CRYSTAL INSTRUMENTS

VIBRATION DIAGNOSTIC SYSTEM

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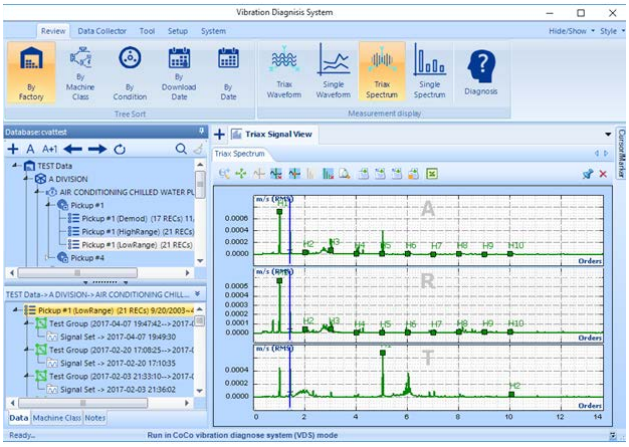


Vibration Diagnostic System (VDS) by Crystal Instruments

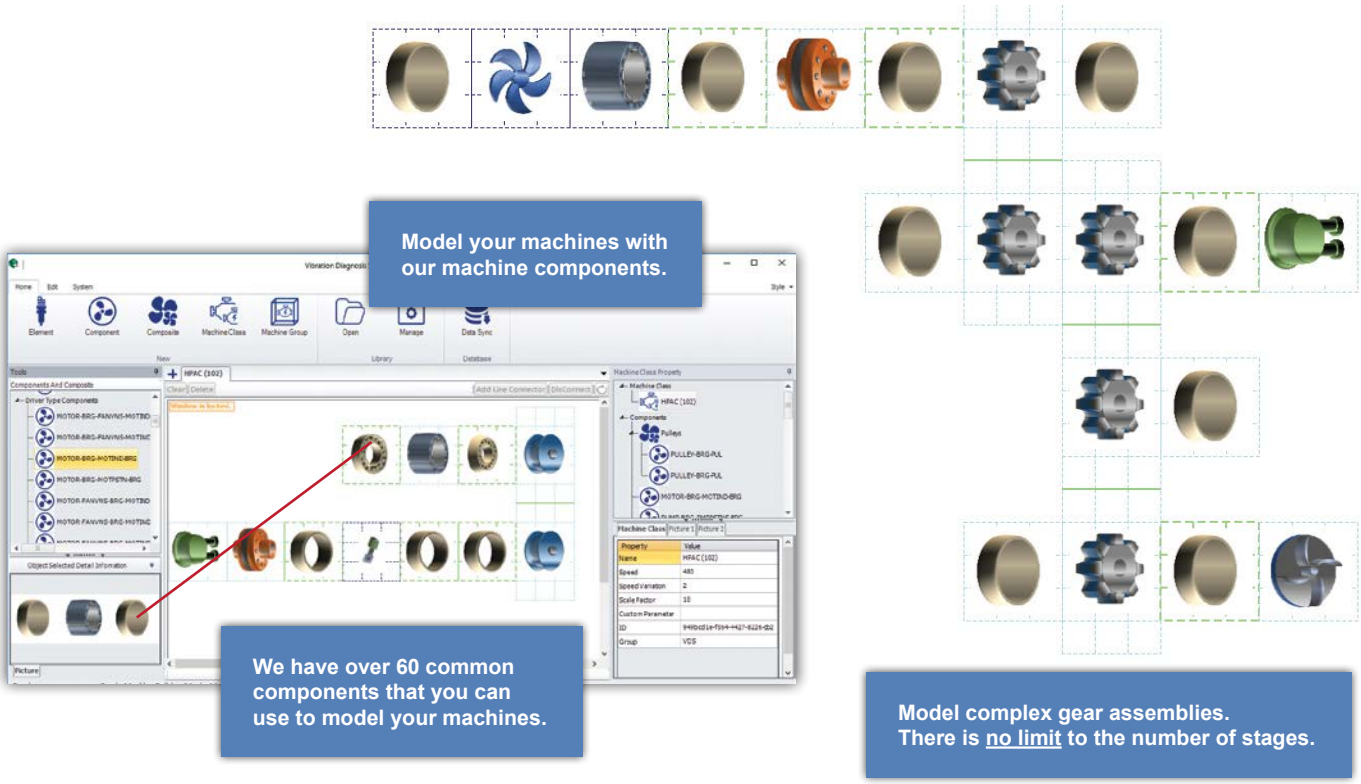
The Vibration Diagnostic System (VDS) is a vibration data management system designed specifically for the machinery Predictive Maintenance (PdM) community. It harnesses the graphic display capabilities of our EDM Software for the work of machinery vibration analysts. It allows the user to quickly get to the data for a machine of interest and display that data in the familiar Tri-axial or Single Axis view. It lets you quickly compare to other data from the same machine, quickly navigate back into the historical data of the machine, and quickly compare the data to that of other machines in the database. The software supports the construction of Average (a.k.a. baseline) data for a class of machines and allows easy comparison to that data as well. When you want to interact with the data you will have a full suite of cursors designed specifically for PdM analysis.

In addition to great graphics we have developed an extensible machine modeling system specifically for vibration analysis. It allows users to model machines based on the elements of the machine that can contribute to the vibration energy of the whole. Model bearings, rotors such as motor bars, couplings such as flexible and fluid couplings, account for slip in things like fluid couplings, model gears and pulley systems, and model turbines by accounting for each stage. It's wide open, you can create new elements to use in your system. But you may not want to do all that, and for you we're including a comprehensive library of machine components such as AC and Induction Motors, Couplings, Gears, Pulleys, Pumps, and other components. With our single and double gear shafts, you will be able to model many kinds of gear boxes with an unlimited number of stages. This ability alone lets you model your machines to view and use to keep track of vibration pickup locations, record the forcing frequencies of each part of the system, and attach attributes such as manufacturer and other part information. But there is more it can do.

VIBRATION DIAGNOSTIC SYSTEM

VDS Features & Support

- Machine Modeling System - allows us to model machine components and to know the relative rotational speeds of all the shafts of the system.
- A method to organize Machine Class Average (baseline) data for each designated pickup location.
- Associate a physical machine with a Machine Class.
- A diagnostic rule processing system based on a forward-chaining, probabilistic, inference engine.
- A method to define machinery faults.
- A method to define recommended actions based on recognized faults.
- Provides functions to support basic vibration analysis



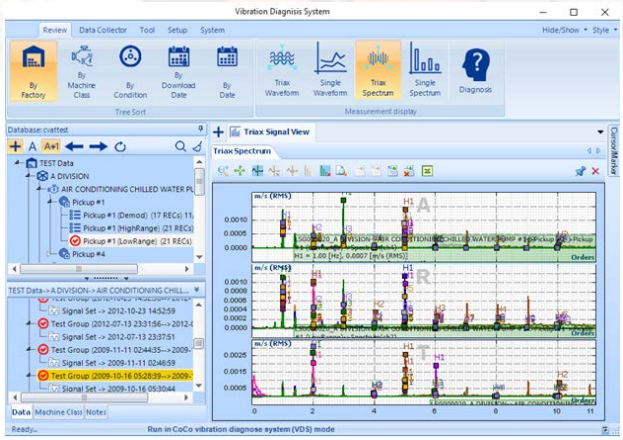
The CoCo-70X is a four channel vibration analyzer with an IP-67 rating, designed specifically for the machinery Predictive Maintenance (PdM) community.

The Machinery Modeling system provides the structure for our narrow band automated diagnostic system. VDS provides the features listed on the left in support of an automated diagnosis system:

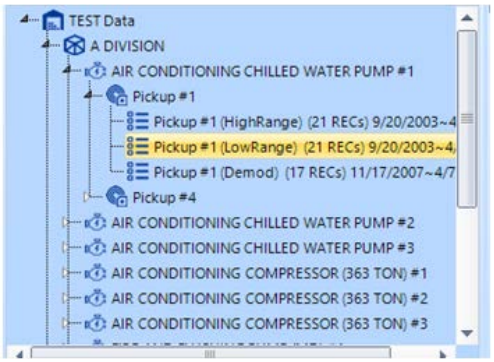
We know that most analysts don't have the time or desire to write their own rules for identifying machinery faults so we hired an expert to write a comprehensive set of rules for all of the machine components in our component library. When you model your machines with our component library you will get the benefit of **Artificial Intelligence (AI)** that will find many common machine problems.

Because our inference engine is based on a well-known open source scripting language called Lua, those that do want to build their own rule base or add to our rules will be able to do so. Using our low level, documented API, and open source tools, anyone could attempt to build or add to a knowledge base. But so as not to disappoint, keep in mind that this is not for the faint of heart, it can be a challenging task. Entities that may want to do this include:

- Predicative Maintenance organizations that specialize in a certain kind of machine and have years of detailed knowledge about these machines, could encode their knowledge with rules, thus extending our system to meet their needs.
- University Engineering departments may want to work with our system to teach and experiment with machine vibration analysis.



Waveform and spectral data are viewable in a single axis or tri-axis view.



Data structure is Factory, Space, Machine, Pickup.

Graphic Analysis

Waveform and spectral data are viewable in a single axis or tri-axis view. Overlay data from previous collection dates or compare with data from other machines. Overlay data with Average and Average + 1 Standard Deviation. Explore the data with a full set of cursors designed for PdM analysis. All the cursors will span the tri-axial dataset when using that view and move in unison across the set. The cursors provided are:

- Single Axis Cursor with optional on graph or off graph data labels
- A Divider cursor reminiscent of the manual divider analysts used to use with paper graphs. You can now do that kind of analysis with our digital Divider.
- A harmonic cursor that can be tuned by the fundamental frequency or any one of the harmonic markers. This can be very useful when you are interested in determining if a certain spectral peak is a harmonic. Just grab the nearest harmonic marker and move it to the peak and the fundamental marker will move accordingly. If the fundamental moved to where you think it should be, you've got your answer!
- A sideband cursor with multiple sidebands.

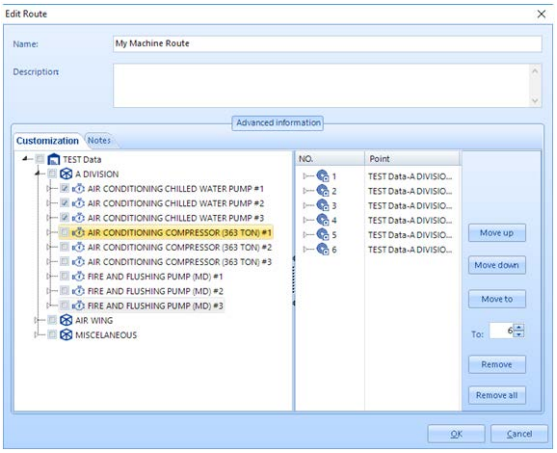
Database

Data structure is Factory, Space, Machine, Pickup. We added "Space" to the data hierarchy to give more control over how you group your machines.

All data is stored in a MS SQL Server database. The database may be accessed locally or served on a network to allow multi-user access. Access to the database as well as program features can be managed with individual user names and passwords. Each user is assigned an access level that can be customized for the tasks that individual needs to perform with the system.

User Levels	***Administrator, Local Administrator, User***

Data Acquisition Set up measurements based on the following parameter options:	
Sensor Configuration	Single, Tri-Axial, Optional Tachometer
Sensor Types	Accelerometer, Velocity
Sensor Sensitivity	Specify a sensitivity value for each channel individually. This helps with lower cost accelerometers.
Sensor Input Modes	AC-Diff, DC-Diff, AC-Single End, DC-Single End, IEPE
Data Types	Waveform, Spectrum
Filtering	Digital High Pass: Supports cutoff frequency between 0.1 Hz and 100 Hz
Averaging	Linear, Peak hold, Exponential, time synchronous
Overlap Processing	%0, %25, %50, %75
FFT Resolution	112, 225, 450, 900, 1800, 3600, 7200, 14400
Time Wave Samples	256, 512, 1024, 2048, 4096, 8192, 16384, 32768
Window Functions	Uniform, Hanning
Display Spectrum Type	peak, peak-peak, RMS or dB
Frequency Domain Axis	Hz, RPM, or Order
Demodulation	24 bandwidth options from 125 Hz to 1.44 kHz up to 32 kHz to 46.08 kHz



VDS supports maintaining one or more machine routes.

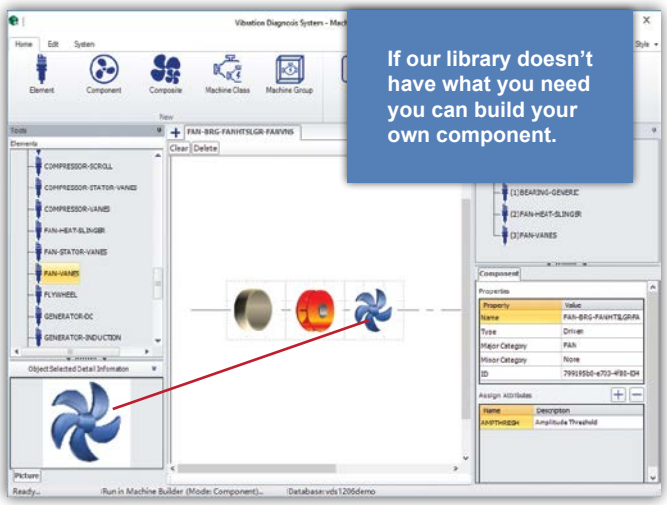
Routes

To analyze data and evaluate machine health we have to go to the machines and collect data. VDS supports maintaining one or more machine routes. Routes can be thought of as a to-do list that is loaded onto a CoCo-70X.

Once uploaded to a data collector the user can use it to gather data for some or all of the machines in the route. The data is then downloaded to VDS for storage in the database. Before the data is placed into the database each set of machine data is grouped together and assigned a Test Group and the user is given an opportunity to check that the data has been grouped properly. The Test Group insures that the data for this data collection cycle will always be identifiable. No need to check data timestamps to insure the data you are analyzing is all from the same collection period.

File Management

All CI products save data in ASAM-ODS format for the greatest compatibility and flexibility. VDS also exports signals in the following formats: .CSV (MS EXCEL) file. The user customizes the export options such as spectrum units, engineering units, data precision and scaling factors.

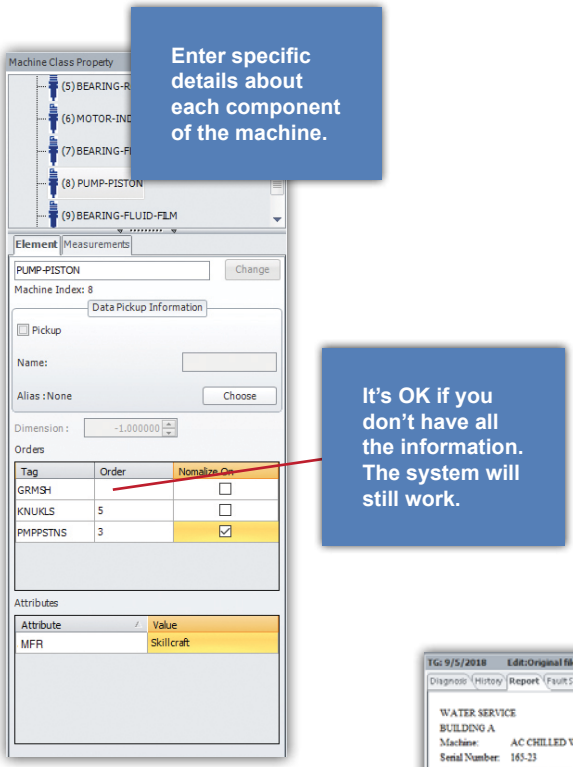


Machine Modeling Library

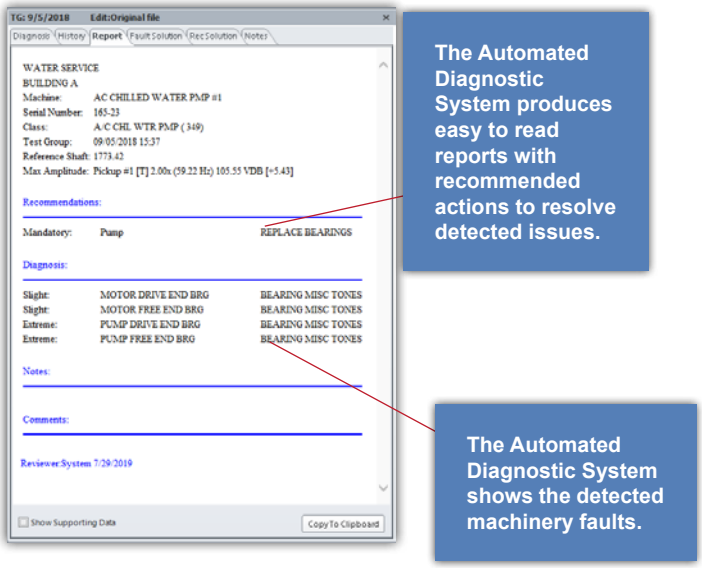
VDS comes with a full machine modeling system called Machine Builder. With Machine Builder, you have full control to model the machines in your enterprise. You are able to start from the ground up to build machine elements, use the elements to build common machine components, and finally put those components together to model physical machines. However, VDS ships with a comprehensive component library so you will likely be able to use our library to model your machines. We call a model of a machine a Machine Class. Once you have built a Machine Class you can designate pickup locations. You can assign attributes to machine elements, components, and machine classes to keep track of physical attributes as well as manufacturer and part information. These models are great references but also support the VDS automated diagnostic system.

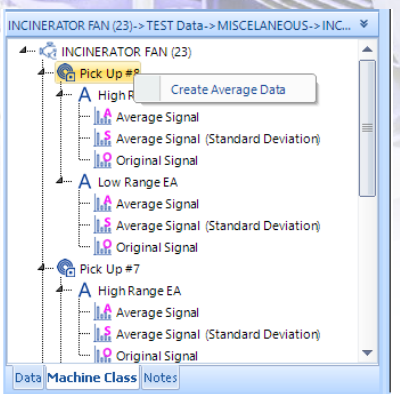
Diagnostic System

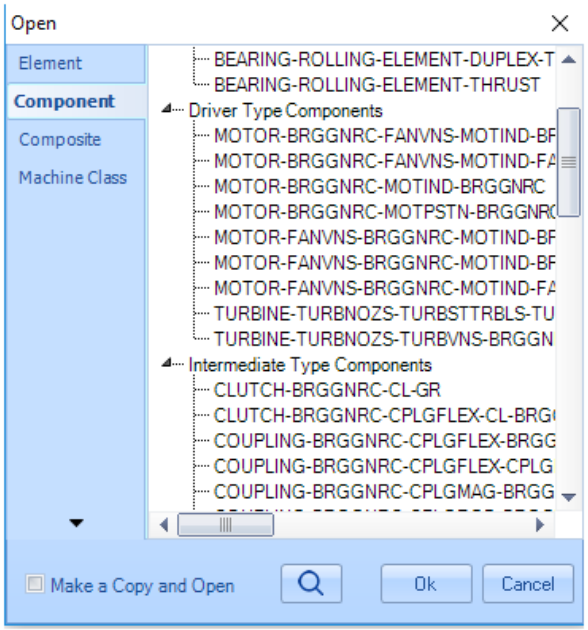
The VDS diagnostic system is based on a rules-based, probabilistic, forward-chaining inference engine. The rules of the system make use of the same information that an analyst uses for manual analysis. One key factor in this system is the construction of Average (baseline) data for each pickup of a Machine Class. Analysts usually prefer 2 data acquisition ranges per pickup location: a "low range" signature with high resolution to capture the signatures of most of the rotating elements of the machine, and a "high range" lower resolution acquisition to capture the signatures of high frequency phenomena such as gear mesh and motor bars. Our system will support this arrangement but is not tied to the 2-range approach. It will support a one range approach or multiple ranges. For some machines, you may like to collect data in 3 ranges of data and the diagnostic system, both manual and automated will accommodate that.



Analysis Ranges	***Unlimited***
Average Data Management	Support for multiple averages for each data range. This allows the construction and assignment of average data appropriate for each machine.







With Machine Builder, you have full control to model the machines in your enterprise.

Machine Class Average Building

The VDS Average Builder lets you build and manage the data you use to create machine class average data. You will be able to see the average and the constituent signals. Pull individual signals out of the average and replace with better data as it comes along. Some machines of a class have anomalous vibration signatures and would not analyses well based on the average data built form other machines of its class. Our average building system will let you keep multiple average for the same pickup and range. When you create a physical machine in your database you will be able to choose which averages to associate with this machine, this benefits both manual and automated analysis.

Track Machine Health

Once a machine, based on a machine class, is associated average data full manual and automated analysis can proceed. When new data is downloaded and placed into the VDS database it can be viewed manually and compared with average data. Usually the data is compared to the average signal plus one standard deviation of the average, but you'll have access to both. When current data is compared to average data for the machine class we can see where the current data is starting to diverge from the average data which represents a healthy machine. Where the analysis is done manually or with our automated system, a record of machine health can be created and associated with the data Test Group. We call this a Diagnosis and in it you will see identified machine faults, recommended actions, and a place for analyst comments. The Diagnosis window supports a configurable review process that allows it's edit history to be maintained. The current machine diagnosis will designate the overall health of the machine and will drive tree color codes and allow sorting by machine health.

Vibration Diagnostic System (VDS) Specifications

Data Storage
Database Engine: SQL Server
Configuration: Local database, Multi-seat served database (2019)
Storage hierarchy: Factory / Space / Machine / Point
Number of machines: unlimited
Main Features
Machine data storage and hierarchal display which can be sorted by Factory, Machine Class, or Data download date
Machine class builder
Machine class baseline average construction offering complete control over each signal ensemble
Automated Machine Diagnostic system based on a probabilistic, forward-chaining inference engine and a diagnostic rule base created by industry experts.
Diagnosis display with ability to modify and keep the change history
Route builder for making lists of machines used by our data collectors to direct data collection.
Connection manager for communicating with our data collectors.
Display Options
Triaxial Waveform
Single Axis Waveform with quick axis change buttons
Triaxial Spectrum
Single Axis Spectrum with quick axis change buttons
View Waveform and Spectrum side-by-side
Graphs will float to take advantage of multiple monitors
Cursors
Vertical single cursor
Two Vertical single cursors with difference output
Harmonic cursor
Sideband cursor
Machine Modeling System
Entities:

Element	A rotating machine part that creates a synchronous tone.
Component	Assembled Elements
Composite	Assembly of components that can be reused
Machine Class	Assembled components

Build your own elements, components, and machine classes.

Pre-built Library of Elements and Components
• AC Motor • Induction Motor • Turbine (up to 9 stages) • Clutch • Flexible coupling • Magnetic coupling • Rigid coupling • Single gear • Double gear • Triple gear • Pulley Assembly • Compressor • Fan • Flywheel • Oil Pump • Pump • Generator • Purifier • ...with many variations.
Data Acquisition
Set up measurements based on the following parameter options:

Sensor Configuration	Single, Tri-Axial, Optional Tachometer
Sensor Types	Accelerometer, Velocity
Sensor Sensitivity	Specify a sensitivity value for each channel individually. This helps with lower cost accelerometers.
Sensor Input Modes	AC-Diff, DC-Diff, AC-Single End, DC-Single End, IEPE
Data Types	Waveform, Spectrum
Filtering	Digital High Pass: Supports cutoff frequency between 0.1 Hz and 100 Hz
Averaging	Linear, Peak hold, Exponential, time synchronous
Overlap Processing	%0, %25, %50, %75
FFT Resolution	112, 225, 450, 900, 1800, 3600, 7200, 14400
Time Wave Samples	256, 512, 1024, 2048, 4096, 8192, 16384, 32768
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