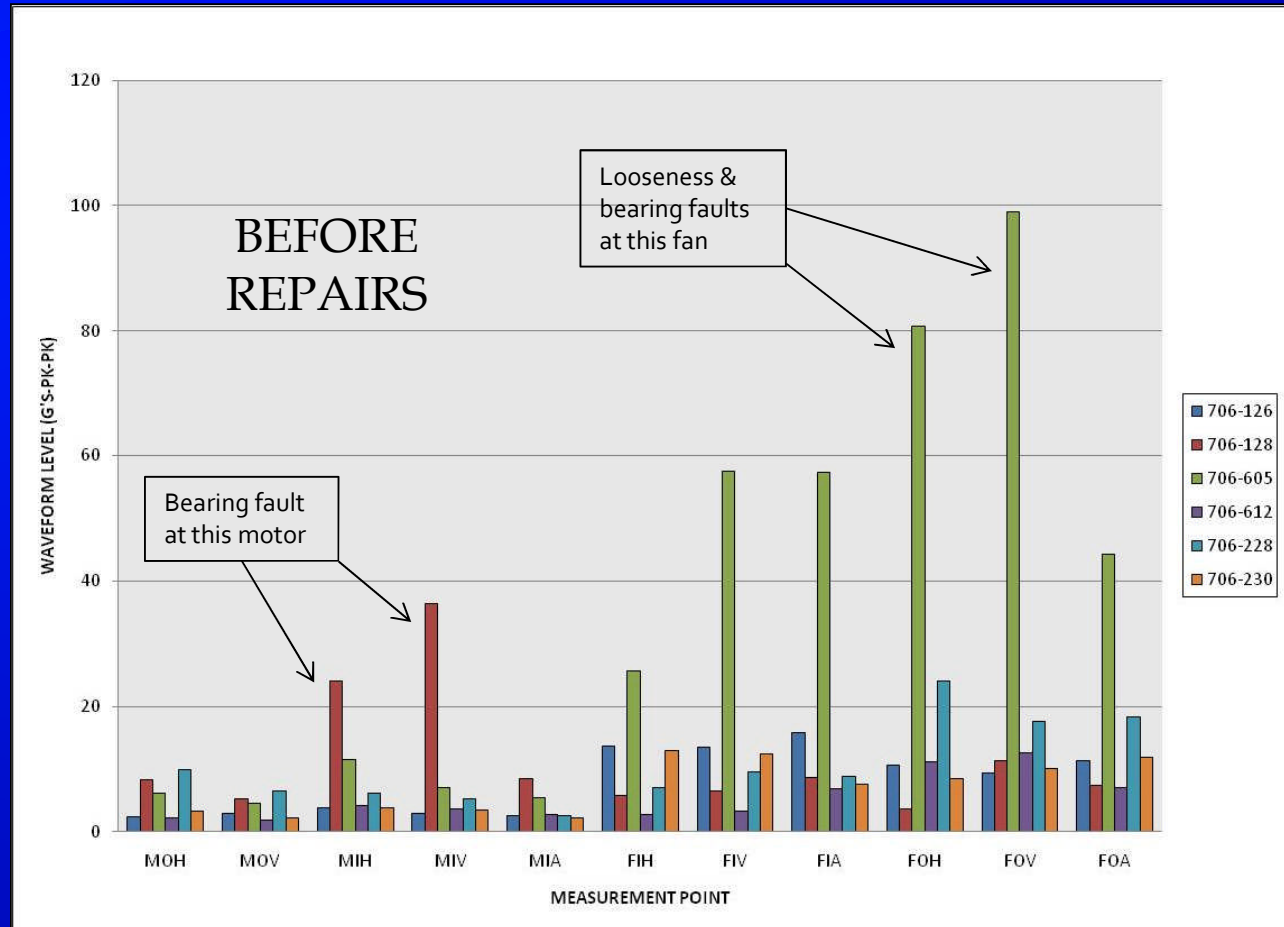
Spectra from the motor with highest waveform levels showing bearing outer race defect frequencies @ 7.71xrpm



Comparative Standards:

Example of comparing similar machines (belt-driven fans) across multiple measurement points (before repairs)

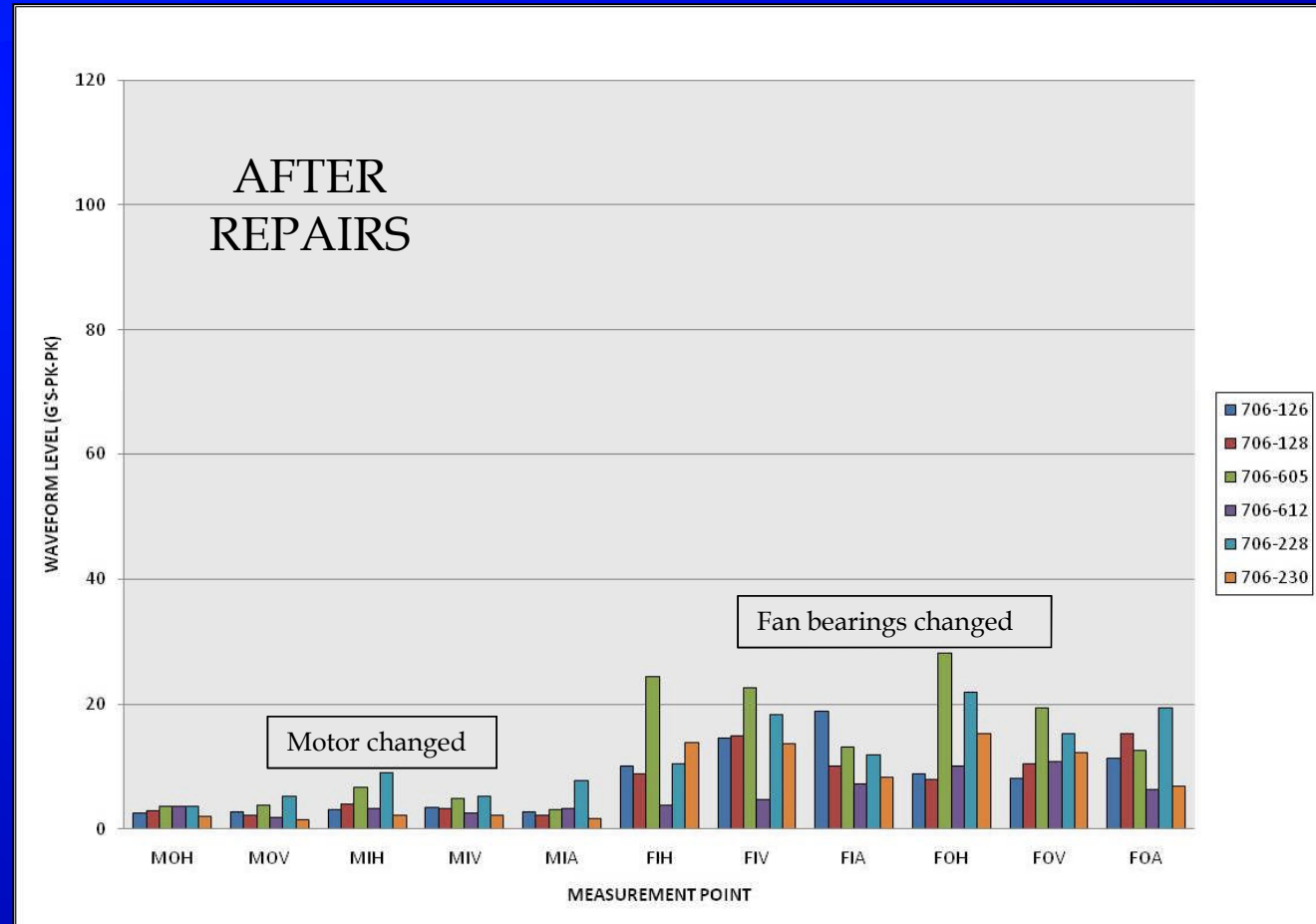
- Each distinct color represents a different fan.
- Compare the waveform level in g's-pk-pk from each fan at each measurement point versus the others.
- This simple way of relating similar machines to one another often makes it easy to both see which machine has the problem(s) and when more than one machine is found to have problems, which one likely has the more severe problem.



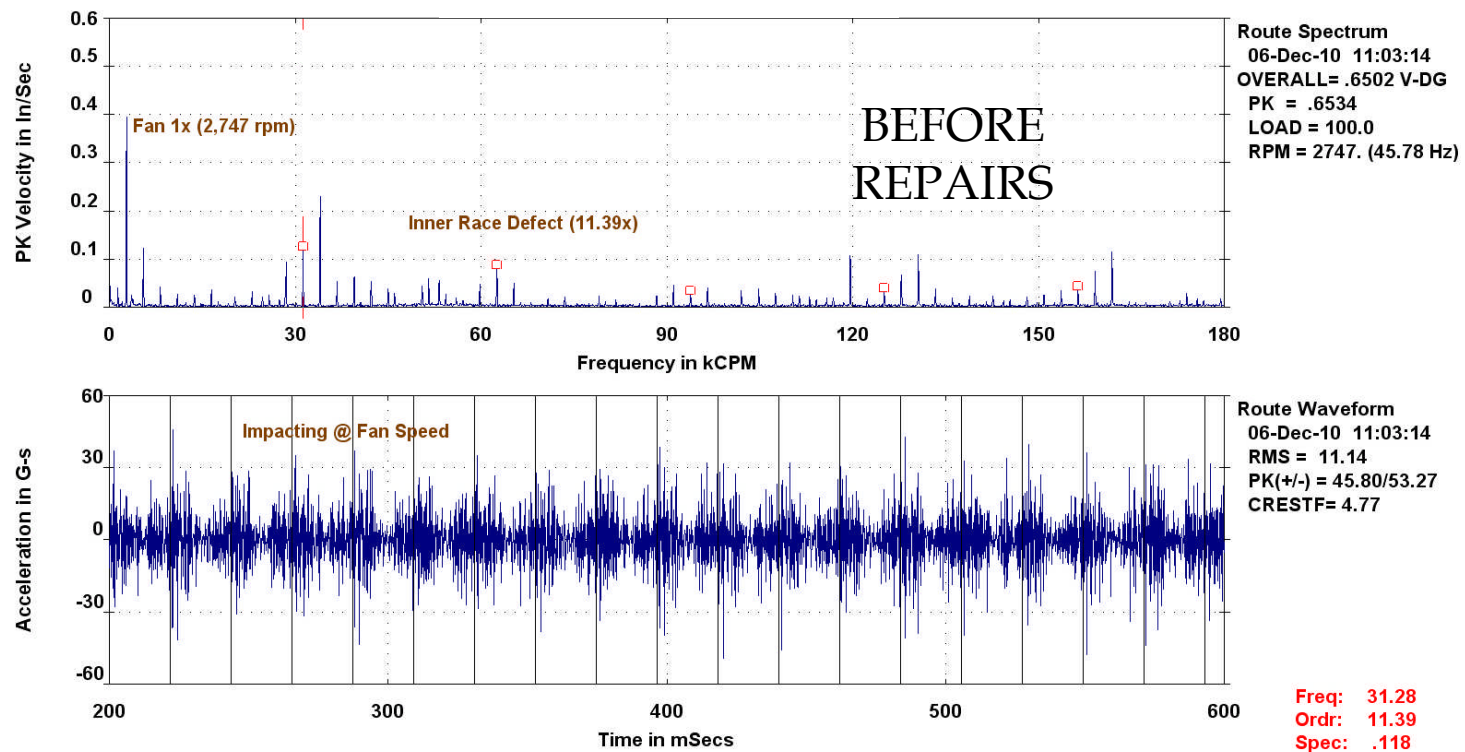
Comparative Standards:

Example of comparing similar machines (belt-driven fans) across multiple measurement points (after repairs)

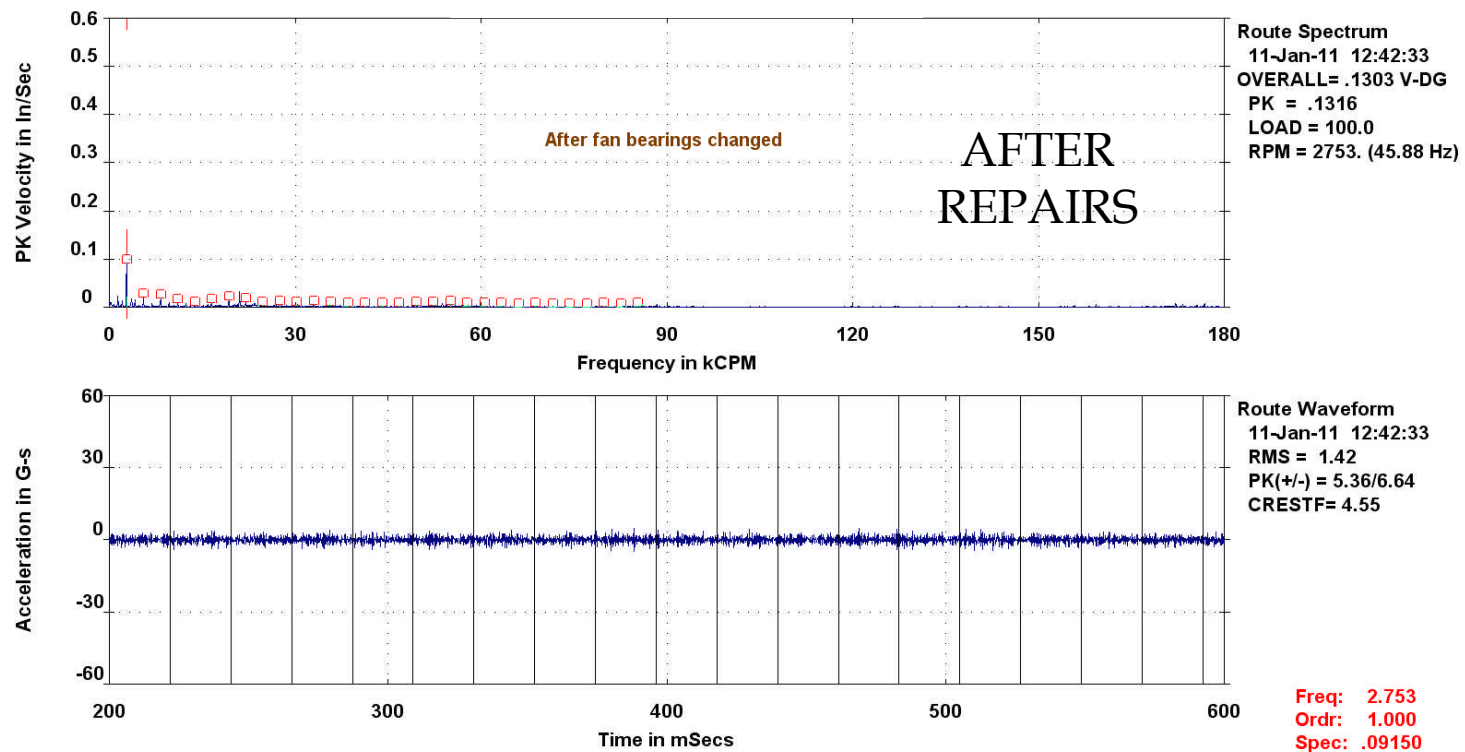
Note how after repairs, the levels agree much better between similar fans from point to point (better grouping).



Fan spectra & waveform data (before bearings changed)



Fan spectra & waveform data (after bearings changed)



REFERENCES, PART 4:

- 18) Berry, Jim, Analysis 1 Manual – How To Implement An Effective Condition Monitoring Program Using Vibration Analysis, 2nd Edition, Chapter 7, Proven Method For Specifying Spectral Alarm Band Levels & Frequencies Using Today's Predictive Maintenance Software Systems, Technical Associates Of Charlotte, PC, 1997
- 19) Eshelman, Ron, Machinery Vibration Analysis 2, Machinery Condition Analysis, p.332, VI Press, IL, 1996
- 20) Blake, Randall, "Statistical Approach To Machinery Condition Monitoring", Mini-Course Notes, 1993 Vibration Institute Symposium

The End - Thank You