

## PhD Plus Vibration Monitoring System With Quantum™ HD Unity



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## Vibration Monitoring Saves Compressors

**Note:** The PhD Plus system is designed for rolling element bearings and not sleeve bearings.

No one likes to talk about compressor failure; however, like all rotating machinery, compressors eventually fail if they run long enough. One advantage of using rolling element bearings, as opposed to sleeve bearings in rotary screw compressors, is that the early stages of failure are relatively easy to detect. With a regular and disciplined periodic vibration analysis program, most bearing failures can be detected in the very early stages.

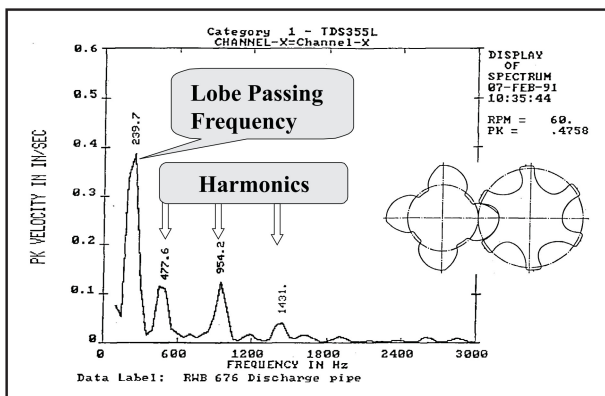
When bearing fatigue is detected in time, the compressor rebuild is much less expensive. This is because only the bearings need to be replaced and not the expensive rotors and housings. Failure detection in the early stages also allows the repair to be scheduled to avoid disruption to the plant's operation. Normally, compressors can continue to run for months after the first signs of bearing failure are detected without risking catastrophic failure, as long as vibration monitoring is used to track the progression of the damage.

### Effective Monitoring Is Not Easy

One of the disadvantages of periodic vibration monitoring is that the technician must often be familiar with many different types of machinery, and is expected to predict failures without giving false alarms.

One of the characteristics of a screw compressor is that the dominant vibration signal is always at lobe passing frequency or one of its harmonics. The vibration signals generated by the early stages of bearing fatigue are a much lower amplitude and at higher frequency than lobe passing and its harmonics.

**Figure 1: Common vibration spectra for screw compressor**



Without specific training on rolling bearing equipped rotary screw compressors, the technician may often give recommendations that are either too conservative or that might miss an important warning condition. Also, because the measurement is periodic, it does not catch a temporary or transient problem that could still be a threat to the compressor.

Onboard vibration monitoring systems overcome some of these problems because they are monitoring the compressor all the time. However, many of the systems for sale

today, often at very high price levels, were designed primarily to monitor sleeve bearing equipped turbo-machinery, or low speed reciprocating machinery. Many of these systems monitor only overall velocity or displacement to track bearing deterioration, or they use proximity probes to determine when rotors have moved from their original positions, indicating loss of bearing integrity. In some cases, the normal lobe passing frequencies in a healthy screw compressor give signal levels well above the alarm levels that could be expected due to bearing deterioration. This means that the systems can easily give false alarms on normal conditions, or miss the early signs of bearing failure because the increase is not significantly above the healthy vibration level.

### The PhD Plus Monitoring System

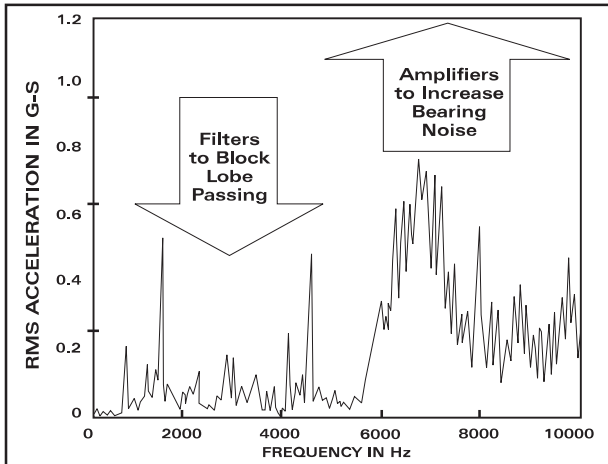
The FRICK® PhD Plus Vibration Monitoring system is a continuous vibration monitoring system that uses the best current technology to detect the early stages of compressor bearing failure. It monitors the compressor continuously and alarms the operator when a condition develops that would indicate the early stages of bearing failure. The bearings are monitored by onboard accelerometers mounted over the bearing positions on both ends of the compressor. The signals from these sensors are then modified and filtered in such a way that the normal vibration levels from compressor lobe passing and its harmonics do not give false alarms. See Figure 2.

The standard FRICK PhD Plus system is designed for non-hazardous Food and Beverage applications. If you want to use the PhD Plus system for a hazardous location application, contact FRICK so we can provide the correct components and installation instructions. FRICK can provide a custom PhD Plus solution for a wide range of hazardous applications.

The accelerometer mounting for compressor monitoring with the PhD Plus system uses two accelerometers. All FRICK SGC compressors are predrilled and tapped with 1/4 in.-28 mounting holes to allow solid attachment of the PhD Plus accelerometers in locations near the bearings on each end of the compressor. The locations are chosen to give a good signal level for both the radial and axial thrust bearings without requiring separate axial probes. The combination of two radial locations have been proven to pick up early stages of bearing fatigue regardless of which bearing position experiences the earliest damage. The FRICK XJF compressors do not have these mounting holes, so mounting bases are glued to the compressor to attach the accelerometers.

The PhD Plus system is tuned to look in the frequency ranges that give the best indication of the early signs of bearing fatigue and to ignore frequencies that might give misleading signal levels. This is a major advantage of the PhD Plus system over most other vibration monitoring systems on the market. It is designed to protect your compressors, based on Johnson Controls knowledge and testing of the best way to detect failures in roller bearing equipped screw compressors.

Figure 2: How PhD Plus monitoring works



Laboratory testing indicated that the system would also detect temporary liquid slugging and allow for automatic rapid shutdown when severe slugging was detected. This is one of the advantages of continuous monitoring over periodic monitoring. Unless your vibration technician has his meter on the compressor when a liquid slug occurs, he cannot save the compressor. The PhD Plus system is continuously monitoring for a severe slug and can rapidly shut down the compressor when this condition is detected.

The output signals from the accelerometers are read by the vibration module. This module processes the accelerometer signal and calculates vibration levels from this raw signal. These values are transmitted to the Quantum HD Unity panel through an Ethernet connection. The Quantum HD Unity monitors the compressor's vibration levels and compares them against programmed, adjustable warning and shutdown setpoints. Adjustable time delays are also available for both the warnings and shutdowns. Alarm and Shutdown levels on the compressor are set in units of g's FRICK or (gF). 1 gF is approximately equal to 9.8 m/s<sup>2</sup>, but the derived signal is not exactly convertible to standard acceleration units. A gF is a derived unit for surface acceleration measurement.

The PhD Plus system is also very effective for monitoring vibration of an anti-friction bearing equipped motor. Because the PhD Plus system is tuned to look for fatigue of rolling element bearings, the failure signature of rolling element bearings in the motor can also be monitored and specific alarm and setpoint levels can be set to detect increasing vibration in the motor bearings. When properly set, the initiation of the motor alarm is often the first indication that the motor bearings need to be lubricated.

The PhD Plus Acceleration Monitoring system is designed to distinguish repetitive impacts from the wide-band-machine vibration signals.

These repetitive impacts are generated by:

- Rolling bearing defects.
- Rubbing or sliding of metal surfaces.
- Imbalance in rotating equipment.

The accelerometer signal is measured as a raw time-based acceleration value. Software in the vibration module

filters and analyzes the signal to highlight the frequencies that indicate compressor problems.

When properly applied and maintained, the PhD Plus system can greatly reduce the risk of catastrophic compressor and motor failure due to a variety of causes. It also gives an overall improvement in operating reliability and reduces the risk of a catastrophic and expensive failure.

**Note:** PhD Plus is not the most effective system to monitor sleeve bearing equipped motors, and it is not recommended for this application.

Figure 3: Quantum HD Unity Control Panel



### Motor Bearing RTD Temperature Sensing

While the Quantum HD Unity controller is effective at measuring motor vibration, it also offers the use of motor resistance temperature detectors (RTD) for monitoring motor bearing condition. Motor vibration levels or Motor bearing temperatures can be used to monitor motor condition.

Motor manufacturers have expressed confidence in the use of motor bearing temperature sensing as an effective method to detect developing problems in rolling element motor bearings. Bearing temperature is more meaningful on motors than compressors because the bearings are grease lubricated on motors, and a developing problem generates a measurable increase in the bearing temperature. This level can be used to alarm for re-grease of bearings, or shutdown for bearing replacement in the event that bearing damage is detected.

The RTD output wires directly to the analog board 1 in the Quantum™ HD and monitors temperature changes in the bearings.

In a majority of applications the most cost effective PhD Plus monitoring solution would use two compressor accelerometers and two motor bearing RTDs in combination (See Figure 10).

## PhD Plus Installation and Setup

The FRICK® Quantum™ HD Unity control panel provides the integration of the PhD Plus Vibration Monitoring System into the compressor control system.

### Vibration Monitoring

The PhD Plus vibration module is connected to the accelerometers through the appropriate FRICK supplied cable assembly. The accelerometers provide the input signal from the machine location being monitored. Two accelerometers connected to two input channels on the vibration module are used for the compressor, one on each compressor bearing housing. Two additional accelerometers are used to monitor the motor bearings. On the vibration module, channels S1 and S2 are used for the compressor accelerometer inputs, while channels S3 and S4 are for the motor accelerometers. The module has a total of four vibration input channels. The vibration module processes the input signal from each sensor and after signal conditioning, transmits the vibration values to the Quantum HD Unity program.

### Installation and Wiring

If the PhD Plus system is purchased with a new FRICK package, it ships with the vibration module and IFM sensors installed and wired. If a retrofit kit is purchased, it may be necessary to install and wire the sensors in the field. This kit includes installation and wiring instructions.

The FRICK SGC compressors are predrilled and tapped with 1/4 in.-28 mounting holes to allow the solid attachment of the PhD accelerometers in locations close to the bearings on each end of the compressor. The CTC accelerometers (IEPE sensors) have 1/4 in.-28 studs and fit these mounting holes. The IFM accelerometers (MEMS sensors) have M8 studs and require an adaptor to install in the SGC mounting holes.

The FRICK XJF compressors do not have mounting holes. For these compressors FRICK provides a mounting base that is glued to the proper locations on the compressor. With the IFM sensors the M8 mounting bases are provided for use with the XJF compressors.

In the FRICK PhD Plus retrofit kit, both the adaptors for the SGC and mounting bases for the XJF are provided, so the same kit can be used with either compressor.

If adding the PhD Plus retrofit box, it can be installed on the FRICK package close to the Quantum HD Unity controller. A (field-supplied) Ethernet cable needs to be run between the vibration module and the Quantum HD Processor Board. The retrofit kit includes a USB to Ethernet adapter that should be installed at the Processor Board. The Ethernet cable must be connected to this USB to Ethernet adapter rather than at the Ethernet port on the Processor Board.

### Quantum HD Unity PhD Plus Setup

The PhD Plus option requires Quantum HD Unity Version 12.02 (Q6) and 11.02 (Q5), or newest versions. If the package does not have a Quantum HD Unity panel with this software version, upgrade the panel before installing the PhD Plus system. Keep in mind that new Quantum HD Unity retrofit panels can be purchased with the PhD Plus feature already installed in the panel.

New FRICK packages and Quantum HD Unity retrofit panels ship with the latest software and have the PhD Plus options Enabled. There may still be cases where these settings need to be reviewed and changed. If the PhD Plus retrofit is installed on an existing package, perform the following steps to configure the software.

After wiring the accelerometers to the vibration module and connecting the Ethernet cable between the vibration module and the USB port on the Quantum HD Processor Board, the PhD Plus option in the Quantum HD Unity software can be enabled.

Refer to the wiring diagram for information on how to install these cables and connections.

To setup the PhD Plus Vibration Monitoring feature, go to the **Configuration** screen, then select **PhD Vibration/Temperature**, which brings you to the **Compressor Bearing** screen.

To enable the two compressor sensors, press the **Compressor Bearing** tab and from the **Compressor Bearing Vibration** list, select **PhD Plus Vibration**, as shown in Figure 4.

Figure 4: PhD Plus configuration - Compressor bearing vibration settings

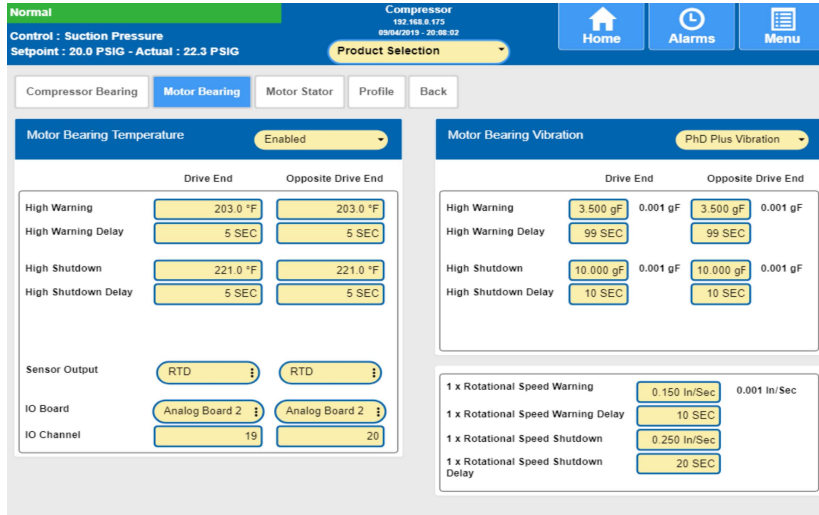
|                     | Opposite Drive End | Drive End |
|---------------------|--------------------|-----------|
| High Warning        | 3.500 gF           | 3.500 gF  |
| High Warning Delay  | 99 SEC             | 99 SEC    |
| High Shutdown       | 10.000 gF          | 10.000 gF |
| High Shutdown Delay | 10 SEC             | 10 SEC    |

|                                     |              |              |
|-------------------------------------|--------------|--------------|
| 1 x Rotational Speed Warning        | 0.150 In/Sec | 0.001 In/Sec |
| 1 x Rotational Speed Warning Delay  | 10 SEC       |              |
| 1 x Rotational Speed Shutdown       | 0.250 In/Sec |              |
| 1 x Rotational Speed Shutdown Delay | 20 SEC       |              |

To enable the two motor sensors, press the **Motor Bearing** Tab and from the **Motor Bearing Vibration** list, select **PhD Plus Vibration**, as shown in Figure 5.

Figure 5: PhD Plus Configuration - Motor Bearing Temperature and Vibration Settings



Once the proper PhD Plus Vibration options are enabled, a **Profile** tab appears at the top of the page. Go to the **Profile** tab to configure the vibration module.

1. Verify that the compressor model for this package is correct. If not, from the **Compressor Model** list, select the model that matches the compressor nameplate.
2. Select the correct sensor type. The standard new PhD Plus system uses IFM accelerometers, which use MEMS technology. If this is a retrofit to an existing PhD system, the sensors may be CTC accelerometers, which are IEPE sensors. The manufacturer is printed on the accelerometer if you need to check which sensor you have. From the **Sensor Type** list, select either **MEMS<sup>(1)</sup>** or **IEPE<sup>(2)</sup>** based on which sensors are used.

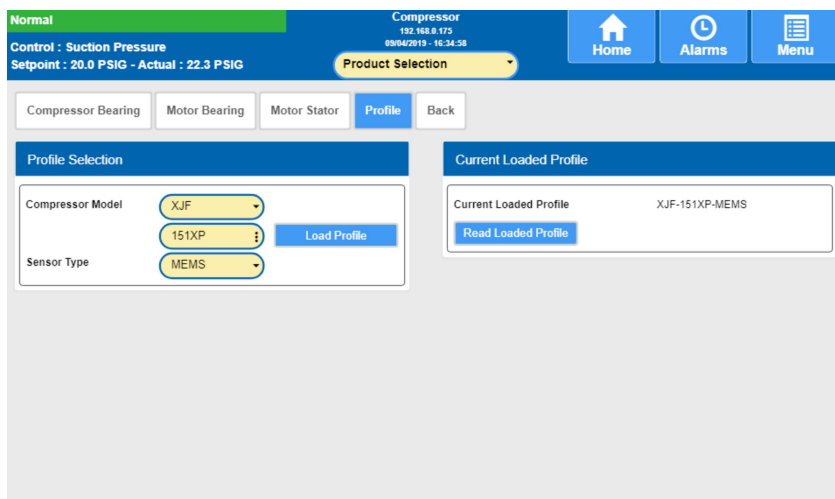
<sup>(1)</sup> Micro-Electro-Mechanical System

<sup>(2)</sup> Integrated Electronics Piezo-Electric

**Note:** It is important that the accelerometers on the package are either all MEMS or all IEPE. The PhD Plus system can not be setup for a mix of MEMS and IEPE sensors.

3. After selecting the **Compressor Model** and **Sensor Type**, press the **Load Profile** button to save this profile to the vibration module. Select **Yes** when asked **Are You Sure?** If this process is completed successfully, the vibration module is configured and begins to monitor the vibration of the compressor and motor based on which options are Enabled.

Figure 6: PhD Plus Profile screen



If an **Operation Not Successful!** message appears, then the configuration was not saved to the vibration module. If this occurs, check the communications connection between the Quantum HD Processor Board and vibration module and confirm that the vibration module is powered on. After the problem is resolved, repeat the Load Profile process listed above.

The **Read Loaded Profile** button reads the current profile file from the vibration module. Use this button to confirm that the correct profile is loaded.

The Quantum HD Unity software stores many preconfigured profiles for the various FRICK compressor models. Based on the options selected, the correct profile is selected and written to the vibration module. There is a standard motor setup that is used for the motor vibration monitoring. If the vibration module is replaced, it is necessary to write the profile to the new module. If your FRICK compressor model is not on the selection list, contact FRICK.

### Field Setup and Adjustment

When the system is ordered with the compressor package, the channels are configured at the factory. For any new PhD Plus system, field adjustment for the alarm and shutdown levels and time delays must be made after running the unit and determining the initial normal levels. This field adjustment is necessary to more closely tune the warnings and shutdowns for a particular application and compressor size. For field adjustment, perform the following steps:

1. After starting the unit, run the compressor at expected design pressures while manually changing slide valve position from maximum to minimum and monitoring the gF level on all channels.
2. If the compressor package has a VSD, also change the speed from minimum to maximum while monitoring the gF levels.
3. Repeat this procedure several times to be sure the measured levels are representative.
4. Record the highest levels detected on each channel and make a record of this reading so that it's not lost.
5. Set the Acceleration High Warning level (gF) for each channel to 2x the highest level seen during initial run for each channel. Normally a 99 second time delay is used on the alarm setpoint to avoid nuisance alarms.
6. Next, set Acceleration High Shutdown level (gF) as 3x the highest level seen during initial running for each channel. Normally a short time delay is used on the shutdown setting, (10 sec).

With some operational history, the alarm and shutdown levels can be adjusted slightly to either give earlier warning of changes, or avoid transient nuisance alarms.

Example setup:

- Run unit and read highest reading on Drive End Bearings at any slide valve position, (for example, say the reading was 2.0 gF).
- Set the Acceleration High Warning at 4.0 gF with a 99 second time delay.
- Set the Acceleration High Shutdown at 6.0 gF with a 10 sec time delay.
- If the Shutdown trips during starting transients set the time delay slightly longer.

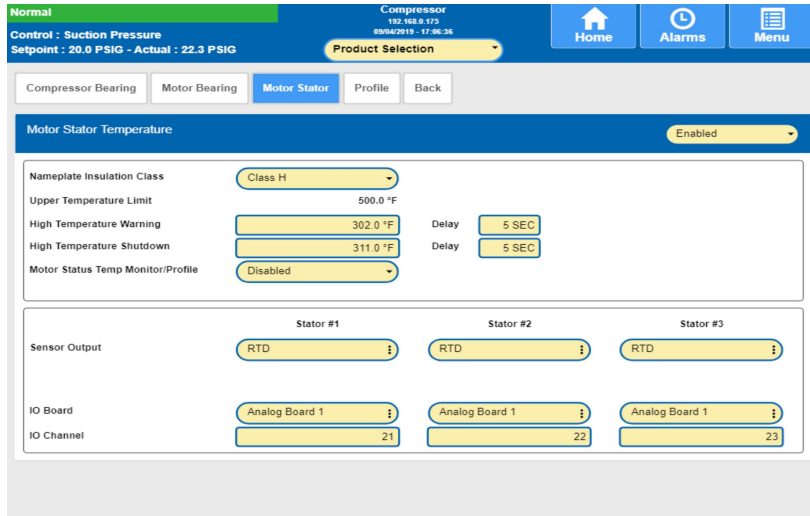
The actual number set in gF is a relative number, and general setting guidelines are difficult to predict ahead of initial running. For example, high power applications and compressors with internal gearboxes generally display higher initial readings than low power applications without gearboxes. The main purpose with PhD Plus is to monitor increasing levels of acceleration in the frequencies that indicate the onset of bearing fatigue.

The PhD Plus Acceleration calculations are designed with the proper filters to separate the defect signal from the wide band acceleration and convert to signals proportional to the defect.

The derived signal, representing the PhD Plus acceleration signal, is compared with the alarm level preset.

The 1 x Rotational Speed Safeties are designed to detect sudden vibration events or catastrophic equipment failure. This includes things like liquid slugging, motor failure, or coupling problems. In most cases, it is not necessary to adjust the 1 x Rotational Speed Warning and Shutdown setpoints.

Figure 7: PhD Plus Configuration - Motor Stator Settings



**Sensitivity and Range Selection**

No field settings or adjustments are necessary.

Figure 8: Accelerometer



**Accelerometer**

- For use with PhD Plus Acceleration System
- Economical, rugged, general purpose
- Sensitivity, 100 mV/g for greater range and to optimize application use
- Designed to meet stringent CE, EMC, UL, CSA, and FM requirements
- Cable shield and braid connected to sensor housing for better noise rejection. Signal wire is white, Return wire is black.
- Corrosion Resistant
- Miswiring Protection

- 1/4 in., 28 mounting stud provided for positive attachment to compressor housings.
- Accelerometer mounting pad and Adhesive Bypac provided for mounting accelerometer to motor bearing areas or other areas not predrilled at the factory.

**Motor Bearing RTD Temperature Sensors**

- The Quantum HD Unity Controller can read the Motor Bearing RTDs but motors must be ordered with optional sensors.
- Bearing RTD is 100 ohm Platinum 2 or 3 wire (3 wire, 0.00385 TCR preferred), spring loaded pressure tube type. Supplied by motor manufacturer.
- The RTD output monitors temperature changes in bearings from 0°C to 180°C

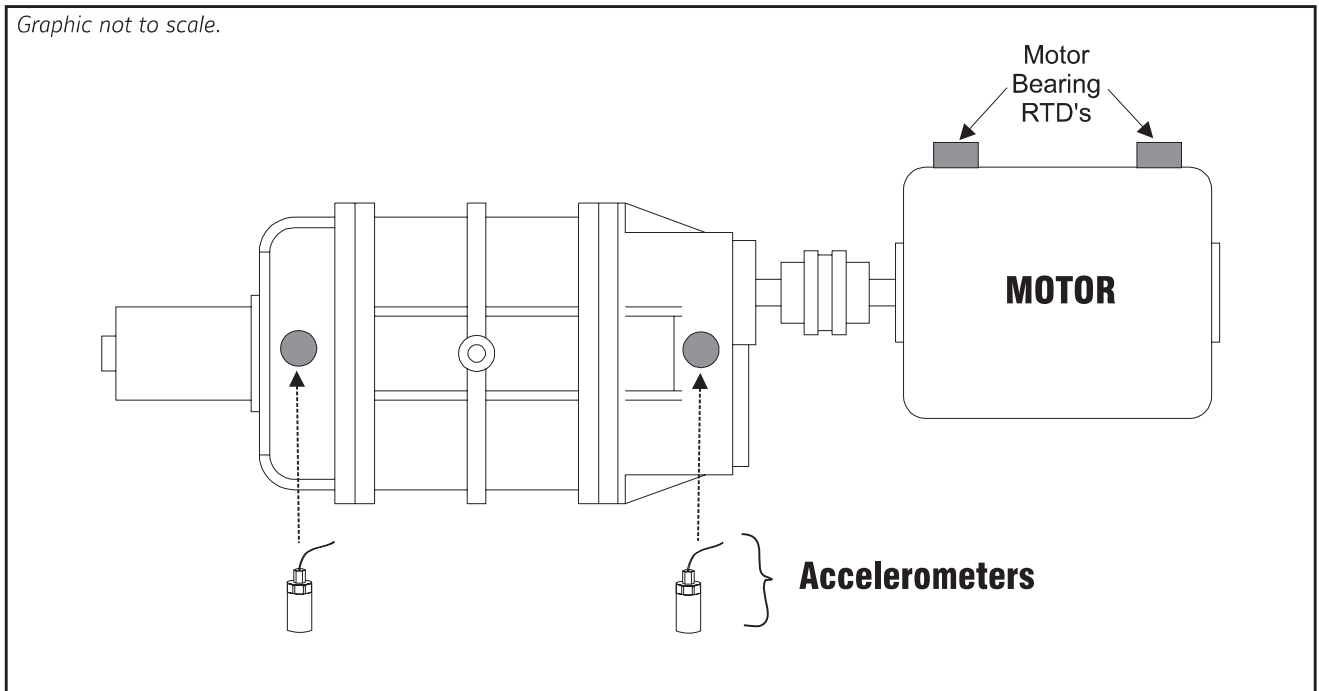
Figure 9: Motor Bearing RTD Temperature Sensor



**Motor Stator RTD Temperature Sensors**

- The Quantum HD Unity Controller can read the Motor Stator RTDs but motors must be ordered with optional sensors.
- Stator RTD is 100 ohm Platinum 2 or 3 wire (3 wire, 0.00385 TCR preferred), mounted in the motor stator. Supplied by motor manufacturer.
- The RTD output monitors temperature changes in windings from 0° to 180°C.

**Figure 10: Basic PhD Plus Vibration Monitoring System - Screw Compressor Accelerometers and Motor Bearing RTD Temp. Sensors**



### PhD Plus Vibration Monitoring Options

Several vibration monitoring options are available based on the application. See Figure 10 for a basic PhD Plus vibration monitoring system.

#### Option 1: Screw Compressor Only

Option 1 includes two accelerometers installed on the compressor. Each accelerometer connects to the vibration module. See Figure 11a.

#### Option 2: Motor Bearing RTD Temperature Sensors

Option 2 includes the wiring of two 100 ohm platinum 2 or 3 wire RTD assemblies. The bearing RTDs are spring loaded pressure tubes. The RTD output wires directly to Analog Board 1 in the Quantum™ HD panel and monitor temperature changes in the bearings. See Figure 11b.

### NOTICE

Price does not include motor bearing RTDs. Order motor with bearing RTD option.

#### Option 3: Screw Compressor and Motor with antifric-tion bearings

Option 3 includes two accelerometers installed on the compressor and two accelerometers installed on the motor. Each accelerometer connects to the vibration module. See Figure 11c.

#### Option 4: Motor Stator RTD Temperature Sensors

Option 4 includes the wiring of three 100 ohm platinum 2 or 3 wire RTD assemblies. The RTD output wires directly to Analog Board 1 in the Quantum™ HD panel and monitor temperature changes in the motor windings. See Fig. 11d.

### NOTICE

Price does not include motor stator RTDs. Order motor with stator RTD option.

### NOTICE

Thermal overload protection of the motor is required by the latest revision of National Electric Code (NEC) for all applications with Variable Frequency Drives.

Figure 11a: Option 1 - Screw Compressor Only

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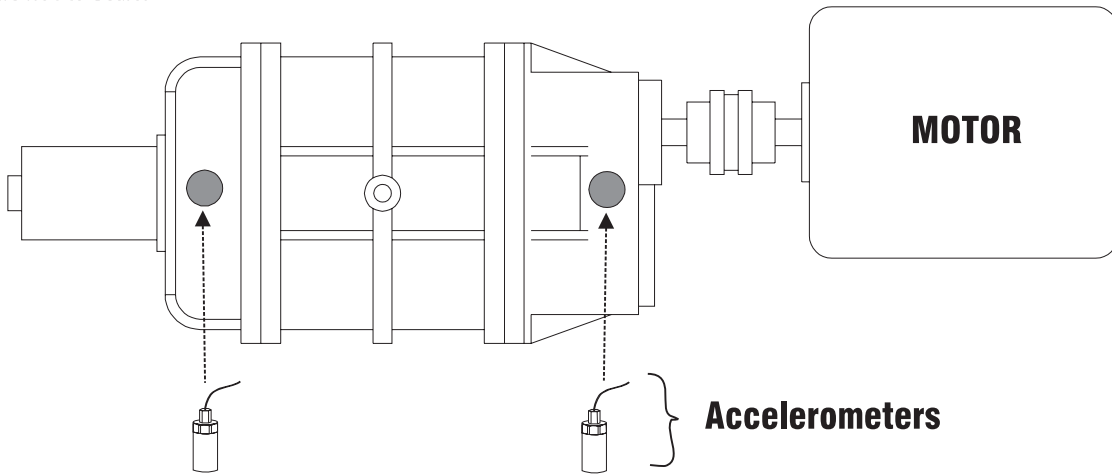


Figure 11b: Option 2 - Motor Bearing RTD Temperature Sensors

Graphic not to scale.

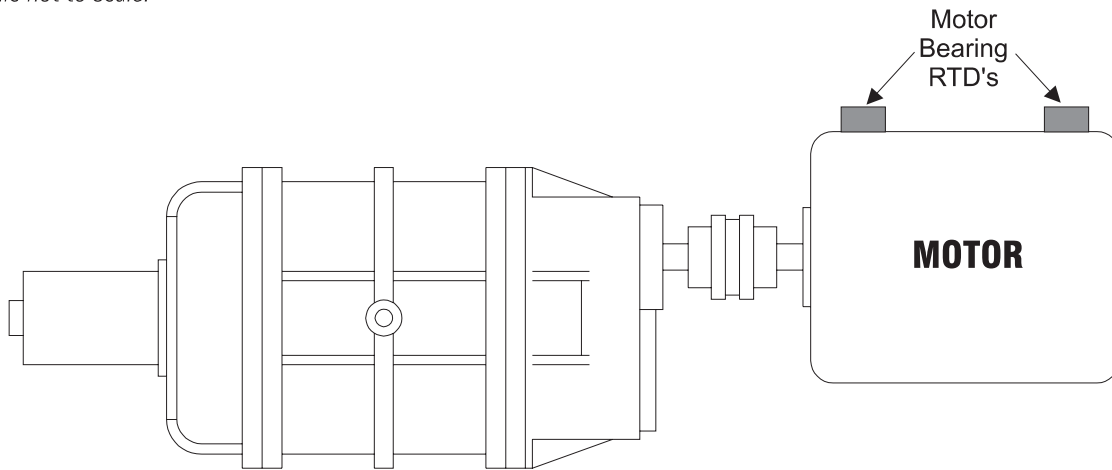


Figure 11c: Option 3 - Motor with Antifriction Bearings

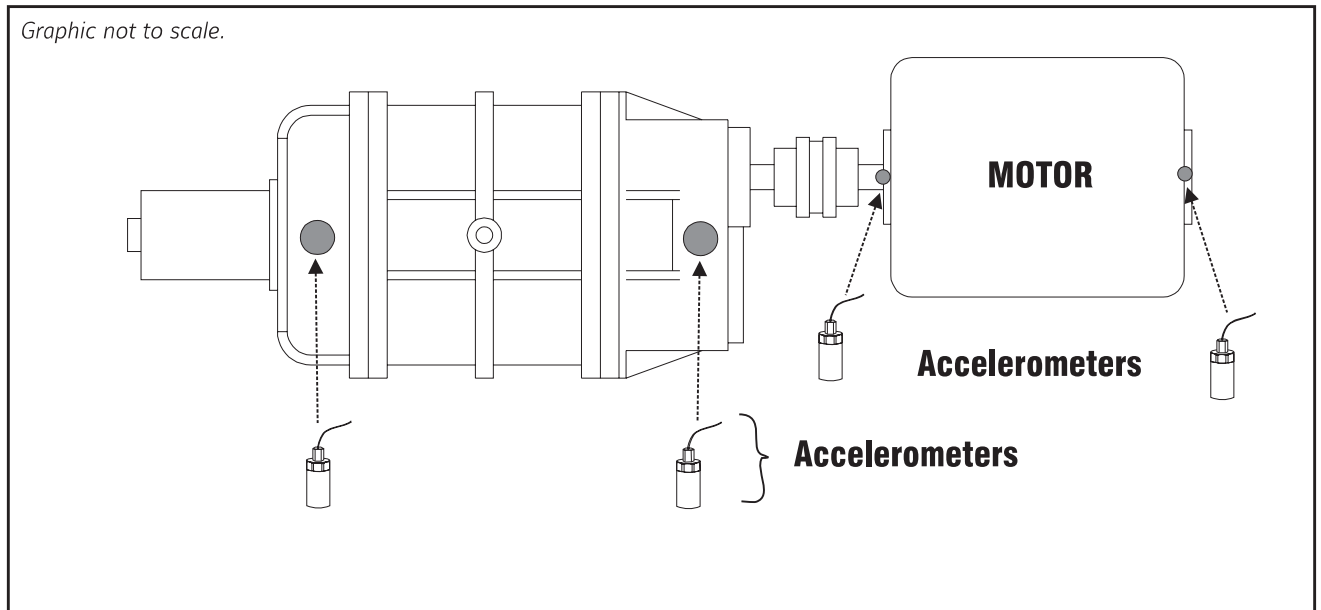
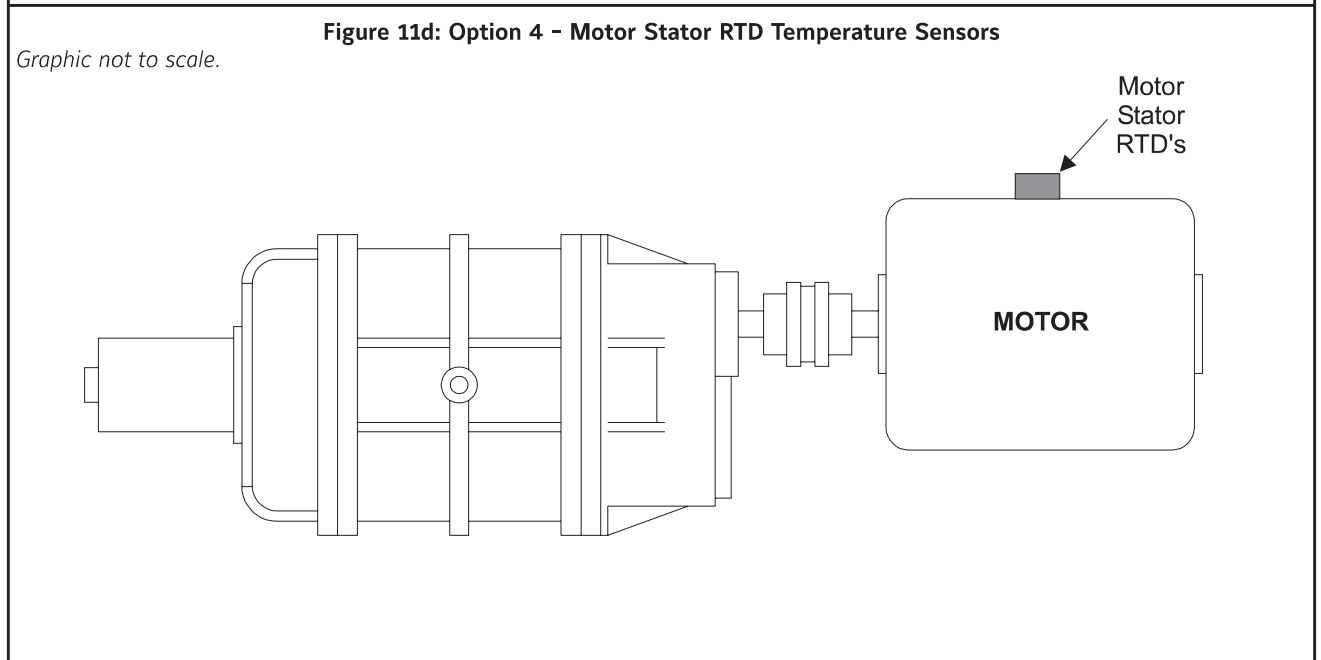


Figure 11d: Option 4 - Motor Stator RTD Temperature Sensors



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