Spectral Dynamics, Inc. *Medium Force Shaker Series* **SD-4400-12/DA-20**

FEATURES

- Air Cooled
- 4,400 lbs (2,000 kgf) Sine Force
- 4,400 lbs (2,000 kgf) Random Force
- 2Inches (51 mm) Peak to Peak displacement
- Large diameter, lightweight armature
- Double Field Coils (Upper and Lower) design
- Ultra-Compact energy efficiency amplifier
- Available combined with slip table
- Sine, Random, and Transient Testing
- Standard cooling blower silencer
- Standard Vertical and Horizontal Operation

Typical System Application

The **Model SD-4400-12** Series Vibration test system is a versatile wide frequency range electrodynamic vibration test system. It is designed to test small to medium sized payloads such as electronic assemblies and components for automotive, aviation, military, medical and electronic manufacturing industries. The system consists of a model SD-4400-12 shaker and is driven by the Model DA-20 power amplifier and a 7.5 KW cooling blower.

◎ Wide Useable Frequency Band

The high performance shaker powered by an efficient DA-20 switching power amplifier operates over a useful frequency range from DC to 3,000 Hz. The amplifier is designed using the latest IGBT module Technology.

◎ High Fundamental Resonant Frequency

A unique light weight stiff aluminum alloy is employed for the armature to increase the first resonance to 2,600 Hz. Increased stiffness reduces the tendency for the resonance to reduce in frequency due to mass loading. An optional magnesium armature is also available.

◎ Air Cooled

Both the SD-4400-12 shaker and DA-20 power amplifier are air cooled for easy installation and economical operation.

◎ High Overturning Moment

The armature design incorporates four robust roller-structures for top guidance and a unique roller-bearing for bottom guidance. The distance between the top and bottom guidance systems is lengthened to enhance stability. The system produces a high overturning moment, adding safety when testing heavy products with high centers of gravity.

◎ Standard Cooling Blower Silencer

The SD-4400-12 system comes standard with a blower silencer that significantly reduces the ambient noise generated by the system. For this system, the low-noise blower with 75 dB is available as an option.

◎ Automatic Internal Pneumatics For High Payload

A superior pneumatic load support system guarantees the high performance at low frequency and a full nominal displacement with a maximum vertical load up to 661 lbs (300 kg) for test specimen and fixture. An optional auto-centering pneumatic load support system is available to enhance the performance of the shaker system.

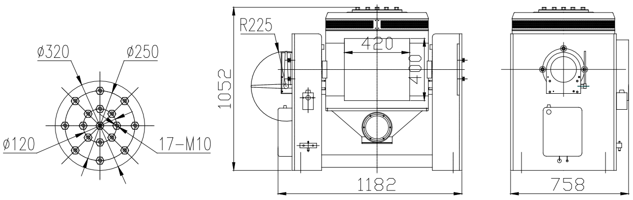
◎ Standard Vertical and Horizontal Operation

The SD-4400-12 shaker comes standard with VH configuration. The shaker can be operated in either a vertical or a horizontal direction and can be used in combination with an integrated or stand-alone slip table or environmental chamber with optional thermal barrier. An optional worm wheel system may be added to the trunnion making it easier to change the thrust direction.

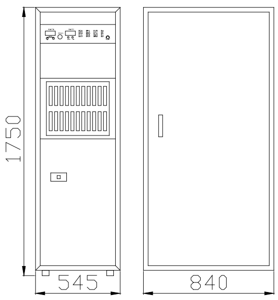
◎ Safety

The armature driving coil and field coil comply with European regulations that require 1600 VDC for 1 minute with resistance not less than 0.5 megaohm. The emergency stop switches on the shaker body and amplifier are installed. All the inner terminals are safe for people.

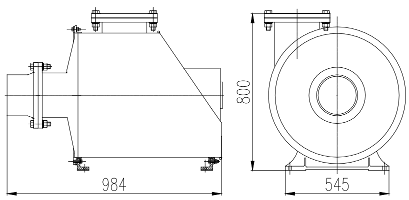
These features and others make the SD-4400-12 a reliable and affordable system for your applications.



Shaker



Power Amplifier DA-20



Blower B-2000LN

2730 Orchard Parkway, San Jose CA 95134 USA www.spectraldynamics.com 1.408.678.3500

SD-4400-12/DA-20
TECHNICAL SPECIFICATIONS

Shaker Specifications	SD-4400-12		
Sine (Pk)	4,400 lbf (2,000 kgf)	*Vertical Load Support*	660 bs (300 kg)
Random (RMS)	4,400 lbf (2,000 kgf)	*Table Diameter*	12.6 Inches (320 mm)
Shock (Pk)	8,800 lbf (4,000 kgf)	*Load Attachment Points (Standard)*	17 stainless steel M10 Inserts (UNC option)
Usable Frequency	DC to 3,000 Hz		
Maximum Displacement (p-p)	2 Inches (51mm)	*Degauss Coil*	Standard
		Stray Flux Density @6 inch (152 mm) above table	< 10gauss (1 mT)
Maximum Velocity	78.7 in/s (200 cm/s)		
Maximum Acceleration	100 g	*Overall Dimensions*	**46.5"L×29.8"D× 41.4"H** 1182mmL×758mmD ×1052mmH)
Fundamental Resonance Frequency (Bare table)	2,600 Hz (nom.) +/- 5%		
Body Suspension Natural Frequency (Thrust Axis)	2.5 Hz	*Weight of Shaker (Uncrated)*	3,740 lbs (1,700 kg)
Armature Effective Nominal Weight	44 bs (20 kg)	*Compressed Air Requirement*	87 psi (0.6 Mpa)

Power Amplifier Specifications	DA-20
Rated Output Capacity	20 kVA
Signal to Noise Ratio	Greater than 65 dB
Amplifier Efficiency	Greater than 90%
Interlock Protection(to prevent the output devices from working outside their specified limits)	•Over-Current •Logic Fault •Input Phase Loss •Over-Voltage •System Fault •Input Under-Voltage •Over-Travel •External Fault •Door Interlock •Over-Temp (Field Coil and Driving Coil)

Blower Specifications	B-2000LN
Blower Power (Full Load)	10 HP (7.5 kW)
Air Flow Rate	Air Flow: 1762 CFM (0.83 m^3/s) Air Pressure: 0.84 PSI (0.0058 Mpa)

System Environmental Requirement	
Operating Room Temperature	32 to 104 degrees F (0 to 40 degree C)
Humidity	0 to 85%, non condensing
System Continuous Duty	not less than 7 hours at the full ratings
Power Supply Requirement	380/415/480 VAC, 50/60 Hz, 3Ph, 42 kW

SYSTEM OPTIONS	
•Slip Table Configuration **•V-Groove Caster and Rail System** **•Table Inserts** **•Head Expander**	•Thermal Barrier •Load Support Air Compensator •Air Caster •Auto-Centering Support-OPCS

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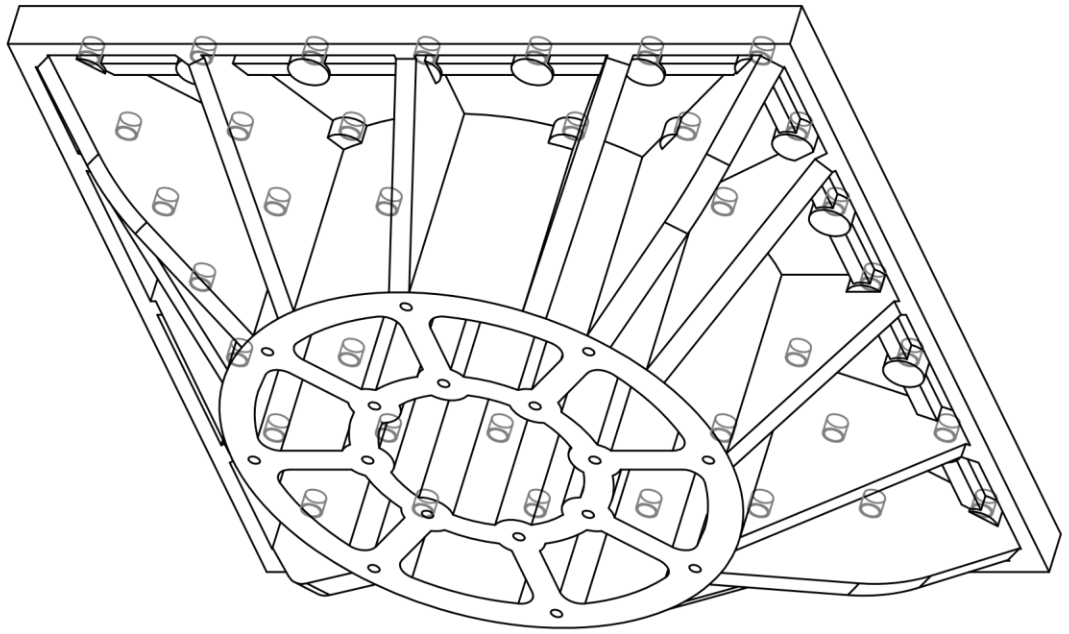

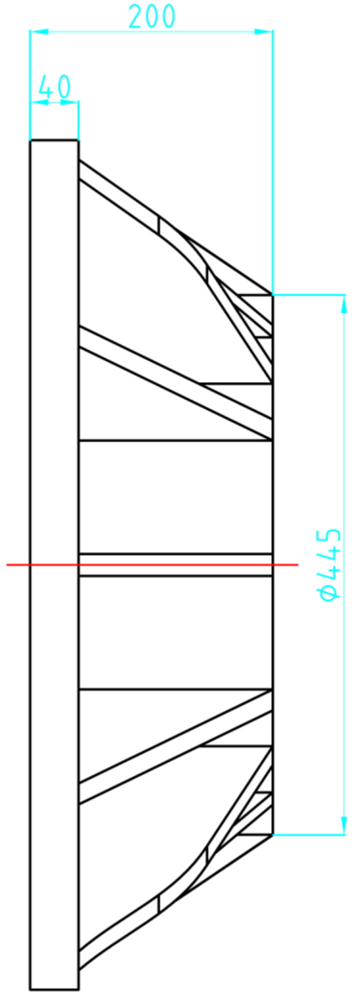

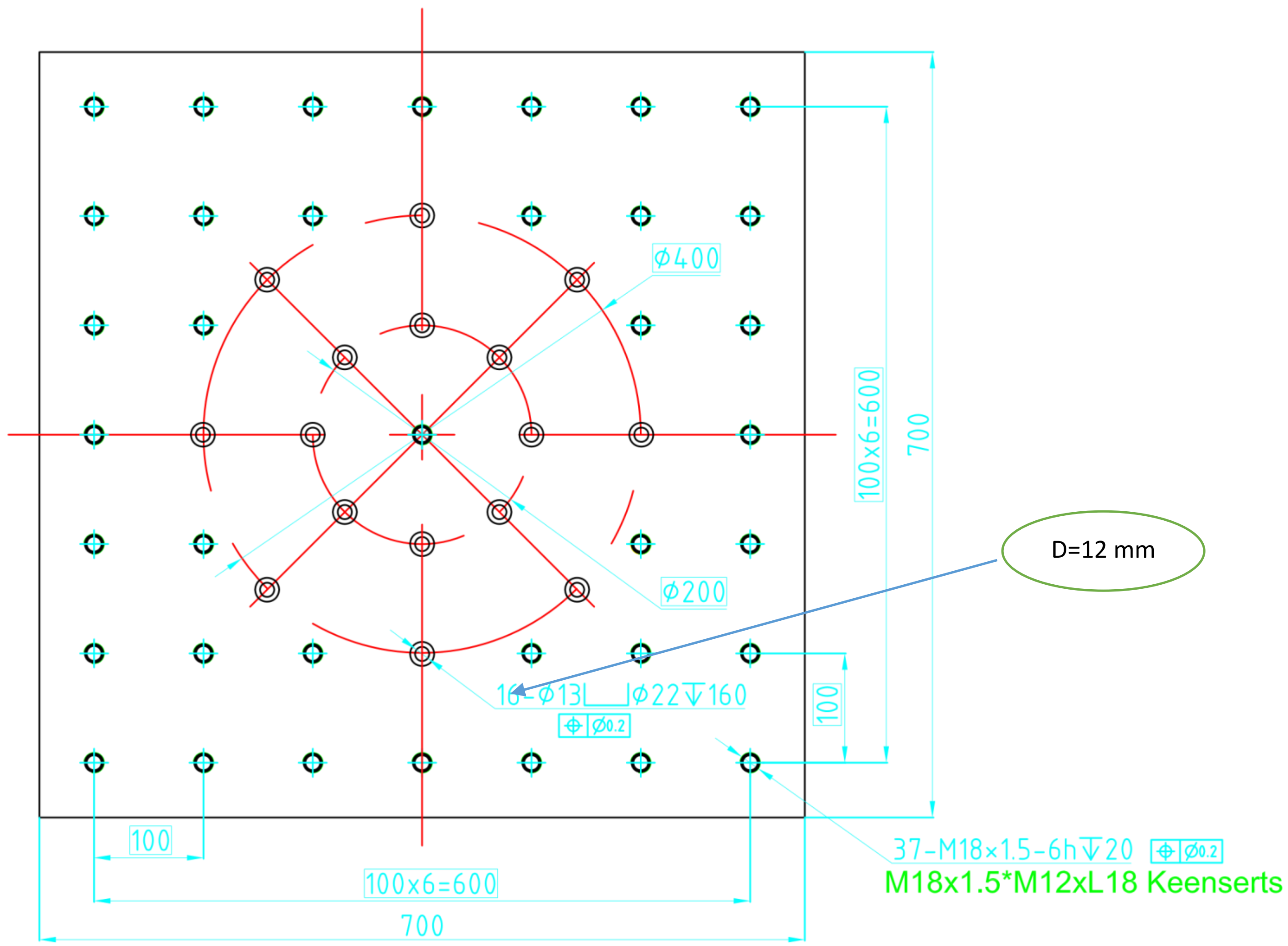

Material	Mg
Height	200mm
Weight	60 kg est.
Resonance Freq.	1500 Hz est.

NOTES:
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2)WITH CONSTANT PRODUCT IMPROVEMENT PRODUCT SPECIFICATIONS MAY BE CHANGED

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Title:
ETS-M544A/HE700SQM Outline

SPECTRAL DYNAMICS

OPERATION MANUAL

ELECTRODYNAMIC VIBRATION SYSTEM

Model: SD-50-440/DA-50

End User: University of Pretoria South Africa

S/N: S1005007

Manufacture Date: August, 2010

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Limited Warranty

All products are warranted to be free of defects in material and workmanship for a period of one year from date of shipment. For this case, the warranty period is 12 months after the acceptance or 14 months after shipment whichever is earlier. If the products are installed, maintained and used in an abnormal manner in accordance with instructions and manuals, this warranty will not apply.

This warranty is limited to repairing and replacing parts which have been returned to Spectral Dynamics Corporation, and, in our opinion, are defective. Service required correcting defects in material or workmanship will be supplied without charge. The Buyer will pay all transportation and taxes incurred. This warranty does not cover costs incurred by the Buyer as a result of purchase of Spectral Dynamics Corporation equipment or any charges for the Buyer's labor for replacement, adjustment or repair unless authorized in advance, in writing. Spectral Dynamics is not liable for consequential damages.

This warranty will not apply to any products which, in the opinion of Spectral Dynamics have been subject to accident, misuse or neglect; altered or repaired with a substitute which might impair the product; or used outside of rated conditions. Spectral Dynamics reserves the right to make improvements in its products, including changes and additions, without incurring obligations to incorporate such improvements in previous units.

This warranty is expressly in lieu of any and all other warranties or commitments, expressed or implied, and any other obligations to the Buyer associated with the use of Spectral Dynamics's products.

This Manual includes complete configuration information. If your shaker system is not configured with some parts, like slip table, head expander, please ignore the relative information.

Page A: Typical Vibration Test System

A Vibration Test System consists of four major components (shown in Figure A-1):

1. The Shaker
2. The Power Amplifier
3. The Cooling Blower
4. The Measurement and Control System
    a) Accelerometers and Cables
    b) Charge Amplifier, depending on which type of accelerometers.
    c) Control System, sometimes including DATA Analysis Software

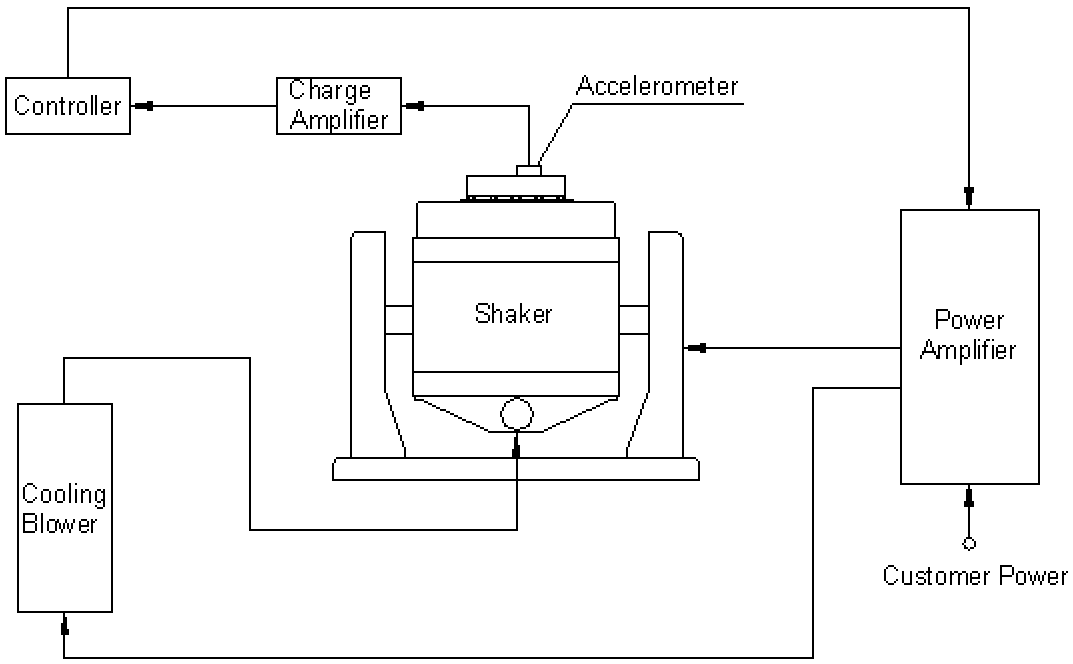


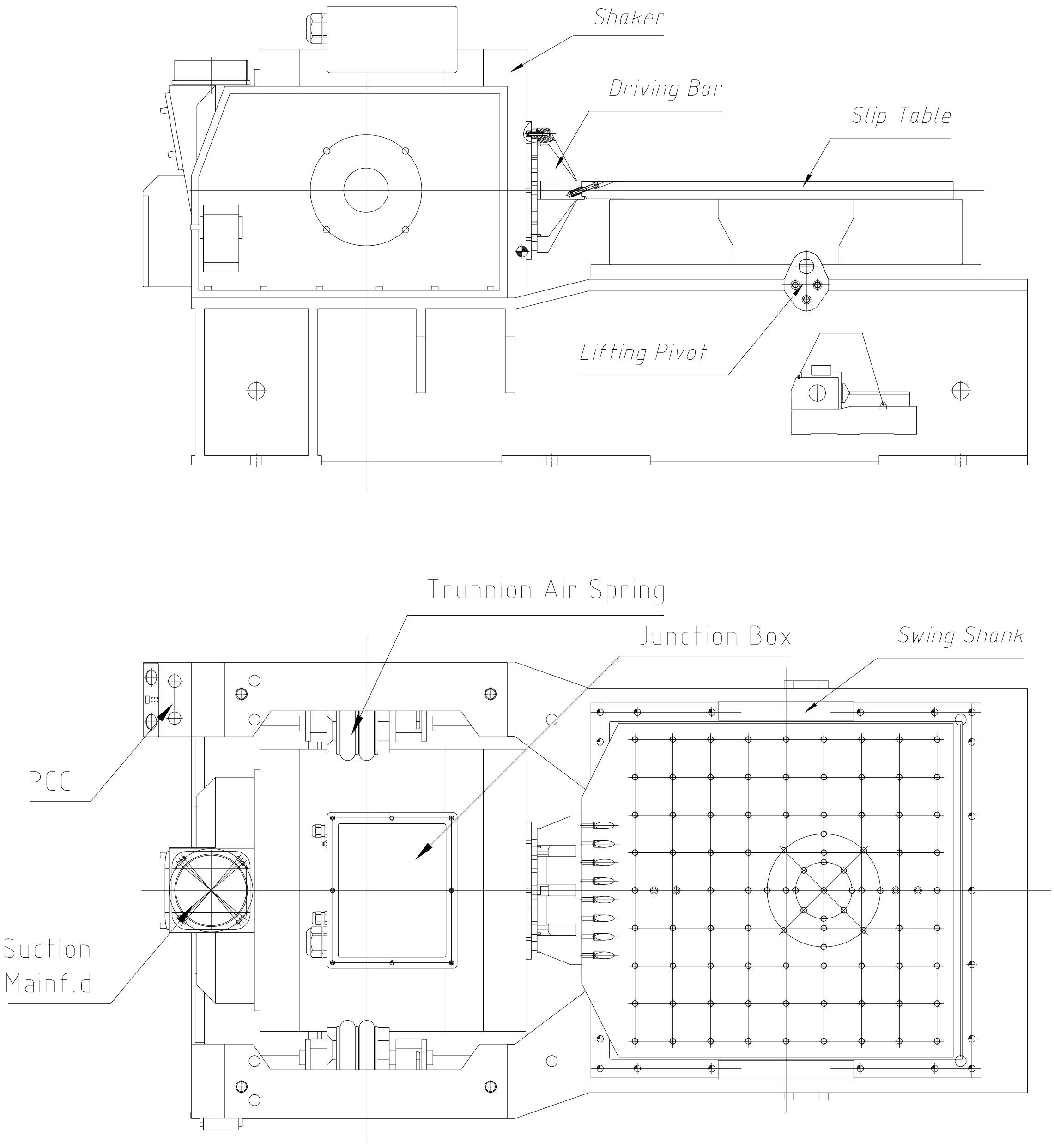
Figure A-1

The drive signal from the Digital Signal Processing Controller is input to the amplifier. The Amplifier takes the low voltage (0-5 volts and milliamps) from the controller and converts it to higher voltages and currents ($0\text{-}100^{+}$ volts and hundreds or thousands of amps) for the shaker.

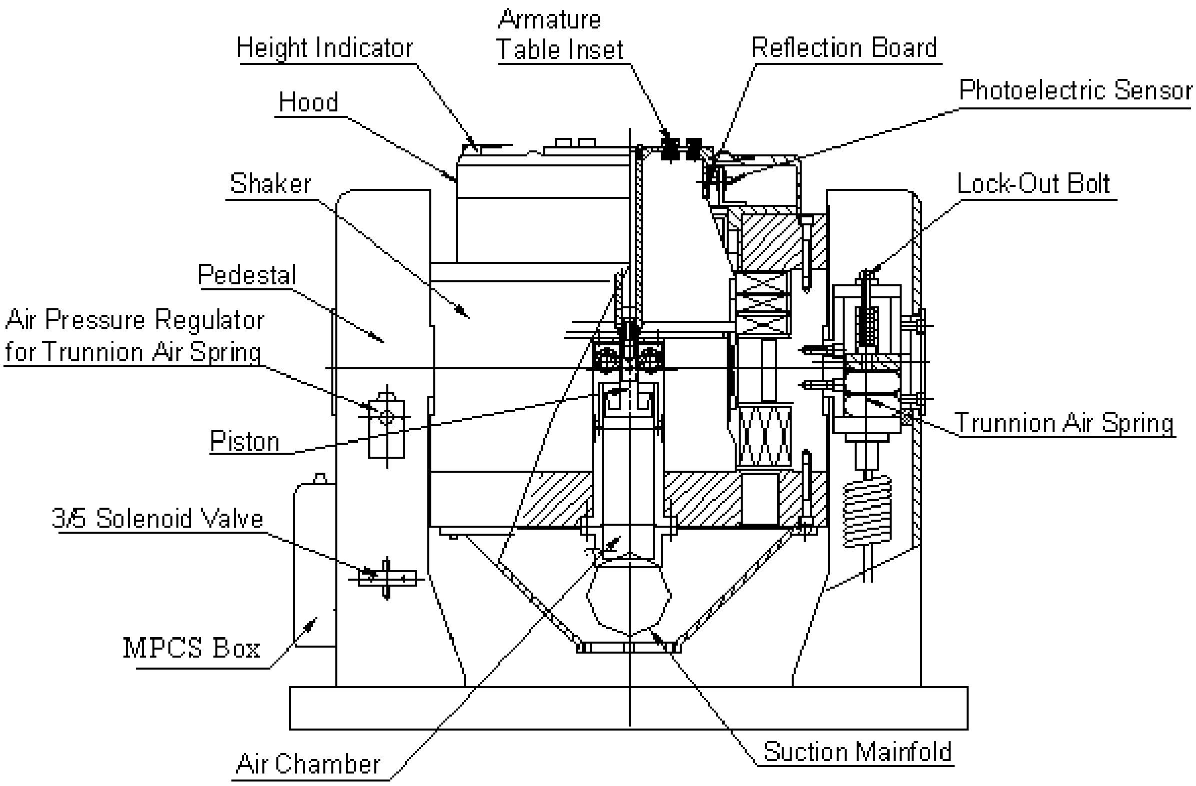
The moving element (slip table or armature) of the shaker is suspended in a strong magnetic field. The current from the amplifier flows through the driving coil attached to the moving element. A force is generated on the wire by the current flowing through the wire in a magnetic field. The suspended moving element is restrained and allowed to move only up and down. The motion of the table follows the characteristics of the current through armature driving coil. Sinusoidal current produces a sinusoidal motion, random currents produce random motion.

The movement of the table is sensed by the accelerometer (pick up transducer). In case of using charge accelerometer, it produces a charge measured in pc (10^{-12} coulombs). The signal conditioner or charge amplifier coverts the charge signal to a normalized voltage one for the controller. This can be anywhere from 1mV/g to 1000 mV/g. The conditioned signal is feed into the closed control loop from the charge amplifier to a pre-defined reference level. The controller continually adjusts the drive signal to the amplifier to maintain the reference level.

Page B: Drawings of Typical Electrodynamic Shaker with slip table



B-1 Shaker with Slip Table



B-2 Vertical Shaker Cutaway Drawing

Page C: Glossary of Terms

ACCELERATION	It is the time rate of velocity changing. Typically measured in "g's peak" for sine testing and "g's rms" for random testing. (1 "g" = 32.2 ft/sec^2, 9.81 m/sec^2).
AIR GAP	It is the area inside of shaker where armature coil is located and where high magnetic flux density is produced. The gap is typically only one half inch wide or less, depending on the size of the shaker.
ARMATURE COIL	AC coil wound at the bottom of the moving element assembly, driven by the amplifier. The wire used for the coil may be copper or aluminum.
ARMATURE TABLE	Top of the moving element assembly mount inserts attached. One insert is in the center of the table and the others are on circular patterns from the center, placed on 4", 8" etc. bolt circle patterns, normally it is standard.
BEARING SHAFT	Shaft matches with the LINEAR BALL BEARING. It provides linear guidance and cross-axial stiffness
BOOT DIAPHRAGM	A rubber diaphragm covering the AIR GAP mentioned above. It is attached to the table (with shrinkage of the rubber material) and the static parts (with a flat ring with several screws). It provides operator safety and prevents foreign objects, like metal particles from entering shaker.
BOTTOM SUCTION COVER	Cover mounted on bottom plate of shaker's bottom plate to provide a plenum for the cooling blower. Blower duct is attached to it and it is designed to make sure air flows through the entire air gap and to maximize the air flow through the shaker
BULL NOSE	Device connecting the shaker armature table to the slip plate. It is sometimes called as "driving bar"
CASTERS	Wheels under shaker. The shaker may be moved from one spot to another. It is normally used with tracks and big foot, allowing the shaker to move under chamber. Sometimes, a kind of pneumatic casters are applied.
DEGAUSS COIL	A DC coil producing a magnetic field which opposes the stray field produced by the field coils, thus reducing the stray flux at the top of the armature table. This is an optional item with some shakers.
DISPLACEMENT	Displacement is the changing of position of a body or particle such as the armature and slip plate and is usually measured from a mean position or position of rest. Typically measured in peak to peak or double amplitude values.
FIXTURE	Device used to attach customer's product to the shaker table. Ranging from simple adapter plates to specially shaped

	supporting units. Poorly designed fixtures will limit the testing capabilities of the vibration test system because of the fixture's resonance.
FLEXURE	They suspend the armature in the air gap also known as "rubber spring" and sometimes they carry current to the armature coil known as a "current spring". Typically, four flexure sets are used. Two carry current to the armature coil and one is used to ground the armature if they carry current.
FLUX PATH	The magnetic field path in the shaker. It should be noted that not all the magnetic flux travels through the iron and air gap. Some flux, known as stray gauss, travels in the air outside of the shaker. The degauss coil attempts to reduce the "stray gauss" above the armature table.
GRANITE	Granite stone ground very smooth and flat, it is the resting surface for the slip plate. Attached to slip table assembly with the oil pan.
GRILL	Typically placed below the hood, it allows air to go through to cool the field coils and armature coils, but prevents any particle, especially metal particles from entering the shaker.
HOOD	Hood is called Top Cover, too. Protective cover of moving parts on the top of the shaker body located around the shaker table. It may or may not extend around to the sides of the shaker.
INSERTS	Threaded, hex head attaching points for the fixture or specimen located on the shaker table. The table itself is made of magnesium. Bolting directly in the magnesium table would not be a strong fitting and would degrade with excessive use. Therefore, the inserts (made of stainless steel or titanium alloy) take the abuse of everyday usage. Many thread sizes are available; consult the factory for options.
ISOLATION AIR BAGS	Isolate shaker vibration from factory floor. It is normally located at the trunnion, or it may also be located at the bottom of the base, such as on low profile shakers.
LINEAR BALL BEARING	Device providing constraint of the trunnion with light frictional movement of mechanical structures (i.e. shafts, sliders, etc.)
LOAD SUPPORT AIR BAGS	Pneumatic air bags to support shaker loads. Located under armature table, the auto-centering option controls air bag pressure to keep the armature in the center of its vertical travel regardless of the payload. Without auto-centering, the operator must manually add and remove air from load support system as needed.
LOWER FIELD COIL	DC coil located in the lower half of the shaker, it provides part, or all (depending on the shaker), of the magnetic flux in the air gap. This magnetic flux is used to generate "FORCE" to the moving element.

MAGNETIC BODY	Magnetically soft steel structure parts of shaker through which the magnetic flux travels (usually referring to the outer parts). Normally they are referred to Bottom Plate, Body Ring, Centre Pole and Top Plate Segments.
MOVING ELEMENT	Also known as "Armature". System operators use the term moving element because the armature is the part that moves. In electrical terms it is an armature. It provides the mounting surface for fixtures and specimens.
OIL PAN	Used as an oil reservoir for the oil used to float the slip plate on the granite.
PADS for COMBO	Rubber pads designed to isolate vibration between two objects. The slip table base rests on these pads as a secondary vibration isolator. The shakers use air bags to isolate them from the base and the combo pad is used to separate the base from the floor. The pads may be stacked to help level the slip table assembly.
Q (QUALITY FACTOR)	The quantity Q is a measure of the sharpness of the resonance of a vibratory system, either mechanical or electrical. In a mechanical system, this quantity is equal to the resonant frequency divided by the bandwidth of the resonance.
RANDOM VIBRATION	Random vibration contains many frequencies all at the same time. The amplitude of the acceleration during random vibration is different at any given instant of time or time period.
RIB	Stiffening member between the armature coil and the armature table. It is part of the casting of the moving element assembly.
RESONANCE	Resonance exists when the response signal is at a maximum. The response signal is often compared to the control signal. The shape of the response curve is measured in terms of the "Q" of the resonance.
SHAKER BASE	One style of shaker base consisting of two separate platforms for supporting the shaker. Other bases and configurations are available, i.e. Low Profile: commonly used to roll under thermal chambers; ST (Slip Table): used for vertical and horizontal operation of the shaker.
SHOCK	A short duration excitation to a system. There are different classifications for shock pulses used today; Classical, Seismic, pyrotechnic, SRS, Crash, etc
SINUSOIDAL (HARMONIC) MOTION	Sinusoidal motion is a motion such that the displacement is described by a sinusoidal function of time. Resulting velocities and accelerations are described by a sinusoidal function. Sometimes it is referred to as harmonic motion.
SLIP PLATE	Slide table attached to shaker table through bull nose or driving bar. It is used to attach fixtures and specimens when

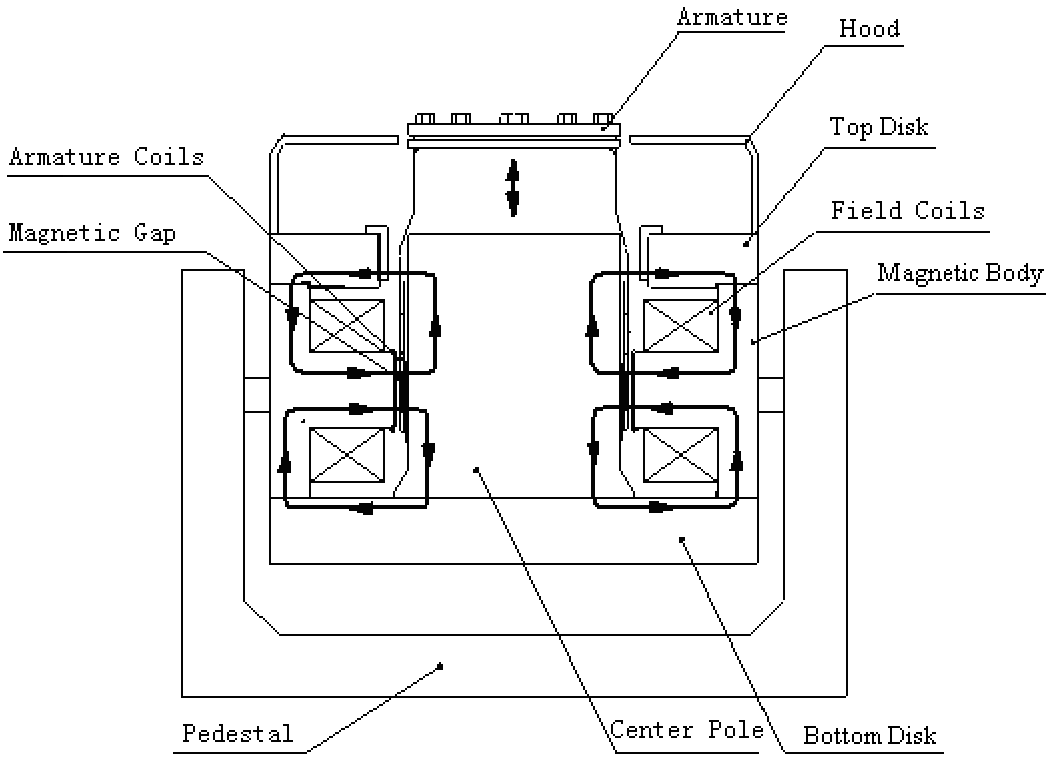
	vibrating in the horizontal direction. It floats on a surface of oil to allow low friction during operation or restrained by hydrostatic bearings to supply bigger over turning moments. Slip plates come in various sizes and shapes.
TOP PLATE	Steel part providing flux path for the magnetic field and supporting armature suspension components.
TRACK	Thin steel rails which provide the rolling surface for the shakers with caster wheels.
TRANSMISSIBILITY	Transmissibility is the non-dimensional ratio of the response amplitude of a system in steady-state forced vibration to the excitation amplitude. The ratio may be one of forces, displacements, velocities, or accelerations. A good fixture design will have its resonance's above the highest frequency of interest in your test.
TRUNNION	Pivoting point of the shaker. Located at the center of gravity of the shaker, it is used to rotate the shaker. Most shakers with trunnion can be rotated up to 90° for horizontal operation.
UPPER FIELD COIL	A DC coil located in the upper half of the shaker. It provides part of the magnetic flux in the air gap. This magnetic flux is used to generate "FORCE" to the moving element.
VELOCITY	Velocity is the time rate of change of displacement. This quantity is measured in terms of peak values for sine testing and rms values for random testing.
VIBRATION	Vibration is the movement of a part or particle about a certain point of reference. Vibration measurements are often expressed in terms of acceleration (commonly known as "g"

Page D: Description of a Shaker Vibration System

The Shaker Vibration System usually consists of four separate parts: the Shaker, the Control Console, the Cooling Blower and the Electric Power Amplifier.

D-1 SHAKER

The Shaker is the heart of the system. It provides the vibrating armature to which the items to be tested is attached. The principal parts of the shaker are shown in the illustration D-1.



D-1

The field coils energize the Shaker body with flux paths as shown, creating a high magnetic flux density in the annular air gap. The field coils are connected to the DC field supply from amplifier. The armature assembly, consisting of the table and drive coil, is suspended in the annular air gap of the shaker. When an alternating current is passed through the drive coil, electro-dynamic force is generated on the drive coil wire causing the table to move up and down as indicated by the double ended arrow shown above. The movement magnitude and frequency is controlled by the drive signal from the vibration controller. The table motion depends on several factors including, but not limited to, the mass of table, load attached, and table suspension stiffness. (NOTE: load attached includes all fixtures, adapters, bolts and units under test).

The main vibration data is Displacement, Velocity and acceleration. Typically, amplifier output and shaker systems performance limits above three data.
First limitation is armature movement displacement. It is dictated by the maximum stroke of the shaker as well as the power amplifier voltage and current output

capabilities.

Second limitation is the velocity which is from approximate 15 to 100 Hz (This depends on different shaker and different load). This is generally associated with the amplifier output voltage capabilities. At this stage, the shaker needs high drive voltage.

The last is the limitation of acceleration which is from approximate 100 to 2000 Hz or above (This depends on different shaker). This is generally associated with the amplifier output current and the shaker heat balance.

Shakers come with three basic base configurations. First is the Low Profile. This type of base contains casters and tracks to allow the shaker to be moved from one spot to another. This type of configuration is commonly used with Environmental Chambers. In order to move the shaker from one spot to another, the operator must deflate the isolation air bags, allowing the shaker to reset on the guide tracks. After the shaker is relocated, the isolation air bags are inflated and the shaker body is isolated from the floor.

Another solution to move the shaker is to use pneumatic air casters. The shaker can be floated on the floor to be moved easily when the air casters on the bottom of shaker base are fed by pressure air.

The second type of base is the Pedestal Base. The shaker is mounted to a base that is made primarily for vertical vibration only. The pedestal base allows the operator to rotate the shaker 90º for horizontal vibration of LIGHT loads or to attach to a separate slip table.

The third type of base is the Slip Table Base. In some cases, the shaker is incorporated with a slip table base to allow quick and simple connection to a slip plate for horizontal testing. Horizontal operation with a slip plate allows testing in a third axis and can permit testing of very heavy payloads which could not be tested vertically due to the mechanical limitations of some armature suspension.

The shaker includes protective interlock features to prevent damage due to over-stroke or over-temperature. These items are described in detail in the Chapter “Door Interlock” in the Amplifier Section of this Manual.

D-2 CONTROL CONSOLE

The control console houses the intelligence of the system. Accelerometers (transducers) detect the motion of the shaker table and send it to the charge amplifiers. The output of the charge amplifier is then connected to the controller. Modern controllers are printed circuit boards mounted in personal computers or using a separate front end box. The controller works to maintain a predetermined reference level. If the signal from the charge amplifier is incorrect, the controller will change its output accordingly to obtain the desired level or spectrum.

D-3 ELECTRONIC POWER AMPLIFIER

The power amplifier input is connected to the control drive signal source and the output is connected to the drive coils of the shaker. The controller generates a low power, low voltage signal which is amplified by the electronic power amplifier. The amplifier has the necessary power to cause the AC currents to flow through the drive coil to generate rated force. The power amplifier is designed to provide the necessary power levels through the operating frequency range without introduction of significant distortion. The amplifier is described in detail in the Amplifier Section of this Manual.

D-4 FIELD SUPPLY

The field supply is the DC source that energizes a coil in the shaker creating a strong magnetic field where the armature coil is suspended. Some shakers are designed with two field coils (upper and lower) and some with one. The DC source is supplied by a three phase transformer. The secondary leads of the transformer are connected to a three phase rectifier module that generates the DC voltage. The field supply is operated from the power amplifier. As the amplifier is sequenced for operation the field supply is automatically turned on at the appropriate time. When the field supply is not contained in the power amplifier as called as Standalone Field Supply, the operation is the same, only the location of the three phase transformer changes.

D-5 CALIBRATION

A Vibration Test System consists of four major components as previous introduction:

1. The Shaker
2. The Power Amplifier
3. The Cooling Blower
4. The Measurement and Control System
    - a). Accelerometers and Cables
    - b). Charge Amplifier, depending on which type of accelerometers.
    - c). Control System including DATA Analysis Software

The various items included in 4a, 4b & 4c determine the results and accuracy of any tests conducted with this test system. These items require Certificates of Calibration on an annual basis.

Items 1, 2 and 3 include metering and factory adjustments intended to assist in maintenance, servicing and adjusting for maximum output. None of these items are involved in determining Test Results

Page E: Electrodynamic Shaker's Principle

Electrodynamic shakers work on the same principle as a speaker. Some basic knowledge of physics is helpful to understand the action. The main principles or laws are:

(1) F (Output Force) = B (Magnetic Density) L (Length of Conductor) I (Current Flow)

A force is generated on a current carrying Conductor (wire) in a magnetic field and

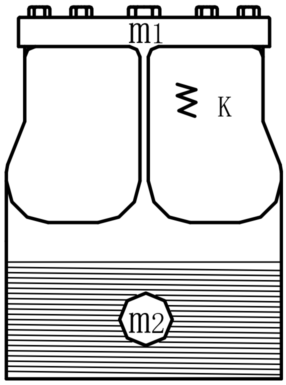
(2) F (E-motive Force) = B (Magnetic Density) L (Length of Conductor) V (Velocity of Conductor)

A voltage is induced across a conductor (wire) moving within a magnetic field.

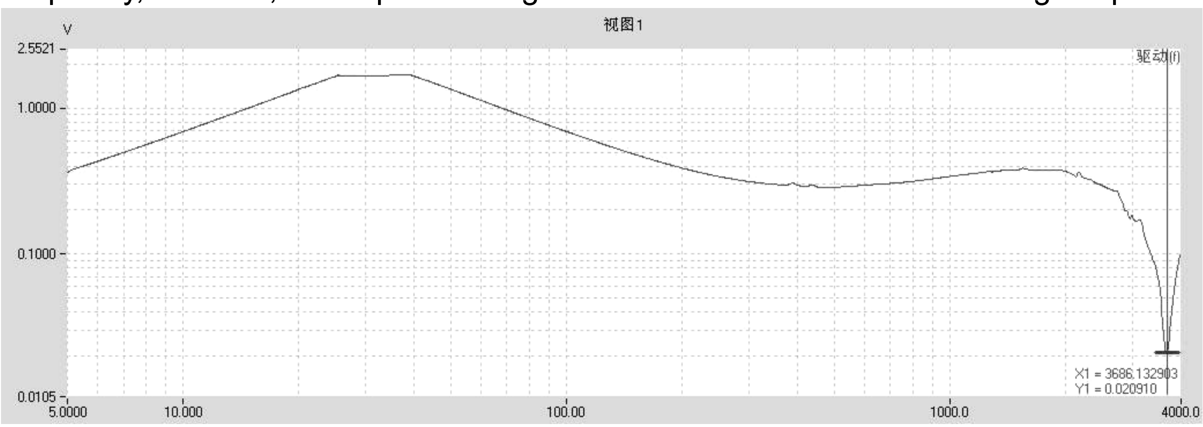
This voltage is subtracted from the voltage generated at the amplifier. Thus this Back EMF is greatest at lower frequencies range especially in the Velocity Frequency Range. At higher frequencies in Acceleration Frequency Range, the table (coil in the magnetic field) movement the Back EMF is very little. The output voltage from the amplifier must be large enough to overcome the Back EMF and generate current in the conductor at lower frequencies. The current in the conductor generates the force to make the table movement.

From the principle (1), we can see that in order to increase the force, you must increase either the magnetic field, length of the conductor (number of turns in the coil), or the current through it. The magnetic field can only be increased to the magnetic saturation point of the iron in the shaker. Normally, the magnetic field has been increased to the saturation in design. The length and diameter of the conductor in the air gap is restricted by the space of the air gap and the current expected to go through the conductor. Along with all this, the heat due to I^2R must be removed by the blower to secure the armature coil and field coil. Shaker design requires compromise between several interacting factors.

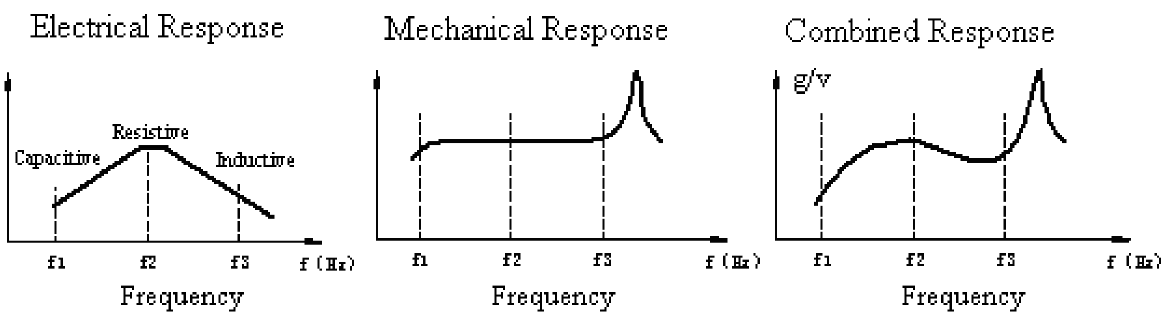
The mechanical impedance of the armature affects the dynamic response of the shaker. The armature assembly has sometimes been compared with a two mass mechanical system. The upper mass is considered the table and the lower mass the suspended coil. Referring to the below diagram, the formula for the frequency of a two mass system is: $\omega_0 = \sqrt{k\frac{(m_1 + m_2)}{m_1 m_2}}$ Where m_1 may be considered the table weight and m_2 considered the coil weight. The k is elastic stiffness. As the more mass attached on the armature table, m_1 increases. If the m_1 approaches to infinity, the natural frequency approaches to: $\omega_0 = \sqrt{\frac{k}{m_2}}$



All electrodynamic shakers have mechanical resonance. For most shakers, the resonance is greater than 2,000 Hz. Adding a fixture and specimen complicates the mechanical impedance of the shaker system. This is why shaker manufacturers rate shakers bare table or with a solid mass (or non resonant load). The load may couple notches or nodes into the shakers response and prevent the operator from reaching full force performance. Below is a typical simplified acceleration verses voltage (g/v) curve of a shaker with no load. From this curve we can see that at Voltage Frequency Range from 11.5 to 13 Hz) it takes more voltage (from the power amplifier) for a max velocity. We also see that at resonance frequency, 3686 Hz, the required voltage will be even more less than the voltage required.



E-1 armature drive voltage diagram



E-2 Mixed Resonance

To operate horizontally, the operator must rotate the shaker and attach it to a 'slip plate'. A slip table allows the shaker to vibrate specimens in the horizontal direction. To the casual observer, the "slip plate" may appear as a solid mass. In reality, it does have a resonance that appears around 1000 Hz depending on different size of the slip plate. The addition of a simple slip table (plate) changes the response considerably. The bull nose (drive bar) connects to the shaker armature and the slip plate. Fixture and test specimen(s) are attached to the plate. When calculating the required force the shaker must generate, be sure to add the weight of the bull nose and slip plate to the weights of your specimen and fixture. With this one addition mass to the shaker system, you can see how it affects the overall response. From this, you can see that if your fixture has a poor dynamic response, it can make controlling the system very difficult.

Dynamic response is one reason fixture design is very important. A well designed fixture will have good transmissibility over the frequency range of testing. Even though the fixture and specimen seem to be solid, it will have nodes and resonance's. Nodal points, lines, or surfaces occur in all systems. A node occurs when the vibration level goes to zero at a specific frequency. When the signal is much less than that seen on other points of the system, it is said to be a notch. A resonance occurs when the vibration level is large compared to other points. If the control accelerometer is placed at a node or notch, the controller will be forced to drive the shaker system very hard to maintain the reference level. Therefore, placement of the accelerometer(s) and control strategy is very important when operating a vibration system. With one control accelerometer, the controller maintains the reference level at that one point. It may be possible for other points on your fixture and/or specimen to be significantly higher or lower than the control point. One point of a fixture might be at 2 g's, and another point at 20 g's. In order to make sure the test level is somewhat uniform on your specimen, other control strategies may be used.

Other types of control strategies are 'averaging' and 'extremal'. Averaging attempts to maintain a more uniform vibration to all points used in control. During averaging, the controller monitors all of the channels used, sums their levels, then divides by the number of channels used, and uses that as the control level. Extremal testing monitors all of the channels used and adjusts the drive voltage to the amplifier such that none of the channels used in the control scheme exceed the reference limits.

Every system comes complete with a "Performance Curve'. This is a plot of acceleration verses frequency on logarithmic coordinates. A typical plot starts at 5 Hz and usually ends at 2000 Hz. This is the operational frequency range of many shakers. The curve usually starts with a line with a slope of two (two decades up in amplitude and one decade over in frequency). The slope of 2 is a trace of the displacement limit of the shaker. Most shakers today have a stroke of 2 inches (51 mm) peak to peak. Then the line intercepts with a line with a slope of 1. This is the constant velocity limit of the shaker. Then the curves flatten to a slope of zero at the maximum acceleration level of the system.

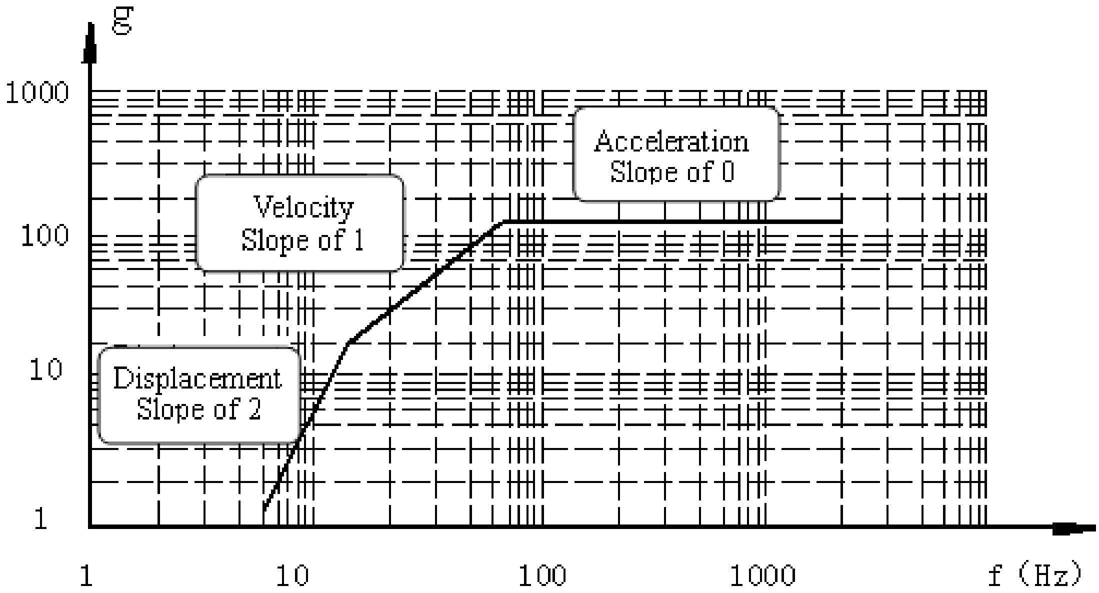


Figure E-3 Performance Curve

It should be noted that the performance curves represent maximum ideal conditions. The acceleration limits are determined by the system force and weight, or "payload”. The maximum ideal acceleration limits are determined by the following equations:

$$g_{\max} = \frac{System \quad Force \quad Rating}{\sum Weight(W_{Armature} + W_{Fixture} + W_{TestLoad})}$$ Vertical

$$g_{\max} = \frac{System \quad Force \quad Rating}{\sum Weight(W_{Armature} + W_{BullNose} + W_{SlipTable} + W_{Fixture} + W_{TestLoad})}$$ Horizontal

NOTE

The effects of placing a fixture and test items on the shaker may (and typically do) reduce this calculated value.

Page F: Newton's Third Law of Motion

Another important law of physics that we have to deal with is Newton's third law of motion: *For every action there is an opposite and equal reaction***.**

The shaker is "isolated' from the floor with the isolation air bags installed in trunnion. The resonance of the air bags is typically below 3 Hz. The resonance of the isolating system varies with the air pressure and the size of the air bags. As the forces in the shaker push and pull on the armature and test item, there is an equal and opposite force on the body of the shaker. At low frequencies the result of equal and opposite forces is seen as "body motion". "Body motion" reduces the total stroke available. For example: If you have 5mm of body motion and the table's absolute motion is 20mm, the total displacement of the shaker table is 25 mm relative to the body. At low frequencies the acceleration forces are small. During most typical tests, as the frequencies increase, so do the acceleration forces. The air bag isolators prevent (isolate) these large forces from being transmitted to the building floor. This allows the vibration system to operate on standard shop floors.

The other thing that can change the performance of the shaker system is the fixture and specimen. If resonant fixtures and specimens are added to the table, the effects can reduce the acceleration capabilities of the system. Therefore, a fixture analysis is very important to determine where to place the accelerometers, and what control method (single, average, or extremal) to use.

Section 1 Specification of shaker system

1.1 Specification

Table 1-1 Important Specifications

SD-50-440 Electrodynamic Shaker		
Generated Force	Sine (Pk)	5000 kgf (11000 lbf)
	Random (Rms)	5000 kgf (11000 lbf)
	Shock (Pk)	10000 kgf (22000 lbf) @6ms
Useable Frequency		5-2,700Hz
Maximum displacement (Peak-Peak)： Continuous duty Shock Between mechanical stops		 51 mm (2 in.) 51 mm (2 in.) 58 mm (2.3 in.)
Maximum Velocity		2 m/s (78.7in/s)
Maximum Acceleration		100g
Fundamental Resonance Frequency (Nominal, Bare Table)		2233Hz
Body Suspension Natural Frequency (Thrust Axis)		3 Hz
Power Supply Requirement		380V/50Hz 3 Phrase
Armature Rated Current		500 A
Armature Rated Voltage		100 V
Armature Coil Resistance		0.025 Ω
Effective Nominal Armature Mass		50kg (110 lbs)
Armature Diameter		440 mm (17.3 in.)
Vertical Load Support		500 kg (1100 lbs)
Load Attachment Points (Standard)		17 stainless steel M10 Inserts
Field Rated Current (DC) hot		75A
Field Rated Voltage (DC)		250 V
Field Coil Resistance R20		3.3 Ω
Drive Coil Isolation Resistance to Armature		>10MΩ
Drive Coil Isolation Resistance to Shaker Body		>10MΩ
Stray Flux Density		4 gauss @ 152 mm above table
The height between shaker body to the armature table surface after remove the top cover		130mm
The maximum noise of the system		114dB @ 1 meter form shaker around 500 Hz and 2500Hz range
DA-50 Power Amplifier		
Rated Output Capacity		50 kVA
Amplifier Frequency response (Sine mode, resistive load)		Full power from 5 Hz to 3000Hz rolling off to 3 dB at 4000 Hz with 6 dB/Octave slope
Distortion (at rated output)		From 5 Hz to 3000Hz less than 1%
Signal-Noise-Ratio		Greater than 65 dB

DC stability	Less than 0.05% of full output voltage with 10% change in line voltage.
Input Drive	1.5 Vrms into 10 K Ohms for full output
Input Power	380 V, 50 Hz, 3 Phase 82kVA
160 Hz Sine Trial Testing	507A/45.2V @100 g

Note：Sine Performance Curve, Random Performance Curve and Shock Curve are all attached in the final test report.

If you want to choose a Cooling Blower matching this shaker system, it must comply with the specifications as shown in the Table 2-2

Table 2-2 B-5000 Blower Specifications

Blower Power (Full Load)	15 kW (20 HP)
Air Flow Rate	1.1 m/s^3
Air Pressure:	0.0077 Mpa

Section 2 Installation

2.1 Unpacking and Inspection

Check the equipment received against the packing list to ensure a complete shipment.

The system was carefully checked before leaving the factory. Inspect the shipping container and the unit closely for the evidence of improper handling. If the unit has been damaged, place an immediate claim with the dealer or distributor from whom the unit was purchased. If the unit shipped directly to you, notify the transportation carrier without delay and file a claim.

A crane or forklift and suitable lifting slings may be used to transport the shaker to the installation site. Large eyebolts are provided by the manufacturer for the purpose. Before attempting to lift the shaker, amount the eyebolts into the tapped holes located on the shaker body and to lift the shaker through the eyebolts.

Table 2-1 Shaker System

Case	Item	Length (mm)	Depth (mm)	Height (mm)	Crated Weight (kg)
1	Shaker SD-50-440	1620	1140	1285	4650
2	Blower B-5000	720	1020	1850	300
3	Amplifier DA-50	610	900	1950	600

The weight and overall dimension of shaker, blower and amplifier are shown as above Table 2-1. The Power Amplifier has four caster wheels underneath the cabinet for moving.

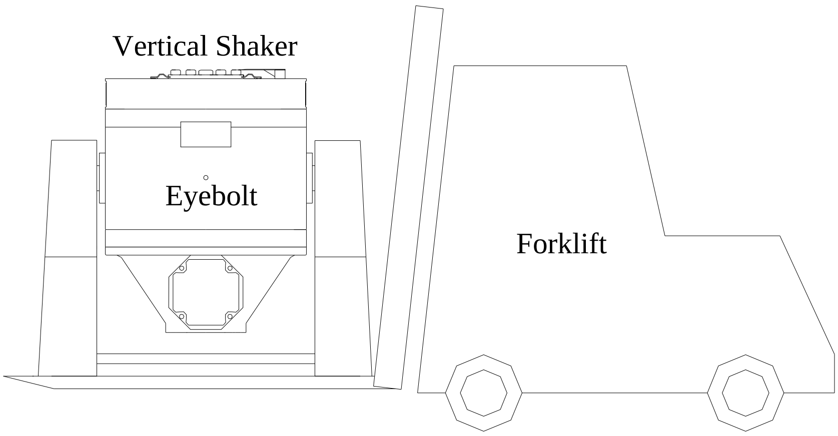


Figure 2-1 Schematic of Conveying the Shaker

2.1.1 Using a Large Fork-Lift Truck

For the smaller shaker, to balance the distribution of the weight, the ideal fork position is the side of the table-board base where the fork-lift truck can lift the whole shaker (as shown in figure 2-1).

Pay attention to cables and coil pipes to prevent to be damaged while forking or lifting the shaker. Lift slowly until the base is apart from the ground and then is transferred to the appropriate position.

2.1.2 Using an Overhead Crane

For bigger shakers, it is proper to use Overhead Crane to lift. Lifting ropes with enough strength are fastened on the four Lifting Eyebolts squarely installed pedestal. Then the whole shaker is lifted by a crane that is capable of the weight of the base, the rope must be strong enough to sustain this weight too.

Insure not to scrap the painted surface of the shaker body.

!CAUTION!

Do not attempt to lift the system by bolts on the armature or slip table, which results in permanent damage to the shaker to slip table.

2.2 Site Selection and Preparation

The vibration test system should be installed in a location, which is free of airborne ferromagnetic, metallic or other foreign particles. Any operation that produces such by-products in the installation area should be performed only after adequate protective measures are taken to prevent ingestion into the shaker air-cooling system. Shaker cooling air enters through plenums located in side of the shaker body. An accumulation of foreign material in these filters can diminish the airflow and affect cooling performance. A buildup of fine ferromagnetic particles passed through the filter and lodged in the close clearances of internal magnetic air gap, will result in eventual electrical breakdown of the armature coil.

Only the lengths of the various interconnection cables and hoses restrict the physical location of the shaker. The shaker should be placed in close proximity to the amplifier for quick and easy monitoring of the equipment by the operator.

Locate the amplifier/instrumentation system in the most efficient manner for greatest production throughout. All front panel controls should be easily accessible and visible for operator(s) and still allow adequate working room to perform fixture and testing.

Recommended minimum clearances are three feet from any wall to allow for easy maintenance access.

Areas of high dust, heat (over 40 deg C) or humidity should be avoided since the amplifier and instrumentation are air-cooled. The environments will increase maintenance requirements.

2.3 Installation the system

2.3.1 Power Amplifier Installation

Insure that all connections made are marked and checked for tightness. Keep the armature cable well-twisted and the endpoint breakout flares to minimum.

The amplifier was tested and shipped with input power configuration as requested on the original purchase order. Inspect and check the power configuration according to Table 1-1.

Warning

There are two Emergency Stop switches configured on the system, one is on the amplifier front panel and another is on the shaker body. (Some small shakers have not one on the shaker body). Release the Emergency Stop switche(s) by twisting the cap CW before hooking up the system.

NOTE

A licensed electrical contractor in accordance with local codes should only do installation of the primary power. Always verify your available input voltage before connecting the primary power.

NOTE

Be sure that there are no cables left hanging where they could short against power components in the lower part of the console. Inspect all wiring to be sure that it hasn't been damaged in shipment. Check all connections to be sure they are tight.

2.3.1.1 Line Input Power Installation

For standard systems the input 3-phase power cable (L1, L2 and L3) should be directed and terminated on the amplifier main power input terminals located rear of the amplifier inside, normally it is an air breaker marked “CB”.

All power or signal cables should be terminated and connected to the terminals with same marked labels. The system is to be protected with a good grounding.

A good grounding is recommended to prevent any ground loop. Install a dedicated ground wire (PE) (Refer to Chapter 4.3.1 of this manual for more information).

Please see “Amplifier Schematic Circuit Diagram” attached at the end of this manual for more information on the input power line connection.

2.3.1.2 Cables-Field, Armature and Interlock Installation

The field, armature and interlock cables are pre-manufactured in standard 6 meters length and are marked and prepared for connection to their respective connectors at the rear base of the amplifier. All user interconnections are accessible in the rear Terminal Strips. All cables exit through the rear Terminal Strips.

The Terminal Strips is located external to the mainframe, at the rear base of the amplifier. As shown in “Amplifier Schematic Circuit Diagram” attached at the end of this manual, this Terminal Strips contains the main input power terminals (L1, L2 and L3 Terminal), cooling system contactor (U, V, W and PE), Over Thermal Switch (SOT), Over Travel Switch (STR), external interlock terminals, armature output (A+ & A-) terminals, and field output (F+ & F-) terminals. For maximum FRI/EMI protection the conduit system for the input power line should extend to this Terminal Strips and cover the input power line securely.

Do not operate the amplifier with any panels or screens removed or with attaching hardware missing.

Connect the other end of the cable to shaker. The shaker Terminal Strips is in the terminal box attached on the shaker body. Open the cover of the terminal box and hook up the cables to the terminal connectors according to the same labels.

2.3.2 Blower Installation

The blower is recommended to be located outside of the test lab to isolate the noise generated by the blower. Locate the shaker cooling blower so that the duct run between the shaker and blower is short and direct to minimize pressure loss in the duct. If a longer air duct is necessary, please consult an authorized personnel or the local agent. The maximum length of the duct supplied by manufacturer is 4.5 meters. Be sure to connect it to the blower inlet, coaxial with the motor shaft, so the blower acts as a suction blower, pulling air through the shaker and exhausting it from the blower.

Wire the blower motor starter to the power source as indicated on "DA-50 Schematic Circuit Diagram" attached at the end of this manual.

Connect air duct between shaker and blower as indicated on Figure 2-3.

The air duct should be mounted firmly to the shaker and blower coupling by screwing the yoke provided as shown in Figure 2-4.

NOTE: SHAKER BLOWER SHOULD BE LOCATED IN AN AREA REMOTE FROM THE SHAKER TI REDUCE THE BACKGROUND ACCOUSTIC NOICE LEVEL AROUND THE SHAKER. A FLEXIBLE DUCT OF 4.5 METER IS SUPPLIED WITH THE SYSTEM. FIXED DUCKWORK (FOR EXAMPLE, THE PVC OR THIN SHEET METAL DUCT WITH SMOOTH INNER SURFACE) OF 200 MM OUTTER DIAMETER CAN BE USED IF THE TOTAL RUN LENGTH DOES NOT EXCEED 7.6 METERS. LARGER 254 MM DIAMETER FIXED DUCTWORK SHOULD BE USED FOR RUN LENGTH FROM 7.6 TO 15.2 METERS. INCREASE TO 305 MM DIAMETER FOR RUNS FOR 15.2 TO 30.4 METERS. IF THE FIXED DUCKWORK IS ADOPTED, THE SUPPLIED FLEXIBLE DUCT WILL BE USED AS TWO ENDS ADAPTOR ONLY, 2 METERS FOR THE END TO SHAKER AND 1 METER FOR THE END TO BLOWER. AND AT THIS SITUATION, THE FLEXIBLE DUCT MUST BE IN SHRINK.

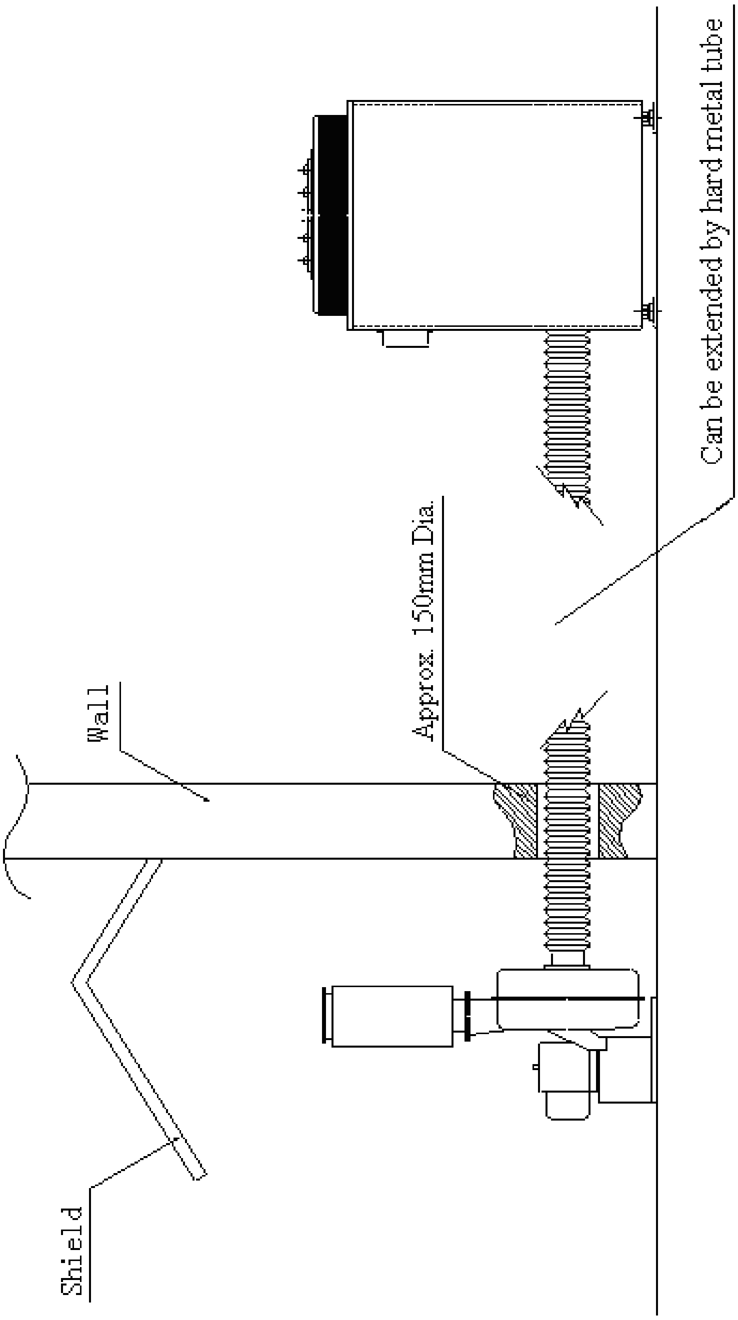


Figure 2-3 Blower Duct Connection

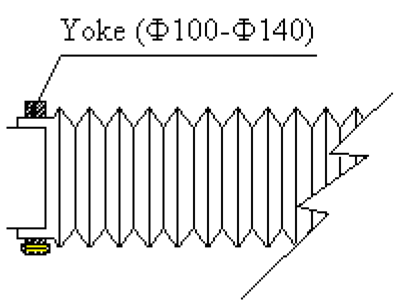


Figure 2-4 Air Duct Connection

2.3.3 Shaker Installation

2.3.3.1 Center the Armature

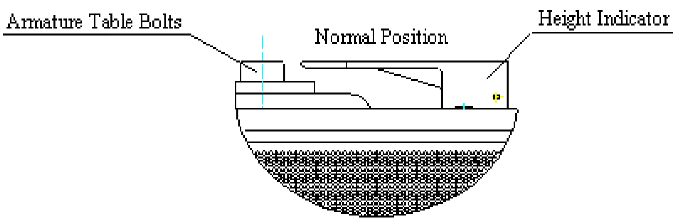
The air chamber inflated supports the armature, fixture and specimen while in the vertical test. Follow the procedure to center the armature.

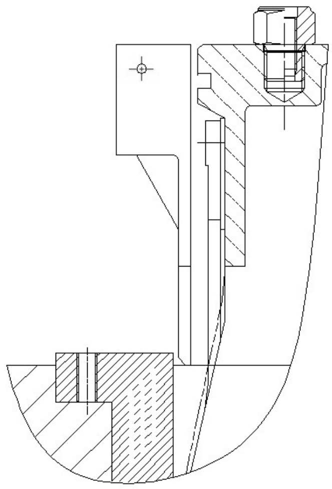
If the shaker system is not configured with PCC-1 (Pneumatic Center Control), please do as below to center the armature to mean position.

There are two pressure air valves at the rear of shaker frame. The left one is labeled as ISOLATOR for the shaker body vibration isolating and the right one is labeled as INNER LOAD SUPPORT for the centering the armature. There is also a pressure air distributor block on the low left with pressure air inlet with quick connector, manual inflator air inlet, outlet to INNER LOAD SUPPORT and outlet to ISOLATOR.

Connect a pressure air source to the quick connector, or if there is no pressure air source at the site connect a manual inflator to the manual inflator air inlet. If the pressure air source is used, lifting and twisting in CW the cap of pressure valve of INNER LOAD SUPPORT to inflate the Air Chamber. Twist the cap in CCW to deflate the Air Chamber. Close the pressure valve by pushing down the cap. If a manual inflator is used, lifting the cap and drive the inflator till the armature is in the correct position and push down the cap to close the valve.

There are two cases to inspect if the armature is in the mean position. The first case is the shaker cooling air grilles is installed, the height indicator showed the normal position of the armature. (Refer to Figure 2-6A). The second case is the shaker cooling air grilles is removed for some reasons, like during maintenance, the height indicator showed the normal position of the armature. (Refer to Figure 2-6B).





Mean Position of Armature

Figure 2-6A Figure 2-6B

2.3.3.2 Lock out the Air Springs

To transport or store the shaker or change the thrust axis, lock out the isolating air bags in the trunnion system as follows:

- Insert the two lock-out bolts in the tapped holes of the trunnion. (Refer to the **WARNING in 6.3 chapter**)
- Tighten the lock-out bolts until the trunnion air springs are fully pressed.
- The air spring suspension system is now locked out.

2.3.3.3 Center the shaker body

According to same procedure described in 2.3.3.1 to position the shaker body in the mean position to get best vibration isolation to the floor. The mean position of the shaker body is indicted by two red line notched near the air bag. Close the pressure valve by pushing down the cap after adjusting.

Section 3 Operation

!CAUTION!

Extreme caution is advised if the hood and air inlet grilles are removed from the shaker. Fingers may be severely injured if caught between the table and the shaker body while in operation.

3.1 Pre-operational Checkout

3.1.1 Check Connector Installations

Insure that all power module ribbon cables and power connectors are installed correctly and fully seated. The ribbon cable key must align with the interface connector in its respective header.

3.1.2 Check Shaker Cables

Check that external cabling for errors. Insure that all connections are correct as required in the “Schematic Circuit Diagram” attached at the end of this manual.

!CAUTION!

Take special care to check the polarity of the armature cables. In particular, terminal “A+” must be Positive.

3.1.3 Starting the Power Amplifier

Turn on the power amplifier as procedures outlined in Chapter 3.2.1.

3.1.4 Verify Blower Motor Rotation

On the amplifier control panel, with the gain switch in the “reset” position, power on the amplifier, press down the green “ON” button, the shaker-cooling blower will be powered. Then press down the red “OFF” button, the blower motor is powered off and the motor’s rotator is still rotating in low speed due to the inertia of motor’s rotator. It is time to check the motor rotation direction.

The blower motor's rotation direction must comply with the arrow on the blower body. It should be checked on initial startup and whenever the system is relocated or the three phase power line is changed.

If the blower is out door, an easy way is as below. Tight a light color material strap as indicator, like a cloth, if the indicator is blown up when the blower is powered on, that means the blower rotation is correct. A short strap like 100mm length is good as the indicator.

The shaker system which out put force is bigger or equal 2000kgf, the Air Flow protection interlock is configured. It will act if the blower rotation is wrong or by any other reasons if the shaker system lose the cooling air flow.

3.1.5 Check Front Panels and Fans

Check that only the front panel indicators marked "LOGIC POWER", "OUTPUT ENABLE and "GAIN ENALBE" are ON and that all fans for the power modules are operating well. No other indicators on the amplifier panel should be illuminated. Refer to Section 4 of this manual for information about the other indicator lights.

!CAUTION!

Illuminating indicator lights other than "Power" "Enable" and "System Ready" should be corrected and cleared before proceeding.

If the fault condition has been corrected, fault indicator lights may be cleared by turning the GAIN control to the reset position.

Re-energize the amplifier power when checks are completed.

3.1.6 Waveform Observation

Observation of the waveform through the use of a lightweight piezoelectric accelerometer and an oscilloscope is the most sensitive test for proper shaker operation. The following test is recommended.

- Mount an accelerometer on the shaker table as recommended by Figure 3-1. Ensure that the accelerometer is isolated from the shaker table to prevent ground loops.
- Connect the accelerometer output to an appropriate amplifying or conditioning system with the accelerometer amplifier output connected to an oscilloscope.

- With the accelerometer mounted and connected as desired, scan the frequency range at several different levels. Note the waveform.
- It is necessary to be able to differentiate between normal and abnormal distortion. Serious departure from a sine wave (abnormal distortion) is usually an indication of armature bearing misalignment or damage. Some distortion at submultiples of the resonance frequency (normal distortion) may be expected due to resonant amplification of the amplifier distortion. A record should be made of the armature resonance frequency and harmonic waveform when the shaker is received which should then be compared with the factory supplied test data for your specific system. A check with this record will enable trained personnel to differentiate between normal and abnormal distortion. A periodic check with this record will minimize troubleshooting time and serves as a very good preventive maintenance check.

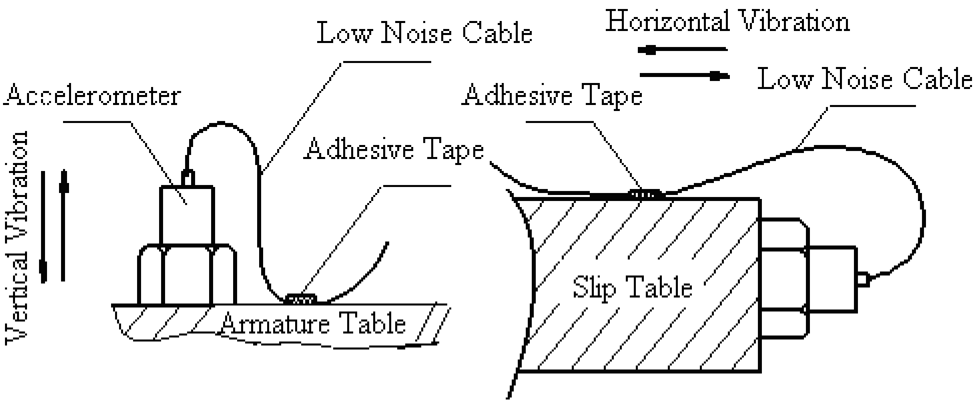


Figure 3-1 Accelerometer Mounting

3.1.7 Low Level Functional Test

Re-energize the Amplifier/Instrumentation System and connect the Drive Signal and instrumentation as required by a typical test (this may be a bare table test as long as there is a feedback accelerometer attached to the shaker table). Apply a low level signal to the amplifier signal input BNC connector. Increase the amplifier gain to observe a response from the shaker table. This completes the functional setup and checkout of the amplifier.

3.2 Operation

> **Warning**
>
> **Please set up the safe areas for the shaker system and warning signs should be set on the working site.**

Warning

The operator should be trained how to operate the shaker system before start the operation.

3.2.1 Operation of the Amplifier and Instrumentation

3.2.1.1 GAIN Reset

Set the gain of the amplifier to the reset position by turning the gain knob counterclockwise (CCW).

NOTE

Gain should be turned to RESET position before proceeding.

3.2.1.2 Switch on Power Supply

(1) Energize the power feed to the amplifier and switch on the main circuit air break switch in the rear of the amplifier. Turn on the twist switch on the inner front panel and power is supplied to the system. The power indicator lights with buzz alarm to self-detection on the amplifier. After the self-detection process is passed, the buzz alarm should stop, and then the cooling fans on the power amplifier begin to run. The "Input Under Voltage", "Offline" and "Power" lights should be illuminated.
(Attention: The "Input Under Voltage" indicator is illuminated. It is normal situation because the secondary main power is not supplied to the system.)
(2) Press "ON" button, the "ON" indicator lights. The "Input Under voltage" indicator light should be off with the power energizing the system. About 15 seconds later, blower begins to run. Later the "Offline" light will be off.
(3) Insure that the system controller is powered up and stabilized. Allow the cabinet fans to run for five minutes to equalize internal temperatures prior to driving the amplifier.
(4) To increase the gain, turn the control clockwise (CW) (tipically to 3/4 of full scope). With the clatter sound, "Ready" and "Enable" lights should be illuminated. And the power amplifier is ready to run.
(5) Set up the control instrumentation required for the test.

Advance the amplifier's gain control as required to allow the controller enough loop gain to capture and servo the system. Start the control system.

To operate the controller, please consult your applicable Vibration Control Manual

!CAUTION!

Whenever the amplifier's gain control is advanced off the reset position, DO NOT plug or unplug any drive signal cables or turn the power on or off to the vibration control system. Unpredictable and/or uncontrollable results may occur that could be hazardous to personal or the equipment.

3.2.2 Running the shaker

Warning

There will be high noise when the system works in high frequency, please adopt some protection, like wearing noise-free ear plug etc.

The starting procedure for the shaker must be followed in a certain sequence to prevent damage to the equipment. The turn-on procedure is as follows:

(1) Turn on power amplifier as the procedure outlined in Chapter 3.2.1. This will energize the blower. Verify blower rotation is correct.
(2) Adjust the armature to the mean position. (Refer to chapter 2.3. 2 for details)

3.2.3 Shut down the system

- Turn the Gain modulator counterclockwise (CCW) to the Reset position
- Shut off input signal from the Controller
- Press MAIN POWER OFF down, cool the amplifier and shaker for 7-10 minutes before shutting off the twist switch of the amplifier.
- Switch off the air break switch to shut off the power to the amplifier.

RECOMMENDATION

Cool the amplifier and shaker for 7 to 10 minutes before shutting off the Power Switch of the amplifier.

3.3 Sine Test

3.3.1 Specification Limits

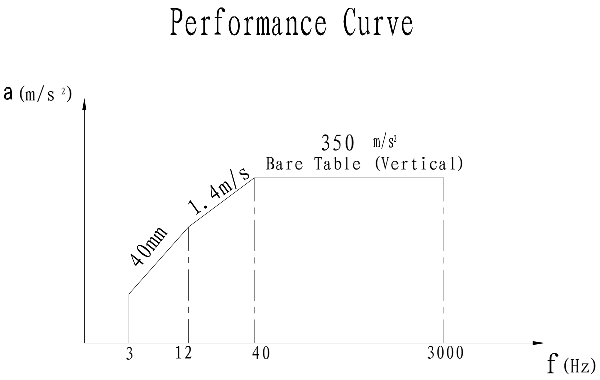


Figure 3-2 Performance Curve

According to the performance curve, set these parameters such as displacement, velocity and acceleration. The three parameters are not obtained in the same frequency band. So it's the limit to be considered before test. Suitable settings are available, while conflicting settings are unavailable.

3.3.2 Max Acceleration Limits

While doing test with specimen, the max available acceleration is different from that of bare table.

For example: (Fixed Acceleration Sweep Test)

F=6000 N (rated force),

M=6kg (Effective moving mass of armature)

m=10 kg (mass of payload)

Then, a_{max} =F/(M+m)=6000/(6+10)=375 m/s^2

3.3.3 Max Velocity Limits

For example: (Fixed Velocity Sweep Test)

Requirements as follows, Specimen mass: 10 kg, a=375m/s^2 , V=2m/s. D_{peak} = 25mm.

The sweep range will be calculated as below.

According to the formula V=2π f D_{peak}, the lowest frequency =V/2π D_{peak} =2X1000/2×3.14×25= 12.7Hz.

According to the formula a=2π f V, the highest frequency = a/2π V =375×1000/(2×3.14×2×1000)=29.8Hz

So this fixed velocity of 2m/s can be accomplished from 12.7Hz to 29.8Hz.

3.3.4 Max Displacement Limits

For example: (Fixed Displacement Sweep Test)

Requirements as follows, Specimen mass: 10 kg, V=1 m/s, Sweep range: 5 to 25 Hz. Judge whether it's available.

First we can calculate the acceleration at 25 Hz according to the formula a= 2π fv. The result, a=2×3.14×25×1=157 m/s^2 < 375 m/s^2. So the force generated at 25 Hz can meet the requirement.

Second we can calculate the displacement at 5 Hz according to the formula D_{o-p}=V/2π f The result, D_{o-p}=1 ×1000/(2×3.14×5)=31.8 mm>25 mm. So it's not available.

Note: D_{o-p}=D_{p-p}/2

3.3.5 Multi-Parameters Limits

For example: (Fixed Displacement Sweep Test)

Requirements as follows, Specimen mass: 10 kg, D_{o-p}=10 mm, Sweep range: 5 to 25 Hz. Judge whether it's available.

First, calculate the acceleration at 25 Hz.

a=(2π f)^2 D_{o-p}=(2×3.14×25)^2 ×10/1000=246.5 m/s^2

Second, calculate the force needed.

F=(m+M)a=(10+6) ×246.5=3944N<6000 N

Third, calculate the velocity.

V=2π fD_{o-p}=2×3.14×25×10/1000=1.57m/s<2 m/s

From the results calculated above, we can see that the test is accomplished.

3.4 Random Test

The random acceleration level that can be achieved on any test specimen is a function of:

1. The shape of the spectral density vs frequency curve (refer to Figure 3-3).

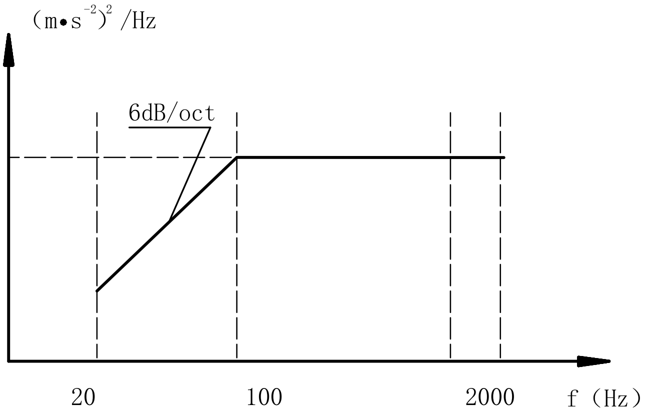


Figure 3-3 Spectral Density vs Frequency Curve

2. The dynamic response of the specimen and fixture (i.e. resonant peaks or notches in the specimen or the fixture).
3. Assuming there are resonant frequencies in the operating frequency range then the location of the accelerometer or accelerometers will affect the g level. Also, if averaging of several accelerometers is used, or if extremal control is used, then the available g level is usually higher.
4. The total mass of the load.

Due to all of these variables, it is difficult to predict an exact g level for a given system. Therefore, all of the shaker manufacturers rate their systems under a specific set of conditions which remove most of the variables. These conditions are:

1). A 6 dB/oct slope spectral density from 20 Hz to 100 Hz, and a flat spectral density (g^2/Hz) from 100 Hz to 2 kHz or ISO 5344.

2). A non resonant load consisting of solid blocks of steel.

3). A heavy load, typically twice or four times the armature weight.

By choosing these standardized conditions, all of the shaker manufacturer ratings can be compared equally. It is also true that these conditions are close to optimum conditions and therefore the (force rating), as calculated from (g rms x total moving mass), is usually the highest achievable.

In the real world of testing, we seldom have these idealized test conditions. Therefore, it is desirable to try to predict what can be obtained under different conditions. To do this we need to know more about the shaker characteristics. All shakers loaded with a large mass can be described by typical curves as shown on Figure 3-4:

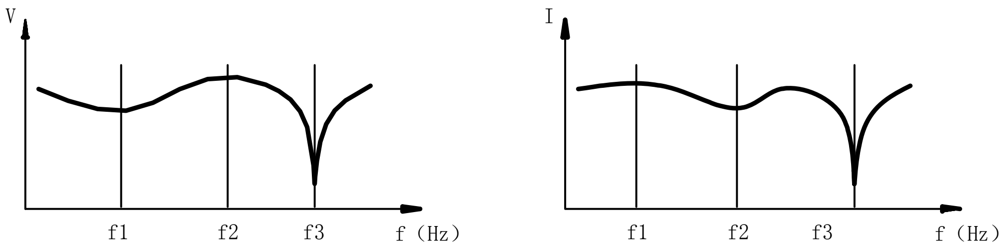


Figure 3-4 Armature Coil Voltage & Current Curve

From these curves it can be seen that the voltage required and the current required depends on the frequency.

For example: At f1 frequency, the voltage required is small, but the current required is large.
At f2 frequency, the voltage required is at a maximum, but the current required is less.

At the resonant frequency of the armature and load f3, both the current and voltage are a minimum.

Note that all shakers have such a resonant frequency.

ESTIMATING PERFORMANCE WITH SHAPED SPECTRUMS

In order to estimate performance we need to define the parameters that might limit the system performance.
Shaker limits: Heat or Temperature Limit, Stress Limit, Stroke Limit, Velocity Limit (steady state & intermittent)
Power Amplifier Liming: Voltage Limit, Current Limit

Assume the Power Amplifier is very large compared to the shaker requirements and therefore only shaker limits apply. In this case, the flowing limits apply:

Shaped spectrum with all the energy below 500 Hz.

Stoke Limit
Depending on the spectrum shape at low frequencies (below 100 Hz), the shaker stroke may limit performance. Newer digital controls predict the required displacement (pk-pk) with reasonable accuracy. During random test, considering 3 Sigma clip coefficient, if the predict displacement is 2 mm, the max acceleration will be 6 mm, three times of predict displacement
Current Limit
When random peak spectrum is above 500 Hz, the shaker requires max current from the amplifier. The random force is about 0.8 times of sine force.
Voltage Limit (Velocity Limit)
The peak sine velocity rating is usually determined by the power amplifier voltage available to overcome the back EMF. Newer digital controls predict the required peak velocity for random tests. The peak velocity for the system is usually listed as an intermittent rating.

Shaped Spectrum with all the energy above 500 Hz.

Stress Limits
In this frequency range, both the current required and the stroke required are small. Therefore, the apparent force limit is usually determined by the stress in the armature.

For 3 Sigma clip coefficient, if the predict acceleration is 333 m/s^2 , the max acceleration will be 1000 m/s^2 and the RMS acceleration will be 333 m/s^2 .

3.4.1 Clip Coefficient

The stated reasons for not clipping are:

1. Clipping does not protect the specimen because the power amplifier-shaker-specimen combination tend to restore the clipped signal back to a more nearly Gaussian distribution and therefore restores some of the peaks. Note that the paper does NOT state that the acceleration peaks will exceed the unclipped level nor does it state that they will be restored to the same level. In practice there is some restoration of the clipped peaks in the acceleration waveform but not to the level obtained with an unclipped drive signal.

2. Clipping changes the frequency content of the drive signal. This is true. Clipping tends to add a small amount of energy spread over the frequency spectrum. The paper refers to this as "raising the frequency noise floor". The controller will reduce its drive level at each of these frequencies in the control bandwidth because the analyzer section of the controller will sense the extra energy and adjust the drive spectrum accordingly. This is not a problem except at the frequencies where the shaker-specimen combination has an extremely high Q resonance. Under these circumstances the controller will reduce its drive at the resonant frequency to the minimum possible {determined by its dynamic range). If the controller has a limited dynamic range, the combination of the residual drive from the controller plus the extra energy resulting from clipping nay result in a peak in the acceleration response which is above the allowable tolerance level.

This inability of the controller to maintain the acceleration spectrum within the desired tolerances is the problem being addressed by this paper. It is a legitimate problem but only one of the many system limits which should be considered.

SYSTEM LIMITS

There are many system limits to be considered:

1. Dynamic range of controller
2. Power Amplifier current limits
3. Power Amplifier voltage limits

DYNAMIC RANGE AND POWER AMPLIFIER LIMITS

If a random test is being conducted at a level of 50% or less of the system capability and the shaker specimen has a high Q resonance which is difficult to control, then the points addressed in the subject paper are valid.

However, as the test level is increased, the peak drive signals (4 Sigma or greater) will eventually be clipped by the power amplifier. However, when the amplifier begins to clip, the effects of clipping discussed in the paper will be the same as if the controller drive signal were clipped. The spectrum noise floor will increase as previously discussed.

As clipping becomes more severe the power amplifier will shut down and the test will be interrupted. However, if the controller drive signal is clipped before going to the power amplifier then the power amplifier would not shut down.

In summary, if a test is conducted with an unclipped controller and the peaks in the drive signal reach the power amplifier voltage limit or the power amplifier current limit, then the peaks will be clipped in the power amplifier just the same as if they were clipped in the controller. As clipping becomes more pronounced the power amplifier will shut down. If the signal is clipped at the controller, before the power amplifier then the power amplifier can conduct a higher level test.

3.5 Classic Shock

The maximum shock performance is limited by either the peak voltage or peak current available from the amplifier, or by the stroke available in the shaker. In mechanical terms, the system is either force limited, velocity limited or stroke limited.

The shock capability of a shaker system is usually limited by the following:

Max Force required < 2 times of rated Sine force
Max Velocity required < 1.8 times of rated Sine velocity
Max Displacement required < Rated as the shaker specification p-p.

NOTICE: REGARDING THE SHOCK FORCE TIMES, IT IS SUBJECT TO THE SHOCK DURATION FOR MOST OF SHAKERS AS BELOW.
If 1.5ms≤duration≤6ms, the shock force will be 2 times of rated sine output force.
If 6ms＜duration≤11ms, the shock force will be between 2 times and 1 times of rated sine output force and the times tends to small along with the bigger duration.
If 11ms＜duration≤30ms, the shock force will be as same as rated sine output force and the rate it tends to small along with the bigger duration.
If 30ms＜duration, the shock force will be lower than rated sine output force.

For example, this is a shaker with 600kgf sine force, rated velocity is 1.8 m/s and the rated displacement is 51mm. Shock test requirements: $M_{armature}$=6 kg, a=50g, D=6 ms, m=10 kg payload.

First check the force needed.
$F=(m+M)a=(10+6)\times 50=800$ kgf < 2×600 kgf.
Second check the maximum velocity needed.
$V_{max}=a\times D/\pi = (50\times 9.8)\times 6\times 10^{-3}/\pi=0.94$ m/s < 2×1.8 m/s

From the results above we can find that the shock test (50g@10ms with 10 kg payload) is available.

Note: While doing the maximum performance shock test, we must consider both velocity limit and displacement limit. In this case, operators may adjust the pre or post wave compensation in the controller.

Considering the response of the armature, the minimum shock duration is bigger than 1.5 ms normally.

3.6 Shock Response Spectrum

SRS testing is a complex subject which has been extensively covered in the literature. The purpose of this discussion is to give an insight as to the capabilities of a shaker system to produce a specific SRS.

DEFINITION

Usually SRS is defined as a plot of SRS "g" vs. frequency. What is SRS "g"? The SRS "g" at a given frequency is not the actual real time "g" of the shock pulse at that frequency. Rather, the SRS "g" is the response of a high Q filter tuned to that frequency.
The steady state response "g" of a filter with a Q of 10 would be 10 times than the real time "g". However, under transient conditions, the filter response is less than 10 times and depends on the duration of the shock pulse at that frequency. Most SRS tests specify that analysis be made with Q=10 (5% damping).

SHAKER SYSTEM CAPABILITY

Assuming analysis with Q=10, a general rule of thumb is that real time "g" must reach at least 1/5 of the desired SRS "g". There is some flexibility in this number depending on the duration of the pulse.

Procedure:

1. Plot real time "g" vs. frequency by dividing SRS "g" by the number 5.
2. Compare real time "g" plot with Sine Performance Curve for the particular payload being tested.
3. If the desired real time "g" is not more than 150% of the steady state sine performance, then the test can be conducted except for the limitations listed below. There are many exceptions where more than 150% can be obtained, depending on the frequency content and fixture, specimen and armature resonances.

Limitations:

1. SRS shock pulses are usually less than 100 ms in duration. At frequencies below approximately 75 Hz it is not possible to complete enough cycles in 100 ms to result in an X 5 output from the SRS filters. Therefore below approximately 75 Hz, divide the SRS "g" by 2 rather than 5. Also, the low frequency capability of the system is limited by stroke or velocity. Neither of these limits can be exceeded and therefore the real time "g" required must be less than the Sine Performance Curve below approximately 75 Hz.
2. Many SRS tests specify performance out to frequencies above the rating for the

shaker". Typical Sine performance of a shaker system is specified to 2 kHz or at the most to 3 kHz. This is because the shaker armature has *a* major resonance in this frequency range. Above the resonant frequency of the shaker armature there will be peaks and notches in the response. At the peaks, very high g levels can be obtained. At the notches, very little acceleration is possible. However, the analysis filters are very broad at high frequencies. Typical analysis is 1/6 octave and therefore, there are only 6 filters between 2000 Hz and 4000 Hz. The broad filters always show some response even if there is a sharp notch within the filter bandwidth.

SUMMARY

All of the above discussion assumes that the fixture and specimen under test does not have severe resonances. It also assumes that the control accelerometer has been mounted in an optimum location based on a sine survey.

In general, SRS performance can be predicted reliably between 100 Hz and 2 kHz. Below 100 Hz, limitation 1 must be observed. Above 2000 Hz, performance cannot be reliably predicted without first conducting a low level sine survey with the actual payload attached.

3.7 Overturning Moment

While doing test, the specimen should fixed in the center of the table without eccentricity. If the specimen and fixture are eccentric, the eccentric moment generated by them must comply the below formula

$$m_t \cdot a \cdot L \leq M$$

M—Max allowable eccentric moment

a— Max Acceleration (m/s^2)

m_t—Mass of Specimen and Fixture kg

L—Eccentric Dimension m

Section 4 Power Amplifier

4.1 General Description

The power amplifier is an efficient, air cooled, modular high-power solid state amplifier designed for continuous operation in vibration testing when used with appropriate shakers and instrumentation. The amplifier consists of three (3) major sections:

- **Power Supply** for Field, Armature, Control and additional power supply.
- **Logical Module** section which contains Modulator, Logic and monitoring of the protective interlocks.
- **Power Module** to amplify the input drive signal to large current to drive shaker armature. There are several power ranges of power modules, like 6kVA and 12kVA.

4.2 Common Sense

Let common sense prevail. If something seems unsafe, it probably is. Please consider the following ground rules and apply them with common sense to your site situation.

1. Only qualified personnel should work on this equipment. (For example: only gained electricians should be allowed to service high power/voltage equipment. Only millwrights/riggers should be allowed to instal1 heavy/bulky equipment.)
2. Do not attempt to service any equipment while it is operating or powered.
3. Do not operate the system alone.
4. Always wear appropriate safety equipment and clothing.
5. Do not operate the system in an explosive atmosphere unless your system has been specially designed and approved for such operation.
6. Seek a second opinion before attempting anything unusual or unfamiliar.
7. Do not defeat, disable, remove or ignore any safety device or label.
8. Do not overload or abuse the system by exceeding any published specification.
9. Keep the system in proper repair with regular maintenance as small flaws can lead to hazardous faults.
10. Keep the equipment area and components clean, free from grease, oil, dirt and clutter.
11. In the event that any component fails such that fumes, gases or liquids are released, avoid the inhalation of fumes, smoke or gases and avoid skin contact

with spilled liquids.

12. Personnel should never be beneath a suspended load for any reason.

4.3 Safety Description

A number of things need to be considered to ensure safety during the installation, operation and maintenance. A lot of protection measures have been taken, including door interlock, grounding and cables etc. These are discussed in detail below.

CAUTION—HIGH VOLTAGES

All power amplifiers are equipped with door interlock switches (in series) which will activate the Door Interlock Alarm in the event a door is opened during system operation. However, even with the system shut down, input power line voltages may be exposed at some points within the amplifier and/or field supply. **It is good practice to always turn off all power when customers make service before opening amplifier doors.**

4.3.1 Grounding, General

The concepts and purposes of grounding are simple but often misunderstood. Grounding of systems and individual pieces of equipment is done for several reasons.
The primary purpose of a ground connection is for personnel protection.

Secondary reasons involve providing a path to conduct unwanted energy safely. The unwanted energy may be noise energy on signal or short circuit energy from a power system.

Thirdly Grounding/grounds are a necessary part of all electrical systems. Ground references may impart stability to a system or may cause problems in the form of noise. Grounding systems are unique to each site situation however; the following principles apply to all electrical systems. The grounding path, materials and installation are all important. Please review this entire section if system ground problems are suspected or if system noise problems are present. Other system noise source possibilities are:

- Poorly designed ground paths.
- Pickup from an unshielded drive signal cable being routed too close to the high magnetic fields of power transformers.
- Power supply electrolytic capacitors that have dried out and now have a higher equivalent series resistance (ESR). These are less effective at filtering the DC and allow more AC 50/60 Hz ripple to pass through to the circuits. This could occur either in amplifiers or instrumentation systems.

4.3.1.1 Ground Definition

What is "ground"? Ultimately, this really is the ground that we walk upon. In fact an alternate term of a ground connection is "earth". All power systems have some connection, reference or protection feature to ground. Ground may be thought of as an infinite electrical current sink able to absorb any amount of electrons. Ground may also be thought of as an electrical resistance element which cannot develop any voltage across itself of which is a 0 Volt reference source. A circuit or circuit element that cannot develop any voltage drop, by definition, must have zero impedance since:

$$E(volts) = I(amps) \times R_{Gnd}(ohm)$$

Equation 4-1

If E=0, then R=0 for any I. In this case R is the ground impedance that, in theory, may absorb any amount of current. However, as a matter of practicality, some ground impedance is always present and must be added to the known circuit impedance.

$$E(volts) = I(amps) \times (R_{Circuit} + R_{Gnd})(ohm)$$

Equation on 4-2

Therefore any declared ground point will experience some voltage elevation above "true" ground if there is current following through that circuit.

4.3.1.2 Chassis Ground

Ground must not be confused with other terms which also use the name "ground" but do not refer to the same thing. Equipment chassis is most commonly taken to be the same as ground. This is not true useless the chassis is connected to ground by design. Metallic chassis and external metal components should be at ground potential. All chassis are constructed in this manner. Generally for safety reasons, metal chassis are connected to a ground through a bond wire between the chassis and an external point that represents the best zero voltage point available. Chassis connections to ground may be by virtue of a connection made by the physical mounting of the chassis. Usually this grounding by virtue of the mounting is not to be relied upon and a dedicated ground wire is added to insure a known ground path.

4.3.1.3 Circuit Common

Circuit common refers to that internal circuit point to which other local voltages are referenced. If a power supply is said to be isolated, this means that its internal circuit common may be thought of as just a point in space with no reference to any other circuit voltage. Non-isolated circuits have some connection to another circuit. This may be through a common ground connection.

NOTE

Isolated circuit common may, in practical fact, lead some voltage to a non-related circuit due to leakage resistance, capacitance or inductance

4.3.1.4 Power Neutral

The power system neutral is that electrical conductor that is both designed to carry current and designed to be as close to “earth” potential as possible. This neutral conductor may be directly provided by the power system or separately derived. A separately derived power system and its neutral have no relationship to the power grid neutral. Neutral conductors are always to be grounded at some point if they are part of the power grid. Separately derived neutrals may or may not be grounded. Even if the neutral is effectively grounded, it will usually be elevated slightly above ground due to the IR voltage drop in the conductor.

4.3.1.5 Grounding Schemes

The most technically correct ground scheme is a single point ground. Even if ground currents flow, a single point ground has essentially no impedance that is common to the several circuits that may be connected to that point. Conversely, a system that has several ground points is susceptible in developing voltage differences between the ground points due to IR drops in the ground impedance. These voltages may mix in the various instrumentation and control circuits and usually cannot be discriminated against. One of the poorest possible ground circuiting schemes is to “daisy–chain” the ground connection. This practically guarantees the addition of ground current/voltage noise to the circuits. Any series or connected ground schemes should be avoided. Also, do not force any circuit current to flow through the metal chassis components. Chassis should not be used as a circuit element, only in a protective or RFI control mode.

- Never break a ground connection while a system is energized. Doing so may un-ground a chassis and causes it to become elevated in voltage, presenting a safety hazard.
- Never use a green/yellow stripe wire for any circuit purpose other than ground.
- Be certain that all exterior metal surfaces of the equipment are at ground potential.

4.3.1.6 Lighting Effects

If there are system ground loop problems, the effects of lightning will almost certainly cause system problems. As lightning strikes the power grid and building structures, it is attempting to find its way back to "earth" potential. If system problems seem to increase during thunderstorm season, this may be due to the effects of atmospheric electricity.

As lightning passes through local grounding structures and circuits, the "ground" potentials may be elevated several hundred colts. Elevated ground potentials will, in general, interfere with proper circuit operations.

Review your local grounding scheme if adverse effects from lightning are suspected.

4.3.1.7 Ground Loops

Ground Loops are a type of system noise or distortion that becomes added to a desired signal. This additional ground loop signal is usually a derivative of the power line frequency. However, it may come from other sources such as the high frequency energy from switching power supplies.

The most common problem is a type of ground loop in the instrumentation systems. Commonly, the signal "low" side (e.g. 115 VAC neutral) is also believed to be tied to "ground". In many system interconnections, this really is not true. Some of the power line neutral current flows in the same ground path as this signal low side connection and the result is an addition of a 50 or 60 Hz component to the drive signal. This generally has nothing to do with the amplifier and would happen with the same grounding setup whether a switching-type or a linear amplifier was used.

The best ground loop solutions are as follows:

- Know the difference in your system between chassis ground, power line neutral and power supply common. The definitions are:
  - Chassis ground is the safe zero voltage potential that all exterior metal surfaces should be connected to. This should be "earth" potential, with the earth being considered an infinite electron sink.
  - The power system neutral conductor is that conductor which is closer to ground potential. The difference between the ground conductor and the neutral conductor is that the neutral is normally expected to carry current whereas the ground conductor is not normally expected to carry current except in fault situation.
  - The electronic power supply circuit common may of may not have any relationship to either the earth, ground of neutral. Separately derived power supplies, that have an isolating transformer, will be floating with respect to ground unless specifically connected to ground on the low or common side.

- Do not force currents to flow through chassis components. In order words, do not use cabinet, structure or framework members to carry signal or power currents.

✧ Break potential ground loops whenever possible by using isolating transformers and connecting only one end of a shielded cable's shield to ground.

- As much as possible, use a single-point grounding scheme to prevent impedance from being present between two ground points. If impedance is present and current does flow, then a ground potential difference will occur. Other 50/60 Hz noise injunction possibilities that may be mistaken for a ground loop are:
- Pickup from an unshielded drive signal cable being routed too close to the high magnetic fields of the power transformers.

Power supply electrolytic capacitors that have dried out and now have a higher equivalent series resistance (ESR). These are less effective at filtering the DC and allow more of the AC 50/60 Hz ripples to pass through to the circuits. This could be in either amplifiers or instrumentation systems.

4.3.2 Cables

Provide an installation environment that will protect all cables. The cables carry high currents and can cause hazardous arcing if damaged. Electrical arcs present fire hazards and electrical shock and burn hazards to personnel.

Route the field, armature and interlock umbilical cables in the mast direct and protected manner between the amplifier and shaker station. Some form of protection is preferred such as a cable tray, wiring trough or gutter. The high-power AC cable to the shaker armature is not shielded. Therefore, avoid running low-level or unshielded signal or data cables in close proximity to its magnetic field.

Do not allow installed cables to rest against sharp metal edges. After time the insulation may cold flow and allow the internal conductor to short against the metal edge.

Insure that all connections will tie made in the most workmanlike marked and checked for tightness. Keep the armature cable well-twisted the endpoint breakout flares to a minimum.

It's recommended to make the cables according to table 4-1 if you do not speak for the cables.

Table 4-1 Recommended Cable Size

Cable name	Connect Terminal	Section area
Armature Cables	A+、A-	≥130 mm^2
Field Cables	F+、F-	≥16 mm^2
Interlock Cables	Refer to "Amplifier Schematic Circuit Diagram"	≥0.5 mm^2

4.4 Power Amplifier Disassembly

The logical module and all power modules are removed from the front of the unit. However access to the rear is required to unplug connectors. The power supply is removed from the rear, with access required from the front to disconnect wiring at the transformer and circuit breaker panel.

4.4.1 Power Module Removal

- Turn off all power to the amplifier. Prior to proceeding to verify power has been off for at least ten (10) minutes, which will allow all charged capacitors to drain.
- Open the front and rear door.
- Unscrew the 4 screws on the power terminal of A+ A- V+ V-. Unplug the ribbon cable at the rear. Unscrew the 2 screws at the both lower corners which are connecting the power module box to mounting rails.
- From the front, remove Four (4) front cover-mounting screws.
- Slide the power module out of the amplifier cabinet.
- Reverse this procedure to re-install. Plug in all ribbon cables (all pins should be right as viewed from the rear).

!CAUTION!

Do not remove the cover of the Power Module. NO USER SERVICEABLE PARTS are inside.

4.4.2 Logical Module Removal

- Turn off power to the Amplifier. Prior to proceeding to verify power has been off for at least ten (10) minutes, which will allow all charged capacitors to drain.
- Open the front and rear door.
- Unplug the ribbon cables at the rear.
- From the front, remove four (4) mounting screws, two (2) holding each side of the chassis to the mounting rails.
- Slide the logical module out from the front.
- Reverse this procedure to re-install. Plug in all ribbon cables (all pins should be right as viewed from the rear).

4.5 Control Panel Indicator

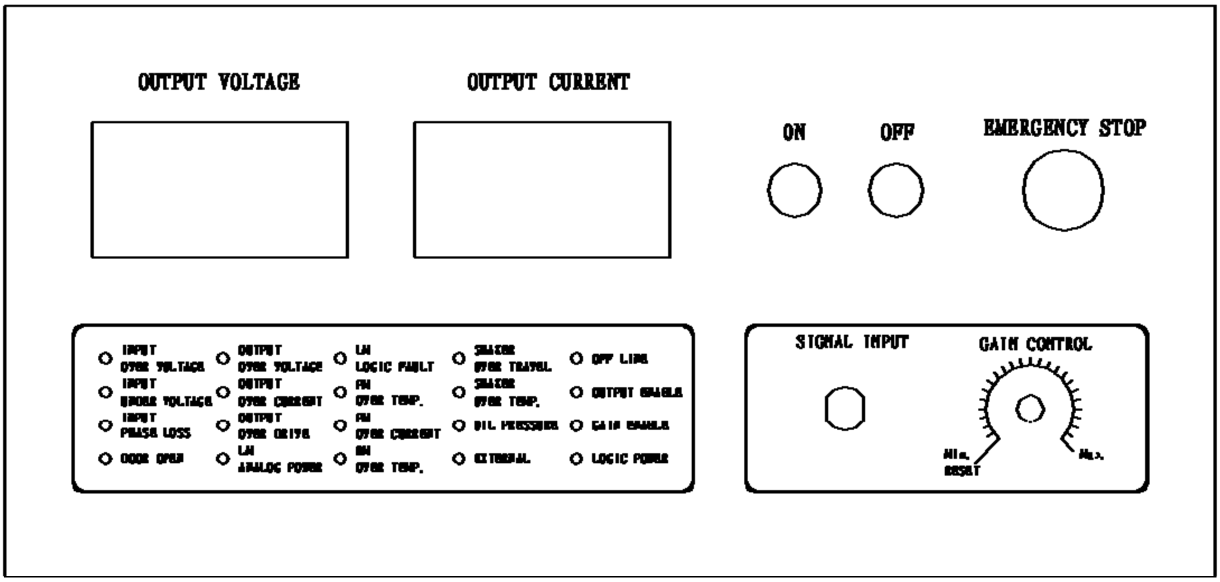


Figure 4-1 Control Panel Indicators

The Logical Module contains the following front panel indicators as Table 4-2.

Table 4-2 Description of Front Panel Indicators

Input Over Voltage	Indicates that Amplifier input voltage has exceed configured requirements.
Input Under Voltage	Indicates that Amplifier input voltage is less than configured requirements.
Input Phase Loss	Indicates that the Amplifier three (3) phase input has lost one or more phases (legs)
Door Open	Illuminates when a door of the power amplifier is open.
Output Over Voltage	Indicates the amplifier's output voltage or the maximum velocity has been exceeded. Refer to Chapter 7.2.2
Output Over Current	Amplifier over current. Verify proper Accelerometer calibration, fixture to shaker armature coupling and force at the armature doesn't exceed manufactures specifications. Refer to Chapter 7.2.3
Output Over Drive	Illuminates when the output voltage has exceeded 90% of rated output voltage. Refer to Chapter 7.2.4
LM Analog Power	Analog Power for the Logic Module. Normally $\pm$12V.
LM Logic Fault	Indicates a problem with the logic module, the IGBT trigger timing is wrong.
PM Over Temp.	Indicates Power Module is overheating. Check to see if the cooling blower is connected and operating properly. Verify blower rotation and proper seal between shaker plenum and blower input duct.
PM Over Current	Indicates that the power module faces damage risk. Need carefully check.
RM Over Temp.	Rectifier Module is over heating, check the cooling fan of the Rectifier Module

Shaker Over Travel	Indicates the peak-to-peak displacement limits of the shaker are being exceeded. Verify test levels and proper armature centering.
Shaker Over Temp.	Indicates that the Shaker is Over Temperature.
Oil Pressure	The Oil Pressure of oil pump is too low!
External	Customer define indicator (AUX1).
OFF LINE	Indicates that the amplifier is not active or able to drive the output. This may be either because there is a trip condition due to an interlock or that the amplifier is in the RESET state.
Output Enable	Output is enabled.
GAIN Enable	GAIN switch is on the RESET position.
Logic Power	Illuminates the digital power of logic module.
EMERGENCY STOP	It could be pushed in any emergency conditions to shut down all contactors including additional power contactor. Rotate it clockwise to reset.
Gain Control	Sets the gain of the amplifier. Zero gain is at the reset detent position, maximum gain is at full CW. Faults may be cleared by turning this control to the reset detent position, if the fault condition has cleared.
Signal Input	Signal input terminal.
Off Switch	Turn off all contactors except for the Gain is turned on..
ON Switch	Turn on all contactors.
Silence Switch	There are two working statuses: Alarm Normal and Silence. If you put the silence switch upward to alarm normal position, the alarm buzzer sounds normally when faults happen. And if you put it downward to silence position, the alarm buzzer won't sound.

4.6 Setup Switches in Logic Module

!CAUTION!

These interlocks are provided to trip the amplifier offline in the event of external malfunction. System damage may result if a required interlock is disabled. Change the switches in Table 4-3 only for authorized servicing or if you are changing the system configuration for some reasons.

The function of each switch is listed in Table 4-3.

Table 4-3 Logical Module DIP Switch Definitions

DIP Switch Code and #	Trip Function (enabled=on) (negative =the fault is tripped when the line level is "low", positive= the fault is tripped when the line level is "high".
S1-S8-1	Slip Plate Oil Pump, enabled, negative
S1-S8-2	Shaker Over Temp., enabled, negative
S1-S8-3	Shaker Over Travel, enabled, negative
S1-S8-4	PM Over Temp, enabled, negative
S1-S8-5	Door Open, enabled, negative
S1-S8-6	Input Under Voltage, enabled, negative
S1-S8-7	RM Over Temp, enabled, negative
S1-S8-8	External, enabled, negative
S5-11-1	Door Open, enabled, negative
S5-11-2	Output Over Voltage, enabled, negative
S5-11-3	Output Over Current, enabled, negative
S5-11-4	Oil Pressure, enabled, negative
S5-11-5	PM over current, enabled, negative
S5-11-6	LM Analog Power, enabled, negative
S5-11-7	Input Phase Loss, enabled, negative
S5-11-8	External, enabled, negative
S12-17-1	Input Over Voltage, enabled, negative
S12-17-2	Input Under Voltage, enabled, negative
S12-17-3	LM Logic Fault, enabled, negative
S12-17-4	Shaker Over Temp., enabled, negative
S12-17-5	Shaker Over Travel, enabled, negative
S12-17-6	PM Over Temp, enabled, negative
S12-17-7	RM Over Temp, enabled, negative
S12-17-8	Undefined

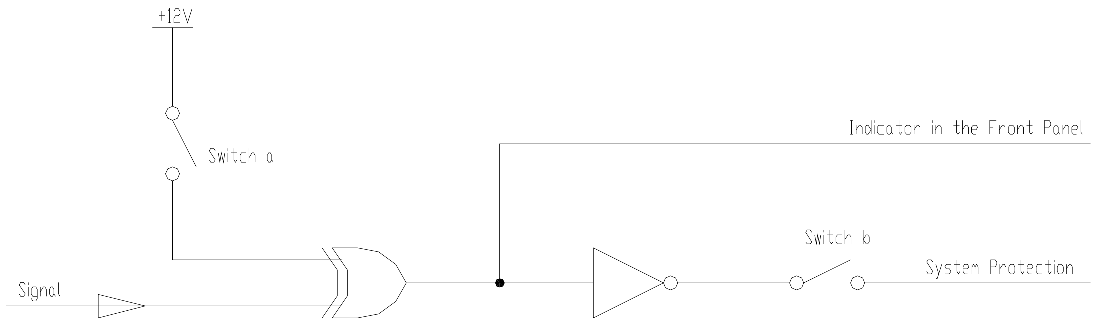
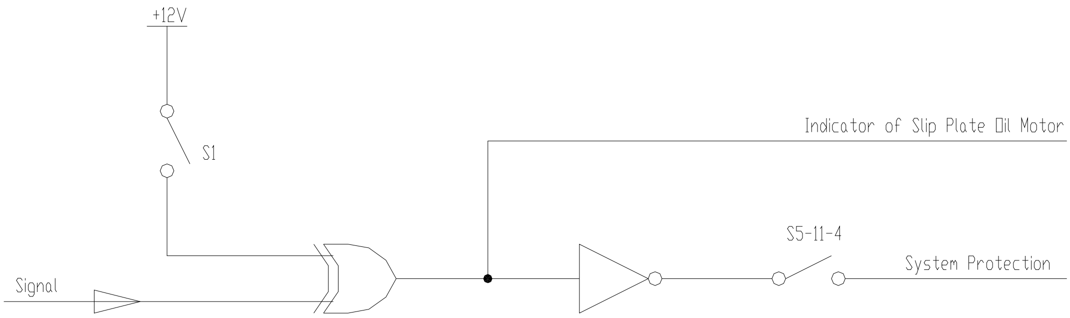


Figure 4-2 Control Principle

*Typically the switches of S1-S8 have functions as "Switch a", while the switches of S5-11 and S12-17 has functions as "Switch b". (Refer to Figure 4-2)

Take "Slip Plate Oil Motor" for example, it's controlled by Switches S1-S8-1 and

S5-11-4 as shown in the figure below.



When S5-11-4 switch is set off, the function “Slip Plate Oil Motor” interlock protection loses invalidation. In this case, the signal of trip of “Slip Plate Oil Motor” can’t be transmitted to the logic board to shut down the system.

S1-S8-1 switch is usually used to check correspondence between indicators and the signal. Sometimes serviceman needs to turn off the switch to isolate the alarm signal.

4.7 Circuitry

a) LM (Logical Module) Analog Power
Monitor the internal ±12V analog power supply between Pin 8 and Pin 4 of 2N1 with a Voltmeter.
b) Door Open
When system is running, the door of amplifier can not be opened.
c) Gain Enable
It indicates that the pot is turned on.
d) Input Over Voltage
The 3-phase AC input is monitored via the amplifier DC supply voltage, which is proportional to the line. Amplifier N30 translates the nominal 214 Volts to a lower level. Amplifier N31 will generate a fault if the line goes above +10%. This will help prevent damage to the amplifier if the input is improperly wired.
e) Input Under Voltage
The 3-phase AC input is monitored via the amplifier DC supply voltage, which is proportional to the line. Amplifier N30 translates the nominal 214 Volts to a lower level. Amplifier N31 will generate a fault if the line goes under -10%.
f) PM (Power Module) Over Temp.
If the power module’s temperature is up to 80ºC， the thermal sensor will decrease its resistance level near to 0 Ohm.
g) PM Over Current
Indicate that the power module faces damage risk and need carefully check.
h) Off Line
This is a red LED that lights whenever a fault condition has triggered a fault. If any of 16 separate faults trip, they will be latched. An orderly shutdown procedure for the amplifier will start at that instant. The amplifier output will be turned off by driving the

gate signal high.

i) Output Over Voltage

An output over voltage is adjustable from 0 to rated output voltage trim pot RP8 on the "OVADJ" part of PCB. It is normally set at slightly above rated output voltage. This may be used in sine mode as a velocity trip set point.

j) Output Over Current

A load over current trip is adjustable from 0 to rated current by trim pot RP7 on the "OLADJ" part of PCB. It is normally set at slightly above rated current.

k) Output Over Drive

This is a red LED that comes on whenever the output voltage is above 90% of rated value, it's adjustable by RP9 on the "OVADJ" part of PCB.

l) Shake Over Travel

The travel of armature must be controlled within maximum value, otherwise Over Travel is tripped.

m) LM logic Power

This is a green LED witch indicates digital power supply of logic module.

n) Output Enable

This is an "all is well" green LED. It lights to indicate that there are no faults and that the system is operating properly.

o) Shaker Over Temp.

The field power supply converter's temperature should be lower than 115 ºC.

4.8 Definitions of Interlock Connection Terminals

The definition of the interlock connection terminals as Table 4-4:

Table 4-4 Definition of the Interlock Terminals

COM	"0" level reference point.
STR	Shaker Over Travel
SOT	Shaker Over Temp.
OP	Oil Pressure
AUX1	User-definable interlock input 1
ES2A,ES2B	Shaker Emergency Stop

Each interlock may be selectively enabled or disabled by a switch on the Logic Module circuit board. Refer to the Chapter 4.6 and Chapter 4.7.

Section 5 Shaker Disassembly

Warning

Avoid being pinched.

5.1 Inspection before Disassembly

Before attempting to resolve a problem in the Shaker, make certain the shaker itself is at fault. A possible source of trouble may be in the related electronic system: malfunction of that equipment may be reflected at the shaker end.

Troubles traced directly to the shaker will be relatively few. Any noticeable change in the operational characteristics, or a change in the usual sound of the shaker while operating, may be a sign of malfunction and should be investigated immediately. Run a check to compare the armature resonance frequency and harmonic distortion against the records made when the system was installed or those provided from the factory. Any great deviation from the original record usually indicates armature misalignment, excessive bearing wear of armature structural failure.

The operational characteristics of the shaker can be changed by an accumulation of ferromagnetic particles in the air gap, or by damage to the field of armature windings from overheating. Overheating may be caused by blower motor failure, improper blower direction of rotation, clogged air-inlet grilles, or excessive field and/or armature current.

5.2 Armature Disassembly

As shown in “Shaker Disassembly Drawing” attached at the end of this Manual

- Loosen the three Hex Head Bolts (1) which are used to fix the Hood; then remove Hood/Top Cover (4) together with the rubber dustproof ring.
- Remove the Center Insert (9). With Hex Wrench (supplied) through the center hole of the armature table, remove the Center Bolt from Shaft (25) to disconnect the armature from the lower guide shaft of Air Support Assembly.
- Unscrew Hex Head Bolts to remove the Upper Guidance Assembly (6).
- Remove the wires from Armature Terminal Board and Over-Travel Switch.
- Unscrew Hex Head Bolts used for fixing the Coil Isolation Collar (8).
- Take out the Armature (10) together with the Coil Isolation Collar (8).
- Reverse this procedure to re-install.

5.3 Disassembly of the Upper Field Coils

As shown in “Shaker Disassembly Drawing” attached at the end of this Manual

- Take out of armature as procedure outlined in Chapter 5.1
- Take off the cover of the junction box, loosen all the wires and remove the Junction Box (19) from Magnetic Body (17).
- Remove the Hex Head Bolts (14) fixing the Top Disk to the Magnetic Body.
- Lift Top Disk (15) by two eyebolts installed.
- Clear out the four spacers between Field Coil and magnetic body.
- Take out the Upper Field Coils (16) by ropes fasten on it. Be careful the field coil power leads during the lifting.
- Reverse this procedure to re-install.

5.4 Lower Guidance System Disassembly

As shown in “Shaker Disassembly Drawing” attached at the end of this Manual

- Disconnect the Armature from the lower guide shaft of Air Support Assembly. (Refer to Chapter 5.1.2)
- Rotate the shaker 90º to horizon direction.
- Remove Air Outlet Cover (31).
- Remove the bolts which fix the Lower Guidance System and Air Support Assembly on the Bottom Disk (22).
- Take out the Lower Guidance System and Air Support Assembly
- Reverse this procedure to re-install.

5.5 Disassembly of the Lower Field Coils

As shown in “Shake Disassembly Drawing” attached at the end of this Manual

- Remove the Lower Guidance System. (Refer to Chapter 5.3)
- Rotate the shaker further 90º to let the bottom side on the top.
- Unscrew Hex Head Bolts (23).
- Lift Bottom Disk (22) and Center Magnetic Pole (21) by two eyebolts installed in the Bottom Disk (22).
- Take out the Upper Field Coils (16) by ropes fasten on it. Be careful the field coil power leads during the lifting.
- Reverse this procedure to re-install.

NOTE

Never loosen the Hex Head Bolts (24) which are used to connect the Center Magnetic Pole to Bottom Disk. Otherwise the Center Magnetic Pole may drop. It’s very dangerous.

5.6 Adjustment after Replacement

5.6.1 Adjustment of Upper Guidance System

When the parts of the Upper Guidance Systems or the Armature need replacing, tightness adjustment is necessary after assembly. Adjust the bolts screwed in the Adjusting Block of the Upper Guidance Assembly (6) to leave equal clearance between the side surface of the armature and each roller of Upper Guidance System. Pull the armature up and down; insure it moves freely without block.

5.6.2 Adjustment of Lower Guidance System

After replacement of the Threaded Ring or Guidance Wheels of Lower Guidance System, tightness adjustment is needed.

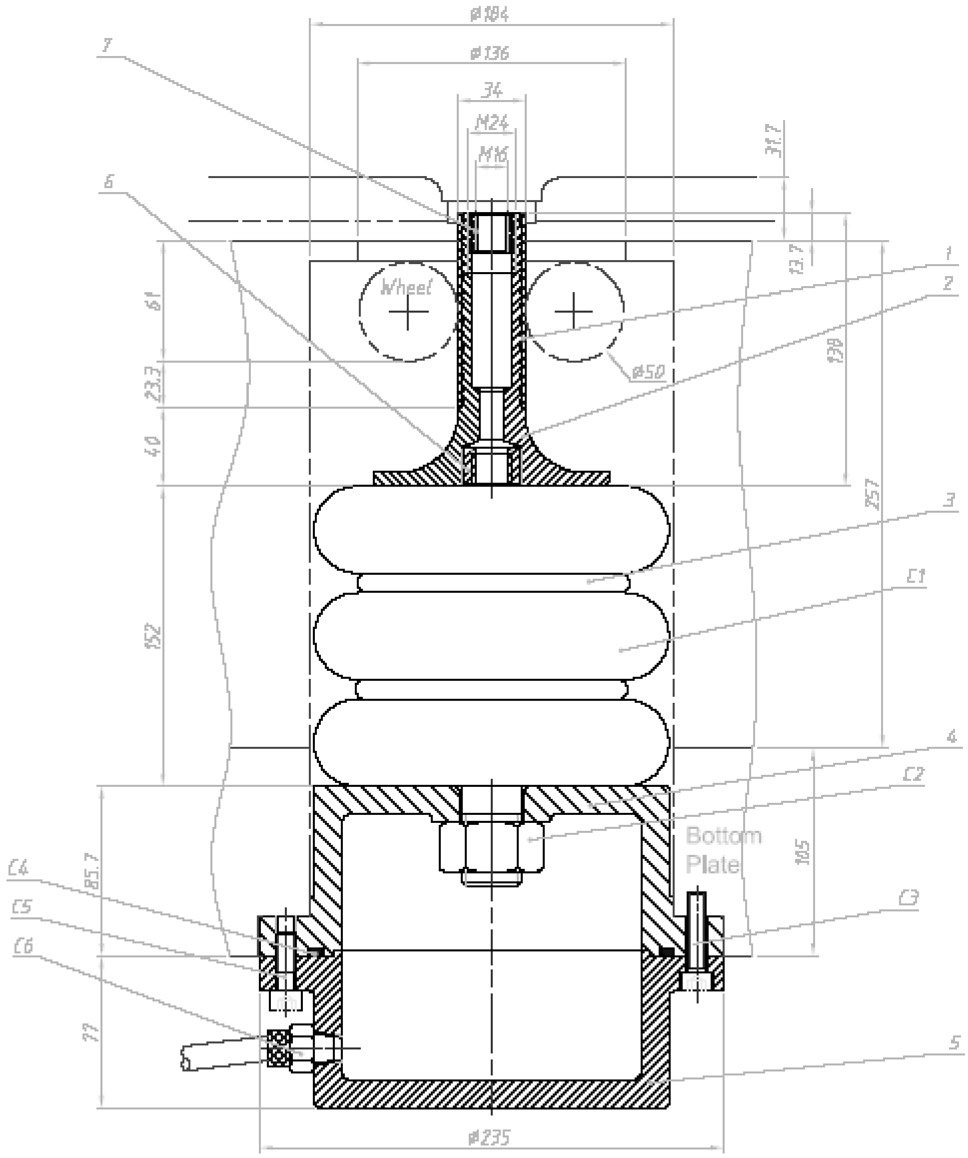


Figure 1

NOTE:

1. While disassembling, the four guidance wheel axles (H) mustn't be adjusted unless there is clearance between the four wheels and the square shaft (I) or the shaft can't move freely among the wheels. In this case, please follow the instructions below:
   Loosen the tightening bolt (F) firstly, and adjust the headless bolt (G) till all the wheels closely contact the shaft (I). Please insure the same tightness. While rotate the wheels, the shaft should move together. If the shaft doesn't move, it indicates too loose, please tighten the wheels. If you can't rotate the wheels, it indicates too tight, please loosen the wheels. After adjustment, please guarantee the shaft in the center axis. Single wheel bearing force must be forbidden.

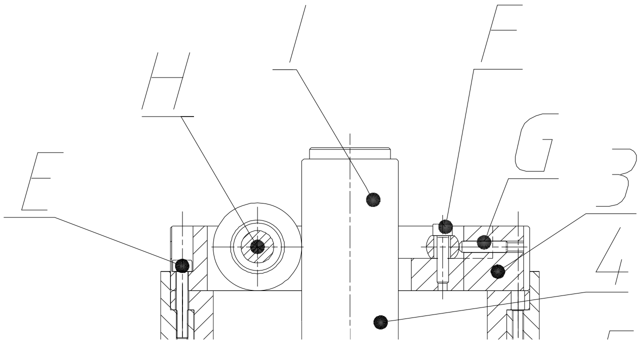


Figure 2

It is as below how to align the guidance shaft.
L1=L2=L3=L4, the error should be within +0.1mm. (Refer to Figure 2)

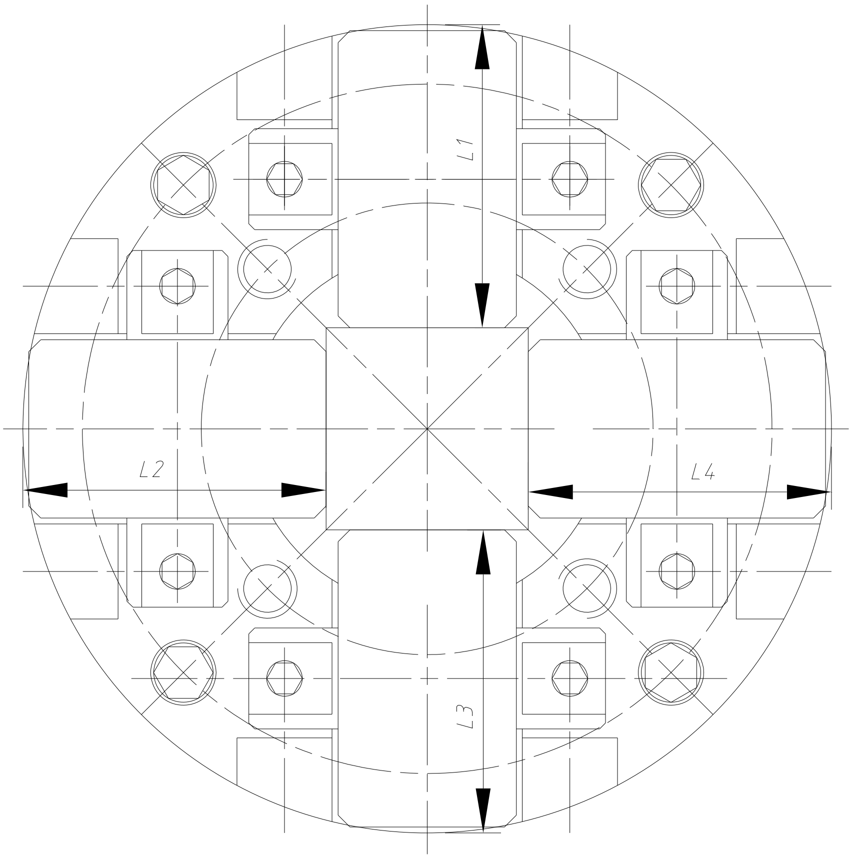


Figure 3

2. While reinstalling the load support system according to Figure 1, please connect the hose to the faucet (B) temporarily for inflating (Shown as Figure 1). Inflate some air in the airbag. Then push the whole support system into the shaker body. While pushing it in, elasticity should be felt. No elasticity feeling indicates less air in the air chamber. It needs pressurizing. Otherwise pushing the air chamber in difficultly indicates too much air. Please depressurize.

5.6.3 Adjustment of Air Chamber

While the air chamber is assembled, first connect the hose and inflate a little air to the air chamber. Anoint on the surface of the chamber and insert it in the center hole of the bottom disk. When push it in, elasticity exists. No elasticity feeling indicates less air inflated in the air chamber. It needs inflating more. Otherwise pushing the air chamber in difficultly indicates too much air. Need deflating before fixing.

5.6.4 Adjustment of Armature

Before installing the armature, insert four Bakelite Bars (600 mm long, 2 mm thick) in the circle air gap of the magnetic body. Then install the armature, adjust the guidance system to insure the four Bakelite Bars the same tight. After adjustment, pull out the four Bakelite Bars. The equal space of the armature in the air gap is the most useful for the heat dissipation.

Section 6 Slip Table

6.1 General Description

The GT (V-Grooved Oil-Film Slip Table) series Slip Tables are ideally suited for sequential 3-axis test capability with minimized cross axis response and high overturning moment; for testing heavy, oversized, or non-symmetrical loads. The GT Series integrated shaker/slip table design offers numerous critical technical features compared to other manufacturer's integrated base designs. These features result in long term durability, high performance and reliability, structural integrity, building isolation, and simplified operation. V-Grooved Oil-Film Slip Tables are designed with a precision granite slab with side shank guide and is combined with a magnesium or high grade aluminum slip plate to provide the most cost effective way to perform general horizontal testing. The slip plate is guided by two front and back base V-Groove Oil-Film bearings to provide high restraint during high moment operation.

WARNING

PLEASE NOT SWITCH OFF THE OIL RETURN VALVE WHEN THE PUMP IS RUNNING!
THE NORMAL WORKING PRESSURE IS 1.0±0.2 MPa. IF THE PRESSURE IS ZERO AFTER TURNING ON THE PUMP, TRY TO CHANGE THE MOTOR ROTATION.
THE PUMP MUST BE OFF DURING THE MAITENANCE, LIKE CLEAN THE FILTER AND CHANGE THE OIL.
THE CORRECT PROCEDURE TO CLEAN THE FILTER OR CHANGE THE OIL IS DETAILED AS BELOW.

1， **Remove the 4 nuts fixing the pump unit to the slip table base; Take the pump out of the base.**
2， **Switch off the oil return valve.**
3， **Remove the oil pipe located on the top of filter. And remove the cover of filter unit.**
4， **The filter core can be removed by screwing and replaced.**
5， **Remove the 4 bolts fixing the filter holder (the black cylinder part) on the pump unit base. Take it to the vessel prepared and turn on the valve; the oil can drain from the filter holder.**
6， **Assemble back reversing above steps.**

Please see the HS-2F oil supply system schematic diagram in Appendix

6.2 Specifications of Slip table (This shaker is not configured Slip Table)

Slip Table		
Useable Frequency (Hz)		
Slip Plate Natural Frequency (Hz)		
Total ST Effective Mass Including Slip plate, Drive Bar and Bearing, except Armature (kg)		
ST Material		
Slip Table Uniformity		
Slip Table Lateral Motion		
Slip Table working size	L (mm)	
	D (mm)	
Overall dimension of Slip Table Base	L (mm)	
	D (mm)	
	H (mm)	
Normal Operating Oil Pressure		
Oil Flow (Nominal)		
Oil Pump Motor Power (W)		
Oil Type		
first time adding oil(L)		

6.3 Connecting the Slip Plate

Turn on the oil pump for a minimum of 5 minutes prior to connecting the Slip Plate. This allows the slip plate to float freely on the granite surface and ensures proper oil distribution and lubrication. The stiff film in the hydrostatic journal bearing is built up.

Prior to rotating the shaker to horizontal situation, attach the slip table drive bar on the armature table. Make sure the mating lip of the driving bar is in the proper orientation to mate with the slip plate. That means the lip always faces the slip plate. Do not tighten the attachment bolts at this stage.

With driving bar attached, slowly rotate the shaker body slightly to the horizontal position. Pull the slip plate away from the shaker body to let driving bar's lip goes below the slip plate.

Push the slip plate towards the shaker body to touch the driving bar. Reverse the direction of rotation, and rotate the shaker so the lip of the driving bar mates with the slip plate. Mate slip plate and driving bar by hands, both interface touch very well, tighten the bolts to connect driving bar and slip plate.

Now, the bolts which are located in the up-half of the armature and not tightened previously are required to be tightened.

Loosen and remove the bolts tightening the driving bar and slip plate. Pull the slip plate to the opposite direction of shaker body to have shaker body rotated to vertical situation. Tighten all the bolts to connect the driving bar and armature hardly.
Again, rotate the shaker body to horizontal situation, tighten all the bolts to connect the driving bar and slip plate hardly.

A good connection of slip table and shaker through the driving bar will be verified by hand-pull-push the slip plate and it can slide smoothly.

WARNING

THE CORRECT PROCEDURE FOR CHANGING THE VIBRATOR'S THRUST AXIS IS DETAILED BELOW. FAILURE TO COMPLY WITH THE CORRECT PROCEDURE CAN RESULT IN SERIOUS PERSONAL INJURY

1，Deflate the isolation air bags in trunnion suspension system to allow the vibrator body to seat on the trunnion.
2，Insert the two isolation trunnion system Lock-Screws of M16 (with 8mm key) through the trunnion; tighten the screws. There is one in each side.
3，Remove the eight (four each side) trunnion securing screws of M16 (with 12mm key).
4，Using the hand wheel, rotate the vibrator to the required axis, until the Rotation stops prevent further movement.

NOTE: Keep full control of the hand wheel throughout this stage to ensure that it does not rotate out of control either side of the point of balance.

5，Insert and tighten the eight Trunnion securing screws removed in step 3.
6，Remove the two isolation trunnion system Lock-Screws inserted in step 2.
Inflate the isolation air bags in trunnion suspension system as required.

6.4 Control Accelerometer Location

CAUTION!!!

Do not attempt tests using slip tables with the control accelerometer mounted on or inside the moving element of the shaker. If a single control accelerometer is used, it must be located near the free end of the slip plate, away from the shaker. The best arrangement is to average a number of accelerometers including one located at the free end.

The reason is the dynamic response of the combined slip plate and moving element forces a node of low acceleration near the junction of the shaker moving element and the slip plate. If the control accelerometer is located near the shaker-slip plate junction, drive from the power amplifier is increased to overcome this low acceleration response. This high drive may cause the test to abort if power amplifier drive limits are exceeded, and the higher drive leads to reduced reliability of the shaker system. Also, overtesting results from the fact that the specimen sees higher g levels than the control accelerometer.

Test levels are more easily obtained if the Specimen and Control Accelerometer are both located at the far end of the slip plate away from the moving element end.

6.5 Optimum Load Placement on Slip Table

Every system exhibits resonance. In systems such as your Combined Slip Table Assembly, these resonances, if exploited properly, can help to improve your system's performance. Engineers have performed an experiment to illustrate the optimum placement of a load to exploit that system's resonances to improve the characteristics of the system.
These observations indicate the optimum load placement is away from the shaker on the slip plate.
Similar improvements are obtained for sine testing.

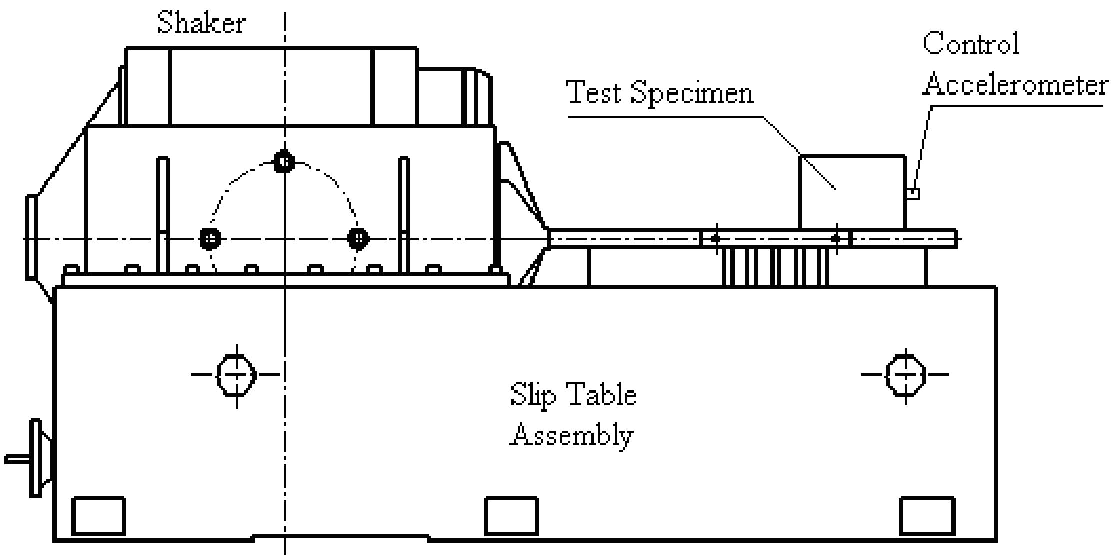


Figure 6-1 Preferred Location

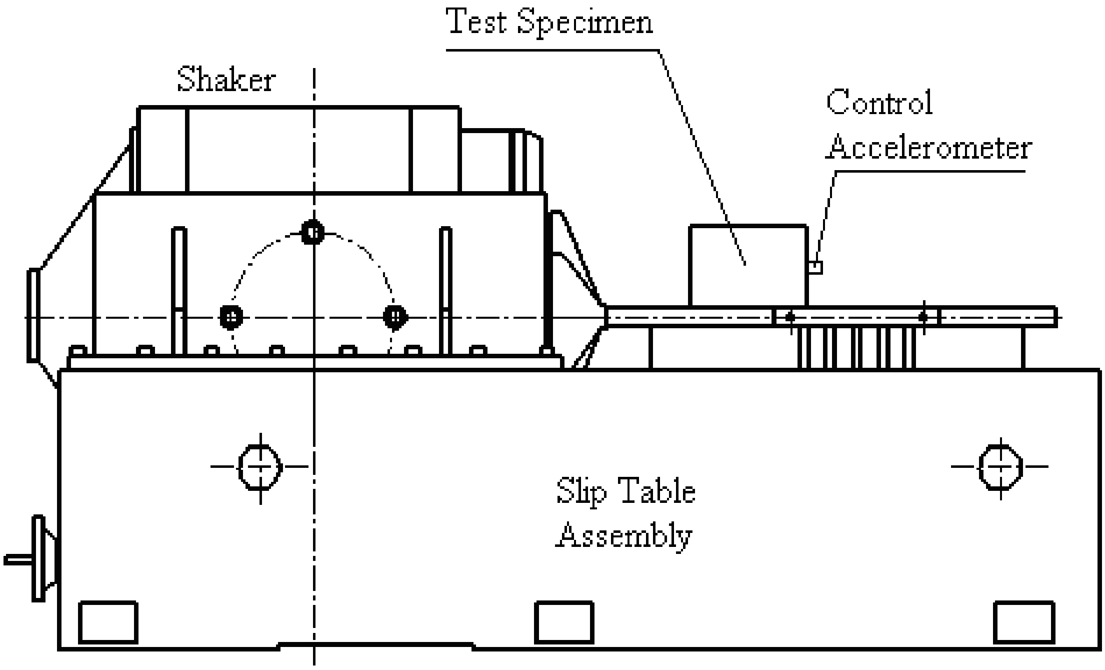


Figure 6-2 Poor Location

Section 7 Fixture

7.1 Specifications of Head Expander (This shaker is not configured Slip Table)

Specifications of Head Expander	
Maximum Useable Frequency (Hz)	
Natural Resonance Frequency (Hz)	
Mass of Head Expander (kg)	
Size of Head Expander	

7.2 Comments of Fixture Design

Vibration test fixtures come in such a large variety of sizes and shapes that it is difficult to give general statements that can be useful for a particular design. However, in working with our customers who are newcomers to the field of vibration, we have found a common problem which we feel warrants pointing out. Customers with long experience in fixture designs and applications, will, of course, be aware of the problem to be discussed here and will have already overcome it.

Many newcomers approach fixture design from the viewpoint of static strength and stiffness. The fixture and load weight are estimated and multiplied by the 'g' level of the test. This yields the force transmitted. This force is usually quite modest in terms of static strengths so that the designer then proceeds to clamp the specimen to the fixture and the fixture to the shaker table with a few bolts and clamping sections which are entirely adequate to cope with these low static forces. This approach tails to account for the dynamic conditions that occur at the higher frequencies encountered in most vibration tests.

Usually, when a fixture is designed with only static loads in mind, a very severe major resonance occurs within the frequency range of the test. The clamping and bolting arrangement, while adequate statically, turns out to be very soft or compliant when analyzed dynamically. In other words, the mass of the test item and fixture is resonant on the soft springs consisting of the clamping arrangement to the shaker table.

There are at least two major objections to this resonant condition. The first is that the test item does not receive the correct "g" level as controlled by the accelerometer in the shaker table. Due to the resonance, the "g" level at the test item can be many times higher than the shaker "g" read on the meter. The results in severe overtesting, sometimes damaging the specimen.

The second is that due to the resonance, there usually occurs a frequency where extremely high amplifier power is required to maintain constant "g" at the shaker table. This can be observed by noting when the amplifier output current approaches the maximum value noted in the manual. This results in severe overdriving of the Unit Under Test and fixture, high distortion, and unnecessary stresses on the vibration system components.

The cure is to design fixtures with the dynamic problems in mind. In practice, this means making the clamps and hold down bolts stiff relative to the masses involved, so that the resonance of the spring-mass system is as high as possible, preferably above the operating frequency.

A second cure is to control from an accelerometer located up on the fixture or test item. This is usually less convenient, for the accelerometer must be moved each time the fixtures are shifted on and off the table. It is sometimes the only solution, as for example, if the test item is so large that the resonance cannot be pushed above the operating frequency. With large test fixtures it is sometimes best to use a multiple accelerometer control scheme, (average or extremal).

NOTE

The max length of the bolts used to tighten the fixture to the armature table or slip plate must be shorter than 20mm. If the bolts are longer, the bottom surface of the armature or slip plate will have protrusions because of the stress of the extra length of the bolts to make some problems.

7.2.1 Case 1

The test items were small electrical components clamped to rectangular aluminum plates 5"×5"×1/2". These plates were then mounted on the fixture which was bolted permanently to the shaker table. The first design for the fixture was a welded box structure of 3/8" thick welded aluminum plates as in Figure 1. It was impossible to run the tests because of the severe resonance below 1000 Hz, and 'g' levels on the test items were over 10 times as great as measured by the shaker accelerometer. The solution was the redesigned fixture shown in Figure 2. This fixture was a solid cube of magnesium with drilled holes to remove weight. Also more of the hold bolts into the shaker table were utilized. The resonance for this new fixture was moved up over 2 kHz and no testing difficulties were found.

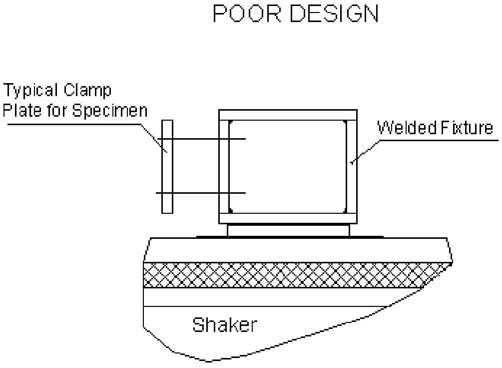


Figure 1

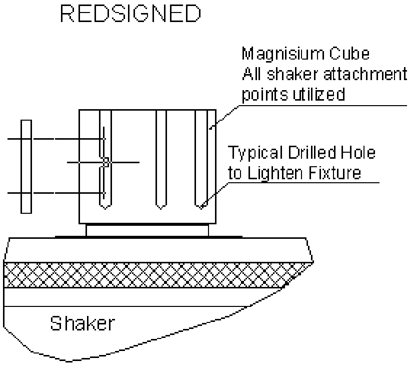


Figure 2

7.2.2 Case 2

In this test specimen fitted into a cubical aluminum fixture. The fixture then was fastened at four points to a 1/4 inch thick aluminum adapter plate. The adapter plate was fastened at four other points to the spring and severe resonance occurred. Two solutions were possible. The fixture could be redesigned to bolt directly to the shaker table, using more than four bolts if possible. The second was to redesign the adapter plate. It was made of magnesium about 1" thick. It was tied to the shaker table using all 13 shaker attachment points available on that shaker table. Additional bolts were added from the fixture to the plate. Figure 3 and Figure 4 show the before and after for this case.

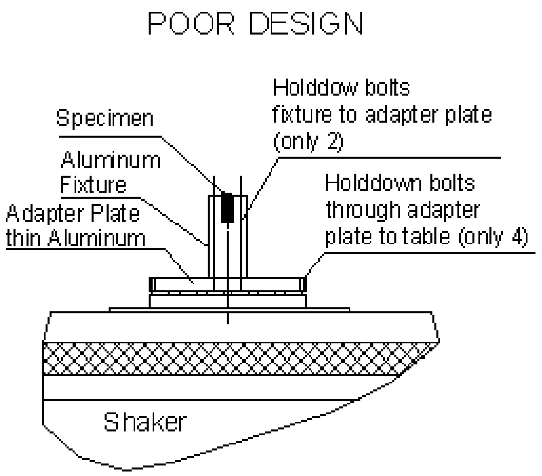


Figure 3

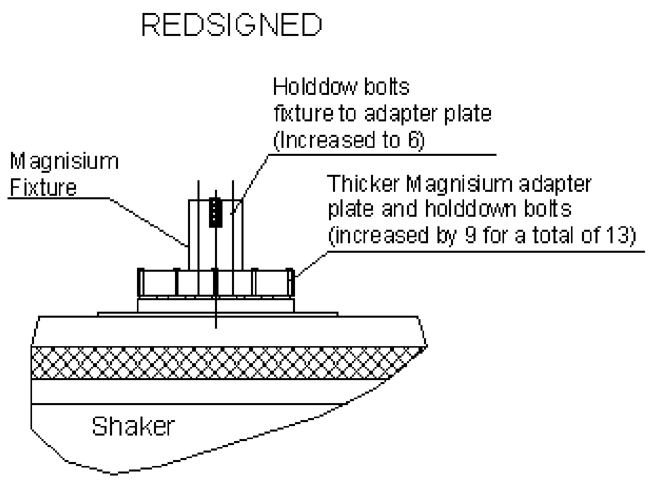


Figure 4

7.3 Summary

Some of the points brought out by the above cases are:

1. Use as many of the hold down bolts to the shaker as possible.
2. Use magnesium instead of aluminum. Magnesium weight is about 65% of aluminum. Plate thickness can be made much thicker and stiffer with magnesium.
3. Avoid thin plates that can act as leaf springs, instead use solid, smaller fixtures. Weight can often be kept down by honeycombing with drilled holes, without affecting stiffness.
4. Use a minimum of joints or mating members. The omission of an intervening adapter plate almost always increases stiffness.
5. Two flat mating surfaces can be helped by a layer of silicone grease on the mating surfaces. This grease results in an adhesive action similar to the oil on Johnson gage blocks. This is particularly effective at high frequencies.

6. Use as many bolts as possible, spaced as close as possible in bolting specimen to fixture, and fixture to adapter plates.

7. The fixture weight should not be the maximum allowed by the system performance. By making the static weight somewhat less, it allows for the higher dynamic loads that occur around resonance frequencies.

Section 8 Calibration and Adjustment

8.1 Recommended Test Equipment

- Digital battery powered digital true RMS 3 or 4 digit multimeter
- 100 MHz dual trace oscilloscope with 10:1 probes and power line ground isolation plug
- clamp-on ammeter, 0-1000 Amps
- sins wave oscillator, 5-5000 Hz, 0.1 % distortion, 600 ohm or less output impedance

!CAUTION!

If there is ONE (1) MODULE, DO NOT attempt to adjust the current limiting to over 150 Amps. The power supply section CANNOT supply this level of RMS current.

8.2 Adjustments

8.2.1 Current Limit

The current limit of the system is adjusted via Fib, located on the Current Limit Sense PCB located in the Logic Module. The Current Sensor Normalization procedure must be performed prior to setting current limit.

To set current limit, drive the amplifier at 300 Hz, sine mode, to either full rated force or maximum power amplifier current, whichever occurs first. A resistive dummy load may substitute for the shaker.

Next, adjust RP6 on the Current Limit Sense PCB until the current begins to lessen. This is the current limit action. Increase the drive to the amplifier by 1dB and verify that the current limit circuit clamps the drive and that maximum drive is not exceeded. Note that a slight increase may occur in the output current, but it will be much less than the relative increase in drive signal.

At the same time, adjust RP7 on the logic PCB until the current begins to lessen, it’s the same as adjusting RP6 on the current limit sense PCB.

8.2.2 Output Over Voltage Trip

An output over voltage trip circuit is provided to allow the amplifier to be limited in its output voltage. This is mast useful in vibration systems to provide a maximum velocity limit for the shaker. Factory default for this setting is 120 Vrms, direct-coupled.

Drive the vibration system to either its maximum velocity level or any desired lower level. Carefully adjust RP8 until the amplifier just trips off-line.

8.2.3 Output Over Current Trip

An output over current trip is provided to allow the amplifier to be limited in its output current. To set current limit, drive the amplifier at 300 Hz, sine mode, to either full rated force or maximum power amplifier current, whichever occurs first. A resistive dummy load maybe substituted for the shaker.

Carefully adjust RP7 set rated output current at 110% of rated current of power.

8.2.4 Output Drive Trip

The overdrive circuit is a warning only based upon the output voltage level. This is an average responding circuit and may be set at the operator's discretion to any level desired.

Factory default for this setting is 90 Vrms, direct-coupled.

For vibration systems operation, drive the system in random mode, wide band, to the systems full force rating, any lower level desired. Carefully adjust RP9 so that the over drive light just illuminates. This is an indicator only.

8.2.5 Output DC Offset

An output DC offset control is provided to allow adjustment of the DC component in the amplifier's output. The DC offset is generally set to be as close to zero as possible. However, it is possible to have the amplifier to provide a DC bias current to the shaker armature to pre-bias it to one direction or the other. Generally, this is not recommended due to the fact that if the amplifier trips off line, all output stops including the DC bias generated by the amplifier.

To set the DC offset, monitor the amplifier's output with a DVM. Short the signal Input to the power amplifier. Advance the gain control fully clockwise. Carefully adjust RP1 for a reading of less than 5 millivolts DC on the output.

8.2.6 Gain/Reset

Front panel potentiometer/switch used to control the overall gain of the amplifier. When the knob is turned fully counterclockwise through the detent, the amplifier is in the RESET state. The input drive is fully attenuated while in this state. Advancing the knob clockwise just off of the detent position, enables the pulse width modulator drive and allows the fault detection logic to respond to system errors.

Section 9 Maintenance

9.1 General

To ensure maximum efficiency, a periodic inspection schedule should be followed. The operational schedule of the shaker determines the inspection schedule. A shaker operating daily should be inspected more frequently than a shaker that is used less frequently. Tightness of electrical connections and screws should be checked on regular basis prior to operating the system. A complete preventative maintenance is recommended after the first 250 hours of operation and each 1000 hours thereafter.

- Clean or suck the dirt inside the power amplifier, shaker and air duct connecting the blower by a cleaner.
- Insure all the cable connections are not loosened, especially the connection on A+, A-, F+, and F- on the rear of the power amplifier.
- Check correct grounding.

9.2 Tools and Equipment

Only an experienced technician utilizing the correct tools should perform disassembly and assembly of the shaker. Service personnel should ensure that they have the correct tools before work on the shaker is started. Some of the tools needed are as follows:

a) T-shape Wrench
b) Inner Hexagonal wrenches.
c) I shape wrench
d) Torque wrench.

The recommended equipment needed to perform the functions outlined in this manual is listed below. Note: Any suitable equivalent may be substituted for the equipment listed:

1) Portable crane of forklift.
2) Lifting straps.
3) Vacuum cleaner or compressed air blower.
4) 500 V Meg ohm insulation tester.
5) Oscilloscope.
6) Multi-meter.
7) Light weight piezoelectric accelerometer.
8) Two blocks made of wood or metal bar stock (6cm×4cm×2.5cm).
9) Two plywood boards (100cm×100cm×1cm).

9.3 Preventive Maintenance

The shaker must be kept clean at all times. The armature should be removed if necessary and the interior of the shaker body cleaned thoroughly in accordance with the manufacture's recommended preventative maintenance schedule vacuuming or compressed air blowing recommended for this operation.

The following parts should be inspected for damage while the shaker is disassembled:

1) Electrical Wiring
2) Terminal Block.
3) Air Chamber for load support
4) Field coils.
5) Armature coils (Driving coils)
6) Air Support Assembly
7) Guidance System

9.4 Annual Tests and Inspections

The following should be performed annually.

- Check the circuit breaker "trip test" (if so equipped). This is accessed through a hole below the circuit breaker handle.
- Clean the transformer and power supply using a shop vacuum.
  Use compressed air to blow accumulated dust from windings.
- Record results on Service Log Sheet.

9.5 Blower Inspections

Blower is used to equalize the heat generated in the shaker to keep the system normally working. So periodic inspections as follows are needed.

- Inspect the connection of the duct, if loosen, tighten it.
- Duct mustn't be cracked or leak, if found, repair or replace it.
- With a pressure meter Measure the air pressure which should correspond with the specifications in this manual. If lower, confirm the cause first before test.

9.6 High-Current Joints Inspections

Cleanliness and tightness of all high-current joints is mandatory to prevent oxidation, overheating and fires.

Periodically (within 250 operating hours after initial installation and yearly thereafter) inspect the following for signs of overheating such as discoloration or melted insulation:

- ●three-phase power lines
- ●main circuit breaker
- ●power transformer
- ●power supply section:
    - ●bridge rectifier modules
    - ●DC supply to power modules terminal blocks
    - ●field & armature output terminal blocks
    - ●capacitor filter bank bus bars
    - ●field & blower fuses and contactors

Do not remove any grease-like compound found on high-current joints. This compound is there to prevent oxidation and improve conductivity.

9.7 Service Log

DATE	PROBLEM	SERVICE DONE	BY

Section 10 Troubleshooting

We are interested in maintenance of your equipment supplied by us. If you encounter difficulty, do not hesitate to ask for advice of assistance. Communicating with us, provide the model number and series number (stamped on the rear panel) of the unit. Describe the difficulty and details on the associated equipment. We will send you service information, if the trouble appears simple. If the system requires servicing, we will send the name and address of the nearest Service Agency.

NOTE

Please insure that this manual is reviewed and understood prior to service of the equipment. Service work should only be done by Authorized personnel.

10.1 General Troubleshooting

Check input power supply to make sure it is normal supply as specified.

Insure the all cable connections are not loosened, especially the connection on A+, A-, F+ and F-.

Pre-operation check out as procedure outlined in 3.1.6 to 3.1.7

.

If all works well as specified, the problem should come from the setup of fixture or head expander or test specimen configuration.

10.2 Reference for Judgment

1). If power modules are found damaged in service, perform the following check:

- With the amplifier powered up but the Gain control in the reset position, press the on button of the main power, use a voltmeter to measure the DC power supply voltage between V+ and V- terminals which connect to the fuses. This must read from 200 Volts DC to 220 Volts. If not, it indicates the fuse may be broken. Replace it with a good fuse of the same pattern.
- If replacing fuse is useless, check the volt between V+ and V- terminals of each power module with a voltmeter. The reading should be from 200 Volts DC to 220 Volts DC. If not, the module may have a problem.
- Need further check as follow. Rotate the gain knob CW (clock wise) not in the reset position. Insure that there is an AC signal from the logic module to the power module. With an oscillograph connected to the A+ and A- terminals at the back of the power module, there will be a sine wave on the monitor. If not, the

power module may have an inner problem. Please contact the representatives nearest for further inspection.

2). Troubleshooting the amplifier may be divided into two categories:

- ✧ The amplifier will not operate at all.
- ✧ The system operates poorly.

It is important to separate system problems from amplifier problems. If system problems are suspected, remove instrumentation to temporary reduce the system to the simplest operable configuration.

- ✧ No Operation (verify no output voltage)
- ➢ If output voltage is present when the amplifier is driven, but there is no shaker response, then the shaker armature circuit may be open (or unplugged).
- ➢ If the system has been working, review the latest done on or around the system.
- ➢ If the Logical Module indicates power, ready and enable with the Gain control advanced and an input signal applied, then the Logical Module is most likely defective. Factory repair of replacement is recommended.

NOTE——Poor Operation

During troubleshooting it is allowable to unplug any or all of the ribbon cable connectors to the power modules. However, be careful not to overdrive those modules that are still connected.

- ➢ Insure that the drive signal source and feedback accelerometer are working and are calibrated.

⊙ If no conclusive problem is found, change the Logic Module.

10.3 Finding Bad power modules

A power module may go bad and cause problems with system operation. It is best to find the bad one and disconnect it from the amplifier. Normally all power modules operate in parallel, driven in sync by the pulse width-modulated drive signals from the logical module.

Symptoms of a bad module may be:

- ➢ Excessive distortion on the output.
- ➢ Ringing present.

!CAUTION!

A severe are will occur if the power connector is reconnected without waiting for the supply to discharge.

To find a suspected bad power module, perform the following steps:

- Turn off all power to the Amplifier, prior to proceeding to next step. Verify power has been off for at least fifteen (15) minutes which will allow all charged capacitors to drain.
- Disconnect the four power cables of A+, A-, V+, V- and ribbon connector at the right rear of the suspect power module. Be sure and insulate all power cables from possible ground points.
- Re-power the amplifier. Drive the system to the point where the abnormal behavior occurs.
- If the problem is now gone, you have found the bad module. Contact us for repair or replacement.
- If the problem is still present, turn off power to the amplifier again. Wait five minutes for the power supply to discharge.
- Reconnect the four power cables of A+, A-, V+, V- and ribbon-connector to that power module.

  Repeat above all steps with next power module. Continue until bad one is found.

10.4 The Impedance of Field Coil and Drive Coil

The body of the shaker and the table are connected to earth ground for the safety of the operator. The armature and the field are electrically isolated from the body of the shaker and each other. The best way to check the impedance of the field is to check the field current. Some system manuals provide the expected field currents for high and low fields. If the field currents differ more than line voltage fluctuation, you need to check the field coil. First, check all fuses, and then check your line voltage.

The resistance measured across the armature current lead should be approximately less than one ohm with the shaker disconnected to amplifier, in most case. If the measured resistance is much greater than one ohm, a damaged armature current lead or an open or failed armature is usually the problem. The most common way to check the armature is to use an ohm meter. Measure the resistance of the coil where the armature current lead connect with the armature (see note above).

10.5 Determine the “health” of Your Shaker System

The 160 Hz check and the axial free table resonance are two tests that help determine the “health” of your shaker system.

For the 160 Hz test, the operator must drive the shaker (with only the accelerometer in the center of the table) at 160 Hz until the output current of the amplifier is at the prescribed value in the system manual. Then note the acceleration seen at the center of the table. If the acceleration at the table does not match the value in the manual, double check the charge amplifier settings and field settings. If the value continues to differ more than 5% and all instrumentation is double checked, it may indicate a problem with the armature.

The free table axial resonance can be found several ways. One method is to use an oscillator and drive the shaker at a low level. Starting at 500 Hz, increase the drive until the response is 2g. Keeping the drive level constant, vary the frequency. Monitoring the response acceleration as you change the frequency, the resonance will be the frequency where the response climbs to a peak then starts to go back down. Another method is to do the sine sweeping test by a controller. Normally, the g level is recommended 10g. The drive plot shown by the controller, like above "E-1 armature drive voltage diagram" will reflect the armature resonance frequency. If you suspect an armature problem, PLEASE consult the factory before proceeding with further troubleshooting.

10.6 User Repairs

NOTE

It is always recommended to have an experienced technician perform all repairs and maintenance on the system.
NO user repairs are authorized during the warranty period.

Fuse Replacement:
The most common repair to be encountered will be fuse replacement. If fuses blow at relatively low drive levels, this may indicate a severe underlying problem that must be corrected. If replacement fuses of equal rating blow shortly after being installed in any circuit, the problem must be isolated and corrected. DO NOT KEEP REPLACING BLOWN FUSES WITHOUT DIAGNOSING AND CORRECTING THE PROBLEM.

10.7 Spare Parts

While the design of this equipment uses highly reliable digital electronics, stocking certain spare parts are recommended to attain maximum amplifier utilization and shorten the mean time to repair (MTTR).
The spare parts are divided into two kinds. One kind is for easy ware parts and another kind is the key parts which need long delivery time and in high cost if damaged.
The easy ware parts including the moving parts and rubber parts as below recommended.

For shaker:
1, Rubber dustproof ring, 1 piece in one shaker
2, Nylon board in upper guidance, 4 pieces in one shaker
3, Guide roller in upper guidance, 4 pieces in one shaker
4, Stainless steel board in upper guidance, 4 pieces in one shaker
5, Armature current lead, 2 pieces in one shaker
6, Lower guide shaft assembly, 1 piece in one shaker

7, Lower guide wheels with nylon sleeve assembly, 4 pieces in one shaker
8, Rubber air bag for load support, 1 piece in one shaker

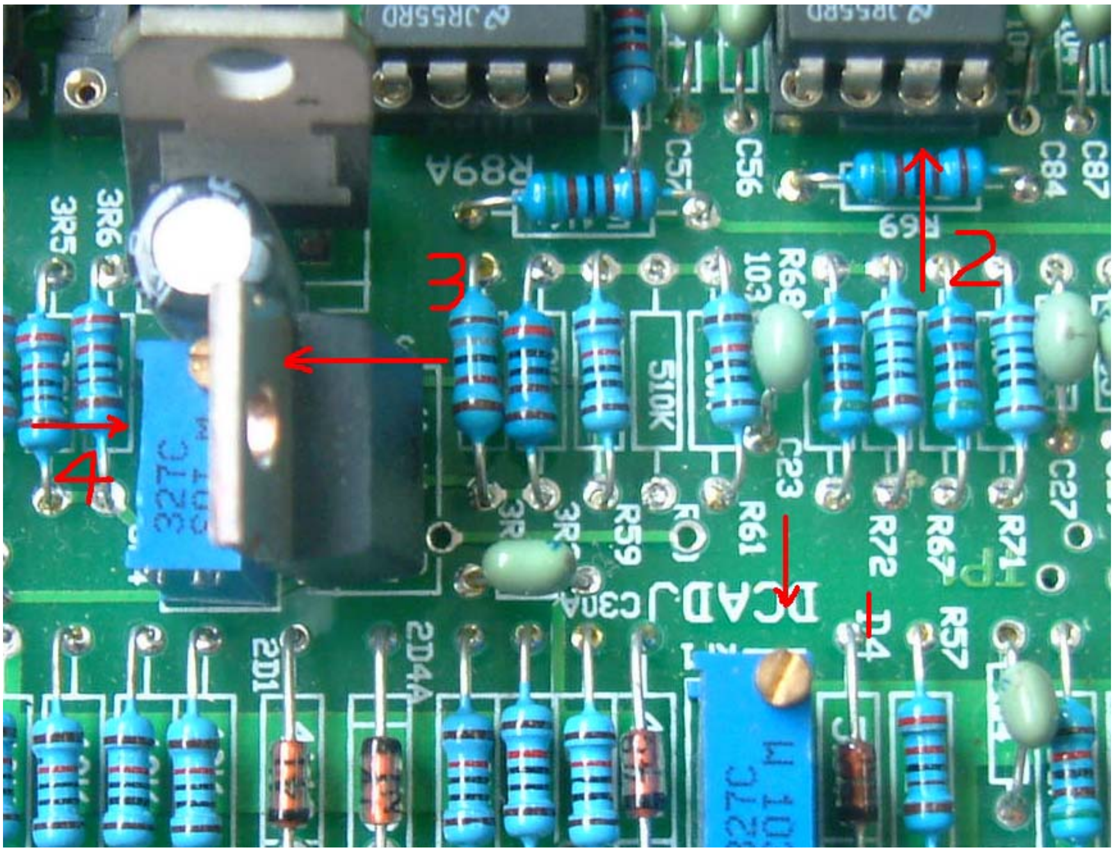
For slip table:
1, Oil filter core
One set of below parts are shipped with the shaker system if configured with slip table.
2, All O seal ring for hydrostatic bearings slip table
3, All combining seal ring for hydrostatic bearings slip table

For amplifier:
1, Axial flow cooling fan in power module
2, Contactors in amplifier
One set of below parts are shipped with the shaker system if configured with slip table.
3, All fuses
4, 18V voltage-regulator tube 1N4746
5, Diode 1N5819

The key parts are recommended as below.
1, Armature
2, Field coil(s)
3, Power module
4, Logical module
5, Hydrostatic bearings for BT slip table

Appendix 1 Typical Faults and Solutions

Fault 1:
Rotate the Gain to min, the armature will give a shock sound which is piping and the armature moves up or down obviously.



Solution:

1. Remove the cover of the Logic Module; then you will see the logic board as shown in the picture above.
2. Rotate the Gain knob to min.
3. Hook the negative probe of the multimeter on ground terminal or metal shell.
4. Touch the positive probe of the multimeter to point 2 shown in the picture above; then adjust the potentiometer (point 1) till the multipmeter displays zero.
5. Change the positive probe to point 3 in picture above; adjust the potentiometer (point 4) to zero.
6. Need to co-adjust the two potentiometers until both of them are near to zero (at least less than 5mV)

NOTICE: DURING ABOVE PROCESS, BE CAREFUL FOR THE ELECTRIC SHOCK TO INJURE YOU.

Fault 2:
While rotating the Gain knob CW, you can obviously feel vibration of the armature

surface by your finger.

Solution:

1. The possible cause is that the signal cable is too long. Please shorten the signal cable. Check the effect.
2. If not improved, try to insulate grounding wire of the plug with tape.

Fault 3:

Over Current or Over Voltage alarm always occur during tests.

Solution:

One possible cause is that the acceleration, velocity or displacement was set too big. Please reset your parameters in the controller.

Another possible cause is that the relative limits of the amplifier are too small. In this case, please remove the cover of the logic module. Find out the RP7 (Over current) and RP8 (Over voltage), rotate clockwise slightly. (Clockwise rotating increases the limit value, while the opposite decreases it.)

Important Notice:

While adjusting RP7 and Rp8 potentiometers, gradually adjustment is necessary. Typically max. 1/6 circle is recommended. Operators mustn't increase it in large scope, or the armature can be burned down because of the big current.

Fault 4: Over travel alarm

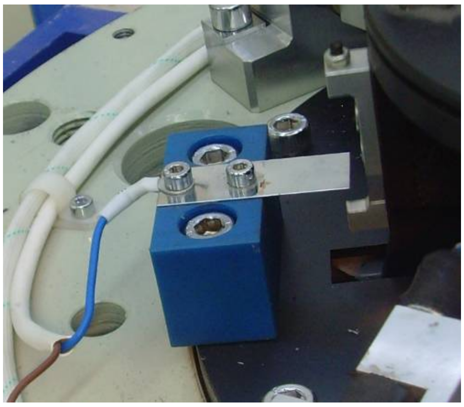
Solution:

Reset the gain and then open it again.

If not solved, the over travel switch may have been bended.

Flatten the switch to recover it to normal status.

The travel switch mentioned here is the previous one which is still used for some domestic customer and long stroke system. Please refer the picture A1-1 below.



A1-1

A1-2

But now we often adopt the new type over travel switch (use two microswitches), it won't be bended, please refer the picture A1-2 above.

Fault 5: Power Module over temperature alarm

Solution:

Check if the fans of the amplifier cases run normally.

Reset the Gain; let the fans run another 5 minutes to dissipate the heat generated by

the power module.
Check if the temp sensor is damaged. The sensor is normal open. The sensor is located on the aluminum heat sink near the IGBT block.

Fault 6: Shaker over temperature
Solution:
Reset the Gains.
Check if the duct between blower and shaker is broken or any air leakage in the cooling loop.
Let the blower go on working another 10 minutes for dissipating heat.

Fault 7: Input over (under) voltage alarm
Solution:
Firstly check whether the real input voltage matches the normal line voltage.
Open the rear door; check the fuses in main circuit to insure them in good condition.
Measure the voltage between the V+ and V- terminals. It should be approx 210V
If all steps are OK above, please remove the cover of the logic box
Find out the RP3 (Over Voltage) and RP4 (Under Voltage) potentiometers.
The clockwise direction increases and the opposite decreases.

Important Notice:

While adjusting RP3 and Rp4 potentiometers, gradually adjustment is necessary. Typically max. 1/6 circle is recommended. Operators mustn't increase it in large scope.

Fault 8: Slip Table Oil Motor
Solution:

1. It won't alarm in the vertical direction.
2. When the power of Oil Motor is off, this alarm indicator will illuminate.
3. Turn on the power of Oil Motor.

Fault 9: PM Over Current
See the definition in Table 4-2
Solution:

1. While turn on the power amplifier without input signal, PM Over Current indicator illuminates, which indicates some power modules are broken.
2. If a signal, especially the random signal has been input to the amplifier and the PM Over Current alarms a few minutes later, turn on the Gain a little, and measure the current of each power module with a clamp meter. Check the equivalence of them.
3. Increase the Gain a little and repeat step 2.
4. If one power module's current is different obviously, there should be module broken in that power module.

Fault 10: Door Interlock alarm
Solution:

1. Check if all doors are closed completely
2. If the doors are OK, there is something wrong with the door switch.

Fault 11:
As soon as the main air breaker is turned on, it rebounds to off.
Solution:

1. There is a short in the system, please check each fuse in main circuit.
2. If each fuse is OK, the main power breaker may be broken. Replace it with a new one.

Fault 12:
There are values displaying in the current display or voltage display of the front panel after resetting Gain.
Solution:

1. Insure the Gain knob has been reset.
2. Use the clamp meter to measure the current of the A+.
3. If clamp meter displays no value, there must be display tolerance.
4. Remove the cover of logic module and find out 2RP3 (Current) and 2RP4 (Voltage). The anticlockwise direction can decrease the actual value. Adjust it to minimum. (Not always zero)
5. If there is an obvious value on the clamp meter, check the grounding and replace the signal cable to a shorter one.

We have enumerated the common faults in operating and given relative solutions. If you meet other problems, please inform us, we'll provide the prompt and effective services.

Maybe other components break down in your operating or you couldn't solve it by solutions provided; please communicate with us for more information. Any try to replace parts by yourself may generate personnel injury.

Appendix 2 Amplifier Electric Diagram

Total 4 pages

Appendix 3 Shaker Outline Drawing

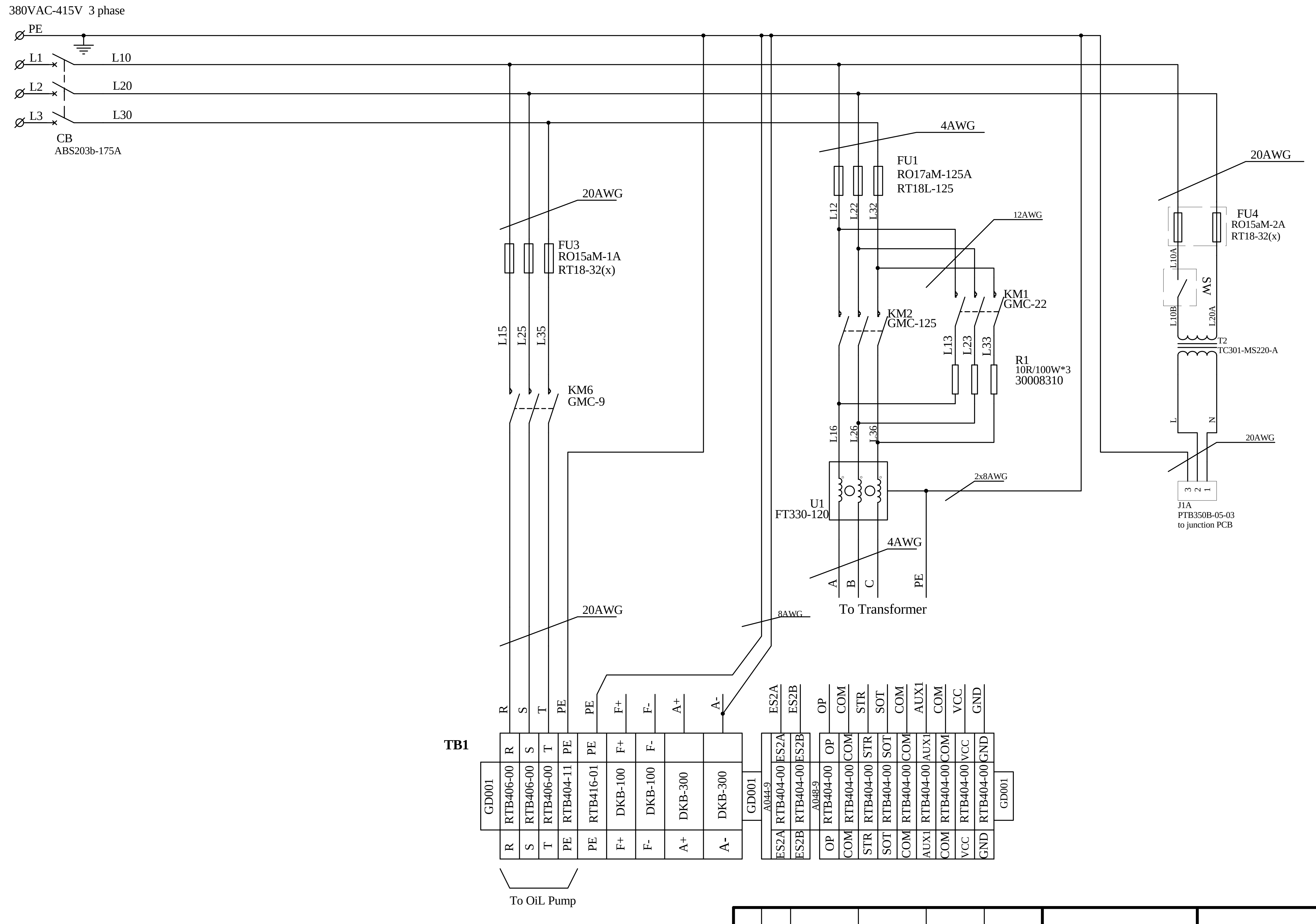
Total 1 page

Appendix 4 PCC-1 manual Rev A

Total 5 pages

Appendix 5 MS153M Motor starter manual Rev A

Total 5 pages



标记	处数	分 区	更改单号	签 名	年、月、日

设计 标准化
校对
审核
工艺 批准

阶段标记 重量 比例

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SPECTRAL DYNAMICS

POWER SUPPLY

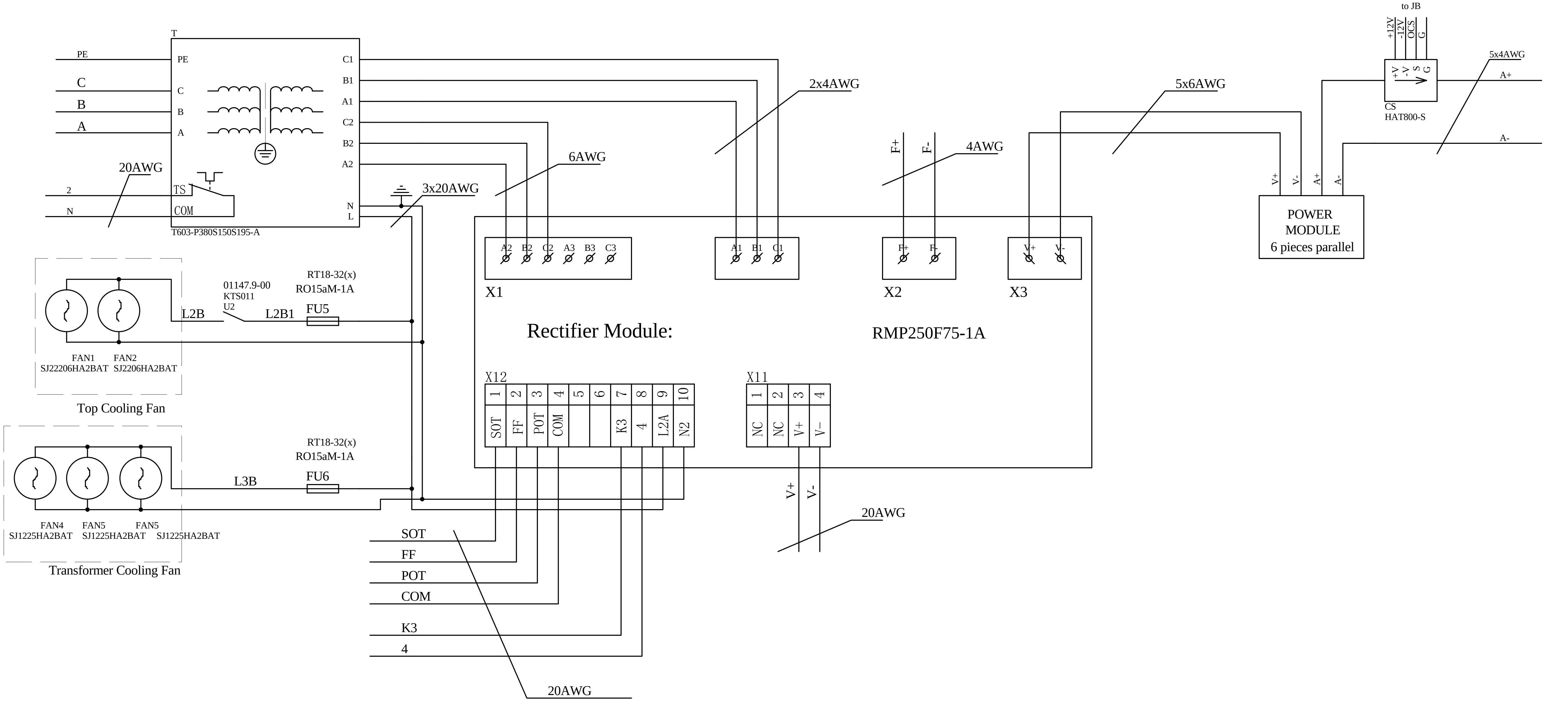
31100071

旧底图总号

底图总号

签 名

日期



旧底图总号

底图总号

签 名

日期

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校对					
审核					
工艺			批准		

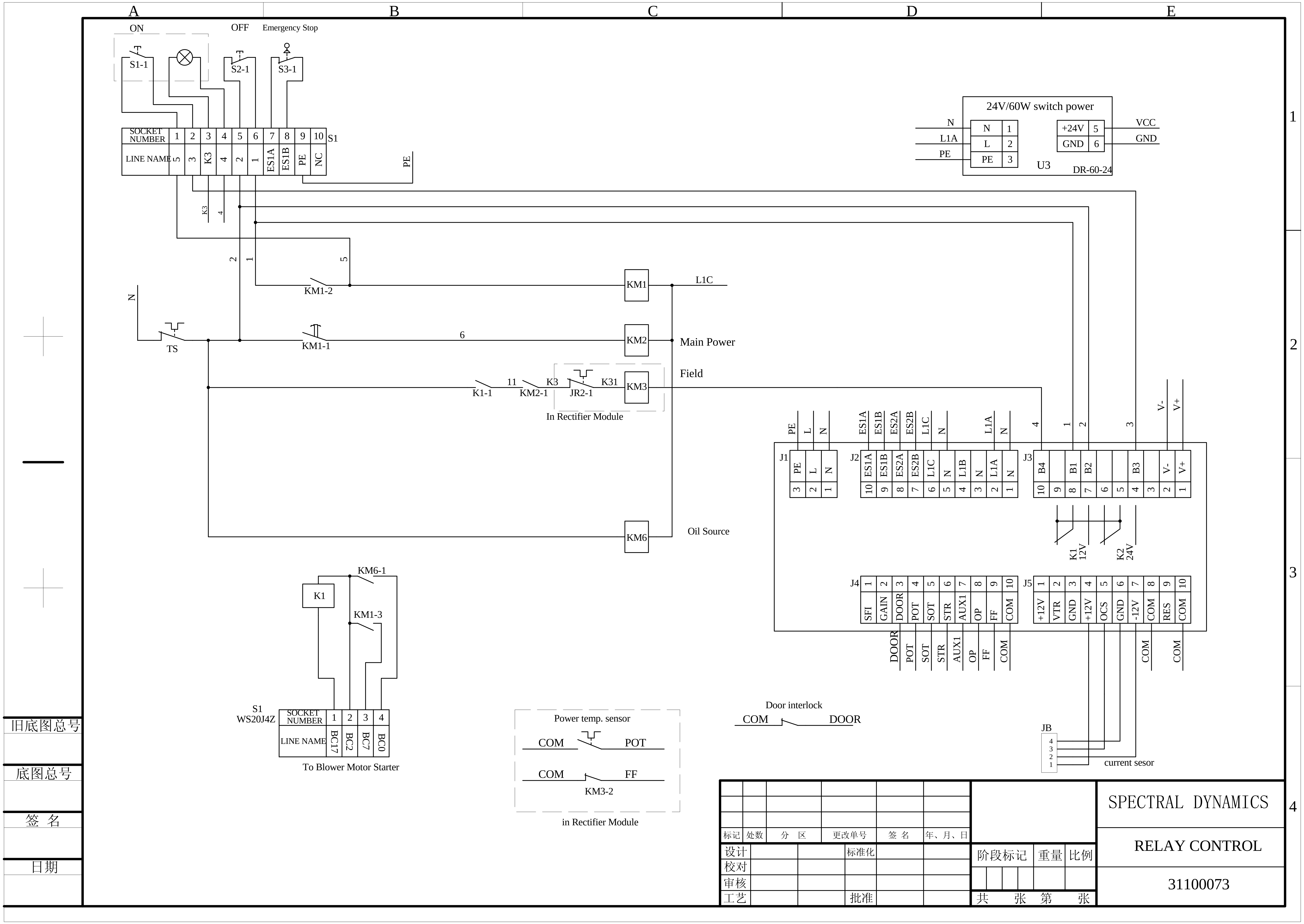
阶段标记 重量 比例

共 张 第 张

SPECTRAL DYNAMICS

RECTIFIER

31100072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OFF
Emergency Stop
S1-1
S2-1
S3-1
SOCKET NUMBER
LINE NAME
1 2 3 4 5 6 7 8 9 10
5 3 K3 4 2 1 ES1A ES1B PE NC
S1
PE
24V/60W switch power
N 1
L 2
PE 3
+24V 5
GND 6
N
L1A
PE
VCC
GND
U3
DR-60-24
KM1-2
KM1
L1C
N
TS
KM1-1
6
KM2
Main Power
Field
K1-1
11
KM2-1
K3
JR2-1
K31
KM3
In Rectifier Module
KM6
Oil Source
J1
PE L N
J2
ES1A ES1B ES2A ES2B L1C N L1B N L1A N
J3
B4 B1 B2 B3 V- V+
K1 12V
K2 24V
J4
SFI GAIN DOOR POT SOT STR AUX1 OP FF COM
J5
+12V VTR GND +12V OCS GND -12V COM RES COM
DOOR POT SOT STR AUX1 OP FF COM
COM
COM
KM6-1
K1
KM1-3
S1
WS20J4Z
SOCKET NUMBER
LINE NAME
1 2 3 4
BC17 BC2 BC7 BC0
To Blower Motor Starter
Power temp. sensor
COM
POT
COM
FF
KM3-2
in Rectifier Module
Door interlock
COM
DOOR
JB
current sesor
旧底图总号
底图总号
签 名
日期
标记 处数 分 区 更改单号 签 名 年、月、日
设计
标准化
校对
审核
工艺
批准
阶段标记 重量 比例
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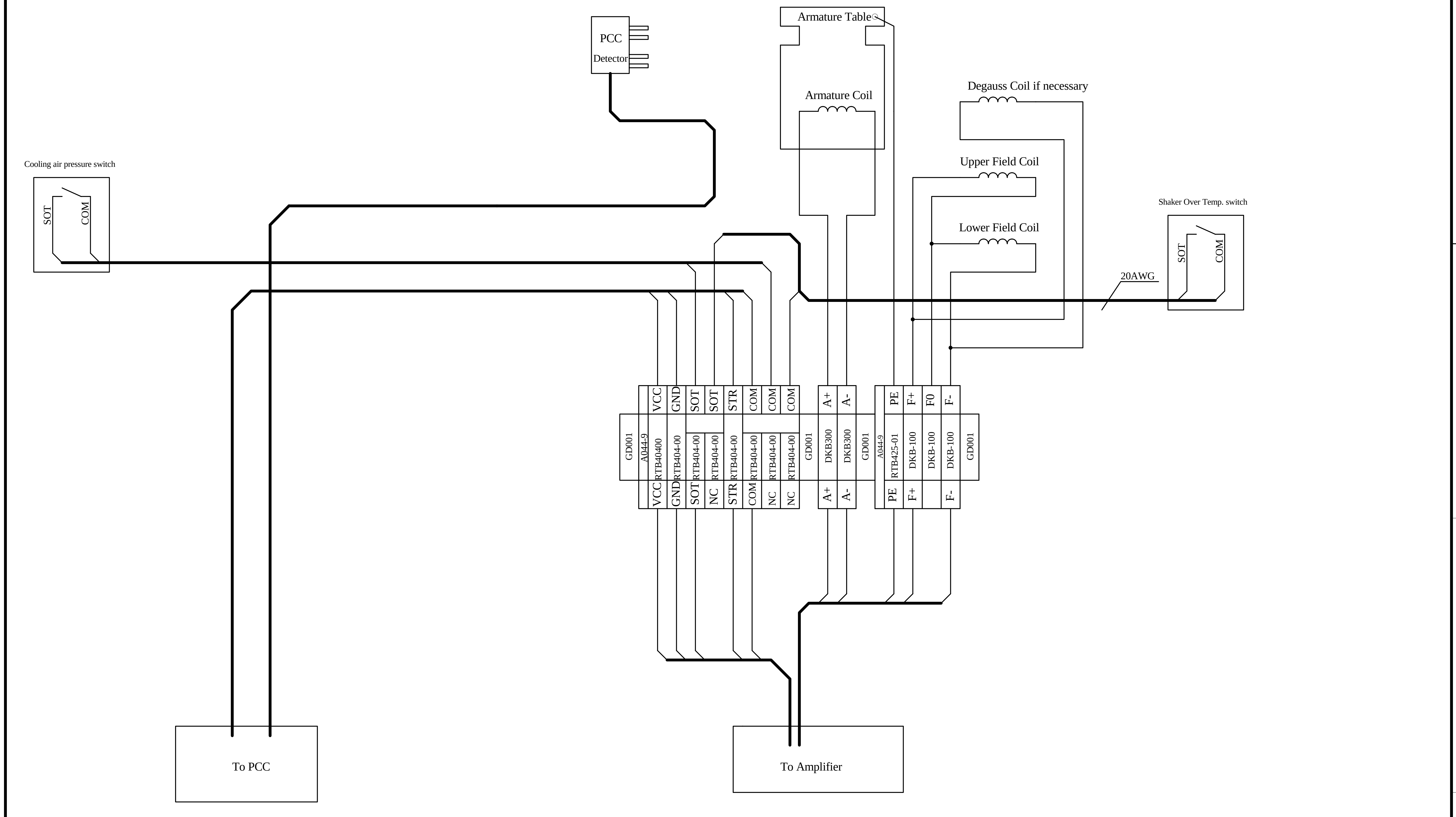
SPECTRAL DYNAMICS
RELAY CONTROL
31100073



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日期

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设计			标准化		
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审核					
工艺			批准		

阶段标记	重量	比例
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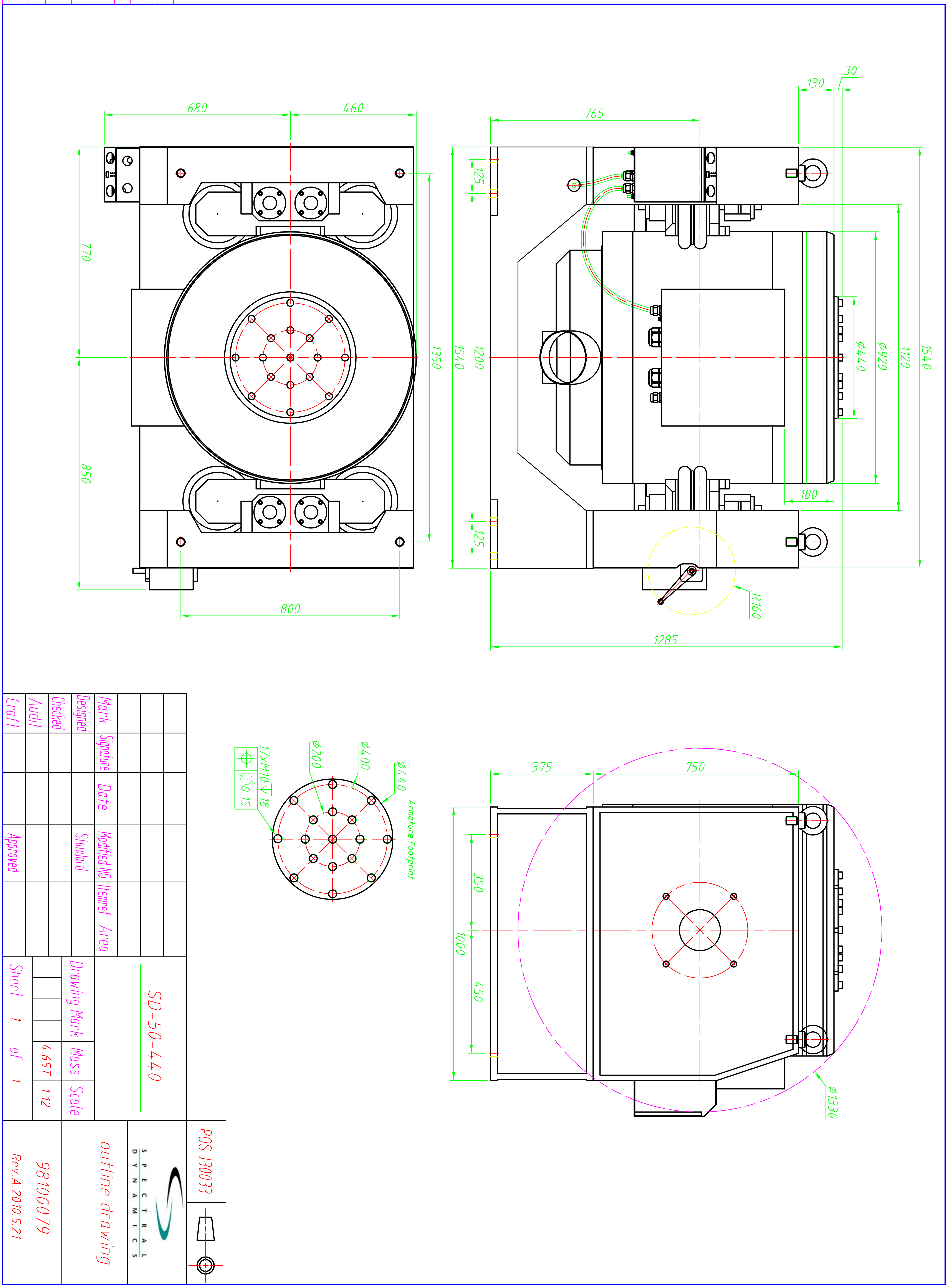
SPECTRAL DYNAMICS

SHAKER CONNECTION

31100074



date
Sign
Total number
Old Number
680
460
770
850
1350
800
765
130
30
125
1540
1200
Ø440
Ø920
1120
180
R160
1285
17xM10 18
Ø0.15
Ø200
Ø400
Ø440
Armature Footprint
375
750
350
1000
450
Ø1330
Mark
Signature
Date
Modified NO.
Itemref
Area
Designed
Checked
Audit
Craft
Standard
Approved
Sheet 1 of 1
Drawing Mark
Mass
Scale
4.65T
1:12
SD-50-440
POS.J30033
outline drawing
SPECTRAL DYNAMICS
98100079
Rev.A.2010.5.21

PCC -1 Pneumatic Centering Controller Operation Manual

1. General

Pneumatic Centering Controller (PCC) includes two pneumatic air circuit systems:

1. An automatic internal load support system to keep the armature centered at the mean position enven with large payloads mounted to the armature, known as automatic centring. This also includes the shaker over travel protection function.

2. An adjustable air system that provides vibration isolation between shaker body and shaker base, know as trunnion isolator system.

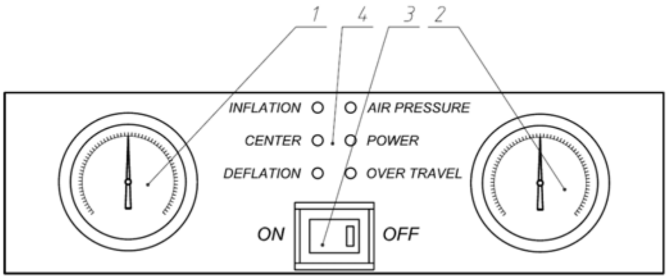


Figure 1 Top View (Pannel)

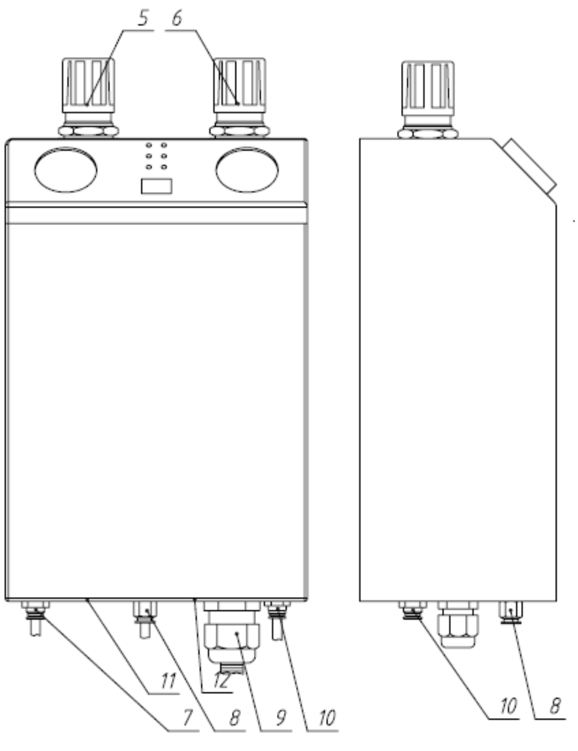


Figure 2 Front and Side View

The detail of each numbered parts are as below.

1. Internal load support air source pressure meter
2. Trunnion islotator air pressure meter
3. Automatic centring ON/OFF control switch

4. Indicators:

INFLATION:

The blue LED flashes when automatic centring is inflating the air into the internal load support air bag.

CENTER:

The green LED lights when armature is in the mean position.

DEFLATION:

The blue LED flashes when automatic centring is deflating the air from the internal load support air bag.

AIR PRESSURE:

The red LED lights when the air pressure is too low, if it lights, the automatic centring is not able to work until the air pressure is higher.

POWER:

The green LED lights when system is powered, it flashes when automatic centring is turned off.

OVER TRAVEL:

The red LED lights when armature is over travel and send signal to amplifier to stop the shaker system. It will keep lighting continuously for several seconds.

5. Internal load support air source pressure regulating valve. Lifting the cap, twist in CW to increase the pressure and in CCW to reduce the pressure. Push down the cap after adjusting to lock the valve.

6. Trunnion isolator aire pressure regulating valve. Lifting the cap, twist in CW to increase the pressure and in CCW to reduce the pressure. Push down the cap after adjusting to lock the valve.

7. Air source inlet

8. To Internal load support air bag

9. Wires holder

10. To Trunnion isolator air bag

11. Manual deflation button position for pushing

12. Manual inflation button position for pushing

2. Automatic Centring

An optoelectronic device automatically controls the air pressure in the load support air bag. As payloads are added or removed from the armature, this system adjusts the air pressure to keep the armature at the center of its stroke (mean position). Shaker over travel protection also provided by this automatic centring system, it sends the interlock signal to the amplifier and the amplifier switched off the output when over travel occurs.

Attention：

1. The automatic centring shall be turned off when shaker system works at horizontal situation, and deflate all the air from the internal load support bag manually!

2. The over travel protection still works when automatic centring is turned off.

3. The Internal load support valve shall be adjusted between 0.3Mpa and 0.5Mpa, normally at 0.4 Mpa.

3. Trunnion Isolator System

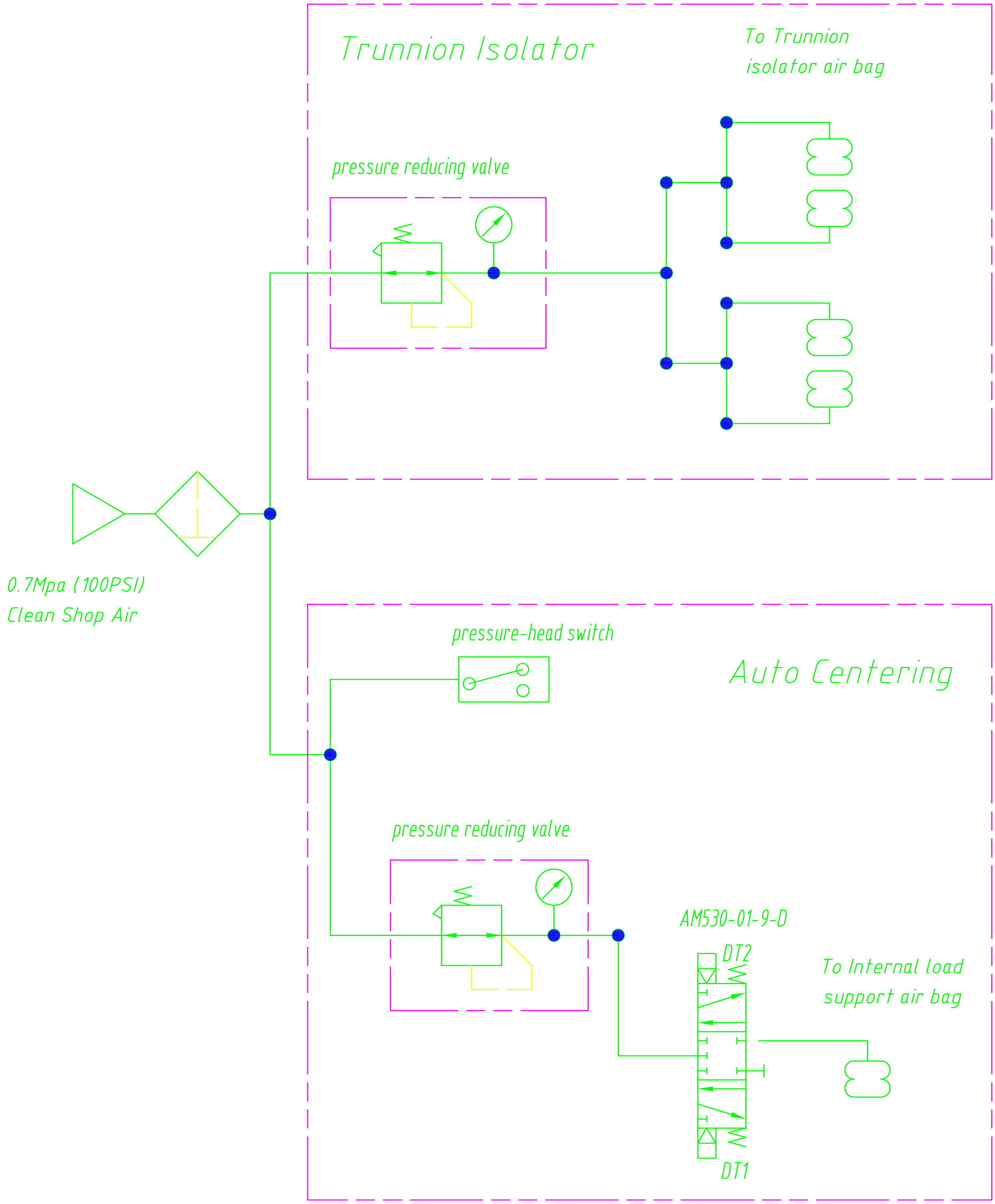
It is necessary to manually adjust and maintain a centen air pressure within the isolating bags to insure the skaker is suspended in the mean position, a pair of position mark is configured, a red arrow on trunnion seat and a red line on shaker body. This pressure depends on the payload on the shaker table. Refer the PCC concept drawing for details.

4. PCC-1 air concept drawing

1 page

5. PPC-1 Electrical drawing

1 page



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Mark	Signature	Date	Modified NO.	Itemref	Area
Designed			Standard		
Checked					
Audit					
Craft			Approved		

Drawing Mark	Mass	Scale

Sheet 1 of 1

schematic of PCC-1

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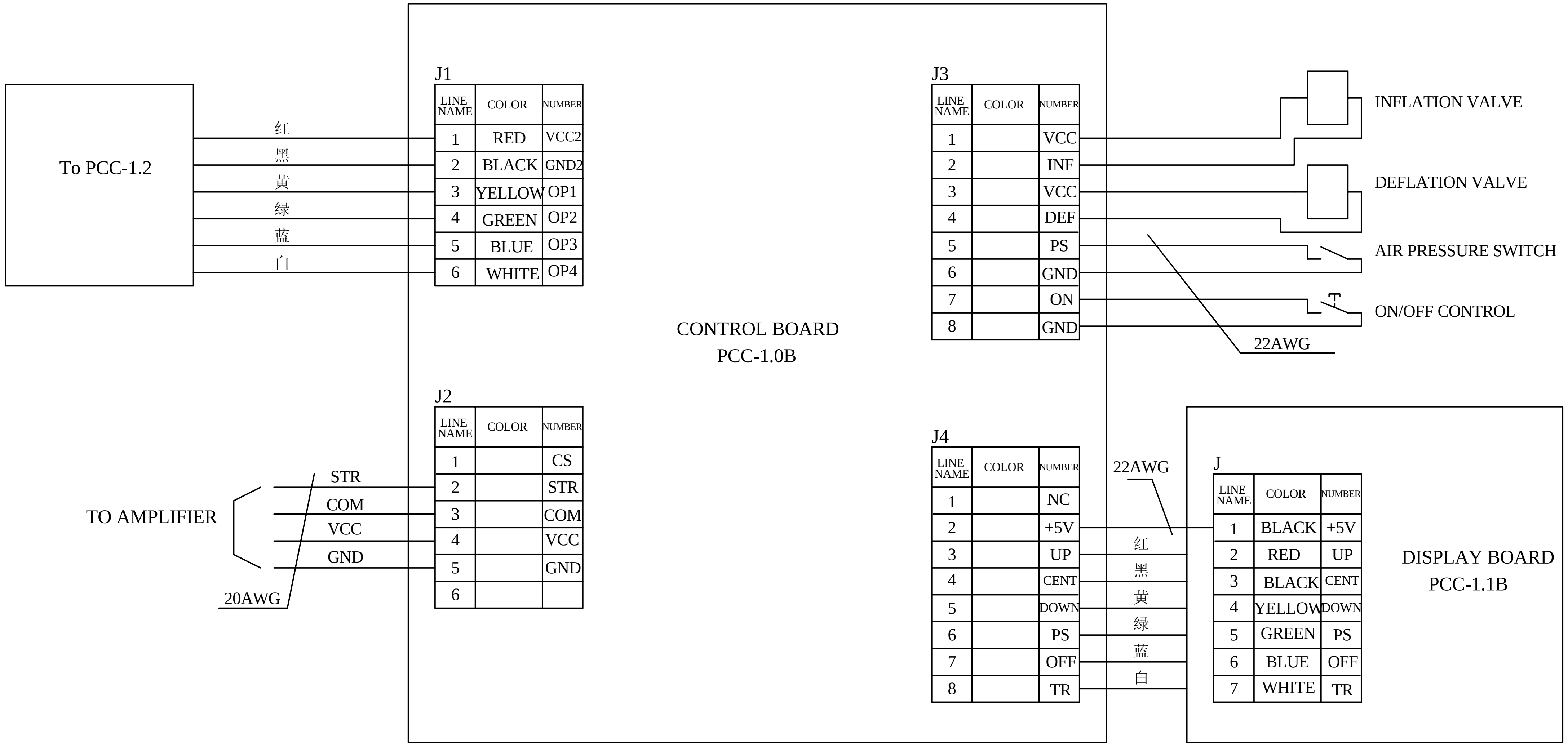

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工艺			批准		

阶段标记 重量 比例

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PCC-1 connection

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Motor starter Operation Manual

(MS153M)

1. General

Motor Starter (MS) is a star-delta controller to run the motor of shaker blower which motor capacity is bigger or equal 15kW with above 380VAC 3 phase or bigger or equal 7.5kW with 220VAC 3 phase. It can decrease the inrush current of power supply when motor is started and protects the motor avoiding over load, phase loss and phase reverse. At the same time, the amplifier can be more reliable due to the separating the motor power supply from the amplifier.

Modle translation:

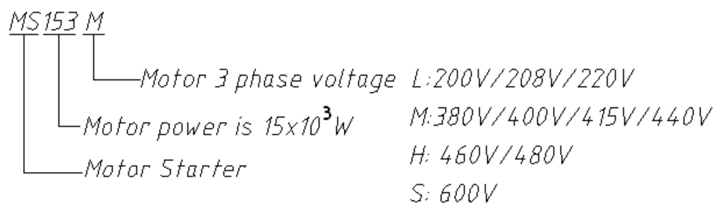


Figure 1 Front Control Pannel

1. Three phase power supply control switch
2. Mode (Local or Remote) selection switch
3. ON control button with GREEN indicator
4. OFF control button with RED indicator
5. Emergency Stop switch

The emergency stop switch is only for motor starter not for amplifier or shaker. The emergency stop can shut off the motor at any case.

2. Installation

2.1 Installation

The MS box shall be installed vertically, please see the MS mounting drawing for more details. Drill the 6 fixing holes (8mm diameter) on the wall according to the holes pattern (referring to below drawing) of the back of this box and use 6 pieces M5 expansion screws to fix the box on the wall.

2.2 Cable connection

There are three sets of cables supplied by manufacture. They are signal cable from the box to amplifier; power cable from the box to blower motor and power cable from box the customer’s power distributor. The standard length of the cables is 6 meters. Connect all cables according to below attached Electrical Connection Diagram. The wires named L1、L2、L3 and PE(Grounding) are connected to the customer’s power distributor 3 phase power supply directly. The independent circuit breaker in customer power distributor is required for the MS.

3. Operation

The motor starter has two control modes, local mode and remote mode. The mode is selected by mode selection switch.

A. Local mode

Local mode is for independent operation, the MS dose not depend on any other device, the motor is controlled by ON and OFF button on the MS panel. This Local mode is for some check out uses.

ON Operation:

Step1: Select the mode switch to local position.

Step2: Switch on the power supply switch. Now the OFF Control Button's RED indicator is lighted.

If the RED indicator does not light, please check below.

a. Reset emergency stop switch by turning it CW.
b. Check the fueses name F1 and F2 inside the box.

Step3: Push the ON button. Now, the ON Control Button's GREEN indicator is lighted and RED indicator is off. The motor works at star connection modes during first several seconds, and then switches to delta connection mode automatically.

If the GREEN indicator does not light and Motor does not run, please check below. Check the phase loss detector PL1 inside the box, and make sure there is no indicator is flashing.

PWR indicater flashing means phase loss, check the fuse set of FU2 and the power supply. RY indicater flashing means phase reverse. Reverse the connections between the power cables and customer power distributor to change the phase order because the the phase order has been fix before shipment.

If the GREEN indicator is off during the motor starting or running, please check below:

a. Check the thermal relay JR1 inside the box and reset it.
b. Check the fuse set of FU2 inside the box.

OFF Operation:

Step 1: Push the OFF button, the motor does not stop at once, it will be delayed about 5 minutes to cool the shaker fully!

Step2: Switch off the power supply control switch after the motor is stopped.

Caution: The input terminals of power supply control switch is still powered!

B. Remote mode

Remote mode is for remote control, any compatibal device can control the moter starter. The ON and OFF button will loss their function if the motor starter works at remote mode. The amplifier has such compatibal interface if the MS is configured in the vibration shaker system.

ON operation (the remote device is amplifer):

Step1: select the mode switch to remote position.

Step2: Switch on the power supply switch. Now the RED indicator is lighted.

If the RED indicator does not light, please check below.

a. Reset MS emergency stop switch by turning it CW.

b. Reset the amplifier emergency stop switch by turning it CW.

c. Reset the shaker emergency stop switch by turning it CW.

d. Check the signal cable from the box to amplifier is in good connection.

e. Make sure the remote device (amplifer) is powered.

f. Check the fueses name F1 and F2 inside the box.

Step3: Push the ON button of remote device (amplifier). Now, the box GREEN indicator is ligted and box RED indicator is off. The motor works at star modes during first several seconds, and then switches to delta mode automatically.

If the GREEN indicator is not lighted and motor does not run, please check below. Check the phase loss detector PL1 inside the box, and make sure there is no indicator is flashing. PWR indicater flashing means phase loss, check the fuse FU2 and the power supply. RY indicater flashing means phase reverse. Reverse the connections between the power cables and customer power distributor to change the phase order because the the phase order has been fix before shipment.

If the GREEN indicator is off during the motor starting or running, please check below:

a. Check the thermal relay JR1 inside the box and reset it.

b. Check the fuse set of FU2 inside the box.

OFF Operation:

Step 1: Push the OFF button of remote device (amplifier), the motor will not not stop at once. It will be delayed about 5 minutes to cool the shaker fully.

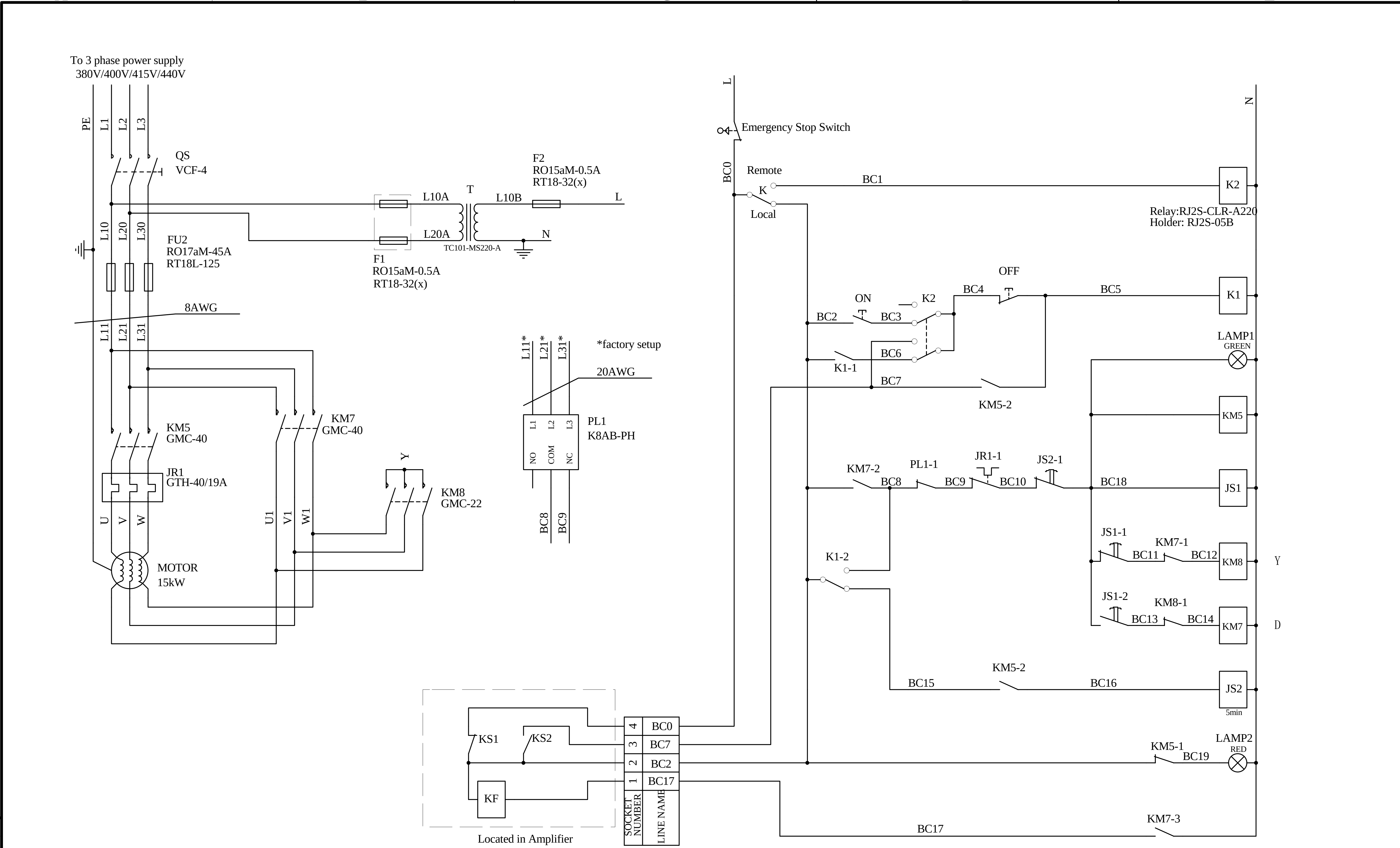
Step2: Switch off the power supply control switch after the motor is stopped.

Caution 1: The input terminals of power supply control switch are still powered after the power supply control switch is switched off.

Caution 2: The amplifier emergency stop switch and the shaker emergency stop switch only can shut off the motor when the MS is at remote mode.

4. MS153M Electrical Connection Diagram attached below

5. MS Mouting drawing attached below



S1
WS20K4Z

KS1: Equivalent with Amplifier Emergency Stop

KS2: Equivalent with Amplifier ON/OFF button Control

KF: Field power supply control relay coil

旧底图总号

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日期

标记	处数	分 区	更改单号	签 名	年、月、日

设计 标准化

校对

审核

工艺 批准

MS153M

阶段标记 重量 比例

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Electrical Connection

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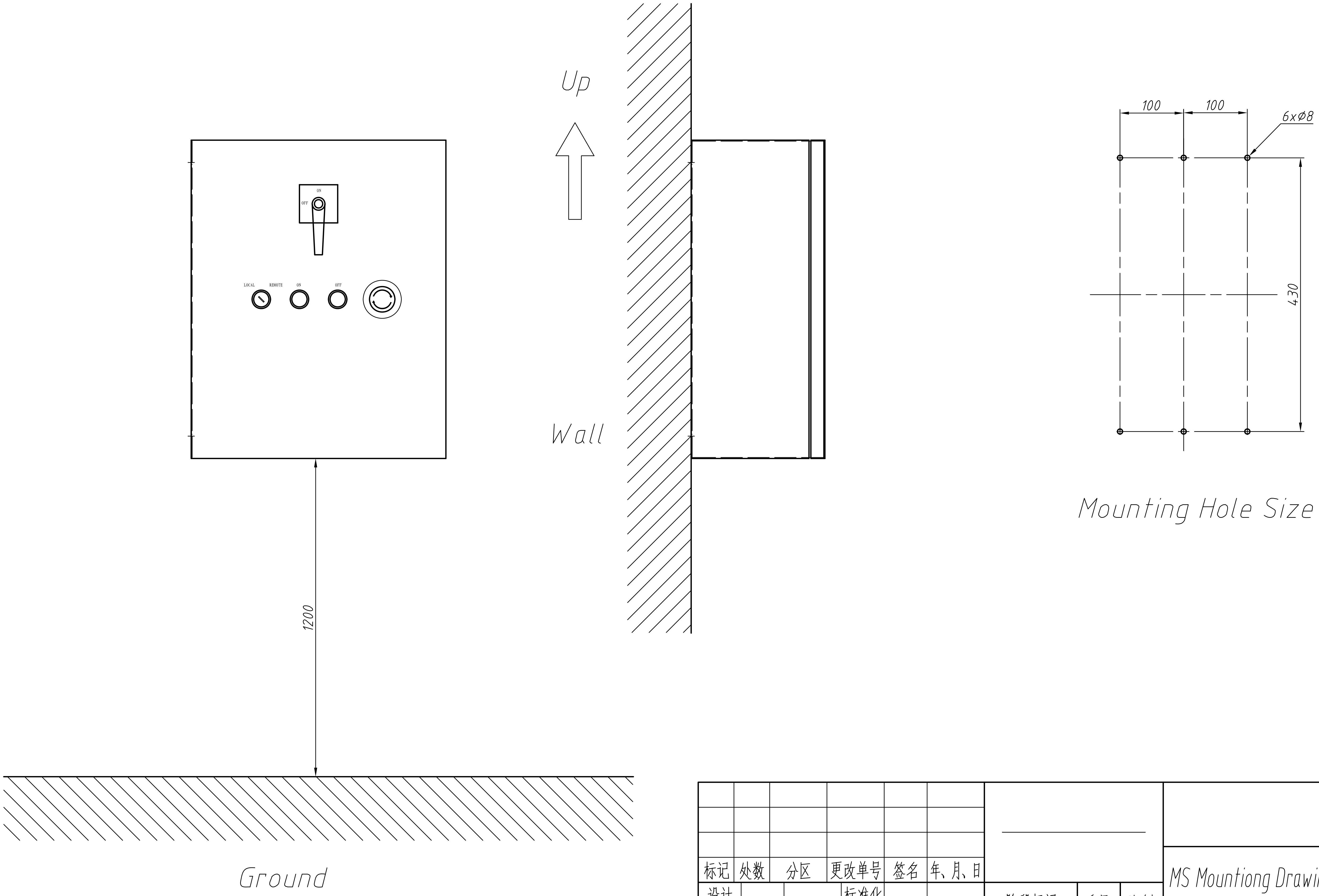

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设计			标准化		
校对					
审核					
工艺			批准		

阶段标记	重量	比例
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MS Mountiong Drawing

30008503

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底图总号	
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日 期	

Worldtest (Spectral Dynamics Shaker) Latest Address

Hi George,

Please note that World Test Systems have moved, our new address is :

Fancourt Office Park
Cnr Northriding & Felstead Ave
Block 12 , Ground Floor
Northriding
2162

Our new contact details are :

Office no. 011 462 6618
Fax no. 011 462 8188 (pending Telkom connection)
Nik's direct fax no. 086 721 9585
Trevor's direct fax no. 086 550 5022

Our email addresses and mobile numbers remain the same :
Nik : nik@worldtest.co.za 083 308 8284
Trevor : trevor@worldtest.co.za 083 625 3995

Website www.worldtest.co.za