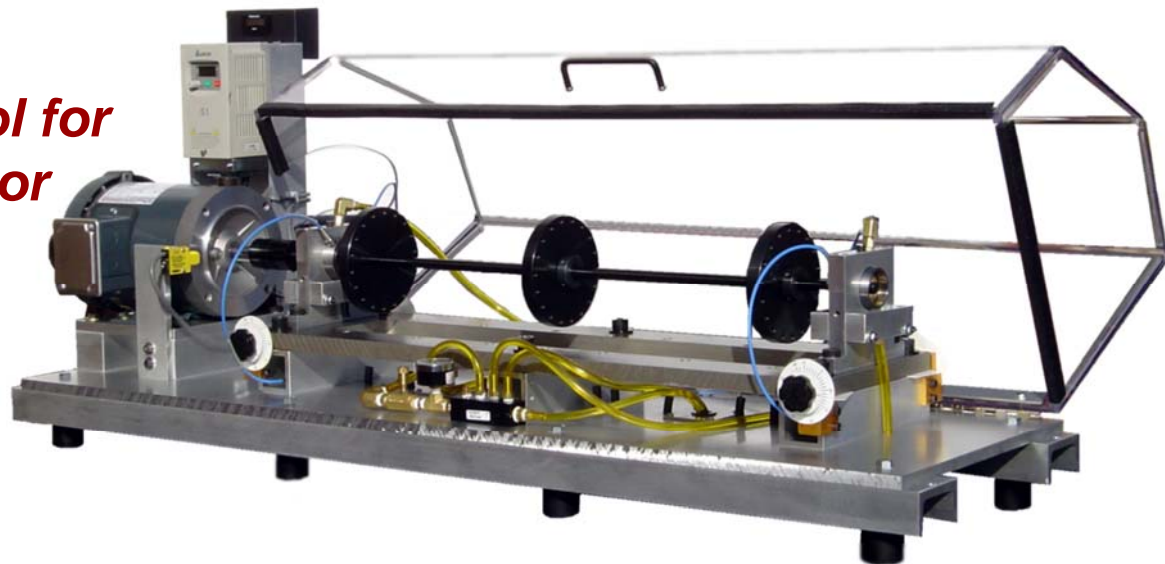


Machinery Fault Simulator Rotor Dynamics Simulator

***An invaluable tool for
research in rotor
dynamics***

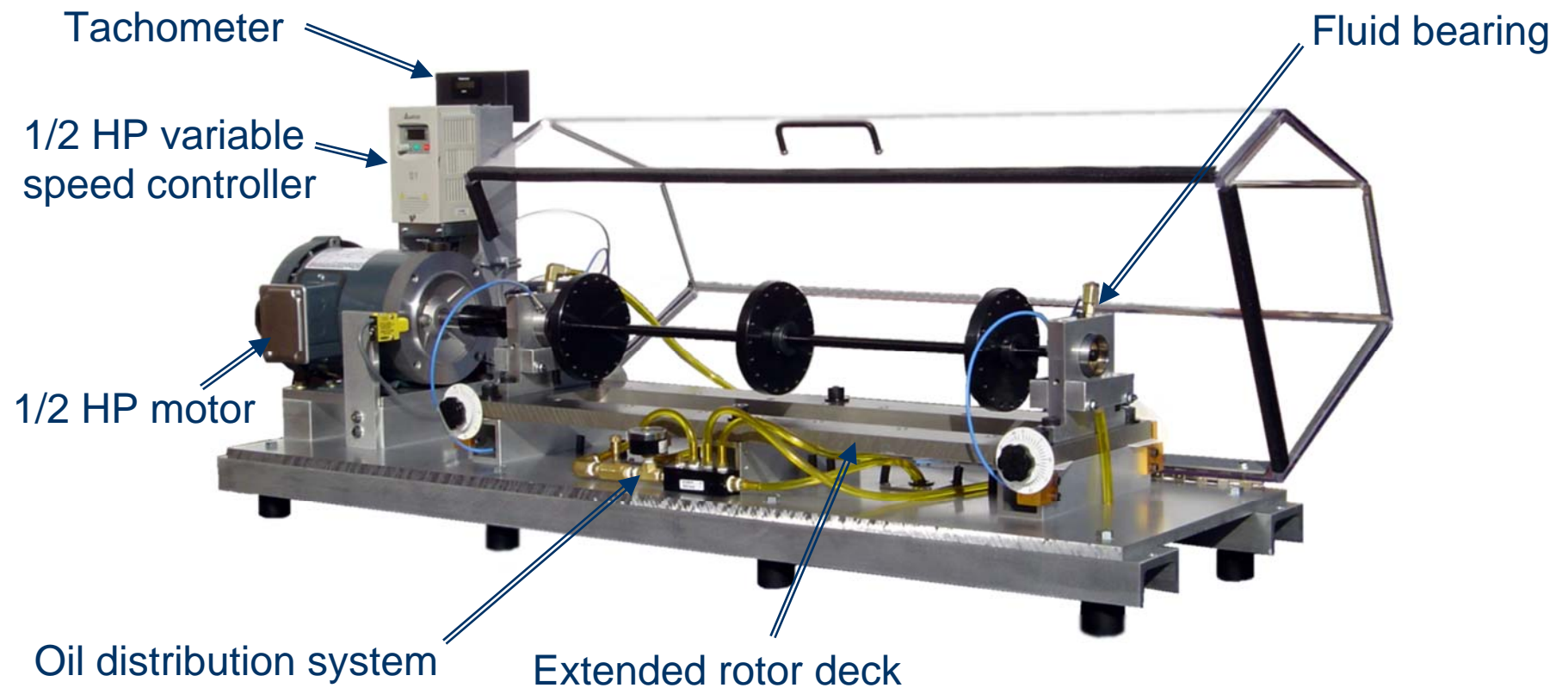


8201 Hermitage Road, Richmond, VA 23228 U.S.A.
TEL +1-804-261-3300/FAX +1-804-261-3303
www.spectraquest.com

Learning Machinery Diagnosis

- ❖ Gain an in-depth understanding of different vibration signatures, controlled experiments on a device that emulates real world machinery are needed.
- ❖ With the MFS-RDS, the expertise required to diagnose industrial machinery problems in well controlled experiments can be developed and enhanced.
- ❖ With a plant running at full production, it is virtually impractical to gain an understanding of the kinetics and dynamics of machinery without adversely affecting production and profits: The MFS-RDS enables offline training and experimentation which in turn will minimize production downtime.

MFS-RDS

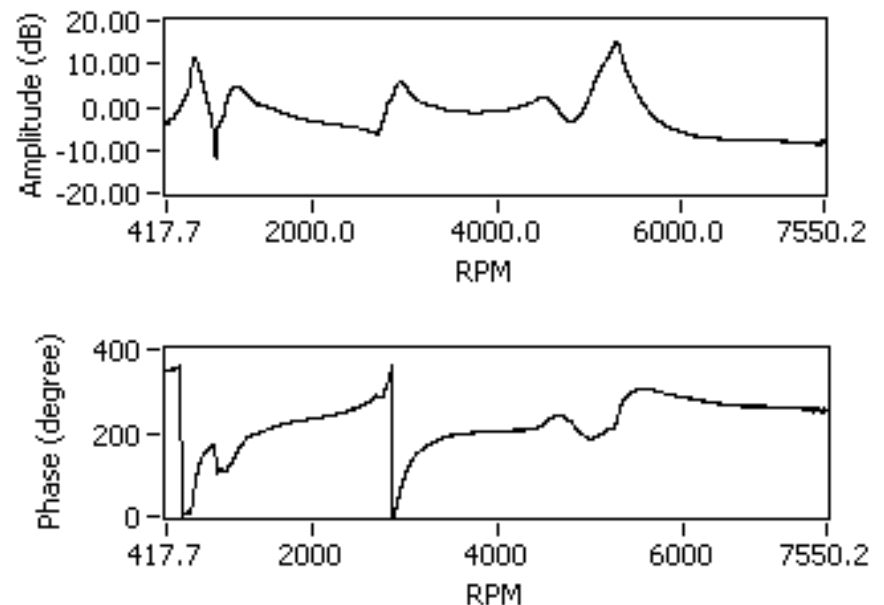


Features

- ❖ Rotor shaft specially designed for fluid film bearing rotor dynamics simulation
- ❖ Different bearing clearance selection and controllable lubrication oil pressure for rotor dynamics study
- ❖ Convenient installation of proximity probes
- ❖ Rigid, slippage-free operation
- ❖ Split bracket bearing housing for easy rotor assembly interchanges
- ❖ Specialized bearings and rotors with split collar ends for easy replacement and installation
- ❖ Rotor shaft slides without removing mounted components for easy changes
- ❖ Couplings, rotors, bearings, and shaft can be changed without removing bearing housings
- ❖ Convenient alignment with jackscrew

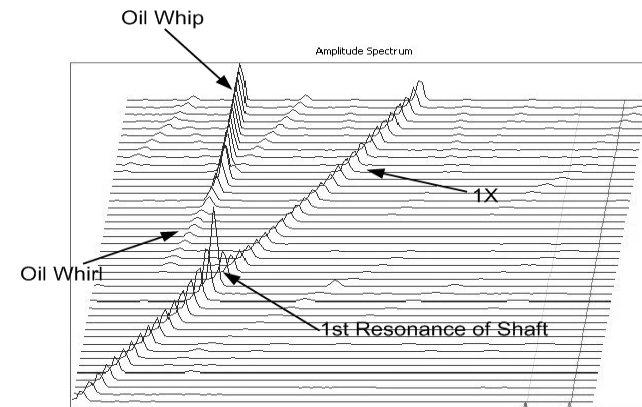
Shaft Resonance

- ❖ Fitted with a resonance kit, perfect tool to gain practical experience in rotating machinery resonance and learn resonance mitigation methods.
- ❖ With different number of rotor disks installed at various locations on the main shaft, resonances up to the third mode can be excited.
- ❖ Bode plot of the main shaft vibration during a coast down test is illustrated in the right figure.
- ❖ Three resonances can be identified.



Fluid Bearing - Oil Whirl and Whip

- ❖ Oil whirl and whip are important instability phenomena associated with rotors supported fluid film bearings.
- ❖ With proper selection of the bearing load (the number of rotor disk), bearing clearance (the selection of bearing cartridge) and oil pressure (adjusting the oil supply valve), the oil whirl and whip can be simulated using the MFS-MG.
- ❖ The waterfall plot on the right illustrates the oil whirl and whip observed on this simulator.
- ❖ The first critical speed of the main shaft (1X), oil whirl and oil whip are all identified in this waterfall plot.
- ❖ In order to observe oil whirl and whip, the simulator must be running at more than twice of the first critical speed of the main rotor shaft.

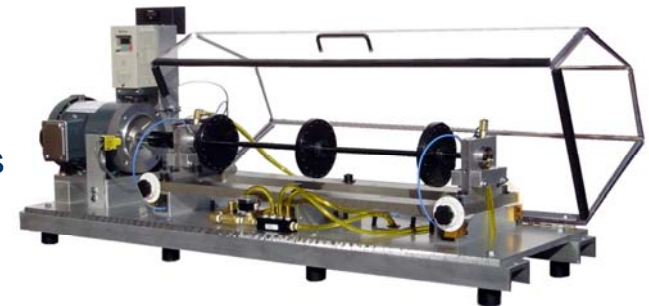


Applications

- ❖ Fluid film supported rotor dynamics studies and demonstration
- ❖ Balance training
- ❖ Shaft alignment training and alignment system assessment
- ❖ Resonance studies
- ❖ Mechanical rub
- ❖ Mechanical looseness
- ❖ Journal and rolling element bearing issues and defects
- ❖ Shaft orbit study

Basic MFS-RDS

- ❖ 1/2 HP variable frequency AC drive with multi-featured front panel programmable controller
- ❖ 3 Phase, 1/2 HP motor, pre-wired self-aligning mounting system for easy installation/removal
- ❖ Built-in tachometer with LCD display and one pulse per revolution analog TTL output for DAQ purposes
- ❖ Pressurized fluid film bearings with features to change bearing clearance, length, and type.
- ❖ Includes two full sleeve bearings with multiple oil inlet ports, tapped holes for mounting two proximity probes at 90 degrees, ability to rotate probe at any angle.
- ❖ Oil distribution and pressure adjustment system including of pump, pressure gage, stainless steel oil tank, back flow safety switch, pressure interlock gauge.
- ❖ Bearing inserts with 0.002" clearance
- ❖ Extended 30" rotor base to allow for rotor dynamics experiments up to three critical speeds and whirl/whip phenomena investigation, and nine bearing mounting positions for shaft span reconfiguration
- ❖ Vibration isolators mounts and base stiffener
- ❖ Two aluminum balance rotors with two rows of holes
- ❖ Three steel resonance rotors with one row of holes
- ❖ Alignment system with calibrated reference dials and jack bolts
- ❖ One 1/2" TGP straight steel shaft
- ❖ Impact resistant clear safety cover with safety interlock



Option Kits

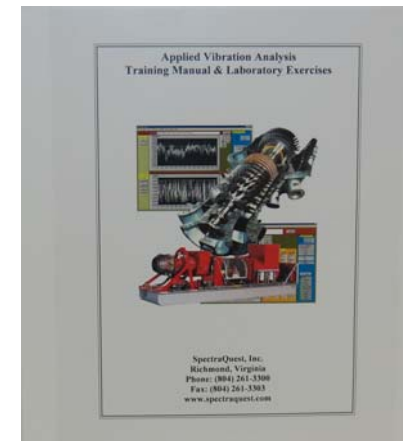
❖ SpectraQuest offers a complete array of option kits enabling detailed investigations of particular and more advance vibration phenomena or machinery faults.

Training curriculum manual	SQI-TRCM
Oil whirl/whip in-depth study kit for 1/2" shaft	MR-OWSK-1/2
3/4" shaft study kit	MR-BSK-3/4
Oil whirl/whip in-depth study kit for 3/4" shaft (Requires MR-BSK-3/4 and MR-OWSK-1/2)	MR-OWSK-3/4
Eccentric rotor (Requires MR-BSK-3/4)	M-ER-3/4
Cocked rotor (Requires MR-BSK-3/4)	M-CR-3/4
Coupling type set (Requires MR-BSK-3/4)	M-CK-3/4
Centrally bent rotor shaft for balance studies (Requires MR-BSK-3/4)	MR-BRS-3/4
Coupling-end bent rotor shaft for alignment studies (Requires MR-BSK-3/4)	MR-CBRS-3/4
Sleeve bearing resonance study kit	M-SBK-1/2
Rolling bearing resonance study kit	MR-RSK-1/2
Higher Resonance Study Kit	M-RDK-1/2
3/4" Rolling Bearing Study Kit (Requires MR-BSK-3/4)	M-RBK-3/4
Cocked bearing housing (Requires MR-BSK-3/4)	M-CBM-3/4

3/4" shaft sleeve bearing kit (Requires MR-BSK-3/4)	M-SBK-3/4
3/4" shaft bearing fault kit (Requires MR-BSK-3/4)	M-BFK-3/4
3/4" shaft bearing loader (Requires MR-BSK-3/4)	M-BL-3/4
1" shaft bearing study kit	MR-BSK-1
1" shaft bearing fault kit (Requires MR-BSK-1)	M-BFK-1
1" shaft bearing loader (Requires MR-BSK-1)	M-BL-1
Crack shaft study kit (Requires MR-BSK-3/4)	MR-CSRK-3/4
Fan vibration kit (Requires MR-BSK-3/4)	M-FVK-3/4
Mechanical rub kit	M-MRK
Damped bearing housing kit	M-DBHK-1/2
PC motor control kit	M-PCK
Shaft alignment kit	M-ATK
Vertical and horizontal bearing force transducer for 1/2" to 1" shafts	M-FTVH

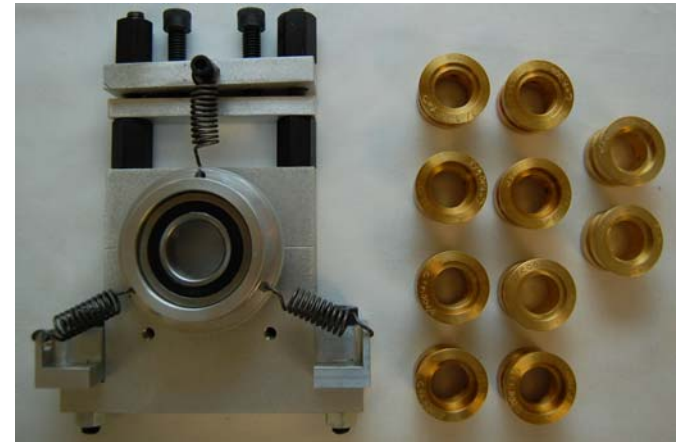
Training Curriculum Manual (SQI-TRCM)

- ❖ Begins with textbook and basic classroom training in the fundamentals of classic machinery vibration, transducers, monitoring, signal processing, analysis, etc; from beginner to upper intermediate levels. It is both hands-on and mathematically oriented, being appropriate for both technicians and engineers.
- ❖ The training curriculum manual begins with textbook and basic classroom training in the fundamentals of classic machinery vibration, transducers, monitoring, signal processing, analysis, etc; from beginner to upper intermediate levels. It is both hands-on and mathematically oriented, being appropriate for both technicians and engineers.
- ❖ A wide array of laboratory exercises to be conducted on the MFS to provide a truly experiential learning environment.
- ❖ Use as a basis for accelerated course preparation and the development of vibration training program.



Oil whirl/whip in-depth study kit for 1/2" shaft (MR-OWSK-1/2)

- ❖ Study effects of bearing clearance, L/D ratio, and rotor loading effects on oil induced instability, and to understand whirl/whip phenomena and how to avoid it.
- ❖ The kit consists of four sleeve bearing pairs to give bearing clearances of 2 and 6 mils (0.001") for two different lengths, two elliptical bearings to avoid whirl/whip instability, and one shaft centering device



3/4" Bearing Shaft Study Kit (MR-BSK-3/4)

- ❖ Study bearing fault frequencies away from multiples rotational speed. The standard 1/2" shaft exhibit fault frequencies close to multiples rotational speed, requiring ultra high resolution spectra to clearly identify bearing fault frequencies.
- ❖ Identify bearing fault frequencies in the presence of defects at multiples of shaft speed without using high-resolution spectra.
- ❖ The kit consists of two bearing inserts with 0.002" clearance, two 6" aluminum rotors with 36 threaded holes, one 3/4" diameter shaft, and one coupling.



Oil whirl/whip in-depth study kit for 3/4" shaft (MR-OWSK-3/4)

- ❖ Study the effect of stiffer rotor on oil induced instability and understand whirl/whip phenomena and how to avoid it. The idea is to understand and control the whirl/whip phenomena. 3/4" shaft provides not only stiffer rotor but also lighter balance, eccentric and cocked disks for more investigation to enhance the understanding.
- ❖ The kit consists four sleeve bearing pairs to give bearing clearances of 2 and 6 mils (0.001') for two different lengths, two elliptical bearings to avoid whirl/whip instability, and one shaft centering device insert.



Eccentric Rotor (M-ER-3/4)

- ❖ Learn the effects of rotor eccentricity on vibration spectra.
- ❖ Determine relationships between eccentricity and unbalance.
- ❖ Develop techniques to locate and correct the effects of eccentricity.
- ❖ Learn the effect of varying the mass moment of inertia on vibration amplitude.
- ❖ The kit consists of one aluminum rotor with an asymmetrically located center and one clamp collar.



Cocked Rotor (M-CR-3/4)

- ❖ Learn the effects of a sheave that has not been fitted to the shaft properly.
- ❖ Learn vibration signature of a cocked rotor.
- ❖ Develop methods to correct cocked rotor problems.
- ❖ Learn the effect of varying the mass moment of inertia on vibration amplitude.
- ❖ The kit consists of a cocked aluminum rotor (0.5 degree off-axis) and one clamp collar



Coupling Type Set (M-CK-3/4)

- ❖ Learn the effects of coupling stiffness on rotor dynamics and vibration signature.
- ❖ Clarify the complexities of machinery shaft misalignment problems (spectral pattern for shaft misalignment is a strong function of coupling stiffness).
- ❖ The kit consists of one gear, one LoveJoy, one rubber, and one rigid steel coupling.



Centrally Bent Rotor Shaft (M-BRS-3/4)

- ❖ Demonstrate the signature of a bent shaft.
- ❖ Observe the difficulty associated with attempting to balance a rotor mounted on a bent shaft.
- ❖ Learn to cope with the alignment issues due to a bent shaft.
- ❖ The kit consists of one 3/4" shaft centrally bent ~0.020"

Coupling-End Bent Rotor Shaft (M-CBRS-3/4)

- ❖ Investigate complicated vibration signature due to gyroscopic effects.
- ❖ Observe the difficulty associated with attempting to balance an overhung rotor on a bent shaft.
- ❖ Learn to cope with the alignment issues due to a bent shaft.
- ❖ The kit consists of one $\frac{3}{4}$ " shaft coupling-end bent ~ 0.010 "

Sleeve Bearing Resonance Study Kit (M-SBK-1/2)

- ❖ Study resonance and critical speed phenomena in sleeve bearings.
- ❖ The kit consists of two customized grease-lubricated, babbitt lined sleeve bearings, two bearing pedestals, and various thickness plastic shims



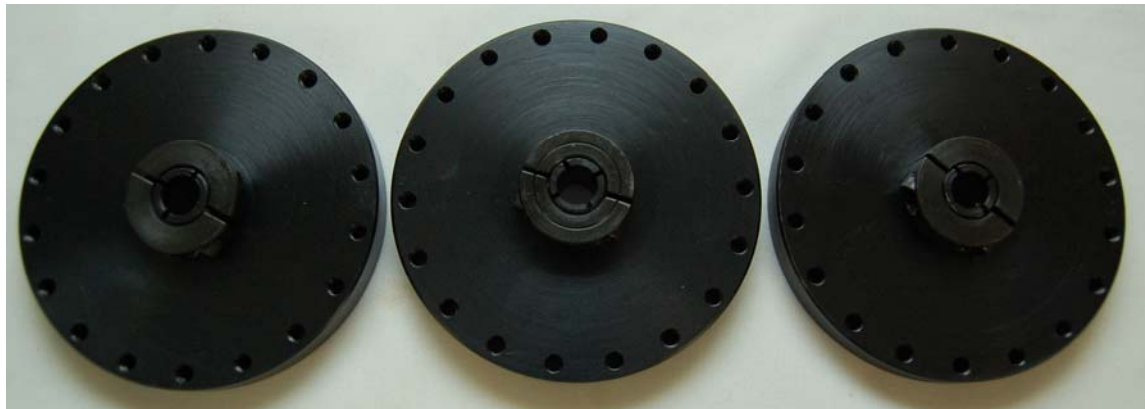
Rolling Bearing Resonance Study Kit (M-RBK-1/2)

- ❖ Study rolling element bearings on the MFS-RDS.
- ❖ The kit consists of two bearing mounting housings, and two 1/2" squeeze lock bearings.



Higher Resonance Study Kit (M-RDK-1/2)

- ❖ Study higher resonance modes by adding disks to 1/2" shaft.
- ❖ The kit consists of three steel disks



3/4" Rolling Bearing Study Kit (M-RBK-3/4)

- ❖ Study rolling element bearings on the MFS-RDS.
- ❖ The kit consists of two 3/4" squeeze lock bearings.

3/4" Shaft Sleeve Bearing Kit (M-SBK-3/4)

- ❖ Investigate waveform and spectral recognition of worn or loose fitting bearings.
- ❖ Modify the clearance of the split bearings with plastic shims.
- ❖ Perform shaft orbital analysis.
- ❖ The kit consists of two customized grease-lubricated, babbitt lined sleeve bearings, two bearing pedestals, and various thickness plastic shims



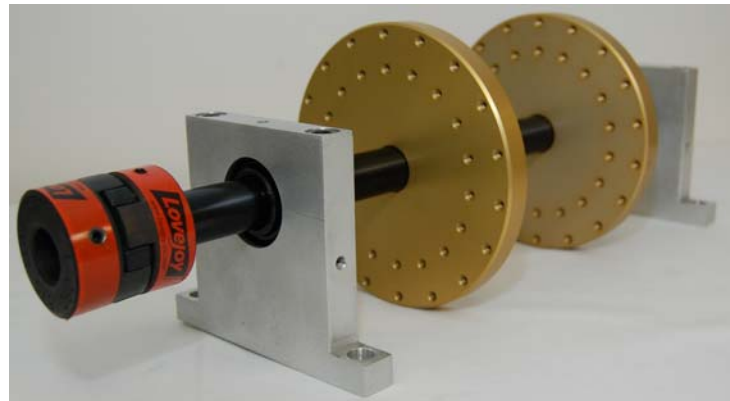
Cocked Bearing Housing (M-CBM-3/4)

- ❖ Recognize the signature of a cocked bearing due to improper seating or due to inconsistent installation.
- ❖ The kit consists of one cocked bearing housing



1" Shaft Bearing Study Kit (M-BSK-1)

- ❖ Study bearing fault frequencies away from multiples rotational speed. The standard $\frac{3}{4}$ " shaft exhibit fault frequencies close to multiples rotational speed, requiring ultra high resolution spectra to clearly identify bearing fault frequencies.
- ❖ Identify bearing fault frequencies in the presence of defects at multiples of shaft speed without using high-resolution spectra.
- ❖ Understand the signal processing issues such as averaging, spectral resolution, and leakage phenomena.
- ❖ The kit consists of two split bearing housings, two 1" inside diameter bearings, one 1" diameter shaft, and one coupling




3/4" and 1" Bearing Loader (M-BL-3/4 & M-BL-1)

- ❖ Investigate bearing radial loading effects.
- ❖ Enhance the spectral amplitude of system.
- ❖ The kit consists of one 3/4" or 1" bore loader weighting 11lb (5kg) and two clamp collars



3/4" and 1" Bearing Fault Kit (M-BFK-3/4 & M-BFK-1)

- ❖ Learn waveform and spectra of classic bearing defects.
 - ❖ Learn about signal processing issues such as averaging techniques, leakage, and spectral resolution on determining bearing faults.
 - ❖ Perform experiments with increasing severity of defects.
- 
- ❖ Determine why an ultra-high resolution spectrum is needed to diagnose a bearing fault when fault frequencies are located close to multiples rotational speed.
 - ❖ Learn how a large signal can mask adjoining low amplitude signal due to spectra leakage.
 - ❖ The kit consists of one inner race defect, one outer race defect, one with ball defect, and one combination of defects

Fan Vibration Kit (M-FVK-3/4)

- ❖ Learn the sound and vibration signatures of fans.
- ❖ Study the effects of volumetric flow rate on pressure rise and fan vibration.
- ❖ Develop the noise and vibration control methods on fans.
- ❖ The kit consists of one six-blade paddle fan, one ten-blade paddle fan, one 12-blade axial fan, and one axial fan obstruction



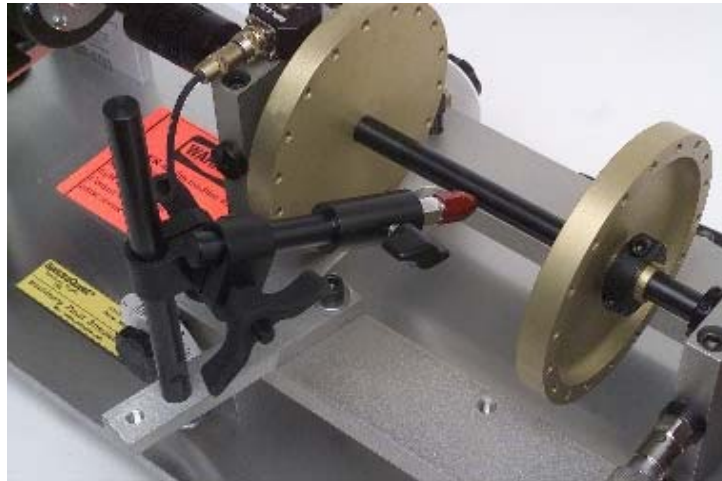
Crack Shaft Study Kit (M-CSRK-3/4)

- ❖ Study the effects of crack on the natural frequencies and vibration behavior.
- ❖ Develop diagnostic technique to detect crack at early stage.
- ❖ Study crack propagation and breathing.
- ❖ Apply advanced signal processing techniques, such as wavelet, joint time-frequency analysis, time series analysis, to study the vibration caused by crack.
- ❖ The kit consists of one shaft with a 4 ½" 4-bolt flange connection to simulate crack, one shaft with slit crack and filler, and one shaft with a deep V-notch crack.



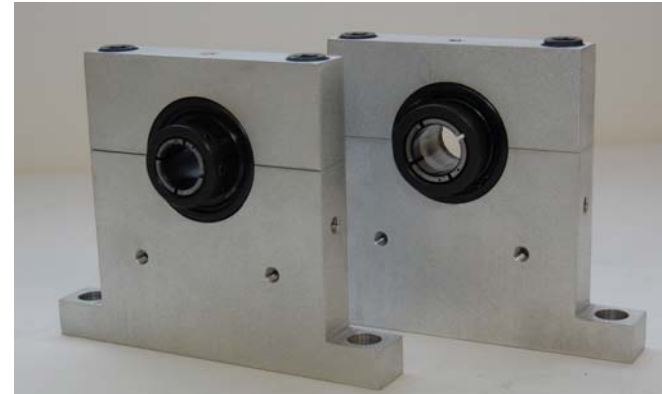
Mechanical Rub Kit (M-MRK)

- ❖ Evaluate typical rub phenomena associated with a variety of materials under different angle, loading, and lubricant conditions.
- ❖ Experiment rubs on shaft or rotor.
- ❖ The kit consists of an adjustable spring-loader rub material holder and four different rub materials



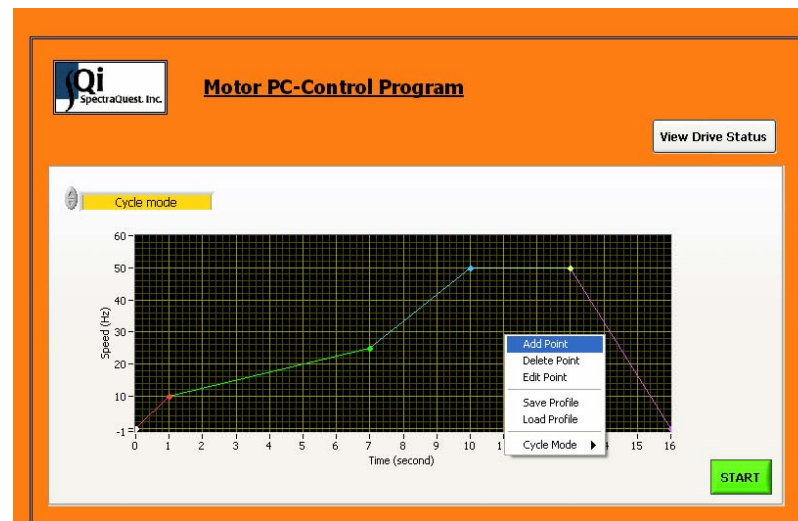
Damped Bearing Housing Kit (M-DBHK-1/2)

- ❖ Study bearing housing with a higher damping factor than the standard housing. Typical rolling element bearing systems are an all-metal structure with virtually no damping.
- ❖ Add damping to a standard rolling element bearing housing.
- ❖ Demonstrate the reduction in rotor resonance amplitude due to the installation of damping.
- ❖ The kit consists of two bearing housings and two ½" bearings fitted with isolators.



PC Motor Control Kit (M-PCK)

- ❖ Operate MFS from remote location.
- ❖ Pre-program speed acceleration, deceleration, and length of run to meet exact requirements.
- ❖ The kit consists of PC software, one interface module to motor drive and cables.



Shaft Alignment Kit (M-ATK)

- ❖ Align shafts precisely with convenient and simple Windows alignment software.
- ❖ Accommodates $\frac{1}{2}$ " to $1 \frac{1}{4}$ " diameter shafts.
- ❖ The kit consists of two precision dial indicators, two mounting brackets/bars, one mirror, one set of feeler gauges, and instructions packaged in a rugged plastic case.



Vertical and Horizontal Bearing Force Transducer for 1/2" to 1" Shafts (M-FTVH)

- ❖ Measure forces exerted on bearings due to coupling misalignment, rotor unbalance, belt misalignment, and belt tension.
- ❖ Establish quantitative tensions for drive belt studies.
- ❖ Learn to relate the vibration signature to forces associated with common malfunctions such as resonance and bearing faults. Learn phase relationship between force and vibration spectrum.
- ❖ Learn nature of rotor dynamic forces due to common defects.
- ❖ Witness 180 degree phase shift between heavy and high spots when rotor goes through a critical speed. Demonstrate how mass unbalance force quadruples when the speed is doubled, but vibration amplitude does not follow the same trend.
- ❖ Verify and refine your rotor dynamic models and enhance modeling skills.
- ❖ The kit consists of one transducer simultaneously measuring vertical and horizontal force and one matching signal conditioner.



Value Packages

- ❖ The MFS-RDS is also available in high value combination packages. From basic to comprehensive, each package is designed to provide you with all the tools needed to study a variety of machinery fault topics:

	Whirl/whip	Alignment	Balancing	Resonance	Bearing defects	Mechanical rub	Shaft crack	Damping	Fan	PC operation	Shaft alignment	Bearing force transducer
PKG 1	X											
PKG 2	X	X	X	X								
PKG 3	X	X	X	X	X							
PKG 4	X	X	X	X	X	X	X	X	X			
PKG 5F	X	X	X	X	X	X	X	X	X	X	X	X

	SQI-TRCM	MR-OWSK-1/2	MR-BSK-3/4	MR-OWSK-3/4	M-ER-3/4	M-CR-3/4	M-CK-3/4	MR-BRS-3/4	MR-CBRS-3/4	M-SBK-1/2	MR-RSK-1/2	M-RDK-1/2	M-CBM-3/4	M-SBK-3/4	M-BFK-3/4	M-BL-3/4	MR-BSK-1	M-BFK-1	M-BL-1	M-MRK	M-DBHK-1/2	M-CSRK-3/4	M-FVK-3/4	M-PCK	M-ATK	M-FTVH
PKG 1	X	X	X	X																						
PKG 2	X	X	X	X	X	X	X	X	X	X	X	X														
PKG 3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							
PKG 4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
PKG 5F	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

Specifications

Electrical	
Motor	3 Phase, 1/2 HP motor, pre-wired self-aligning mounting system for easy installation/removal
Drive	1/2 HP variable frequency AC drive with multi-featured front panel programmable controller
RPM range	0 to 6000 rpm (short duration) variable speed
Current Measurement	Power leads accessible for current measurements
Tachometer	Built-in tachometer with LCD display and one pulse per revolution analog TTL output for DAQ purposes
Voltage	115/230 VAC, Single phase, 60/50 Hz
Mechanical	
Shaft Diameter	1/2" diameter; Turned, Ground, & Polished (TGP) steel
Bearing	Two full fluid film bearings with multiple oil inlet ports, provisions to mount proximity probes at any angle. Bearing mounts can be mounted in nine different position for variable rotor span
Rotor Base	30" long, completely movable using jack bolts for easy horizontal misalignment and standard shims for vertical misalignment. Pinned for easy realignment.
Rotors	Two 6" aluminum with 36 threaded holes at 10 degree intervals for introducing unbalance
Oil Distribution System	Pump, pressure gage, stainless steel oil tank, back flow safety switch, pressure interlock gauge.
Safety Cover	Lockable clear, impact resistant hinged plastic cover with motor interlock switch to shut down motor when cover is raised
Foundation	1/2" (12.7 mm) die cast aluminum base, base stiffener and eight rubber isolators
Physical	
Weight	Approximately 125 lb
Dimensions	L=50" (125cm), W=14" (36cm) , H=25" (65cm)