OPERATION MANUAL

Electro-dynamic Vibration Test System

Model: TS3-150

Serial No.: TBD

GWS TEST INSTRUMENT CO., LTD.

WELCOME

Thank you for choosing Vibration Equipment from GWS TEST INSTRUMENT CO., LTD.
We recommend reviewing this manual and familiarizing yourself with your equipment prior to operation.

Please make sure all operators are properly trained before operating this system to insure operator and product safety.

Accessories included with your GWS® system may vary, depending on the version, model and configuration. Please refer to your packing list to confirm the items included with your system.

Due to continuous product development and improvement, these specifications are subject to revision without notice. GWS TEST INSTRUMENT CO., LTD. reserves the right to make substitutions and modifications in the specifications of any products, provided that such substitutions or modifications do not materially affect the performance of the products or the purposes for which they can be used. If you have any questions, please don’t hesitate to contact us.

We look forward to supporting many years of vibration testing in your lab.
Thank you for choosing GWS®.

Content

1. Unpacking and Installation

IMPORTANT: READ BELOW BEFORE LIFTING

IMPORTANT: Prior to unpacking please inspect the package for damage.

Take photos and IMMEDIATELY REPORT damage to SHIPPER and supplier or manufacturer.

Identify the center of gravity marked on packing.

Take care to balance load to avoid capsizing.

- Whenever possible, we strongly recommend using a professional rigging company.

Make sure that the loading capacity of all moving equipment and slings is properly rated and exceeds the total equipment mass. The equipment mass can be found marked on the packaging-case and noted on the shipping documents.

Unpacking

USE CAUTION as the equipment may have shifted during transit or unpacking.

The removed wooden crate may contain sharp objects such as nails.

Technician should wear appropriate protective gear and steel toed shoes.

- You may need the following unpacking tools

Crow bar hammer wrench knife (electric) screwdriver

- Use care in selecting proper unpacking position and method.
- NOTE: Some cables & accessories may be packed in a separate accessory box.
- Please confirm receipt of all items on packing list. Immediately notify supplier of any shortages or discrepancies.
- Take extreme care not to damage any cables or hoses.
- Equipment is fixed on the bottom of the wooden crate for transit. Carefully remove the bottom after unpacking and dispose of the dismantled waste properly.
- Please check the packing list and identify packing accessories. Parts, such as lifting rings and positioning screws, are used to move the shaker system and should be retained for future use.

Equipment Positioning

IMPORTANT!! NEVER LIFT VIA the vibration surface or slip table, which may cause permanent damage to the vibration system.

We recommend installing a rubber isolation strip between the pedestal and ground after positioning.

- We recommend using a professional rigging company to lower the risk of damage and injury.
- Prior to lifting, please confirm the target installation area is level and is rated for sufficient load capacity to ensure safety and steadiness of vibration shaker after positioning.
- You may need cranes, forklifts or other auxiliary tools to help.

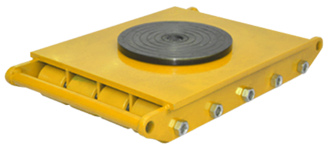
Forklift

Crane

Hoisting belt

Hydraulic forklift

Heavy crowbar



Tank wheel

- **Handling with forklift：**

(1) We recommend forklift position is from the side of the shaker pedestal (see image below), which allows the forklift to lift the entire shaker.

(2) If it is not possible to lift from the side position, use short lifting slings for four lifting rings at the top of the frame and additional lifting lugs on the side for slip table.

(3) Use caution not to damage the cable or hoses when lifting or hoisting the shaker. Lift the shaker slowly until it leaves the ground, then move it to appropriate position.

Above: Handling with forklift

- **Handling with Crane**

  (1) Attach a strong sling to each lifting ring and then lift the entire equipment with a crane – verify that all equipment is adequately rated to support the mass of the equipment.

  (2) The system is equipped with lifting rings positioned as follows: side of the shaker, top of the power amplifier, top of the blower, and screw hole on head expander (if included). Take care to select the appropriate lifting rings for best control and balance prior to moving. The lifting rings are not suitable for long-distance moving.

  (3) Use caution so slings do not damage the painted surface of shaker.

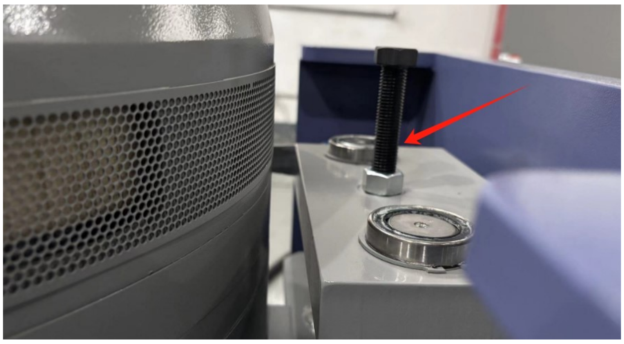
- **Casters**

  The power amplifier includes casters and can be easily rolled into position. Remember to always unlock the casters before moving and always lock the wheels after positioning.

NOTE: Please label and store shipping parts for later use.

Equipment installation

- The transport protection devices such as L-shaped angles and screws can be removed after the equipment is positioned. **Remember to remove trunnion lock screws before testing.**



⚠WARNING: Improper installation by an unqualified party may invalidate your warranty.

2. SYSTEM SPECIIFICATIONS

1. Shaker Specifications				
Vibration Exciter TS3-150	**Sine (kN)**	3	**Max. load (kg)**	120
	Random (kN)	3	**Armature mass (kg)**	3
	Shock force (kN)	6	**Armature diameter (mm)**	150
	Frequency range (Hz)	5-4,000	**Body suspension Fre. (Hz)**	3
	Max. acceleration (m/s^2)	1000	**Armature inserts(standard)**	13*M8
	Max. velocity(m/s)	2	**Stray flux density**	＜3 mT (30 Gs)
	Max. displacement (mm)	25	**Fund. resonance Fre. (Hz)**	2,900 (nom.) ±5%
Power Amplifier PWA3	**Voltage**	TBD	**Connection cables**	6 meters
	Power (kVA)	3	**Max. output current (A)**	50
	Max. output voltage (V)	60	**Power requirement (kVA)**	6.5
Blower CD200	**Power (kW)**	0.75	**Air pressure (kPa)**	1
	Air flow (m^3/s)	0.1	**Air pipe (m)**	4

2. Installation Specifications	
Power requirement:	1) TBD; 2) Independent air-break switch of no less than 45A should be configured in the distribution cabinet.
Ground requirement:	1) Levelness < 3%, you can place rubber isolation pads with about 10mm thickness under the system; 2) Smooth surface without cracks, steps or sharp objects, bearing capacity ≥ 1 ton/m^2; 3) Don't place the shaker system on suspended floor.
Environmental requirement:	1) Temperature range: 5°C~40°C; 2) Humidity range: 0～90% (no condensing);

	3) No corrosive gas, dust free, better with air conditioner (refer to laboratory environment).
Air source requirement:	1) The provided compressed air should be free of oil, water, gas or dust; 2) Pressure: ≥ 0.6Mpa; 3) Connection: input 1/4 BSP.

3. Standard Equipment Configuration Parameters	
Cooling method:	☑ air-cooled ☐water-cooled
Self-centering device:	☐ yes ☑no
Auto-rotation device:	☐ yes ☑no
Indicator scale:	☑ armature inflate height indicator ☐ bottom vibration isolation air bag indicator

3. SAFETY WARNINGS & REMINDERS

ALWAYS USE CAUTION WHEN OPERATING EQUIPMENT.
IMPROPER OPERATION MAY CAUSE PERSONAL INJURY AND EQUIPMENT DAMAGE.
PLEASE READ ALL SAFETY WARNINGS AND OPERATING INSTRUCTIONS CAREFULLY BEFORE INSTALLING AND OPERATING.

3.1 Safety Warnings

[Warning] Please select appropriate circuit breaker in accordance with the power supply required in the specification. We recommend always using a licensed electrician who is familiar with the codes in your location.

[Warning] When connecting the system power supply, the user shall prepare a grounding terminal with grounding resistance of less than 4 Ω to connect the system's cabinet to the grounding terminal to ensure personal safety.

[Warning] Before installing the power supply, make sure the circuit breaker to the power supply is OFF, to avoid the possibility of dangerous voltage caused by the opening of power amplifier door.

[Warning] Considering that the system requires 380V three-phase input, even if the system is disconnected, the input power line voltage is still dangerous, and some electric points may be exposed to the outside. For your safety, please make sure to disconnect the circuit breaker before opening the door.

[Warning] Please do not disassemble the equipment without permission; otherwise it may cause electrical and mechanical damage AND WILL VOID YOUR WARRANTY.

[Warning] Please do not disassemble the equipment without permission, or it will cause damage to the equipment. If you need to disassemble the equipment, please contact the manufacturer or reseller. The disassembly of key components such as armature, field coil, and power amplifier must be performed by a technician who has been trained and certified by the manufacturer or reseller.

[Warning] Please do not touch the equipment with your body or other parts during operation, which may cause personal injury.

⚠ [Warning] Please pay attention to the safety of lifting and handling during installation of head expander and fixture. Do not perform installation under powered condition.

⚠ [Warning] Any resonance may cause physical discomfort. If you feel chest distress or physical discomfort during the test, please seek for medical attention immediately. When the device is powered on, it may cause discomfort to people with heart disease. As a result, people with heart disease should stay away from the equipment.

⚠ [Warning] Please wear earplugs during the test; otherwise it may damage your hearing after long time working.

⚠ [Warning] Untrained personnel shall not operate the equipment without permission, or it will cause personal injury.

⚠ [Warning] Any improper operation may cause personal injury, so please read the operation procedure carefully before operation.

⚠ [Warning] Pay attention to the safety of handling and clamping. Please wear proper protective equipment such as a safety helmet and safety shoes during handling process.

⚠ [Warning] The system will create a strong magnetic field state during operation. Do not place electronic products or metal parts close to the shaker. We already included a degaussing coil to limit the stray flux density less than 1 mT (10 gauss) at 152mm above table. But don’t get too close to the shaker for safety consideration.

3.2 Operating Safety Reminders

A Quick Start Guide is included and should be consulted before daily use. Please refer to this manual for detailed operating instructions. Before operating the equipment, please familiarize yourself with all the documentation provided with your system.

Chapter 5 and Chapter 6 of this manual provide you with step by step operating instructions for daily use. Please review these steps regularly to ensure your requirements remain within the capabilities of this equipment.

Abnormal noise during use of the equipment may indicate there is a problem, and all testing should be immediately stopped and the test set-up inspected for potential damage. If noise continues, please contact supplier as the equipment may be damaged.

In case of emergency, press the emergency stop button on the power amplifier to prevent electric shock.

This equipment should only be used in clean, dry, ambient conditions. Operating this system under improper environmental conditions may damage the shaker. High temperature, high humidity, salt spray, and excessive dust can cause damage to components and mechanical parts.

The power amplifier door must be closed when the system is operating, otherwise the system will not work. The power supply must be OFF before installing the system or opening the power amplifier cabinet door.

3.3 Warning Symbols

	Caution Mechanical injury		High voltage
	Caution Safety		Ear Protection Required
	Non-professionals are forbidden to disassemble the system		Do not touch
	Please refer to operation instructions		Cut off the power before opening the cabinet door

4. SYSTEM STRUCTURE

4.1 System Overview (pictures for reference only)

An Electro-dynamic shaker consists of several components:

- Shaker body or Exciter
- Power Amplifier
- Cooling system (air-cooled system)
- Controller (Optional)
- Sensor (Optional)

4.2 Shaker Body

①Frame ②Shaker body ③Trunnion vibration isolation ④Armature insert

⑤Terminal box ⑥Screw (frame) ⑦Ventilation hood ⑧Trunnion shaft

4.3 Power Amplifier

①Cabinet

②Control panel

③Emergency stop

④Heat dissipation system

⑤Positioning wheel

⑥Lifting eyebolt

⑦Door lock

4.4 Cooling System

4.5 Controller

4.6 Sensor

5. CONNECTIONS and START-UP

We strongly recommend contracting with the supplier or their authorized representative to perform the initial start-up and check out of your new shaker system.

This system uses high voltage power and should only be installed by a qualified professional. Please note: Improper installation could void your warranty.

[IMPORTANT]: SWITCH OFF THE FACILITY POWER DISTRIBUTION CABINET AND POWER AMPLIFIER MAIN POWER SWITCH BEFORE WIRING!

INSPECT & VERIFY EQUIPMENT AND CONNECTIONS –>INITIAL POWER UP –> OPERATIONAL CHECK OUT

EQUIPMENT PLACEMENT ⇒ CONNECT TO FACILITIES ⇒ PERFORM SAFETY CHECK

5.1 Placement of Equipment

(1) We strongly recommend installing this equipment on the ground floor.

[NOTE]: User should consider noise levels, venting, power requirements and environmental conditions when selecting a location to install your system

(2) Please ensure that the power supply voltage is consistent with the rated voltage requirements of the equipment. Please refer to the *System Specifications (Chapter 2) of* this manual for the rated voltage of the equipment.

(3) Please confirm that the required wire cable, connections and terminal boxes meet the requirements in Chapter 2 - *System Specifications* included with this manual.

(4) Please align the mounting hole at the bottom of the equipment to the mounting hole in the foundation and fix with screws (if applicable).

(5) Please confirm that the transport protection device has been removed after positioning.

(6) For the transportation and lifting of the equipment, please refer to Chapter 1 of this Manual.

5.2 Equipment connections

5.2.1 Connection of field power supply

(1) Wiring requirements are included in the Appendix- see *Electrical Schematic Diagram*.

(2) Perform system wiring according to steps shown below.

[IMPORTANT]: WIRING IN STRICT ACCORDANCE WITH THE WIRE LABLES!

- **Power supply cable (L1, L2, L3, and PE) (see Figure 5.2.1-1):**

1) Hookup facility three phase power to L1, L2 and L3 connections in back of Amplifier;

2) Run ground wire from PE terminal adjacent to L1-L3 in Amplifier to dedicated ground rod or facility ground.

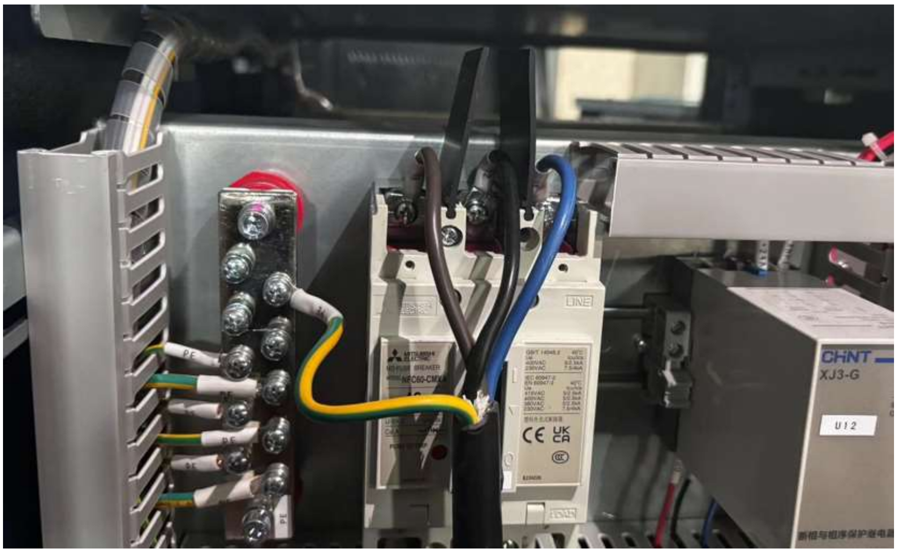
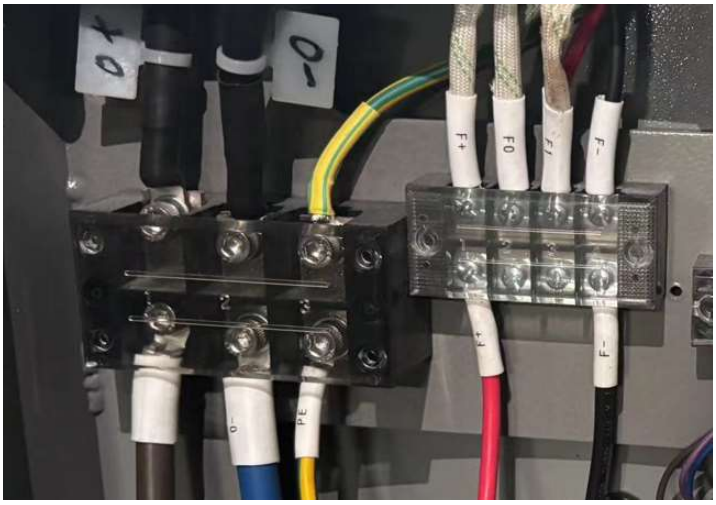


Figure 5.2.1-1 PE, L1, L2, L3

- **Output cable (O+, O, F+, F-, and PE) (see Figure 5.2.1-2):**

Run O+, O, F+, F- and PE from shaker terminal box (rear part of shaker) to corresponding terminals in power amplifier (back of amplifier, lower part);

Figure 5.2.1-2 PA end



shaker end

- **Blower power supply cable (U, V, W, and PE) (see Figure 5.2.1-3):**

Run the U, V, W and PE cables leading out from the blower to corresponding terminals in power amplifier (back of amplifier, lower part).

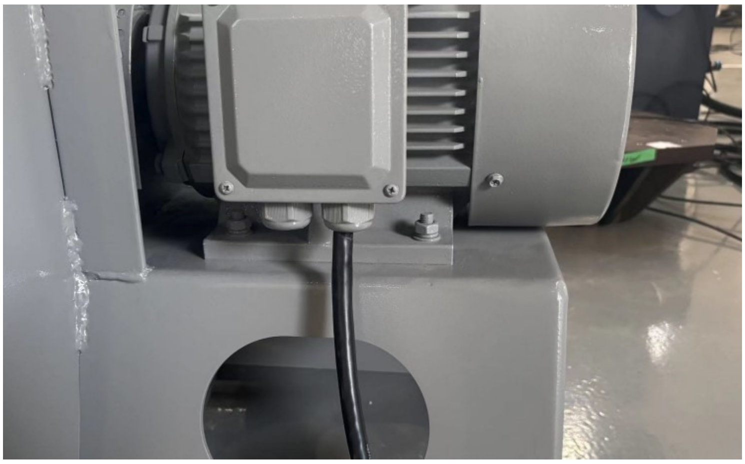


Figure 5.2.1-3 PA end blower end

- **Protection cable (see Figure 5.2.1-4)**

Run shaker protection cables from power amplifier (front of amplifier, lower part) to shaker terminal box.

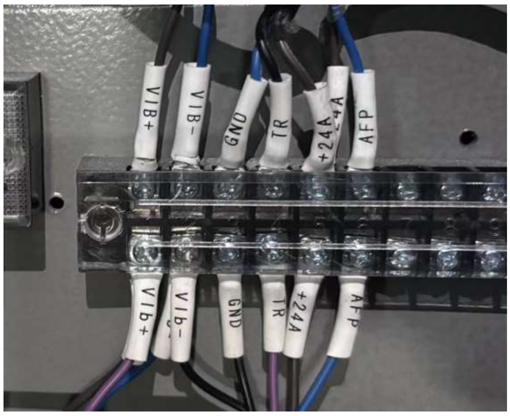



Figure 5.2.1-4 PA end shaker end

5.2.2 Connection of air source

(1) Connect one end of supplied air pipe to shaker air valve seat (shaker frame), and the other end to facility air source;

(2) Verify air source is clean and dry and adjust the pressure to 0.6-0.8 Mpa.

Figure 5.2.2 air valve seat

5.2.3 Cooling Blower Check

(1) Please connect the blower cables U, V, W and PE to the power amplifier as referred in 5.2.1;

(2) Power on the power amplifier and click “ON” to run the blower, there will be failure displayed on the interface if there is wrong or lack phase. Exchange any two cables of L1, L2, L3 and run the blower again to check whether the blower can run normally.

[Warning] The rotating direction of the blade is indicated on the blower.

Double confirm the rotating direction of the blade: turn on the power amplifier key and press “ON” to power on the power amplifier (DO NOT SET THE GAIN), the blower will start running in this case. Then press “OFF” and press emergency stop button immediately to stop the blower. Observe whether the rotation direction of blower is consistent with the direction indicated.

[Warning]: If the rotating direction of the blower is not sucking air across the armature and exhausting the heat remotely, the cooling system will not be able to provide cooling for the equipment, which will lead to equipment damage.

[NOTE]: The blower is recommended to be place at back of the shaker, the distance between shaker and blower better within 3 meters. Sufficient airflow is critical for reliable operation. Please limit the length of the ducting run and number of bends between the shaker and the blower to avoid restricting airflow. When blower location requires additional length and/or bends, it may be necessary to increase the size of the blower. Please consult supplier.

5.2.4 Connection of (optional) auxiliary shaker body parts

(1) Connection of (Optional) head expander: Prior to lifting the head expander, check the armature surface to ensure the mounting surface is free and clear of all matter and oil contamination. Check the mounting side of the head expander and confirm surface is clean and has no obstructions. Align the head expander screw connection holes with the armature insert connection holes and then insert, tighten and lock the screws. Refer to the Appendix of this manual for the torque of the screws.

(2) Connection of (Optional) slip table (when so equipped - optional): refer to Chapter 6.

5.3 Safety Check

5.3.1 Grounding protection

(1) When installing the amplifier, the input power MUST be grounded, and the required ground resistance should be less than 4Ω.

(2) Please refer to Control Manual and make sure whatever controller you have selected is also grounded in accordance with the manufacturer's instructions

5.3.2 Confirmation of voltage

(1) Use a multimeter to verify the input voltage of the power supply (facility power) and the input voltage of the power amplifier.

(2) The input voltage should be within ±10% of the rated voltage of the equipment. Please refer to the equipment configuration instructions to verify the rated voltage.

5.3.3 Short Circuit Prevention Safety Check

(1) When the power amplifier air switch is off, measure the resistance between any two phase power lines of the output end UVW, and the measured value should be no less than 0.38MΩ.

(2) When the power amplifier air switch is off, measure the resistance between the output end UVW of power line and the ground wire, and the measured value shall be no less than 0.22MΩ.

5.3.4 Checks before Power-up

(1) Check whether the oil level of the oil source is within the range of the indicated value. Refer to

Chapter 6.1 for the hydraulic oil specifications; (required when optional slip table is included)

(2) Verify Armature Centering. It is necessary to confirm that the upper surface of the armature inserts and the upper surface of the height indicator are on the same level. Refer to Chapter 6 of this manual for details.

(3) Check whether the height indicator of the trunnion vibration isolation airbag is aligned with the scale. Refer to Chapter 6 of this manual for the adjustment of inflation height of the trunnion vibration isolation airbag.

(4) The inflation height of the bottom vibration isolation airbag should be in line with the indicator scale (if applicable).

[Warning] Only after the safety checks specified in 5.3 of this manual has been completed can the equipment be powered on.

STOP! DO NOT APPLY POWER!!!

IF YOU HAVE PURCHASED START-UP ASSISTANCE (Recommended)

OUR TECH WILL VERIFY THE CONNECTIONS AND COMPLETE THE START-UP WHEN ON-SITE

5.4 Initial Power-up

5.4.1 Equipment power on and inspection

(1) Power on the power supply cabinet and turn on the field power supply. Open the rear door of the power amplifier and switch on the circuit breaker. Then close the rear door;

(2) Confirm air source connection;

(3) Turn the amplifier key to “ON” and the PLC display of the power amplifier should enter the login in state.

5.5.5 Connection of required peripheral Instrumentation (controller and accelerometers)

(1) Install the selected controller and connect the computer to amplifier. Refer to Control Manufacturer’s instructions for installing and operating your Controller.

(2) Connect the two ends of accelerometer cable to the sensor and controller separately. Consult Control Manufacturer’s instructions for specifying the sensor type and calibration factors.

(3) Attach the bottom end of the drive sensor to the armature.

[NOTE]: Controller and accelerometers may be purchased with shaker system or acquired separately. Please refer to your purchase order or our corresponding proposal to confirm what is included.

5.4.3 Equipment inspection

(1) Perform Mechanical inspection: Check whether the armature and the slip table work normally and whether there is abnormal sound;

(2) Electrical check: Whether there is short circuit, circuit break and fault alarm.

(3) Index inspection: Check the dynamic range, first resonance frequency, random, shock, and module current sharing condition.

[Note]: 1g sinusoidal sweep or 1g 20 to 2000 Hz random test is recommended as the first test.

[Warning]: When start up is included, final inspection and initial power-up must be conducted by the supplier or their agent.

5.5 Operation procedure of power amplifier

5.5.1 Power amplifier startup

(1) Turn the key switch on the front door of the power amplifier to ON. At this time, the touch screen is powered on and enters the start up screen.

Figure 5.5.1-1 Welcome page

5.5.2 Language selecting

(1) Click login icon to enter the password “1218”. If your system is configured with no password, you can enter language selection page directly.

Figure 5.5.2-1 Login screen of PWA power amplifier

(2) Choose the appropriate language.

Figure 5.5.2-2 Language selection of PWA power amplifier

(3) Enter system operation interface.

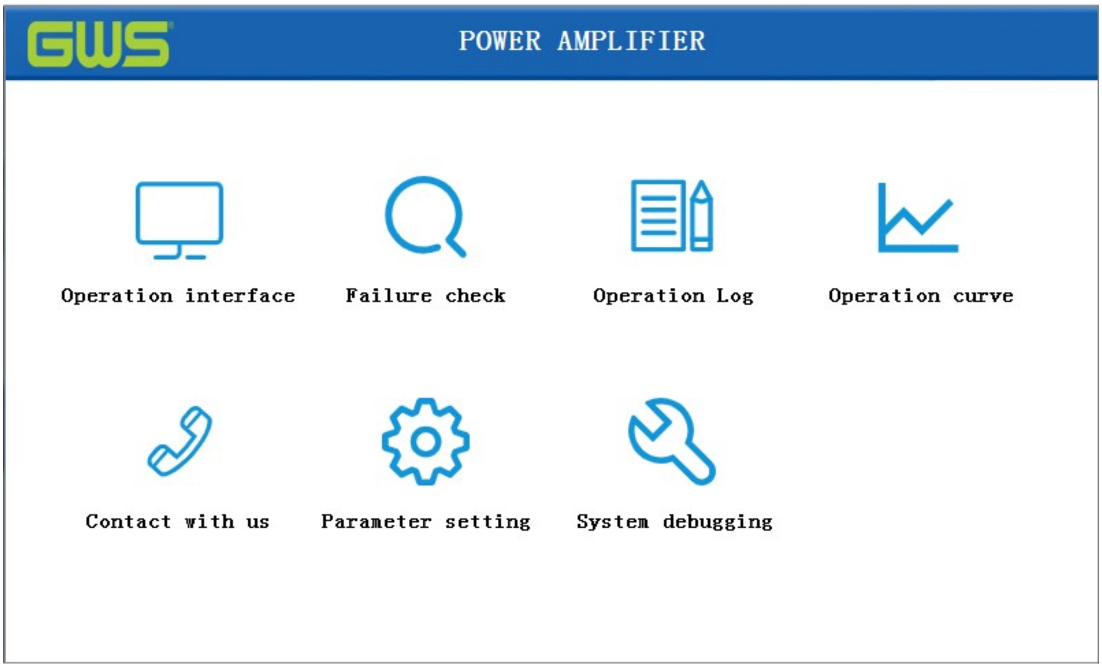


Figure 5.5.2-3 Operation interface of PWA power amplifier

5.5.3 System parameters setting

The system interface mainly includes: Operation interface, Failure check, Operation log, and Contact us, etc.

(1) Click the Operation interface icon to enter the operation interface

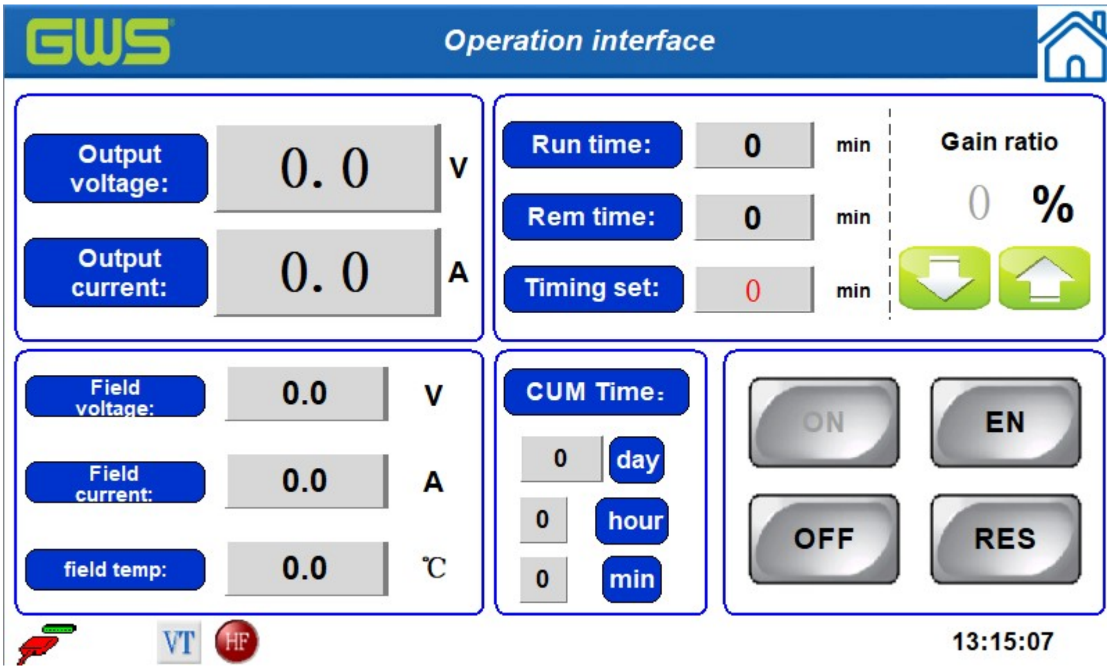


Figure 5.5.3-1 Operation interface of PWA power amplifier

ON	ON
EN	Enable
OFF	OFF
RES	Reset
Gain ratio 0 %	Gain adjustment
CUM Time: 0 day 0 hour 0 min	Accumulated running time
Output current:	Output current
Output voltage:	Output voltage
Field current:	Field coil current
Field voltage:	Field coil voltage
field temp:	Field coil temperature

(2) The operation interface cannot be entered if there is a fault. There is an alarm at the bottom of the page. Click on the Failure check to check the failure details. Don’t delete failure records.

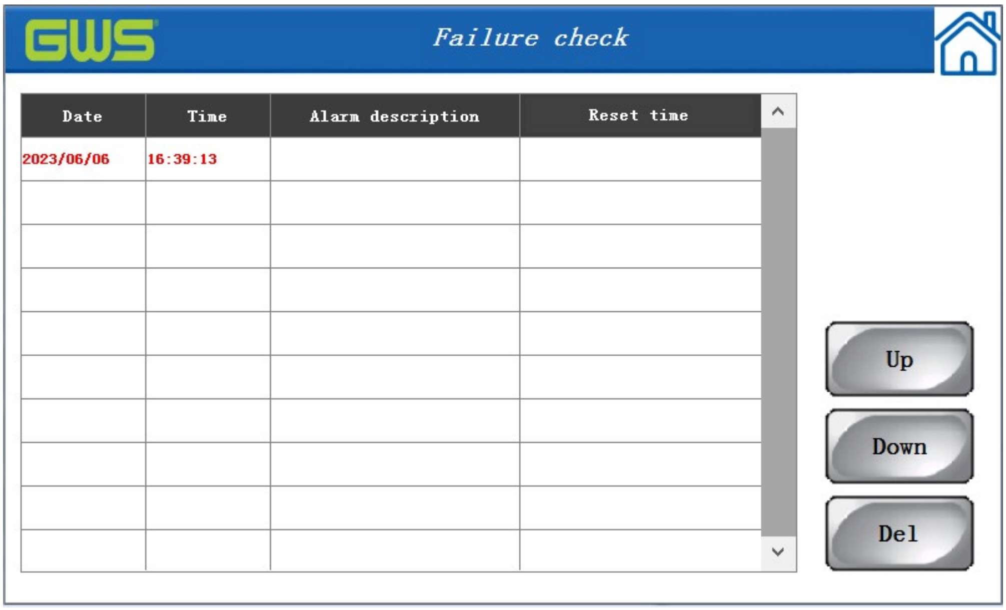


Figure 5.5.3-2 Failure check

(3) In the operation interface, click the **“ON”** button, and the power amplifier will automatically start the main power supply. The system will start slowly with the action of the contactor. After about 11 seconds, it will automatically switch to the enable state.

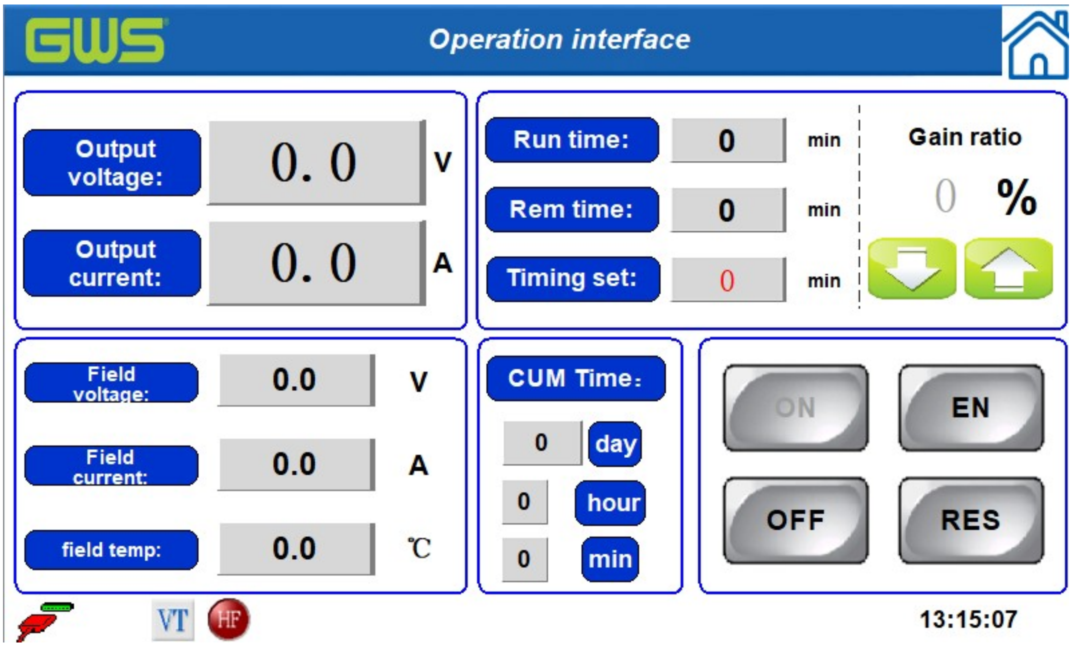


Figure 5.5.3-3 Operation interface of power amplifier- startup

(4) The power amplifier output gain can be set after clicking the **“EN”** button. It can be adjusted with button 

(you can also enter the gain through keyboard 

). It is not recommended to set the gain to 100% directly. The power amplifier will have corresponding output if control signal is provided. When the response of the vibration shaker is observed, the gain can be set according to the test conditions.

5.5.4 System powering off

After the test is completed, stop the operation of the controller, click the power amplifier button **“RES”**, the system gain turns to 0, and the power amplifier output is turned off at that time. The system automatically switches the reset button to the power off state. Click the power off button **“OFF”**, the system will shut down the main power supply and the main components will stop running. At this time, the cooling system will continue to operate for about 10 minutes, and the cooling system will be automatically shut down after the shaker body is completely cooled.

[Warning] Do not plug or unplug the input signal wire after system powering on and before resetting!

Turn the key switch to OFF and the power supply of touch screen will be closed.

Turn off the air switch at the input end of the power amplifier and turn off the corresponding air switch of the power distribution cabinet.

6. Equipment Operation

6.1 Armature Centering adjustment (for systems without automatic centering device)

(1) Connect the air source to the air inlet valve of the shaker body;

(2) Place the height indicator on the top hood;

(3) Open the air source, and set the air source pressure to 0.6 - 0.8MPa;

(4) Pull up the knob of the central air chamber pressure regulator and rotate in clockwise to inflate the central airbag;

(5) The armature will continuously rise with the increase of the inflation pressure; keep the upper surface of table insert at the same level with that of the height indicator.

(6) Excessive inflation will cause the upper surface of table insert higher than that of the height indicator. At this time, you should rotate the pressure regulating valve in counterclockwise to release some pressure, and the armature will drop with the release of air pressure.

(7) After the adjustment is completed, press the knob of the pressure regulating valve to finish the pressure regulating process.

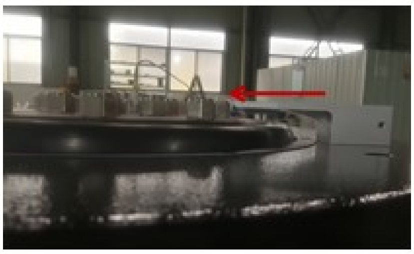
[Warning] Before each test, it is necessary to confirm that the upper surface of the table insert is at the same level with that of the height indicator; otherwise, the armature parts might be damaged. The maximum pressure adjustment shall not exceed 0.6MPa.

(1)

(2)

(3)

(4)



(5)

(6) (7)

6.2 Adjustment of height of the trunnion vibration isolation airbag

(1) Connect the air source to the air inlet valve of the shaker body;

(2) Open the air source, and set the air source pressure to 0.6 ~ 0.8MPa;

(3) Pull up the knob of the isolator air pressure regulator and rotate in clockwise to inflate the trunnion vibration isolation airbag;

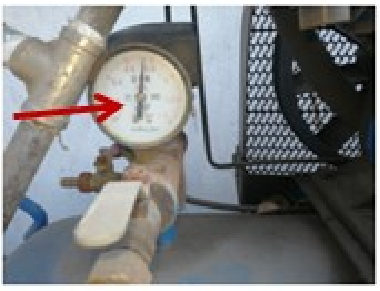
(4) The pointer will continuously rise with the increase of inflation pressure. Adjust until the pointer aligns with the center of the scale.

(5) If there is too much inflation, you can counterclockwise rotate the pressure regulating valve to release part of the air pressure, then the pointer will decrease with the release of the air pressure.

(6) After the adjustment is completed, press the knob of the pressure regulating valve to finish the pressure regulating process.

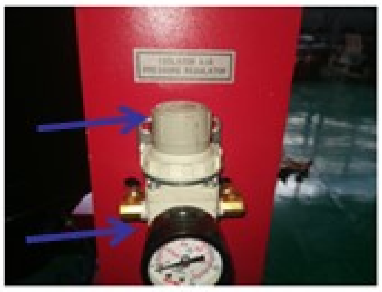
[Warning] Before each test, please make sure that the pointer of the airbag and the scale gauge are aligned, otherwise the test process will be affected.


(1)


(2)

(3)


(4)


(5) (6)

6.3 Installation of head expander (if applicable)

(1) First, lift the head expander and check the joint with the armature to ensure that there is no sundries or oil contamination;

(2) Align the connection hole of the head expander screw with the connection hole of the table insert and then fasten the screw. Refer to the Appendix of this manual for screw torque.

6.4 Installation of fixtures (if applicable)

(1) First, lift the fixture and check the joint with the shaker to ensure there is no sundries or oil contamination. The connection surface of fixture should be flat.

(2) Fix the fixture with the armature or head expander or slip table.

(3) Check whether the trunnion vibration isolation airbag and the armature are in the central position, if not, please adjust according to above mentioned;

(4) The test can be performed after installing the specimen.

[Note] The size of the fixture should not exceed the size of the fixed table, otherwise the test index will be inaccurate.

[Note] Requirements of the fixtures: The flatness of the contact surface between the fixture and the table shall not be greater than 0.1mm, and the positioning of the fixing hole shall not be greater than ϕ0.3mm.

6.5 Start up and shutdown process of air-cooled shaker

(1) Check whether the two ends of the blower pipe connecting with shaker body and blower are fixed properly, check the frame fixing screws;

(2) Open the air source and the pressure of air source shall be set to 0.6-0.8 Mpa;

(3) Adjust the height of vibration isolation airbag and the arrow position should align with the red line;

(4) Adjust the central position of the armature with the help of height indicator (Place the height indicator on the top hood and observe the top surface of the height indicator should be aligned with the armature insert surface);

(5) The sensor can be installed by glue (like 502 glue) or screw thread connection. Stick the bottom of the sensor to the armature insert or the top of the slip table. Connect the sensor wires with the

sensor and controller respectively;

(6) Turn on the power supply of the controller and set the test curve;

(7) Turn on the power amplifier according to the operation procedure, set power amplifier gain.

(8) Click on the start button of the controller to start the test;

(9) Turn off the power amplifier gain and field coil after finishing the test, and turn off the power amplifier key switch after waiting for 5 minutes;

(10) Turn off the controller;

(11) The glue or adhesive tape at the joint and the bottom of the sensor should be cleaned up after the test;

(12) If the system is not used for long time, open the rear door of the power amplifier and switch the main power control to "OFF".

7. REFERENCES: FORMULAS and PRINCIPLES

Before using the device, please confirm whether your equipment capability meets the test requirements. Evaluate whether the test conditions meet the equipment requirements based on the products, fixtures, and equipment you need to test. The vibration, shock and collision test process are related with below factors including equipment capabilities, specimen dimension, shape and mass, installation method, fixture structure and sensor distribution methods.

7.1 Common formula for vibration test

7.1.1 Formula of force (F)

$F = (m_0+m_1+m_2+ \ldots\ldots) A$..............................Formula (1)

Where: F—Force (exciting force) (N)

m_0—Effective mass of moving elements of the vibration shaker (kg)

m_1—Auxiliary table mass (kg)

m_2—Specimen (Includes fixtures, mounting screws) mass (kg)

A—Acceleration (m/s^2)

7.1.2 Interchange formula for Acceleration (A), Velocity (V), Displacement (D)

7.1.2.1 $A=\omega v$ ....Formula (2)

Where: A—Test acceleration (m/s^2)

V—Test velovity (m/s)

$\omega=2\pi f$ (Angular velocity)

f is the test frequency (Hz)

7.1.2.2 $V=\omega D\times10^{-3}$ ....Formula (3)

Where: V and ω are synonymous with "7.1.2.1"

D—Displacement ($mm_{0\text{-}p}$) Single peak

7.1.2.3 $A=\omega^2 D\times10^{-3}$ ....Formula (4)

Where: A, D and ω are synonymous with "7.1.2.1", "7.1.2.2"

Formula (4) can also be simplified as：

$$A=\frac{f^2}{250}\times D$$

Where: A and D are synonymous with "7.1.2.3"，but the unit of A is g

$1g=9.8m/s^2$

Thus: A≈$\frac{f^2}{25}\times D$, at this time, the unit of A is m/s^2

7.1.3 Calculation formula for smoothing crossover point frequency of fixed-frequency sweep test

7.1.3.1 Calculation formula of acceleration and velocity smooth crossover point frequency

$$f_{A-V}=\frac{A}{6.28V} \quad \text{..Formula (5)}$$

Where: f_{A-V}—Acceleration and velocity smooth crossover point frequency (Hz) (A and V are synonymous with above)

7.1.3.2 Formula for calculating the smooth crossover point frequency of velocity and displacement

$$f_{V-D}=\frac{V\times 10^3}{6.28D} \quad \text{.....................................Formula (6)}$$

Where: f_{V-D} —Acceleration and velocity smooth crossover point frequency (Hz) (V and D are synonymous with above)

7.1.3.3 Calculation formula for the smooth crossover point frequency of acceleration and displacement

$$f_{A-D}=\sqrt{\frac{A\times 10^3}{(2\pi)^2\times D}} \quad \text{...................................Formula (7)}$$

Where: f_{A-D}— Acceleration and displacement smooth crossover point frequency (Hz), (A and D are synonymous with above)

According to"7.1.3.3", Formula (7) can also be simplified as：

$$f_{A-D}\approx 5\times\sqrt{\frac{A}{D}}$$ The unit of A is m/s^2

7.1.4 Calculation formula for scan time and scan rate

7.1.4.1 Linear scanning is relatively simple：

$$S_1=\frac{f_H-f_1}{V_1} \quad \text{..Formula (8)}$$

Where: S1—Scan time（s or min）

f_H-f_L—Scan broadband, f_H is the upper limit frequency and f_L is the lower limit frequency (Hz)

V_1—Scan rate (Hz/min or Hz/s)

7.1.4.2 Logarithmic sweep：

7.1.4.2.1 Octave calculation formula

$$n=\frac{Lg\frac{f_H}{f_L}}{Lg2} \quad \text{……………………………………Formula (9)}$$

Where: n—Octave（oct）

f_H—Upper limit frequency (Hz)

f_L—Lower limit frequency (Hz)

7.1.4.2.2 Scan rate calculation formula

$$R=\frac{Lg\frac{f_H}{f_L}/Lg2}{T} \quad \text{……………………………Formula (10)}$$

Where: R—Scan rate (oct/min, or)

f_H—Upper limit frequency (Hz)

f_L—Lower limit frequency (Hz)

T—Scan time

7.1.4.2.3 Scan time calculation formula

$$T=n/R \quad \text{……………………………………………Formula (11)}$$

Where: T—Scan time (min or s)

n—Octave (oct)

R—Scan rate (oct/min or oct/s)

7.1.5 Common calculation formula for random vibration test

7.1.5.1 Frequency resolution formula:

$$\triangle f=\frac{f_{\max}}{N} \quad \text{……………………………………Formula (12)}$$

Where: △f—Frequency resolution (Hz)

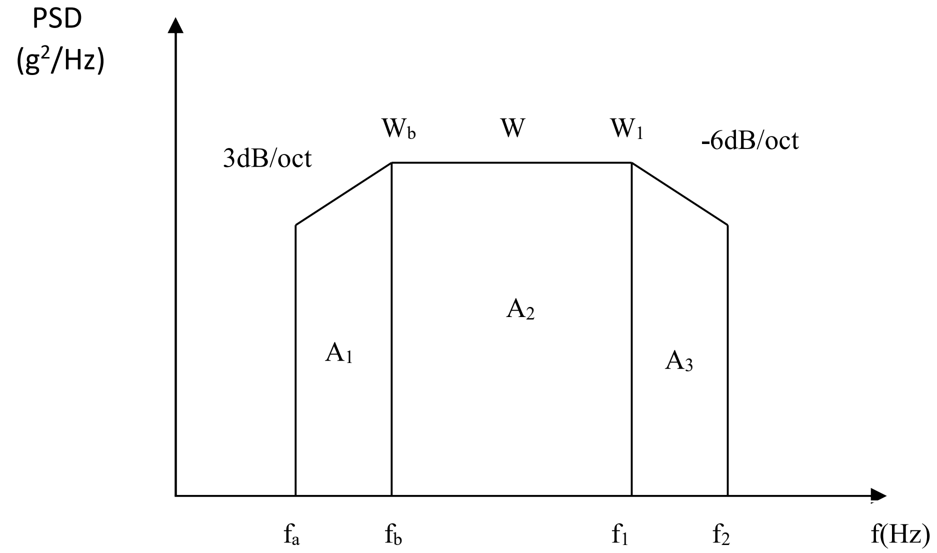
f_{max}—Maximum control frequency

N—Number of spectral lines (lines)

f_{max} is an integral multiple of △f

7.1.5.2 Calculation of total root-mean-square value (rms value) of random vibration acceleration

(1) Using ascending, descending and flat spectrum calculation formulas



A_1 is ascending spectrum

A_3 is descending spectrum

A_2 is flat spectrum

Power spectral density graph (a)

$A_2=W\cdot\triangle f=W\times(f_1-f_b)$ ....Flat spectrum calculation formula

$A_1=\int_{f_a}^{f_b} w(f)df = \frac{w_b f_b}{m+1}\left[1-\left(\frac{f_a}{f_b}\right)^{m+1}\right]$ ... Ascending spectrum calculation formula

$A_1=\int_{f1}^{f2} w(f)df = \frac{w_1 f_1}{m-1}\left[1-\left(\frac{f_1}{f_2}\right)^{m-1}\right]$ ......Descending spectrum calculation formula

Where: m=N/3, N is the slope of the spectral line (dB/octive)

If N=3, then n=1, the following formula for descending spectrum must be used.

$$A3=2.3w_1f_1 \quad \lg\frac{f_2}{f_1}$$

Total rms value of acceleration:

$g_{mis=}\sqrt{A_1+A_2+A_3}$ （g） ....Formula (13-1)

Assuming that: $w=w_b=w_1=0.2g^2/Hz$ $f_a=10Hz$ $f_b=20Hz$ $f_1=1000Hz$ $f_2=2000Hz$

$w_a \rightarrow w_b$ spectral slope is 3dB, $w_1 \rightarrow w_2$ spectral slope is -6dB

Calculated using the ascending spectrum formula:

$$A_1=\frac{w_b f_b}{m+1}\left[1-\left(\frac{f_a}{f_b}\right)^{m+1}\right]=\frac{0.2\times 20}{1+1}\left[1-\left(\frac{10}{20}\right)^{1+1}\right]=1.5$$

Calculated using the flat spectrum formula: $A_2=w\times(f_1-f_b)=0.2\times(1000-20)=196$

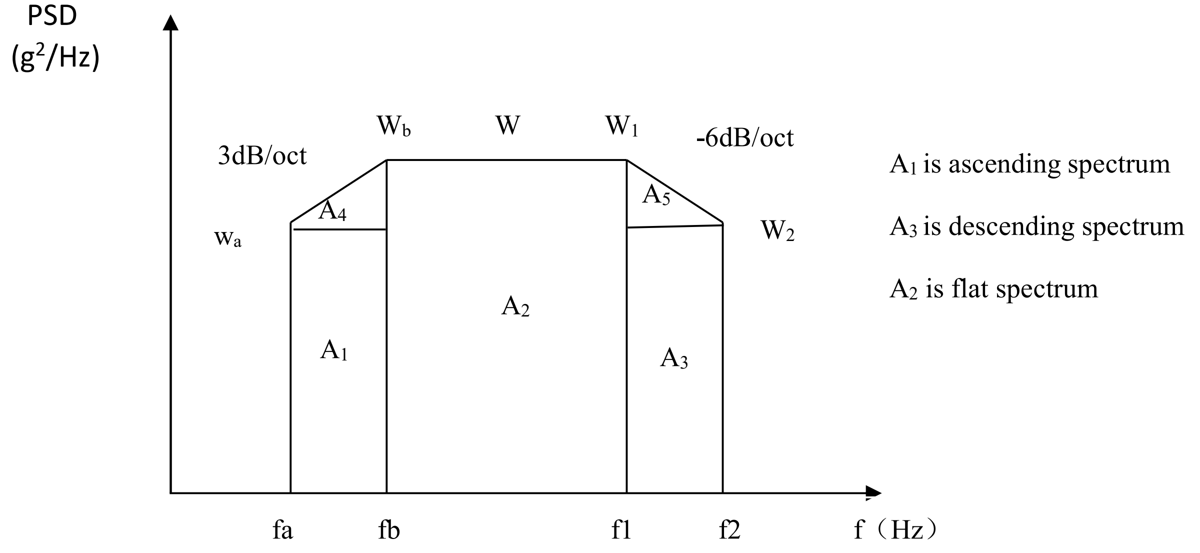
Calculated using the descending spectrum formula:

$$A_3=\frac{w_1 f_1}{m-1}\left[1-\left(\frac{f_1}{f_2}\right)^{m-1}\right]=\frac{0.2\times 1000}{2-1}\times\left[1-\left(\frac{1000}{2000}\right)^{2-1}\right]=100$$

Calculated using the formula of the total rms value of acceleration:

$$g_{mis}=\sqrt{A_1+A_2+A_3}=\sqrt{1.5+196+100}=17.25$$

(2) Calculate the total rms value of acceleration using the flat spectrum calculation formula.



Power spectral density graph (b)

For the sake of simplicity, the power spectral density graph is often divided into several rectangles and triangles, calculate w_a and w_2 using the ascending slope (e.g., 3 dB/oct) and the descending slope (e.g., -6 dB/oct). Then calculate the area and sum of area of each geometry, then calculate the total rms value of the acceleration $g_{rms}=\sqrt{A_1+A_4+A_2+A_3+A_5}$ (g)……………………………Formula (13-2)

Note: The results of the second calculation method are often larger than that calculated by ascending spectrum descending spectrum. They are available as approximate estimates, but cannot be used for accurate calculations.

For example, Assuming that $w=w_b+w_1=0.2g^2/Hz$ $f_a=10Hz$ $f_b=20Hz$ $f_1=1000Hz$ $f_2=2000Hz$

Since the w_a of f_a rises to the w_b of f_b, the slope is 3dB/oct, and $w_b=0.2g^2/Hz$

$$10\lg\frac{w_b}{w_a}=3dB \qquad \text{so } w_a=0.1g^2/Hz$$

And because w_1 of f_1 falls to w_2 of f_2, the slope is -6dB/oct, and $w_1=0.2g^2/Hz$

$$10\lg\frac{w_2}{w_1}=-6dB \qquad \text{so } w_2=0.05g^2/Hz$$

Divide the power spectral density curve into three rectangles (A_1 A_2 A_3) and two triangles (A_4 A_5), and then calculate the area of each geometry separately. Then:

$A_1=w_a\times(f_b-f_a)=0.1\times(20-10)=1$

$A_2=w\times(f_1-f_b)=0.2\times(1000-20)=196$

$A_3=w_2\times(f_2-f_1)=0.05\times(2000-1000)=50$

$$A_4=\frac{(w_b-w_a)(f_b-f_a)}{2}=\frac{(0.2-0.1)(20-10)}{2}=0.5$$

$$A_4=\frac{(w_1-w_2)(f_2-f_1)}{2}=\frac{(0.2-0.05)(2000-1000)}{2}=75$$

Total rms value of acceleration $g_{rms}=\sqrt{A_1+A_2+A_3+A_4+A_5}$

$=\sqrt{1+196+50+0.5+75}$

$=17.96$ (g)

7.1.5.3 Known total root mean square of acceleration $g_{(rms)}$ value, calculate the acceleration power spectral density formula

$$S_F=\frac{g^2{}_{rms}}{1980}\times1.02 \text{ ……………………………………………Formula (14)}$$

Assuming: Total rms value of acceleration is $19.8g_{rms,}$ calculate acceleration power spectral density S_F

$$S_F=\frac{g^2{}_{rms}}{1980}\times1.02=\frac{19.8^2}{1980}\times1.02=0.2(g^2/Hz)$$

7.1.5.4 Find the formula for calculating the maximum Xp-p peak-to-peak displacement (mm)

The accurate method is to find the displacement spectral density curve, calculate the root mean square value of displacement, and multiply the root mean square displacement by three times to obtain the maximum peak displacement. (If the displacement spectral density is a curve, it must be calculated by integration). In engineering, it is often only necessary to estimate a rough value. Here is a simple estimation formula.

$X_{p\text{-}p}=1067\cdot\left(\frac{w_o}{f_o^{\ 3}}\right)^{\frac{1}{2}}=1067\times\sqrt{\frac{w_o}{f_o^{\ 3}}}$ …………………… Formula (15)

Where: $X_{p\text{-}p}$—Maximum peak-to-peak displacement ($mm_{p\text{-}p}$)

f_o—Lower limit frequency (Hz)

w_o—PSD value at the lower limit frequency (f_o) (g^2/Hz)

Assuming: f_o=10Hz w_o=0.14g^2/Hz

Then: $X_{p\text{-}p}=1067\cdot\left(\frac{w_o}{f_o^{\ 3}}\right)^{\frac{1}{2}}=1067\times\sqrt{\frac{w_o}{f^{\ 3}}}=1067\times\sqrt{\frac{0.14}{10^3}}=12.6mm_{p-p}$

7.1.5.5 Calculate the acceleration power spectral density slope (dB/oct) formula

$N=10\lg\frac{w_H}{w_L}/n$ (dB/oct)………………………………Formula (16)

Where: $n=\lg\frac{f_H}{f_L}/\lg 2$ (oct: octave)

w_H—Acceleration power spectral density value at frequency f_H (g^2/Hz)

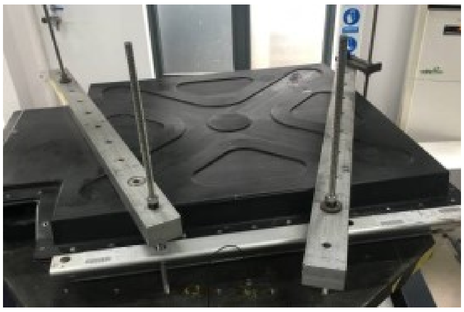
w_L—Acceleration power spectral density value at frequency f_L(g^2/Hz)

7.2 Clamping of the specimen

7.2.1 Fix the specimen with a simple fixture

(1) Fix the specimen on the slip table or head expander of the vibration shaker using the simple fixture or rope, which can also be fixed on the table insert for testing.

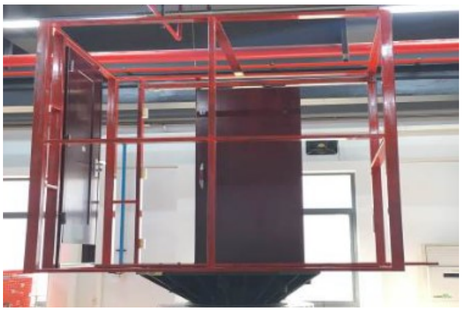
(2) This clamping method is the most common way for vibration testing. Depending on the test unit and installation method, it can be achieved by pressing strip or special fixture.



(3) The screw size must be the same as the table insert. During installation, we need to determine the tightening degree of the screw according to the installation condition of the specimen. Do not crush the test sample.

7.2.2 Fix the specimen with a special fixture

(1) The specimen is fixed on the slip table or the head expander of the vibration shaker by a special fixture.



(2) Fixture requirements on where the fixture is in contact with the slip table or the head expander: the flatness of the contact surface between the fixture and the table should be no more than 0.1mm, and the position of the fixing hole should be no more than ϕ0.3mm. The design and production of the fixture can be carried out by experience or referring to 7.3.

(3) When fixing and installing the fixture, it is important to pay attention to the size and weight of the fixture to prevent damage to the equipment. During the test, it is necessary to pay attention to whether there are parts or oil falling on the specimen.

7.3 Design and manufacture of test fixtures

7.3.1 The test fixture is an intermediate device that connects the specimen with the vibration test equipment, which is related to whether the test can be carried out smoothly and will affect the credibility of the test results (over test, under test).

7.3.2 Test fixture requirements

It is desirable to transmit the motion and energy of the vibration test equipment to the specimen without distortion, that is, it can be regarded as a rigid body in the test frequency range, the first natural frequency of which should be higher than the highest frequency of the test.

In practice, for small fixtures, it can be regarded as rigid body during low frequency tests; for large fixtures, it is unrealistic to regard it as rigid body during high-frequency tests. In the resonance region, the input, output, and motion parameters of each point will not maintain the same value, which will affect the test.

Mechanical: Satisfy the installation requirements of the specimen, try to simulate the actual installation status of the specimen; satisfy the installation requirements of vibration test equipment, pay attention to the coincidence of the center of gravity; at the same time, consider the versatility, processing technology, convenience, lead time, economic applicability and so on.

Mass: It should be as light as possible under the premise that it can meet test conditions and vibration test equipment capability requirements.

Transfer characteristics: Refer to the fixture standard proposed by Sandia Company of the United States as follows:

Specimen	Allowable transfer characteristics	Allowable orthogonal motion	Fixed point allowable tolerance
Small parts with mass of about 2kg	- ＜ 1000Hz, no resonance frequency; - ＞ 1000Hz, 3 resonance frequencies; 3dB bandwidth ＞100Hz, magnification factor ＜5	Y and Z direction vibration＜X direction (up to 2000Hz)	- ＜1000Hz, ＜±20% - 1000-2000Hz, ＜±50%
General parts with mass of around 7kg, and volume of about 164cm^3	- ＜ 1000Hz,no resonance frequency; - ＞ 1000Hz, 4 resonance frequencies, 3dB bandwidth ＞ 100Hz,	Y and Z direction vibration＜X direction (up to 2000Hz)	-＜1000Hz, ＜±30% -1000-2000Hz, ＜±100%

	magnification factor ＜5		
Shaped mechanical parts, electronic equipment with mass of around 5-25kg, and Volume of about 0.03m³	- ＜ 800Hz, no resonance frequency; -800-1500Hz, 4 resonance frequencies, 3dB bandwidth ＞ 100Hz, magnification factor ＜5 -1500-2000Hz,3dB bandwidth ＞ 125Hz, magnification factor ＜8	- ＜ 100Hz, Y and Z direction vibration＜X direction - ＜ 1000Hz,Y and Z direction vibration＜2 times of X direction -Individual points outside the 200Hz resonance zone ＜ 3 times of X direction	-＜1000Hz, ＜±50% -1000-2000Hz, ＜±100% -Between two individual points outside the 200Hz resonance area ＜ ±400%
Larger devices with mass of around 25-250kg, and volume of about 0.2m³	- ＜ 500Hz, no resonance frequency; -500-1000Hz, 2 resonance frequencies, 3dB bandwidth ＞ 125Hz,magnification factor＜6 -1000-2000Hz, 3dB bandwidth ＞ 150Hz, magnification factor ＜8	- ＜ 500Hz, Y and Z direction vibration＜X direction -500-1000Hz,Y, Z direction vibration＜2 times of X direction -1000-2000Hz, Y, Z direction vibration ＜ 2.5 times of X direction -Individual points outside 200Hz resonance zone ＜ 3 times of X direction	-＜500Hz, ＜±50% -500-1000Hz, ＜±100% -1000-2000Hz, ＜±150% - Between two individual points outside the 200Hz resonance area ＜ ±200%

Large equipment with mass of ＞250kg, and minimum side size ≥60cm	- ＜ 150Hz, no resonance frequency; -150-300Hz, 1 resonance frequency, magnification factor ＜3 -300-1000Hz, 3 resonance frequencies, 3dB bandwidth ＞100Hz, magnification factor ＜5 -1000-2000Hz, 5 resonance frequencies, 3dB bandwidth ＞200Hz,magnification factor＜10	- ＜ 300Hz, Y and Z direction vibration ＜ 1.5 times of X direction -300-2000Hz,Y and Z direction vibration ＜ 2.5 times of X direction -300-1000Hz,Y and Z direction vibration outside the 100Hz resonance region ＜ 3.5 times of X direction -1000-2000Hz, Y and Z direction vibration outside the 150Hz resonance region＜4 times of X direction	-＜400Hz, ＜±505 -400-2000Hz, ＜±100% - Between two individual points outside the 200Hz resonance area＜±200%

7.3.3 Type of fixture

Fixtures are divided into two categories: special and general. Special fixtures should be specially designed and manufactured based on specific objects. The main types of general fixtures include:

Integral type: the shapes include cube, hemisphere and cone, etc.; suitable for medium and small parts; multiple mounting surfaces so that the shaker can perform multi-axial test; commonly manufactured from aluminum or magnesium alloy or damping alloy; good transfer characteristics, high natural frequency (stiffness) and mass ratio.

Combined type: the shapes include L-shaped, T-shaped, closed box shaped, open box shaped and cylindrical shaped, etc.; suitable for medium and small parts; multiple mounting surfaces so that the shaker can perform multi-axial test; commonly shaped from metal plate welding or screwing, it can also be shaped by an integral piece of material; good transfer characteristics; convenient and economical.

Truss type: suitable for single direction test for large specimen; usually shaped from welding steel such as square steel, round steel and angle steel, etc.; poor transfer characteristics; but it’s structural damping can be increased by filling damping materials such as polyurethane foam and sand inside the structural steel.

Flat plate type: suitable for single direction test for medium and small specimen; usually shaped from aluminum, magnesium alloy and steel pieces in integral; threaded holes or T-slots can be processed on the plate; good transfer characteristics.

7.3.4 Fixture design

Data collection: Specimen characteristics; Test equipment characteristics; Test conditions, etc.

Mechanical Design: mechanical interface between specimen and test equipment; test direction; coincidence of center of gravity; mass; the material is preferably aluminum, magnesium and alloys with large specific stiffness (elasticity modulus/density) and large damping, steel is not recommended; the preferable process is integral casting, followed by welding and screwing. The symmetrical closed shape is preferred.

Simulation calculation: modal analysis to calculate the natural frequency and vibration mode; response analysis to calculate the response characteristics of each point; strength analysis to evaluate whether the dynamic strength is satisfied. If possible, fix the armature and the fixture together for simulation analysis.

Optimized design: make continuous optimization on the basis of simulation analysis to meet the requirements of mechanical interface, test conditions, transfer characteristics, dynamic strength and so on.

7.3.5 Fixture manufacturing

Casting: Excellent damping characteristics (the damping will be lost once processed), suitable for complex sections, large frequency weight ratio. Sand casting is better than die casting; poor processing or welding performance, low alloy content and yield strength.

Integral processing: suitable for small specimen, fast and convenient. Transfer characteristics are related to design.

Welding: Short cycle and low cost; It is prone to waveform "distortion", which is easy to break under vibration load. Stress must be removed after welding.

Screwing: Convenient, combinable and versatile; Poor transfer characteristics, prone to waveform "distortion", matching surface accuracy requirements, bolt pre-tightening force requirements, bolt span requirements, high-strength bolts, hardened steel flat washers, aluminum-magnesium material plus steel hard-threaded bushings to avoid shear transmission vibration.

Fixture requirement: The flatness of the contact between the fixture and the table should be no more than 0.1mm. The position of the fixing hole should be no more than ф0.3mm.

Others: strictly follow process requirements for adhesion; use threaded bushings and wire thread inserts for soft base material; pay attention to shear force for the slip table, etc.

7.3.6 Fixture test

Transfer characteristics: sinusoidal sweep test to measure natural frequency, "Q" value (magnification and 3dB bandwidth), fixed point deviation, orthogonal characteristic. It can also be tested by modal test analysis methods.

The ratio of the first resonance frequency between specimen and fixture is around 0.5~1.4; fixture acceleration transfer characteristics are between +20dB~-3dB; the lateral vibration of the fixture is usually 〈30%.

Test sequence: first the fixture, then the specimen + fixture, then place the specimen + fixture on the vibration shaker. The simple fixture error is reasonable between 5% to 15%, make some correction if > 15%. Consider the repeatability and reciprocity of the test.

7.4 Test condition confirmation

Before the test, the following conditions are required to determine whether the equipment can meet the test requirements.

Taking the vibration test as an example, according to the Formula of 7.1.1 force (F) (Formula 1), the following information is required before the test:

Condition	Symbol	Unit	Remarks
Moving elements mass	m_0	kg	Armature mass can be acquired from the configuration instructions

Mass of auxiliary table	m_1	kg	Slip table: slip table mass + mass of drive bar; Vertical direction: head expander mass;
Specimen mass	m_2	kg	Specimen mass+ fixture mass+ mass of mounting screw
Test frequency range	F	Hz	
Acceleration	A	m/s^2	Acceleration as provided in g, the conversion formula is as follows $1g=9.8m/s^2$

Calculate the required force F and displacement d of the equipment according to the known conditions, and then check the equipment parameters to determine whether the test requirements can be met. Test conditions can also be entered into the controller to confirm that the parameters meet the test requirements.

7.5 Vibration system limitations

7.5.1 Restrictions of sine vibration

7.5.1.1 Restrictions between vibration parameters

According to the bare load rated frequency range f=(5～3000)Hz, maximum rated acceleration amplitude $a=1000m/s^2$, maximum rated velocity amplitude V=1.8m/s and maximum rated displacement amplitude D=51mm, we can get the bare load vibration parameter range of the vibration shaker as shown in Figure 10-1. It can be concluded from formula (6) in Section 2.6 and formula (1) (2) (3) in Section 1.4: four parameters have restrictive relations during sine vibration. By knowing two parameters, we can obtain the other two parameters. See Figure 10-1, it is easy to find out that the maximum value of the three parameters will not be achieved at the same time and will be limited in the rated frequency range. A test parameter should be pre-calculated and verified to see whether it is within the vibration system parameter range.

7.5.1.2 Limit of maximum acceleration amplitude

The maximum acceleration amplitude allowed by the test system varies with the mass of the specimen (including the fixture).

Take TS-10 as an example, F=10000N, m =10kg, if m_{load}=20kg, according to formula (6)：

$a=F/m=10000/(10+20)=333.3m/s^2$

It is obviously seen that there is big difference of parameter range between the bare table and loaded table.

7.5.1.3 Maximum velocity amplitude restriction

Take the fixed acceleration sweep test of the following test parameters as an example：

The mass of the specimen (including the fixture) is 20kg. Acceleration $a=120m/s^2$, sweep range: 10～500Hz.

According to formula (6) a=10000/(20+10) =333.3 m/s^2, 120 m/s^2＜333.3 m/s^2, the system exciting force is satisfied.

But from formula (1) a =2πfV, it is known that V=a/2πf =120/62. 8=1. 91 (m/s)＞1. 8 (m/s)

Since the velocity value exceeds the rated velocity of the system, the system cannot meet the test parameters.

7.5.1.4 Limit of maximum displacement amplitude

Taking the fixed velocity sweep test of the following test parameters as an example:

The specimen (including the fixture) has a mass of 20kg. Velocity V=1.7m/s， sweep range: 5Hz～25Hz.

Check the acceleration at upper limit frequency,

From formula (1) a=2πfV=2×3.14×25×1.7= 267m/s^2＜333.3 m/s^2, the system exciting force is satisfied.

Displacement amplitude at lower limit frequency,

From formula（3）D=V×1000/2πf =1.7×1000/(2×3.14×5)=54mm＞51mm

Since the displacement at the low end of the frequency exceeds the maximum displacement of the system, the system cannot meet the test parameters.

7.5.1.5 Multifactorial restrictions

Take the positioning sweep frequency test of the following test parameters as an example:

The mass of the specimen (including the fixture) is 80kg. Displacement D=13mm,sweep range: 5～25Hz.

First calculate the acceleration at the upper limit frequency,

By Formula (1) a=(2πf) 2D=(2×3.14×25)2×13/1000= 320.4m/s2,

For system excitation F=ma=(80+10)×320.4=28836＞10000 N

Then calculate the velocity at the upper limit frequency V=2πf

D/1000=2×3.14×25×13/1000=2.04m/s＞1.8m/s

Since both the exciting force and velocity exceed the rated parameters, the test parameters cannot be met.

7.5.2 Random output of the system

7.5.2.1 Relevant factors of random output

(1) Power spectrum density and frequency curve;

(2) Frequency response of specimen (especially the track of resonance peak or resonance valley points);

(3) Assuming that the resonance frequency is within the test frequency range, the position of the accelerometer will affect the acceleration value. Moreover, if a large number of values averaged by the accelerometer are used, or if extreme value control is used, the effective acceleration level will usually be high.

(4) The total mass of the load.

Due to the variation of these factors, it is difficult to make an accurate estimate of an existing system. Therefore, all shaker manufacturers make their systems under a special set of conditions, which can eliminate most of the uncertainties. These conditions include：

1) A slope and a straight power spectrum density (g^2/Hz), a slope of 3dB/oct from 20 to 80Hz, a flat spectrum from 80 to 2kHz or refer to ISO5344.

2) A load with a higher resonance frequency, the weight is 2 to 4 times of the armature.

By selecting these standardized conditions, it is estimated that all shaker manufacturers' random output can be compared equally. These conditions are basically the most appropriate and usually can get the highest random value.

In the user's test, it is hard to get these ideal test conditions. Therefore, it is desirable to be able to predict what can be obtained under different conditions. In order to achieve this we need to know more about the characteristics of the vibration shaker. All loads and various shakers can be described by typical curves, as shown in Figure 10-1：

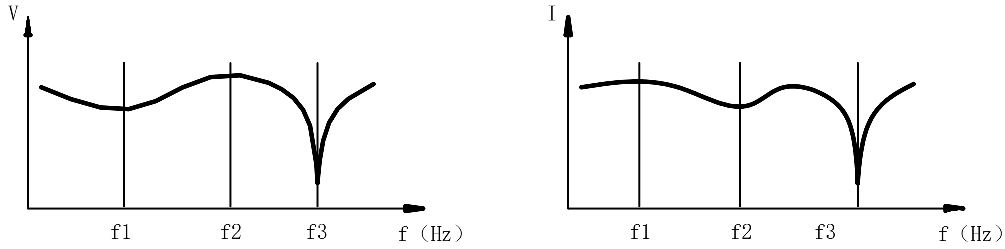


Figure 10-1 Driving voltage and current curve of armature

It can be seen from these curves that the voltage and current output required by the power amplifier depend on the frequency.

For example: At f1, the required voltage is low, but the required current is large.

At f2, the required voltage is the highest, but the required current is small.

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

All shakers have such basic characteristic.

7.5.2.2 Random exciting force restrictions

(1) The upper limit frequency of the random vibration spectrum is lower than 500Hz.

At this time, the random excitation force is limited by the vibration shaker travel limit, the power amplifier output current and output voltage.

Travel limit: At the lower end of the vibration spectrum frequency (below 100 Hz), it is limited by the vibration shaker travel. Nowadays the new digital vibration controller can predict the displacement (P-P) required by the shaker. In random vibration, when the clipping coefficient is 3 Sigma, the maximum displacement will be 6 mm when the predicted displacement is 2 mm. The above predicted displacement is 1/3 of the rated displacement.

Current limit: When the highest frequency of the random spectrum is lower than 500 Hz, the current required for the power amplifier is the highest, at this time the random exciting force is 0.7 times of the sinusoidal exciting force.

Voltage limit: that is, the velocity limit. The sinusoidal velocity is usually determined by the output voltage of the power amplifier. The new digital vibration controller predicts the peak velocity required for random testing.

(2) The upper limit frequency of the random vibration spectrum is higher than 500Hz

At this time, the random exciting force is limited by the mechanical strength of the vibration shaker.

Mechanical strength limit: in this frequency range, both the required output current of the power amplifier and the shaker travel are small. Therefore, limiting the rms value of the test depends on the mechanical strength of the armature. When the clipping coefficient is 3Sigma, the predicted acceleration is 333m/s^2, the maximum acceleration will be 1000m/s^2, and the maximum rms acceleration should be no greater than 333m/s^2.

7.5.2.3 Random clipping factor

There are many system limitations need to be considered when performing random vibration.

(1) Controller dynamic range limit;

(2) Power amplifier output current limit;

(3) Power amplifier output voltage limit.

If the random test is performed at 50% or less of the system capacity and the specimen has a high Q resonance that is difficult to control, it is difficult for the controller to control the spectrum within tolerance. However, with the increasement of test level, the peak of the drive signal ≥ 4 Sigma will eventually be clipped by the power amplifier. When the power amplifier starts clipping, the above-mentioned clipping effect would be the same as the controller signal clipping, and the spectral noise will increase.

When the clipping of the power amplifier becomes severe, the power amplifier will be disconnected and the test will be ceased. However, if the controller drive signal is clipped before entering the power amplifier, the power amplifier will not be disconnected.

In summary, if the controller is not clipped during the test, when the peak of the drive signal reaches the voltage limit or current limit of the power amplifier, the peak will be clipped in the power amplifier just as it is clipped in the controller. The power amplifier will protect when clipping becomes severer. If the controller's signal is clipped before entering the power amplifier, the power amplifier can perform a higher level of testing.

7.5.3 Shock performance

7.5.3.1 Classic shock

(1) The test of the maximum classical shock capability is carried out under the premise that the bare load is equal to or greater than 2 times of the armature mass and the half sine wave pulse duration is less than or equal to 6ms;

(2) The system displacement and system velocity will be limited when testing the maximum classical shock capability. In this case, the compensation of the front and rear peaks of the vibration controller can be adjusted;

(3) Maximum shock performance is limited by useful peak voltage or peak current of the power amplifier and the effective travel of the shaker. In the field of mechanics, the system is limited by force, velocity and travel.

7.5.3.2 Classic shock restrictions

(1) Limited to the output of the system, that is, the power amplifier output current and voltage limits; in the case of a classic shock, the output of the system is about twice of the sine output;

(2) Maximum required velocity limit; at the time of the classic shock, the velocity of the system is about 1.5 times of the sinusoidal velocity;

(3) Maximum required displacement limit.

7.5.3.3 Shock response spectrum

The theory of shock response spectrum test is complicated. The purpose of this part is mainly to illustrate the ability of the vibration system to perform shock response spectrum tests.

(1) Definition

Usually the shock response spectrum is interpreted as the curve of the corresponding frequency of a shock response acceleration. What is the shock response acceleration? The shock response acceleration at a given frequency is not the real-time acceleration of the shock pulse at that frequency, and the shock response acceleration is the response of the high Q filter at that frequency.

A Q=10 filter has a steady-state response acceleration that is 10 times of the real-time acceleration. Nonetheless, under transient conditions, the filter response is less than 10 times and depends on the shock pulse duration at that frequency. Q=10 (5% damping) is specified for most of the shock response spectrum tests for analysis.

(2) Vibration system capability

Assuming Q=10, the general rule is that the real-time acceleration must reach at least 1/5 of the required shock response acceleration, which varies depending on the duration of the pulse.

(3) Procedures:

① The curve of real-time acceleration versus frequency will be divided by the shock response acceleration by 5;

② Compare the real-time acceleration curve with the sinusoidal performance curve with particular effective payload;

③ The test can be performed if the required real-time acceleration is less than 150% of the steady sinusoidal performance, except for the limits listed below. Depending on the frequency content and the fixture, for the specimen and the armature resonance, there are many exceptions, over 150% is acceptable under these conditions.

(4) Limit:

① The impulse duration of the shock response spectrum is typically less than 100 ms. At frequencies below about 75 Hz, it is impossible to complete enough cycles within 100 ms to generate an X5 output from the shock response spectrum filter. Therefore, at frequencies below about 75 Hz, the shock response acceleration should be divided by 2 instead of 5.

Moreover, the low frequency ability of the system is limited by the travel or velocity. It cannot exceed any of these limits. Therefore, the required real-time acceleration must be less than the sinusoidal performance curve below about 75Hz.

② It is stipulated by many shock response spectrum tests that the performance to be achieved should exceed the rated frequency of the vibration shaker.

The sinusoidal performance of a typical vibration system is specified at 2kHz, or at most 3kHz. That is because the armature of the vibration shaker has a main resonance in this frequency range. Exceeding the armature resonance frequency will cause peak and valley responses. At the peak, a very high magnitude of acceleration can be obtained. As for the valley value, it might be a very small acceleration. However, at very high frequencies, the bandwidth of the analysis filter is very wide. A typical analysis is 1/6 octave. Therefore, there are only six filters between 2,000 Hz and 4,000 Hz. The wide filter always shows a lot of responses even with a deep valley in the filter bandwidth.

7.5.3.5 Summary

All of the above statements are assumed under such a case that the fixture and the specimen under test have no serious resonance. And it is assumed that the control acceleration sensor has been installed at a suitable position based on the sine check.

In general, the performance of the shock response spectrum can be reliably predicted in the range of 100Hz to 2KHz. Below 100 Hz, limit must be observed. Above 2000 Hz, performance cannot be reliably predicted without firstly running a low level sinusoidal check with an actual effective payload.

7.5.4 Eccentric moment

The center of gravity of the specimen (including the fixture) is installed at the position away from the center of the table, the eccentric moment generated shall not be greater than the eccentric moment allowed by the vibration shaker:

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

Where: M—Allowable eccentric moment, unit: N·m

a— Acceleration amplitude, unit: m/s^2

m_t—Mass of specimen, fixtures, etc., unit: kg

L— Eccentric distance, unit: cm

8. MAINTENANCE

8.1 Category of parts

8.1.1 Main parts

Composition	Main parts
Shaker body	Armature, field coil, dust shield, top hood, top hood air window, armature insert, upper guidance roller, torsion spring, upper guidance plate, U-current or armature lead, degaussing coil, central magnetic pole short circuit ring, magnetic body short circuit ring, lower guidance shaft, lower guidance roller, central airbag, vibration isolation airbag, trunnion guidance shaft, trunnion guidance bearing, rotation system (gearbox), reduction gear, electrical part of rotation system, turbine worm, chain of rotation system, vibration isolation airbag at bottom of the shaker
Slip table	Oil source, rotation system motor, drive bar, slip plate, barrel, swing bar, guiding rail, throttle bolt, oil pipe, oil baffle device
Cooling system	Electric motor, muffler, blower blade, water pump, radiator, flow meter, filter element
Power Amplifier	Front panel, module, drive panel, inductor, axial flow fan, contactor, thermorelay, fuse holder, terminal holder, fuse, centering system, switching power supply, voltage and current of armature, voltage and current of field coil, touch screen, PLC module, transformer, cables

8.1.2 Main wear items

Composition	Main parts
Shaker body	Torsion spring, upper guidance roller, dust shield, lower guidance roller
Slip table	Filter element, armature barrel, sealing ring, hydraulic oil, barrel
Cooling system	Blower pipe, filter element
Power amplifier	Fuse
System	Sensor, sensor cable

8.2 User's responsibility and instruction

(1) Keep this manual properly;

(2) Please carry out the maintenance and inspection of your equipment by the manufacturer or its agent in accordance with the provisions of regular maintenance in the manual;

(3) Promptly notify the manufacturer or its agent of any failure of your equipment;

(3) WARNING: Any changes and / or modifications to this equipment without the written authorization of the supplier may damage your equipment and will void your warranty (e.g. power amplifier modification, modifying the mechanical structure of armature, hydraulic system, or circuitry, etc.).

(5) Before using the equipment, please familiarize yourself with all the information provided in this manual to avoid damage caused by improper operation or negligence. If additional training is needed, please contact GWS TEST INSTRUMENT CO., LTD. to discuss the training and education options available.

8.3 Daily maintenance

8.3.1 Necessity of daily maintenance

The vibration test system consists of several parts. In the process of operation, each part will inevitably have different degrees of abrasion, looseness or other wear. If maintenance is not performed regularly, the performance of the equipment will deteriorate, and a reduction in the service life and safety of the equipment may result.

Common items requiring regular inspection include, but are not limited to the following:

(1) For systems with Slip Tables: It is important to regularly check the oil level for your system. Much like the oil in any engine, over time the oil level will gradually decrease and the oil will become polluted. Maintaining the oil level and regularly changing the oil and filter is necessary to avoid performance degradation and failure and maintain reliable operation;

(2) Some parts of the vibration test system consist of rubber and nylon components (e.g., guide wheel plate). To avoid these components aging, cracking, etc., these parts should be inspected and replaced regularly as part of your annual maintenance plan.

(3) Wear items such as torsion springs and guide wheels should be inspected regularly and replaced at the first evidence of degradation. WARNING! If these parts are used beyond their wear limit, serious accidents may occur;

(4) Safety checks should include verify the torque parameters of the fastened parts such as nuts and bolts, which may loosen over time due to external factors. Maintaining the proper torque is critical to safely operating this equipment;

To insure continued reliable operation of your GWS® vibration equipment, it is important to perform regular inspections and replace wear items promptly when needed. We recommend doing an annual preventative maintenance service on all vibration test equipment. Please contact your supplier for a detailed proposal.

8.3.2 Routine System Maintenance

(1) Safety checks should be routinely performed prior to testing.

(2) Verify interlocks and safety features are functioning normally before each use;

(3) Inspect the sensor wires for damage and confirm accelerometers are calibrated and functional;

(4) Clean the dust off the dust shield and inspect the dust shield for damage prior to each use;

(5) Clean the dust off the air window at the top of the shaker hood regularly to prevent mesh blocking;

(6) Check and tighten the armature inserts and screws on the slip table;

(7) Check the exhaust duct to insure airflow is unobstructed and duct is free of foreign matter

(8) Routinely inspect and dust the amplifier, cleaning modules, front panel, and axial fans (recommended monthly);

(9) Slip Table: Routinely inspect the oil level of the oil source and the cleanliness of the oil

(10) Check the fuse of power amplifier and blower to verify they are in good condition every month.

8.4 Preventative Maintenance

8.4.1 Scope of Maintenance Work

Regular preventative maintenance can be scheduled based on calendar days or operating hours. Preventative maintenance is divided into two categories: standard maintenance and major maintenance. We provide various parts and accessory packages to accommodate your maintenance requirements.

8.4.2 Maintenance Schedule

The equipment should be maintained according to the following table under normal conditions of use:

Maintenance Schedule at specified operating hours or period of use*	h×1000	2	4	6	8	10	12	14	16	18	20
	Months	12	24	36	48	60	72	84	96	108	120
Wear parts package A		●		●		●		●		●	
Wear parts package B			●		●		●		●		●
Standard maintenance		●		●		●		●		●	
Major maintenance			●		●		●		●		●

***whichever comes first**

8.4.3 Maintenance parts package

Standard Wear parts package A includes: torsion spring, fuse

Special Wear parts package B includes: torsion spring, fuse, upper guidance wheel panel, dust shield, armature insert, filter element, engine oil, sealing ring, external circulation filter element

Based on an analysis of your specific system usage and a thorough inspection of your equipment, we can customize and quote a custom parts package specifically configued with whatever parts are required for maintaining your specific system. For example, customers routinely running high displacement conditions may require more frequent replacement of certain parts, such as the U spring, while customers running other applications may require these parts be replaced less frequently.

8.4.4 Maintenance service contents

The contents of regular maintenance include those marked with ☆.

The contents of special maintenance include those marked with ☆ and★.

Maintenance list of Shaker						
Serial No.	Item	Clean	Replace	Tighten	Detect	Check
1	Dust shield	☆	★			
2	Air window of top hood	☆		☆		
3	Armature insert		★	☆		☆
4	Upper guidance wheel			★		★

Maintenance list of Shaker						
Serial No.	Item	Clean	Replace	Tighten	Detect	Check
5	Torsion spring		☆			
6	Upper guidance wheel plate		★	★		☆
7	Internal wiring of shaker			☆		☆
8	U spring			☆		☆
9	Degaussing coil			☆	☆	
10	Armature frame	★				☆
11	Armature coil	★			☆	☆
12	Field coil	★		★	☆	☆
13	Central magnetic pole short circuit ring	★				★
14	Magnetic body short circuit ring	★				★
15	Lower guidance pillar	★		☆	★	
16	Lower guidance wheel	★		☆		★
17	Central airbag			★		☆
18	Vibration isolation airbag			★		☆
19	Trunnion guidance axis	★		★		☆
20	Trunnion guidance bearing	★		★		★
21	Rotation system (gearbox)			★	★	
22	Reduction gear	★		★		
23	Electrical parts of rotation system	★		★		
24	Turbine worm			★		☆

Maintenance list of Shaker						
Serial No.	Item	Clean	Replace	Tighten	Detect	Check
25	Ratchet wrench			★		☆
26	Chain of rotation system	★		★		☆
27	Aseismic airbag on the bottom of shaker body	★		★		☆

Maintenance list of power amplifier						
Serial No.	Item	Clean	Replace	Tighten	Detect	Check
1	Front panel	☆				☆
2	Module	★		☆		☆
3	Drive panel	☆				☆
4	Inductor	★		★	★	★
5	Axial flow fan	☆		★		☆
6	Contactor			☆		☆
7	Thermo relay			☆		
8	Fuse holder			☆		
9	Terminal holder			☆		★
10	Fuse				★	
11	Centering system	☆		★	★	
12	Switching power supply				★	
13	Voltage &current of armature				☆	
14	Voltage & current of field coil				☆	
15	Touch screen			★	★	
16	PLC module			★		★
17	Transformer	☆		★		

Maintenance list of power amplifier						
Serial No.	Item	Clean	Replace	Tighten	Detect	Check
18	Cables			☆		☆
19	Over displacement				☆	
20	Overvoltage protection				★	
21	Overcurrent protection				★	
22	Direct protection of module				★	
23	Oil source protection				★	
24	Air pressure protection				★	
25	Flow protection				★	
26	Pressure protection				★	
27	External circulation protection				★	

Maintenance list of slip table and head expander						
Serial No.	Item	Clean	Replace	Tighten	Detect	Check
1	Clean of oil tank	☆				★
2	Filter element	★	★			
3	Oil replacement		★			
4	Electrical parts of oil source			★		★
5	Sliding plate barrel					☆
6	Slip table guiding rail			★		☆
7	Adjustment of horizontal connection			★		☆

8	Head expander thread					☆
9	Auxiliary supporting airbag of head expander			★		☆
10	Auxiliary supporting guidance of head expander			★		☆

Maintenance list of cooling system						
Serial No.	Item	Clean	Replace	Tighten	Detect	Check
1	Cooling blower	☆			★	☆
2	Ventilation hood	★		☆		☆
3	Blower pipe					☆
4	Sealing ring		★			★
5	Muffler			★		★
6	Air channel	★				★
7	Clean of internal circulation water tank	★				★
8	Heat exchanger	★				★
9	Internal circulation pressure				☆	
10	Flow sensor			☆	★	
11	Clean of pipeline	★				
12	External circulation filter element	★	★			☆

Maintenance list of shaker and power amplifier indicator		
1	Items	Test
2	Dynamic range	☆

3	First resonance frequency	☆
4	Random	☆
5	Shock	☆
6	Module current sharing	☆

Maintenance list of control system			
1	Hardware (each channel)	Test	Check
2	Software	☆	
3	Computer	☆	
4	Sensor	☆	★
5	Sensor cable	☆	★

8.5 Failure and failure code

8.5.1 Power amplifier alarm

The power amplifier may display the following alarm. Reasons for alarm and countermeasures are as follows:

Serial No.	**Failure description**	**Failure cause**	**Failure level**
1	Control power abnormal	Front panel power supply problem, damage of switching power supply or power supply chip on front panel.	III
2	Logical error	The output drive signal of front panel causes simultaneous breakover of IGBT upper and lower bridge.	III
3	Input under voltage	The input DC bus voltage is lower than the set value.	I
4	Input over voltage	The input DC bus voltage is higher than the set value.	I
5	Output over current	Output current of power module exceeds permissible value.	III

Serial No.	Failure description	Failure cause	Failure level
6	Output over voltage	Output voltage of power module exceeds permissible value.	III
7	Direct module protection	Power module output short circuit.	III
8	Over-displacement protection	Displacement of shaker exceeds permissible range.	III
9	Module over-temperature protection	The temperature of radiator in power module exceeds permissible range.	II
10	Transformer overheat protection	The temperature of transformer exceeds permissible range.	II
11	Air pressure protection	The front and rear pressure of the cooling blower is not enough.	III
12	Field coil over-temperature	The temperature of field coil exceeds permissible range.	III
13	Armature over-temperature	The temperature of armature exceeds permissible range.	III
14	Output software over current	The integral output current of power amplifier exceeds the set value.	II
15	Output software over voltage	The output voltage of power amplifier exceeds the set value.	II
16	Rectifier module overheat	The temperature of three-phase rectifier bridge exceeds permissible range.	III
17	Field coil thermo relay overheat	Thermo relay protection of field coil loop.	III
18	Blower thermo relay overheat	Thermo relay protection of cooling blower loop of the shaker body.	III
19	Door switch open	The door may be in an open status during	I

Serial No.	Failure description	Failure cause	Failure level
	failure	the starting process of power amplifier.	

8.5.2 Common failure and failure code

Failure code	Failure description	Reason description	Trouble shooting
E0101	Armature locking	Short circuit ring protrudes	Repair by the equipment manufacturer or its agent
		Field coil shifting	
E0103	Armature overheat protection	Armature inter-turn circuit	
		Temperature sensor damage	
E0104	Over-displacement of armature	DA separation board failure	
		Central air chamber regulating valve failure	Replace
		Automatic centering system failure	Repair by the equipment manufacturer or its agent
		Torsion spring break	Please repair under the guidance of equipment manufacturer or its agent
		Incorrect sensor sensitivity setting	Reset the parameters
		Over-displacement switch spring break	Repair by the equipment manufacturer or its agent
		Armature is not in the central position	
E0105	Abnormal sound when armature works	Central screw of armature insert break	
		Armature husking	
		Armature lead wire loose	
		Cracks on the armature frame	

Failure code	Failure description	Reason description	Trouble shooting
		Lower guidance wheel loose	Tighten
		Lower guidance pillar loose	Tighten
		Armature collides with foreign matters	Please repair under the guidance of equipment manufacturer or its agent
		Field coil loose	Please repair under the guidance of equipment manufacturer or its agent
		Central screw loose	Tighten
E0303	Ignition inside top hood	Degaussing coil short circuit	Please repair under the guidance of equipment manufacturer or its agent
E0304	Shaker body air leakage	Vibration isolation airbag damage	Please repair under the guidance of equipment manufacturer or its agent
		Pressure regulating valve damage	Replace
		Valve core damage	Replace
		Leakage at the connection	Re-installation
		Central airbag damage	Please repair under the guidance of equipment manufacturer or its agent
E0305	Large magnetic flux leakage	Degaussing coil short circuit	
		Degaussing coil fuse short circuit	
E0307	Overheat of shaker body	Blower runs in reverse	Reconnect
		Blower pipe quick connector fall off	Reconnect
		Blower pipe fall off or damage	Replace

Failure code	Failure description	Reason description	Trouble shooting
		Temperature sensor damage	Please repair under the guidance of equipment manufacturer or its agent
		Thermo relay damage	Please repair under the guidance of equipment manufacturer or its agent
		Foreign matters inside blower pipe	Clean up
		Impurities in external circulation water	Clean up
E0308	Failure of air pressure protection	Air pressure switch broken	Replace
E0314	Abnormal sound of shaker body	Controller output failure	Operation inspection
		Lower guidance wheel loose	Tighten
		Vibration isolation airbag fixed screw loose	Tighten
		Upper guidance wheel panel loose	Tighten
		Poor installation of head expander	Reinstallation
		Unscrewed screws on head expander	Tighten
		Height of vibration isolation airbag exceeds the limit	Adjust
		Overload operation	Check and reset the parameters
		Armature damage	Repair by the equipment

Failure code	Failure description	Reason description	Trouble shooting
			manufacturer or its agent
		Central screw loose	Tighten
E0317	Auxiliary supporting locking	Misaligned auxiliary support fixing screw	Repair
E0327	Shaker body smoking	Field coil damage	Repair by the equipment manufacturer or its agent
		Degaussing coil short circuit	
E0329	Degaussing coil burned	Inter-turn short circuit	
E0601	Oil application on slip table	Oil pressure exceeds the limit and oil film is too thick	
		Improper installation of fixture leads to table deformation	
E0602	Abnormal sound of slip table	Guide rail locking	
		Drive bar screw loose	Please repair under the guidance of equipment manufacturer or its agent
		Slip plate collides with the cover of swing bar	Repair by the equipment manufacturer or its agent
E0603	Oil spilling of slip table	Oil return pump damage	Replace
		Oil return pipe bend	Settle
E0604	Slip table locking	Guiding rail screw break	Repair by the equipment manufacturer or its agent
		Guiding rail wear	Repair by the equipment manufacturer or its agent
		Overloaded	Please repair under the guidance of equipment

Failure code	Failure description	Reason description	Trouble shooting
			manufacturer or its agent
		Oil-way blocking	Please repair under the guidance of equipment manufacturer or its agent
		Uneven bottom surface of loading fixture and specimen	Repair
E0606	Abnormal operation of rotation system	Reverse phase sequence of electrical motor	Reconnect
		Rotation system damage	Replace
		Reduction gear damage	Replace
E0611	Oil leakage of slip table	Epoxy damage between oil baffle case and pedestal	Please repair under the guidance of equipment manufacturer or its agent
E0614	Slip table stuck	Poor oil delivery	Please repair under the guidance of equipment manufacturer or its agent
		Guiding rail wear	Repair by the equipment manufacturer or its agent
E0701	Too little oil source pressure	Oil pressure gauge damage	Replace
		Reverse phase sequence	Reconnect
		Overflow valve damage	Replace
E0702	Oil leakage of oil source	Connection loose	Tighten
		Sealing ring damage	Replace
		Bonded washer damage	Replace
E0704	Low oil level protection of oil	Oil return pump damage	Replace
		Oil return pipe bend	Settle

Failure code	Failure description	Reason description	Trouble shooting
	source		
E0705	Pressure protection	Improper pressure setting	Reset the parameters
E0708	Thermo relay protection	Thermo relay damage	Replace
E0710	Oil source strike	Oil tank filter mesh block	Clean up
		Control box of oil source damage	Please repair under the guidance of equipment manufacturer or its agent
		Oil source fuse damage	Replace
E0712	Abnormal oil pump	Filter mesh block	Clean up
		Thermo relay damage	Please repair under the guidance of equipment manufacturer or its agent
E0713	Motionless of oil gauge pointer	Oil gauge damage	Replace
E0802	Abnormal sound inside power amplifier	Capacitor damage	Replace
		Screw loose inside module box	Tighten
		Poor contact of contactor	Replace
E0803	Fail to add signal into power amplifier	PLC damage	
		75A fuse damage	
		Module box driver panel damage	
		Isolator damage	
E0805	Gain output on power amplifier	Front panel damage	
		MPCS damage	
		Grounding wire failure of power amplifier	Reconnect

Failure code	Failure description	Reason description	Trouble shooting
		Isolator damage	Replace
E1001	Blower strike	Blower fuse damage	Replace
E1003	Blower abnormal sound	Blower electrical motor bearing damage	Replace
		Foreign matters inside blower	Clean up
E1004	Blower moves while working	Unfixed	Fix
E1304	Control open-loop	Sensor or sensor line damage	Replace
		Signal wire damage	Replace
		Front cabinet failure	Replace
		Open circuit of armature coil	Repair by the equipment manufacturer or its agent
		Power amplifier gain is not turned on	Reset the parameters
		No output of controller	Reset the parameters
		Too small test magnitude	Reset the parameters
E1405	Test interruption	Power amplifier alarm	Reset the parameters
		Incorrect installation of sensor	Reset the parameters
		Incorrect parameter setting of controller	Reset the parameters
E1409	Shaker body interference	Earthing problem	Reconnect
		Segregation board damage	Replace
E1416	DC signal of armature	Isolator damage	Replace
		Signal wire damage	Replace
E0316	Water leakage of shaker body	Leakage of armature	Repair by the equipment manufacturer or its agent

Failure code	Failure description	Reason description	Trouble shooting
		Leakage of magnitude body short circuit ring	Repair by the equipment manufacturer or its agent
		Leakage of field coil	Repair by the equipment manufacturer or its agent
		Field coil water inlet and outlet pipe damage	Replace
		Connector of field coil water inlet and outlet pipe damage	Replace
E1104	Low water level protection	Leakage at the joint	Repair
		Water evaporation	Clean up
E1105	External cooling water protection	Water tank filter mesh plug	Settle
		Low pressure and flow of cooling tower	Repair
E1106	Armature water flow protection	Flow sensor damage	Replace
		Flow sensor block	Clean up
E1107	Field coil water flow protection	Flow sensor damage	Replace
		Flow sensor block	Clean up
E1115	Water tank temperature protection	Heat exchanger block	Clean up
		Impurities in the external circulation water	Clean up
		Filter mesh block	Clean up
E1124	Water tank water temperature protection	Low flow of external circulation	Repair
		External circulation is not turned on	Settle
E1125	Water tank failure	Water tank solenoid valve damage	Replace

Failure code	Failure description	Reason description	Trouble shooting
		Emergency stop line loose	Tighten
E1126	Water tank abnormal sound	Electric circuit control problem	Replace

8.6 Maintenance for common failures:

8.6.1 Failure examination for shaker

(1) Armature failure

Failure description: Armature locking, armature strike, armature over-heat protection, armature over-displacement, armature abnormal sound while working;

Identification:

Identification for locking, poor work performance of armature: manually inflate and deflate the air in the armature and observe whether the armature moves with the inflation and deflation, or when the armature is in the center position, press the armature manually to see if it can move.

Identification for strike of armature: use the resistance gear of multimeter to measure whether the circuit of armature is broken. In general, the resistance of armature is very small with only a few Ω or less. But if the circuit of armature is broken, the resistance will be very large.

Identification for overheat protection of armature: firstly, check whether there is any problem with the cooling system. If there is no problem with the cooling system, check if there is any problem with the temperature sensor. If not, it can be judged that there is problem with the armature winding;

Identification for over-displacement of armature: check whether the armature is at the central height. If yes, disassemble the top hood to check whether the armature over-displacement switch is damaged. If not, it can be judged that there is problem with the centering system;

Identification for abnormal sound of armature while working: remove the central table insert and check whether the central screw inside the armature is loose. If not, start the machine with controller and the increase the acceleration from small to large. Meanwhile, observe whether the output waveform has obvious change when there is abnormal sound. If there is obvious gap in the armature, it may rub with other parts. If there is no problem in the small magnitude but the poor waveform under large magnitude, there may be problem with the armature itself;

(2) Failure of degaussing coil

Failure description: ignition inside the top hood and large magnetic flux leakage

Identification for ignition inside the top hood: disassemble the top hood to observe whether there is ignition on the degaussing coil and measure whether the degaussing resistance value is normal;

Identification for large magnetic flux leakage: check whether the field coil is damaged, measure whether the field coil resistance is normal and check the fuse of field coil is damaged;

(3) Identification for shaker body overheating: check whether there is any problem with the cooling system. For the air cooling shaker, check whether the cooling blower pipe is damaged and whether the quick connector of blower pipe falls off. If the blower has been moved, check whether the blower is rotating in the correct direction. For the water cooling shaker, check whether the external circulation filter mesh is blocked. If there is no problem with above identifications, then check the temperature of the field coil when the shaker is overheated (displayed on the power amplifier). If the temperature of the field coil is not high, check whether the power amplifier thermo relay is switched on and confirm the thermo relay can be reset, If there is no problem with the thermo relay, there may be a problem with the field coil;

(4) Field coil trouble shooting: measure whether the resistance of the field coil is normal in case of power failure. If it is abnormal, which indicates that there is a problem with the field coil. If the resistance is normal, start the machine to observe whether the field coil voltage and current are normal, and measure the voltage and current between F+ and F0 and between F- and F0 respectively;

(5) Identification for water leakage of armature: observe whether there is any trace of water under the shaker body and whether the armature flow displayed on the power amplifier is normal;

(6) Identification for locking of auxiliary support: loosen the fixing screw of the auxiliary support guide bearing and check whether the auxiliary support can move;

(7) Identification for air leakage: it is necessary to firstly determine whether it is the armature leakage or vibration isolation airbag leakage or overall leakage. If it is overall air leakage, check the inflation valve seat; if it is the vibration isolation airbag leakage, check it’s air pipe joint, pressure regulating valve and the vibration isolation airbag itself; if it is the armature leakage, check the

armature pressure regulating valve, air pipe joint and central airbag;

Identification for the failure of air pressure protection: Check whether there is any problem with the air pressure switch;

(8) Identification for abnormal noise of shaker body: when abnormal noise occurs on the shaker body, check whether it is under large displacement test conditions. If the displacement is relatively large, then observe whether there is collision on the vibration isolation airbag; otherwise, it is necessary to check whether the armature is in the central position, whether the central screw is loose, whether the upper and lower guidance of armature is loose, and whether the controller and signal wire are normal;

(9) Identification for water leakage of shaker body: in case of water leakage of the shaker body, check whether the water pipe joint behind the shaker body is loose at first. If not, observe whether the field coil and armature flow displayed on the power amplifier is normal; if the armature flow is not normal, dismantle the top hood to check whether the water pipe joint of the armature is leaking; if there is no leakage, dismantle the armature to check whether the armature and the field coil are leaking;

(10) Identification for shaker body smoking: open the top hood and observe whether the U spring or armature lead is damaged. Check the resistance of degaussing coil, fuse, and field coil voltage and current resistance.

8.6.2 Failure check for slip table

(1) Identification for oil application on slip table: check whether the pressure of the oil source is normal, whether internal of the front of the slip table is padded with sponge, and if so, check whether the installation weight of the specimen is concentrated on one side;

(2) Identification for oil spilling of slip table: check whether the oil returning pipe of the oil source is bent, whether the oil returning pump is normal, whether the direction is reversed, and whether the filter element of oil returning pump is blocked;

(3) Identification for slip table locking or stuck: check whether the oil source works well, loosen the drive bar to check whether the slip table can be pushed. If it can be pushed, which means that the slip table is not connected well. If it cannot be pushed, it is necessary to check whether the guiding rail inside the slip table is stuck and whether the oil outlet is blocked;

(4) Identification for abnormal operation of electric rotation system: check whether the

electrical motor is normal, whether the reduction gear is normal and whether the transmission shaft is normal;

(5) Identification for oil leakage of slip table: observe whether the oil leakage is under the oil baffle case or at the oil pipe joint;

(6) Identification for low oil level of oil source: check whether the oil returning pipe is bent and whether the oil returning pump and filter element are normal;

(7) Identification for oil source pressure failure: confirm whether the machine has been moved at first. If yes, replace the power supply phase sequence. If the machine has not been moved, check whether the slip table can be pushed, if yes, it indicates that there may be some problems with the oil pressure gauge. If it cannot be pushed, check if there is a problem with the regulating valve;

(8) Identification for oil leakage of oil source: check whether the oil pipe joint at the oil leakage position is loose, if not, check whether the sealing ring and the combined gasket at the oil leakage position are damaged;

(9) Identification for oil source pressure protection: check whether the setting value of oil source pressure is too low;

(10) Identification for thermo relay protection: check if the thermo relay pops up and cannot be pressed down;

(11) Identification for oil source strike and abnormal operation of oil pump: check whether the fuse of the oil source is damaged, whether the filter element of the oil source is blocked and whether the power supply of the oil source is normal;

8.6.3 Failure check for power amplifier

(1) Identification for the failure to power on strong current with the power amplifier: check if the electric leakage switch is working, if there is a short circuit in the power amplifier, and if the contactor is damaged;

(2) Identification for abnormal sound inside power amplifier: check if the contactor is in poor contact and if there is any component damage inside the power amplifier;

(3) Identification for the failure to add signal into power amplifier: check if there is a problem with the power amplifier front panel, if there is a problem with the signal isolator and if there is a problem with the 75A fuse;

(4) Identification for gain output on power amplifier: disconnect the signal wire connecting

with the controller to check whether there is still any output. If there is no output, check the common-ground problem of power amplifier and the controller. If there is output, then check the power amplifier front panel and MPCS. Remove VCE from MPCS to check whether there is output of the power amplifier. If yes, it can be jugged that there is a problem with the power amplifier front panel;

(5) Identification for ignition of power amplifier: turn off the main power switch before inspection, then observe whether there is capacitance damage or wiring terminals loose at the ignition position, and whether the contactor cannot be closed normally;

8.6.4 Failure check for controller

(1) Identification for non-response (strike) of controller: check whether the network connection of the controller is normal. If it is abnormal, check the data cable and network port of the controller. If it is normal, measure whether there is output when the controller is started (it can be measured with a multimeter). If there is no output, it indicates that there is some problem with the output end of controller;

(2) Identification for open-loop: first, confirm whether the test condition is a small magnitude test, whether the acceleration is less than 0.5g, and the sensor sensitivity. If the sensor sensitivity is too small, there may be open-loop failure alarm as well. After eliminating the sensor problem, it is necessary to confirm whether the installation direction of the sensor is consistent with the movement direction of the shaker body. If not, adjust the direction of the sensor to be consistent with the movement direction of the shaker body. Check whether there is a problem with the sensor wire (use multimeter resistance gear to measure the on-off of the sensor wire) and replace the sensor to determine if it is the sensor problem; observe whether there is output of the power amplifier when starting up. If there is only voltage but no current, there is a problem with the armature; if there is neither voltage nor current, there is a problem with the power amplifier front panel;

(3) Identification for inaccurate values: firstly, it is necessary to confirm if the position of sensor at different positions deviates much from the control points. If the deviation is relatively large, it may be caused by the table uniformity characteristic. If the deviation between the control sensor and the set value is relatively large, check whether the sensor wire is normal and whether the installation direction of the sensor is correct;

(4) Identification for the problem that vibration shaker is in motion but controller does not display the acceleration: check whether the sensor wire is normal, and measure whether the sensor is disconnected with multimeter resistance gear. If the sensor wire is normal, replace the sensor to test whether it is normal;

(5) Identification for bad control curve: when encountering such problems, firstly observe the control curve problem appears in what frequency range. If the control curve fluctuates within the industrial frequency range of the power supply, then it is a power supply industrial frequency interference issue. In this case, the controller, the power amplifier and the shaker need to be tested in common-ground. If the control curve is not good under other frequencies, it is necessary to distinguish in which state the control curve is not good. If it is not good in the vertical bare table state, it is necessary to check the sensors and wires as well as the internal components of the shaker body such as the upper guidance and torsion spring. If it is not good in the horizontal bare table state, it is necessary to check whether the slip table is not well connected. If it is not good in the state of the fixture and specimen, it is necessary to confirm whether the fixture is flat and whether there is resonance between the fixture and specimen, etc.

(6) Identification for abnormal dynamic range: firstly, it is necessary to determine whether the frequency point of dynamic abnormality is the frequency multiplication of the power supply operating frequency. If yes, there may be a grounding problem. If not, the shaker guidance needs to be adjusted.

Solution for test interruption: when the test is interrupted, you should firstly check the failure alarm information of the controller, whether the power amplifier is interrupted or the controller is out of tolerance and judge according to the actual situation. If the control is out of tolerance, it is necessary to check the fixture sensor and other contents. If the power amplifier is interrupted, it shall be processed according to the interruption information.

(7) Identification for specimen movement: if the position of the specimen moves during the test, it is necessary to check whether there is any problem in fixing the fixture.

(8) Identification for shaker body interference: when the interference occurs in the control curve, it is necessary to check the grounding of the power amplifier and the shaker body, and it is also necessary to pay attention to whether the grounding of the input end and the output end of the controller are not connected;

(9) Identification for the failure to carry out shock test: firstly, confirm the acceleration of the specimen. If the acceleration is small, check the sensor sensitivity and controller control parameter settings, and whether there is interference on the power amplifier. If it is not a small magnitude shock, check whether the sensor and cable are normal and whether the signal wire is normal.

(10) Identification for the failure to carry out random test: firstly, confirm the acceleration of the specimen. If the acceleration is small, check the sensor sensitivity and controller control parameter settings, and whether there is interference on the power amplifier. If it is not a small magnitude shock, check whether the sensor and cable are normal and whether the signal wire is normal.

(11) Identification for automatic power off: check whether there is any problem with the power supply of the controller. If power strip is used, check whether there is any problem with the power strip;

(12) Identification for the failure to increase the magnitude: check whether there is any problem with the sensor wire and sensor;

(13) Identification for DC Interference: the shaker keeps moving upwards or downwards when powering on, check if there is any problem with the power amplifier front panel.

8.6.5 Failure check for cooling system

(1) Identification for blower strike: check whether the blower fuse is normal. If there is no problem, check whether the electrical motor of the blower is normal;

(2) Identification for abnormal sound inside the blower: check whether there are foreign matters inside the blower. If not, check whether the bearing of the blower is damaged and whether the blower blades collide with the blower frame.

(3) Identification for blower’s movement while working: check whether the blower is firmly fixed, if it cannot be firmly fixed at the site, you can place rubber pads under the blower;

(4) Identification for low water level protection: check whether the filling amount of distilled water in the water tank exceeds the liquid level sensor. If not, please fill distilled water and check whether there is water leakage in the water tank or the shaker body.

(5) Identification for external cooling water protection: if it is the first installation, please check whether the pressure and flow of the external circulation meet the requirements. If it is not the first installation, please check whether the filter element of the external circulation is normal and

whether the water volume in the cooling tower is sufficient.

(6) Identification for armature water flow protection: after shutdown, check whether the armature flowmeter is blocked. If there is a flowmeter, replace it to determine whether there is a problem with it.

(7) Identification for field coil water flow protection: after shutdown, check whether the field coil flowmeter is blocked. If there is a flowmeter, replace it to determine whether there is a problem with it.

(8) Identification for water tank temperature protection: check whether the external circulation filter element is blocked. If not, check whether there is impurities in the external circulation water. If the external circulation is normal, check whether the radiator is working normally.

8.6.6 For other problems, you can contact the equipment manufacturer or the agent. Please complete the maintenance work under their guidance. Otherwise, it can only be repaired by the equipment manufacturer or the agent.

8.7 Equipment modification or upgrading

For equipment upgrading, the equipment manufacturer or its agent shall propose an upgrading or modification plan after systematic inspection of your equipment. PIV and its agents can provide the following services:

(1) Replacement of power amplifier;；

(2) Software upgrading of power amplifier;

(3) Software upgrading of control system;

(4) Customization of mechanical parts;

(5) Modification of equipment function.

[Warning] If you modify the equipment system by yourself, please read 7.3 *Exemption of three-guarantee liability* and 7.4 *User's responsibility and instruction* of this manual. Please pay attention to the safety during the modification process.

9. APPENDIX

9.1 GLOSSARY (in alphabetical order)

A:

ACCELERATION: The change in velocity, the rate of such change. Units= Gs, Gravity units. 1 G = 32.2 feet per second, per second.

ACCELEROMETER: Device for measuring vibration.

AIR GAP: The area around the drive coil where there is high magnetic flux density. The air gap is usually 10mm in width or less, which depends on the size of the shaker.

AMPLITUDE: The extreme range from the mean. The level above zero.

ARMATURE COIL: Cables used to transfer current to the drive coil, one of which is for armature grounding.

B:

BOTTOM COVER: It provides magnetic circuit for the magnetic field. The central magnetic pole is installed in the middle part and ventilation hood is installed in the lower part. The central through hole is assembled with load support air bags. It also has bolts used to compress tightly the lower field coil.

BROAD-BRAND RANDOM VIBRATION: The frequency components vibrate randomly over a broad band.

C:

CENTRAL MAGNETIC POLE: It is used to generate magnetic circuit with high flux. The inner short circuit ring is welded on the middle part to form a working air gap together with the outer short circuit ring on the magnetic body. It also has aequilate grooves to ensure the space for armature movement. The lower guidance assembly and support structure are installed in the middle lower part.

CONTROL POINT: The installation point of the sensor used to control the vibration magnitude in the vibration test.

COOLING BLOWER: A device with high negative pressure and large flow that can dissipate the heat inside the shaker.

CROSSOVER FREQUENCY: The frequency in which the characteristic quantity of vibration changes from one relation to another in the vibration test.

D:

Db: A base 10 logarithmic scale.

DEGAUSSING COIL: A DC coil that can generate magnetic field to offset the stray field produced by field coils, which can thus reduce the stray flux at the top of the armature table. (Optional)

DISPLACEMENT: The distance traveled. Units= mils (thousandths of an inch)

DRIVE BAR: The device to connect the shaker and slip table.

DRIVE COIL: The AC coil winded around the bottom of the moving element assembly, driven by power amplifier. The winding material is copper or aluminum.

DURATION OF SHOCK PULSE: The time it takes for the shock pulse to rise from the base line value to the maximum value and then fall to the base line value.

DUST SHIELD: A rubber diaphragm that covers the gap between the armature table and the top hood, which is used to prevent dust from entering the shaker.

E:

ENVIRONMENTAL VIBRATION: All vibrations caused by a given environmental condition, usually a combination of vibrations generated by many vibration sources near and far.

EXCITER: It used to generate vibration force which can be applied to other devices or machines.

F:

FIXTURE: The device used to clamp the specimen to the vibration shaker, including simple metal plate to specially shaped supporting part. A fixture that cannot meet the design requirements will limit the performance of the vibration test system.

FORCE: The maximum dynamic value generated by the shaker or exciter.

FREQUENCY: The number of times occurring in a given period of time.

FREQUENCY RESPONSE CHARACTERISTIC: It is a response characteristic of the system in the fixed frequency range, which will deliver vibration steadily. It also can deliver a force, displacement, velocity, or acceleration. The lowest natural frequency of a good fixture must be higher than the required frequency in the test.

FUNDAMENTAL WAVE: The sinusoidal quantity of the fundamental frequency of the frequency.

G:

GRANITE PLATE: It is a flat and smooth plate made of natural granite, which is the contact surface of the slip plate. An oil film is created on the surface to make the friction force as small as possible during slip table movement.

GRAVITY: The force that the earth attracts other objects to itself.

GUIDANCE SHAFT: The connection component of the magnetic body and pedestal, and it provides guidance when the magnetic body moves up and down through the isolation structure.

H:

HALF-SINE SHOCK PULSE: An ideal shock pulse with a half-sine curve in which the magnitude of the motion changes with time.

HARMONIC: A precise multiple of a fundamental frequency.

HARMONIC WAVE: The sinusoidal quantity of an integer multiple of the fundamental frequency of the frequency.

HAZARD FREQUENCY: The frequency that can always cause product failure.

HEIGHT INDICATOR: A measuring wedge that can judge whether the armature table is at balance position.

HERTZ: One cycle per second (cps).

I:

INSTALLATION FIXTURE: The fixtures that used to fix the specimen

L:

LIFTING RING: Fixed on the two sides of the shaker, and it is used to lift the shaker and slip table.

LOWER FIELD COIL: DC coil located in the lower half of the shaker. It generates strong magnetic flux in the air gap which is used to generate “force” for the shaker.

LOWER GUIDANCE PILLAR: The shaft connected with the armature which provides linear guidance and vertical axial stiffness to the moving elements.

LOWER GUIDANCE STRUCTURE: It is the axial structure in the shaker to ensure axial guidance of armature during vertical movement, which guarantees good performance of the system.

M:

MAGNETIC BODY: It provides magnetic circuit for the magnetic field. Field coils are fixed on upper and lower part, and outer short circuit ring is welded in the middle part.

MAGNETIC 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 flux, travels in the air outside the shaker. The degauss coil attempts to reduce the "stray flux" above the armature table.

MONITORING POINT: The installation point of selected sensor to monitor and measure the vibration magnitude of the table and the response of the specimen in the vibration test.

MOVING ELEMENT: The main part is known as "Armature" (including table, frame and drive coil). For the moving element, it also includes the supporting parts on the armature. Armature provides mounting surface for fixtures and specimens.

N:

NARROW-BRAND RANDOM VIBRATION: The frequency components vibrate randomly over a narrow band.

NATURAL FREQUENCY: The frequency determined by the mass and stiffness of the system itself. In general, multi-degrees of freedom systems have several natural frequencies which are arranged in order of magnitude, and the lowest is the first natural frequency.

O:

OCTAVE: The increase in frequency by a factor of 2.

P:

PAYLOAD SUPPORTING STRUCTURE: It is located under the armature to support the moving elements. Depending on different payloads, the air pressure in the air bags should be adjusted based on the height indicator.

PEAK VALUE: It is the maximum value of a certain quantity in a given interval. The peak value of vibration is usually the maximum deviation between the magnitude and its average value, the positive peak value is the maximum positive deviation, and the negative peak value is the maximum negative deviation.

PEDESTAL: A component used to support the shaker with two kinds of structures. One is a vertical bracket to support shaker body only, the other is a conjoint structure to support both shaker body and slip table.

Q:

Q FACTOR: Q factor is a dimensionless parameter that describes how underdamped an oscillator or resonator is. It is approximately defined as the ratio of the initial energy stored in the resonator to the energy lost in one radian of the cycle of oscillation.

R:

RANDOM VIBRATION: All frequencies in a spectrum occurring simultaneously at random G levels at each frequency.

REAR PEAK SAW TOOTH SHOCK PULSE: An ideal shock pulse with a rear-peak saw tooth curve in which the magnitude of the motion changes with time.

RESONANCE: The increasing intensity of vibration.

RESONANCE TEST: The vibration test performed at a resonant frequency of a specimen with a given amplitude of acceleration or displacement for a specified period of time.

RESONANT FREQUENCY: The frequency at which at item resonates.

S:

SENSOR: A device that converts a perceived physical quantity into a required measuring physical quantity.

SENSOR CHARGE SENSITIVITY: The charge output obtained by the sensor after being subjected to a unit mechanical quantity.

SENSOR VOLTAGE SENSITIVITY: The voltage output obtained by the sensor after being subjected to a unit mechanical quantity.

SERVO: An automatic control system that uses feedback.

SHAKER BODY: It is a permeability steel structural component composed of center magnetic pole, magnetic body, top cover and bottom cover, etc.

SHOCK: A sudden, powerful impact.

SHOCK RESPONSE SPECTRUM: The arrangement of the maximum response of a series of single-degree of freedom linear systems subjected to the same shock (or impact) in the frequency domain according to the natural frequency of the system (displacement, velocity, acceleration). It is a function of the natural frequency of the system.

SHOCK TEST: A test used to verify the capability of the specimen to withstand impact load.

SINE VIBRATION: The input signal is a sine wave of specific frequency.

SLIP TABLE: It is used to install the fixture and specimen to realize horizontal vibration. The slip table has different dimension and size, and it is connected to the shaker by drive bar.

SPECTRUM: The collection of frequencies included.

SWEEP: The progression of sine waves through a given range and rate.

SWEEP FREQUENCY: A process in which the controlled variables (usually frequency) continuously pass through a certain area.

SWEEP FREQUENCY VELOCITY: The rate of change of controlled variable (usually frequency) over time during frequency sweeping, i.e. df/dt, where “f” is controlled variable and “t” is time.

SYSTEM: A combination of related parts that can perform certain functions.

T:

TABLE INSERT: The connecting holes for fixture or specimen installation, which are threaded hex nuts or threaded bushing screwed inside the armature table. The armature itself is made of magnesium alloy or aluminum-magnesium alloy. Providing that the fastening screws are directly mounted on the aluminum-magnesium alloy table surface, which will reduce the service life of the armature during repeatedly disassemble process of specimen. Therefore, a dedicated table insert is provided.

TABLE SUSPENSION SYSTEM: Elastic supporting and guiding component.

TOP COVER: It provides magnetic circuit for the magnetic field. Upper guidance system is installed on the upper part. The central through hole is for the out part of the central magnetic pole. It also has bolts used to compress tightly the upper field coil.

TOP HOOD: The top hood is covered on the shaker to protect the operator's safety and prevent sundries from entering the shaker.

TORSION SPRING: Suspension system support, with rubber to connect two steel plates. One side is connected with the shaker body, and the other side is connected with the moving elements. It is part of the moving elements suspension stiffness and support.

TRANSFER FUNCTION: A transfer function of an electronic or control system component is a mathematical function which theoretically models the device's output for each possible input. The transfer function of a system is defined as the ratio of Laplace transform of output to the Laplace transform of input where all the initial conditions are zero.

TRANSMISSIBILITY: It is the ratio of the same dimension response amplitude of the system to its excitation amplitude under steady forced vibration. It can be the ratio of force, displacement, velocity or acceleration.

TRAPEZOIDAL SHOCK PULSE: An ideal shock pulse with a trapezoidal curve in which the magnitude of the motion changes with time.

TRUNNION: Pivoting point of the shaker located at the center of gravity of the shaker, which is used to rotate the shaker. Most shakers with trunnions can be rotated up to 90°.

U:

UPPER FIELD COIL: DC coil located in the upper half of the shaker. It generates strong magnetic flux in the air gap which is used to generate "force" for the shaker.

V:

VELOCITY: The speed of an object. Units = Inches per second

VENTILATION HOOD: A cover fixed at the bottom of the shaker to prevent dust from entering the shaker and provide sealing channel for the blower.

VIBRATION: Motion back and forth.

VIBRATION ENDURANCE TEST: A test used to verify the structural strength, fatigue performance and working performance of the specimen under vibration condition.

VIBRATION ISOLATION AIRBAG: Pneumatic air bag made by rubber to isolate vibration during shaker working process. The air volume should be adjusted according to the table payload.

VIBRATION SHAKER: A test device on which the test sample is fixed on the table for vibration test and measuring instrument calibration, the vibration parameters of which are controllable.

VIBRATION TEST: A test conducted to understand the response, fatigue strength, and working performance of the specimen under vibration conditions.

- End of Glossary -

9.2 Thread tightening torque

Thread tightening torque

Thread tightening torque of common basis material (revised version, for reference of technicians)										
Thread	As (mm^2)	Standard torque (N·m) / Basis material: PTFE, PE, ABS, PP, PF, UF, MF	POM, PMMA, PS, PC, PVC, PSU, Epoxy glass cloth board PA (nylon)	HT200, T2, AZ40M (AZ31B), ZM5(T6), 5A05(H112)	QSn6.5-0.1, ZG200-40, Q235A, H62, 10, QA19-4, ZL104 (T6), ICrl8Ni9Ti	(4.6 grade screw) QBe2, QT400-18, 20, 2A12 (H112), QA19-4, 6061 (T6)	(5.6 grade screw) 40Cr, 35, 45, TA2	(6.8 grade screw) 65Mn, 7A04 (H12)	(8.8 grade screw) 40Cr, 35, 45, TA7, TC4 (HBS>240)	(10.9 grade screw) 40Cr, 35, 45, Qbe2 (HRC>32)
M3	5.03	0.03	0.09	0.21	0.43	0.51	0.64	0.86	1.3	1.9
M4	8.78	0.07	0.2	0.5	1	1.2	1.5	2	3	4.5
M5	14.2	0.15	0.4	1	2	2.4	3	4	6	9.1
M6	20.1	0.26	0.69	1.7	3.4	4.1	5.1	6.8	10.3	15.4
M8	36.6	0.62	1.7	4.2	8.3	10	12.5	16.5	24.9	37.4
M10	58	1.2	3.3	8.2	16.5	19.8	24.7	32.9	49.4	74.1
M12	84.3	2.2	5.7	14.4	28.7	34.5	43.1	57.4	86.2	129.3
M14	115	3.4	9.2	22.9	45.7	55.1	68.6	91.4	137.2	205.8
M16	157	5.3	14.2	35.6	71.2	85.6	107	142.7	214	321
M18	192	7.4	19.7	49.2	98.2	117.8	147.2	196.3	294.5	441.7
M20	245	10.4	27.8	69.5	139	166.9	208.6	278.3	417.5	626.2
M22	303	14.2	37.9	94.8	189.3	227.2	284	378.6	567.9	851.9
M24	353	18	48.1	120.3	240.6	288.7	361	481.2	721.8	1083
M27	459	26.4	70.5	176	352	422.4	527.9	703.9	1056	1584
M30	561	35.8	95.5	239	478	573.6	717	955.9	1434	2151
σ p0.2 (MPa)		⩾15	⩾40	⩾100	⩾200	⩾240	⩾300	⩾400	⩾600	⩾900

Instructions:

1.Standard torque formula: M=0.142 X σ p0.2 X As X d/1000

where① σ p0.2—material yield strength, unit Mpa; ② As—thread active area, unit mm; ③d—thread nominal diameter, unit mm ; ④M—torque, unit N·m

2. The selected standard tightening torque should be no less than that of the basis material;
   for the same thread pair, the tightening torque should be decided by the material with lower tightening torque

3. The screwing length should be greater than 1.2 times of the full diameter of thread.
   Normal tightening: 1~1.05 times of tightening torque, important component tightening: 1.2~1.25 times of tightening torque

4. For the material not listed in the form (or the thermal treatment condition or yield strength σ p0.2 of material is not in consistent with specific technical document), please refer to specific technical document.

5. Engineering plastic has very small tightening torque, which might be damaged by direct threading.
   Generally, it can be connected with the external thread after the set screw or wire screw is covered.

9.3 System outline drawing

See attached

9.4 Electrical schematic diagram

See attached