RSA-G2

Dynamic Mechanical Analyzer

Getting Started Guide

Revision C Issued May 2014

Notice

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Introduction

Important: TA Instruments Manual Supplement

Please click the TA Manual Supplement link to access the following important information supplemental to this Getting Started Guide:

- TA Instruments Trademarks
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Notes, Cautions, and Warnings

This manual uses NOTES, CAUTIONS, and WARNINGS to emphasize important and critical instructions. In the body of the manual these may be found in the shaded box on the outside of the page.

NOTE: A NOTE highlights important information about equipment or procedures.

CAUTION: A CAUTION emphasizes a procedure that may damage equipment or cause loss of data if not followed correctly.

MISE EN GARDE: UNE MISE EN GARDE met l'accent sur une procédure susceptible d'endommager l'équipement ou de causer la perte des données si elle n'est pas correctement suivie.

A WARNING indicates a procedure that may be hazardous to the operator or to the environment if not followed correctly.

Un AVERTISSEMENT indique une procédure qui peut être dangereuse pour l'opérateur ou l'environnement si elle n'est pas correctement suivie.

Regulatory Compliance

Safety Standards

For Canada

CAN/CSA-C22.2 No. 61010-1 Safety requirements for electrical equipment for measurement, control, and laboratory use, Part 1: General Requirements.

CAN/CSA-C22.2 No. 61010-2-010 Particular requirements for laboratory equipment for the heating of materials.

For European Economic Area

(In accordance with Council Directive 2006/95/EC of 12 December 2006 on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limits.)

EN 61010-1:2001 Safety requirements for electrical equipment for measurement, control, and laboratory use, Part 1: General Requirements + Amendments.

EN 61010-2-010:2003 Particular requirements for laboratory equipment for the heating of materials + Amendments.

For United States

UL61010-1:2004 Electrical Equipment for Laboratory Use; Part 1: General Requirements.

UL61010A-2-010:2002 Particular requirements for laboratory equipment for the heating of materials + Amendments.

Electromagnetic Compatibility Standards

For Australia and New Zealand

AS/NZS CISPR11:2004 Limits and methods of measurement of electronic disturbance characteristics of industrial, scientific and medical (ISM) radio frequency equipment.

For Canada

ICES-001 Issue 4 June 2006 Interference-Causing Equipment Standard: Industrial, Scientific, and Medical Radio Frequency Generators.

For the European Economic Area

(In accordance with Council Directive 2004/108/EC of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility.)

EN61326-1:2006 Electrical equipment for measurement, control, and laboratory use-EMC requirements-Part 1: General Requirements. Emissions: Meets Class A requirements per CISPR 11. Immunity: Per Table 1 - Basic immunity test requirements.

For the United States

CFR Title 47 Telecommunication Chapter I Federal Communications Commission, Part 15 Radio frequency devices (FCC regulation pertaining to radio frequency emissions).

Safety

WARNING: The operator of this instrument is advised that if the equipment is used in a manner not specified in this manual, the protection provided by the equipment may be impaired.

AVERTISSEMENT: L'utilisateur de cet instrument est prévenu qu'en cas d'utilisation contraire aux indications du manuel, la protection offerte par l'équipement peut être altérée.

CAUTION: Read the operating and maintenance instructions that were supplied with your air dryer. Failure to properly operate and maintain your air dryer will result in extensive damage to this instrument.

MISE EN GARDE: Lisez les instructions d'installation, d'utilisation et de maintenance fournies avec votre déshydrateur d'air. L'utilisation et la maintenance inappropriées du déshydrateur d'air entraînent d'immenses dégâts sur l'instrument.

Instrument Symbols

The following label is displayed on the RSA-G2 Dynamic Mechanical Analyzer (DMA) for your protection:

Symbol	Explanation
	This symbol indicates that you should read this Getting Started Guide in its entirety. This guide contains important warnings and cautions related to the installation, operation, and safety of the instrument. Ce symbole indique que vous devez lire entièrement ce guide de démarrage. Ce guide contient d'importants avertissements et mises en garde relatifs à l'installation, à l'utilisation et à la sécurité de l'instrument.
	This symbol indicates that a hot surface may be present. Take care not to touch this area or allow any material that may melt or burn come in contact with this hot surface. Ce symbole indique la présence possible d'une surface chaude. Prenez soin de ne pas toucher cette zone ou de laisser un matériau susceptible de fondre ou de brûler entrer en contact avec cette surface chaude.

Symbol	Explanation
	This symbol on the rear access panel indicates that you must unplug the instrument *before* doing any maintenance or repair work; voltages exceeding 120/240 VAC are present in the cabinet. If you are not trained in electrical procedures, do not remove the cabinet covers unless specifically instructed to do so in the manual. Maintenance and repair of internal parts must be performed only by TA Instruments or other qualified service personnel. Ce symbole apposé à l'arrière du panneau d'accès indique vous devez débrancher l'instrument avant d'effectuer des travaux de maintenance ou de réparation ; présence de tensions excédant 120/240 VCA dans cette armoire/ce circuit. Si vous n'êtes pas formé aux procédures électriques, ne déposez pas les couvercles de l'armoire sauf indications spécifiques contenues dans le manuel. La maintenance et la réparation des pièces internes doivent être effectuées uniquement par TA Instruments ou tout autre personnel d'entretien qualifié.
	This symbol indicates that you must keep your fingers away from the sample loading area. Ce symbole indique que vous devez éloigner vos doigts de la zone de mise ne place des échantillons.

Please heed the warning labels and take the necessary precautions when dealing with those parts of the instrument. The *RSA-G2 Getting Started Guide* contains cautions and warnings that must be followed for your own safety.

Electrical Safety

You must unplug the instrument before doing any maintenance or repair work; hazardous voltages are present in this system.

You must unplug the instrument before doing any maintenance or repair work; voltages as high as 120/240 VAC are present in the common cabinet.

DANGER: There are no customer-replaceable fuses in the RSA-G2. High voltages are present in this instrument. If you are not trained in electrical procedures, do not remove the cabinet covers unless specifically instructed to do so in the manual. Maintenance and repair of internal parts must be performed only by TA Instruments qualified service personnel.

DANGER: L'RSA-G2 ne contient aucun fusible remplaçable par l'utilisateur. Présence de tensions élevées dans cet instrument. Si vous n'êtes pas formé aux procédures électriques, ne déposez pas les couvercles de l'armoire sauf indications spécifiques contenues dans le manuel. La maintenance et la réparation des pièces internes doivent être effectuées uniquement par le personnel d'entretien qualifié de TA Instruments.

Chemical Safety

Use only the gases listed in Chapter 1. Use of other gases could cause damage to the instrument or injury to the operator.

WARNING: If you are using samples that may emit harmful gases, vent the gases by placing the instrument near an exhaust.

AVERTISSEMENT: Si vous utilisez des échantillons qui émettent des gaz nocifs, ventilez les gaz en plaçant l'instrument près d'un échappement.

Thermal Safety

DANGER: During an experiment, the furnace, sample, clamp, and other environmental options can become very hot or very cold to the touch.

DANGER: Pendant l'expérimentation, le four, l'échantillon, la bride de serrage et d'autres options environnantes peuvent devenir très chauds ou très froids au toucher.

WARNING: Keep all temperature control options in both their closed and maximum open position a minimum of eight inches from any wall or object.

AVERTISSEMENT: Gardez toutes les options de commande de température en position fermée ou d'ouverture maximale à une distance minimale de huit pouces d'un mur ou d'un objet.

Mechanical Safety

DANGER: Keep your hands clear of the motor while it is running. If you need to touch it, turn OFF the motor first.

DANGER: Éloignez vos mains du moteur lorsqu'il tourne. Si vous devez le toucher, arrêtez d'abord le moteur.

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Chapter: 1

Introducing the RSA-G2

Overview

The TA Instruments RSA-G2 Dynamic Mechanical Analyzer (DMA) tests the dynamic mechanical properties of solid materials by using a servo drive linear actuator to mechanically impose an oscillatory deformation, or strain, upon the material being tested (hereafter referred to as the sample). This deformation can also be a step change in position, or a constant rate of deformation (step strain tests, for example). To maintain consistency throughout rheometric documentation and TRIOS software, the actuator will be referred to as the motor, even though in this case the motion is axial. The sample is coupled between the motor and a transducer, which measures the resultant force generated by sample deformation. Strain amplitude and test frequency are set by the operator, and the actual sample deformation is determined by the measured motor and transducer displacement.

The RSA-G2 works in conjunction with a controller, TA Instruments TRIOS software, and a Forced Convection Oven (FCO) to make up a rheological system. Note that the FCO is the only environmental system that can be used with the RSA-G2.

Your controller is a computer that performs the following functions:

- Provides an interface between you and the instrument
- Enables you to set up experiments and enter parameters
- Runs the experiments and stores experimental data
- Allows you to calibrate the instrument
- Runs data analysis programs

The following pages provide a brief description of the components available with the system.

NOTE: For technical reference information, theory of operation, and other information associated with the RSA-G2 and not found in this manual, see TRIOS online help.

System Components

The RSA-G2 system can be set up in several different configurations, depending upon your needs. The following items may be part of a system:

- RSA-G2 test station
- Modular power supply
- Geometries (optional)
- Forced Convection Oven
- LN2 Controller (optional)
- Chiller (optional)
- DETA (optional)

These components are briefly described in this chapter. For details regarding each part, please refer to the online help accessed through the TRIOS software.

RSA-G2 Test Station

An RSA-G2 test station, shown in the figure below, consists of several components. The primary components are the linear motor, stage, linear transducer, keypad, touch screen display, an environmental control option, and various geometries needed for experiments.

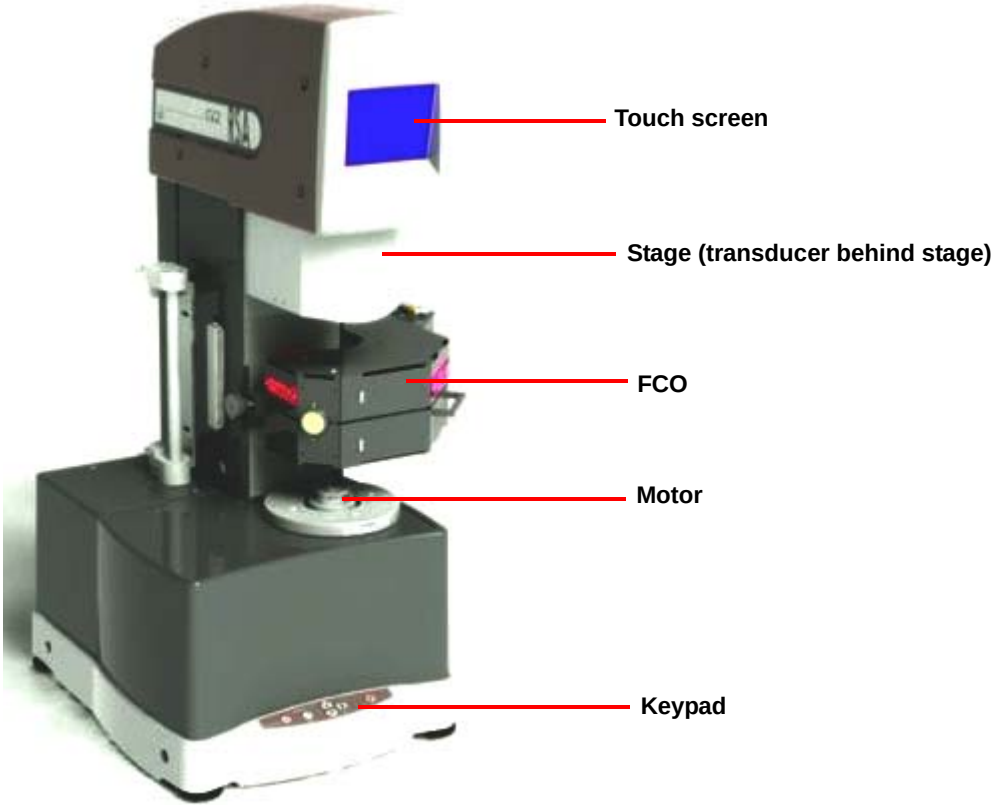

Figure 1 RSA-G2 test station.

Stage

The stage is a motorized platform that supports the transducer. The stage can be raised and lowered to facilitate sample loading using the keypad on the front of the test station, the touch screen, or through TRIOS software control. The rate at which the stage moves can be adjusted through software.

RSA-G2 Keypad

The keypad, shown in the figure below, is an external device on the front of the instrument that is used for several types of control. The indicator lights show green when that function is on and red when it is off.

The instrument power status light has five states applicable to the status light. These are: (1) Blinking green is displayed when the instrument is powering up. (2) Steady green indicates that the instrument is fully powered and ready to operate. (3) Blinking red indicates that the instrument is powering down.

(4) Steady red is displayed when the instrument is in the standby state. (5) Light off indicates that the power switch is off at the power supply.

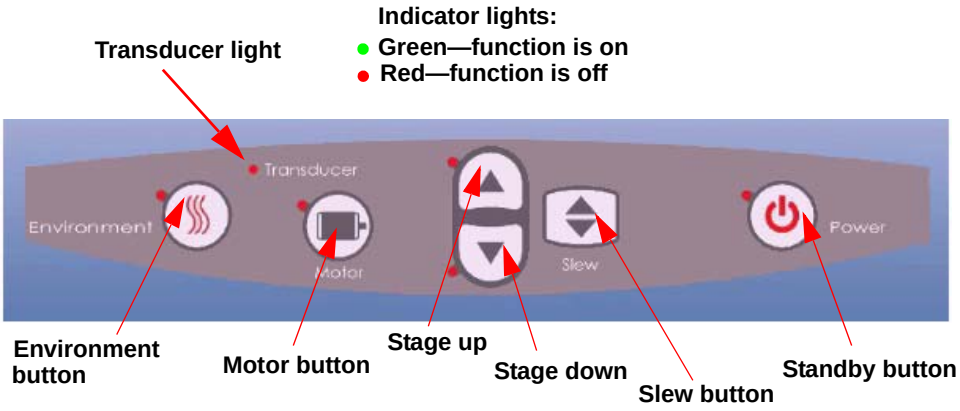

Figure 2 RSA-G2 keypad.

NOTE: When the red lights next to the Stage up and Stage down buttons are on, the stage has reached its maximum or minimum height and can no longer travel in that direction anymore. A single flashing light next to the button indicates that the stage is disabled in that direction because a force overload has occurred. Both lights lit together indicates that the transducer is not functioning and, as a result, the stepper is not allowed to move at all.

The functions on the keypad are described briefly below:

- ***Environment button***: This button is used to turn the FCO on or off. The light beside the button tells you the state of the environmental unit.
- ***Transducer light***: This light indicates when the transducer is either on or off.
- ***Motor button***: Use this button to toggle between motor on and off. The light beside the button tells you the state of the motor. If the transducer and motor are both off (lights are red), pressing the motor button will also reset the transducer (if a force overload occurred and caused it to turn off).
- ***Stage up button***: This button raises the stage. The light beside the button indicates the state of the stepper motor.
- ***Stage down button***: This button lowers the stage. The light beside the button indicates the state of the stepper motor.
- ***Slew up/down button***: When the slew button is used in conjunction with the motor up or down buttons, the stage moves very quickly. To slew the stage downward, press and hold both the slew and stage down buttons. To slew the stage upward, press and hold both the slew and stage up buttons.
- ***Standby button***: When you press this button, the instrument slowly powers down after the oven has come down to the stabilization temperature of 50°C. Then the power to the instrument shuts off. The light beside the button indicates the status. To put the instrument immediately into standby mode, press and hold this button for at least 10 seconds.

RSA-G2 Touch Screen

The RSA-G2 has an integrated touch screen display for local operator control. Interactive functions such as gap zeroing, sample loading, and setting temperature can be performed at the instrument. The functions shown on the screen change depending upon the menu being used. This section briefly describes the interactive functions shown on the touch screen displays.

NOTE: For detailed information on the functions performed with the touch screen not found in this manual, see TRIOS software online help.

The RSA-G2 Instrument Touch Screen

The **Instrument** tab of the touch screen displays the main instrument functions and gauges. This allows you to monitor the motor position, normal force, gap, temperature, and data zones and points. Buttons on the screen are available to perform gap control, set the temperature, and stop the test.

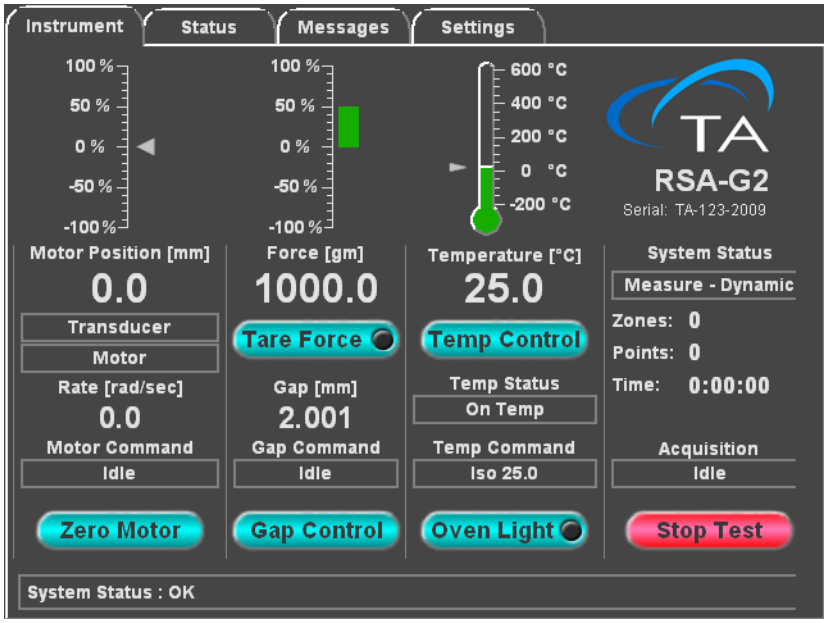

Figure 3 RSA-G2 Instrument touch screen.

The RSA-G2 Status Touch Screen

The **Status** tab (shown in the figure below) displays the instrument status regarding air pressure, temperature sensors, system status, and network communication status. It also provides easy access to system information and diagnostics that may be used to troubleshoot your instrument.

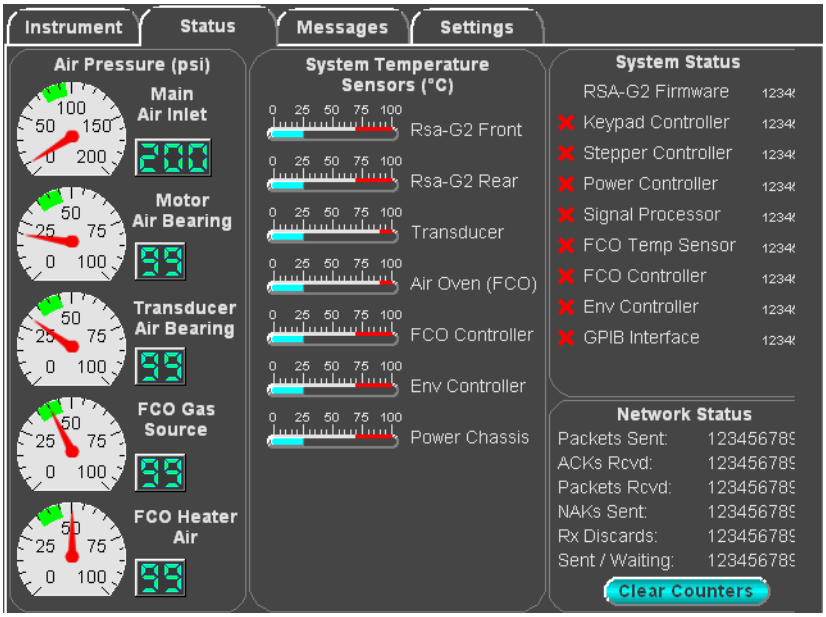

Figure 4 RSA-G2 Status touch screen.

The primary use of this screen is to provide an overview of all the instrument components and serve as a troubleshooting tool.

The RSA-G2 Messages Touch Screen

The **Messages** tab (shown in the figure below) displays status messages that can be used for troubleshooting.

Figure 5 RSA-G2 Messages touch screen.

The RSA-G2 Settings Touch Screen

The **Settings** tab is used to identify your RSA-G2 instrument, its location, and network (IP) address information. In addition, you can adjust FCO camera focus and light and calibrate the touch screen.

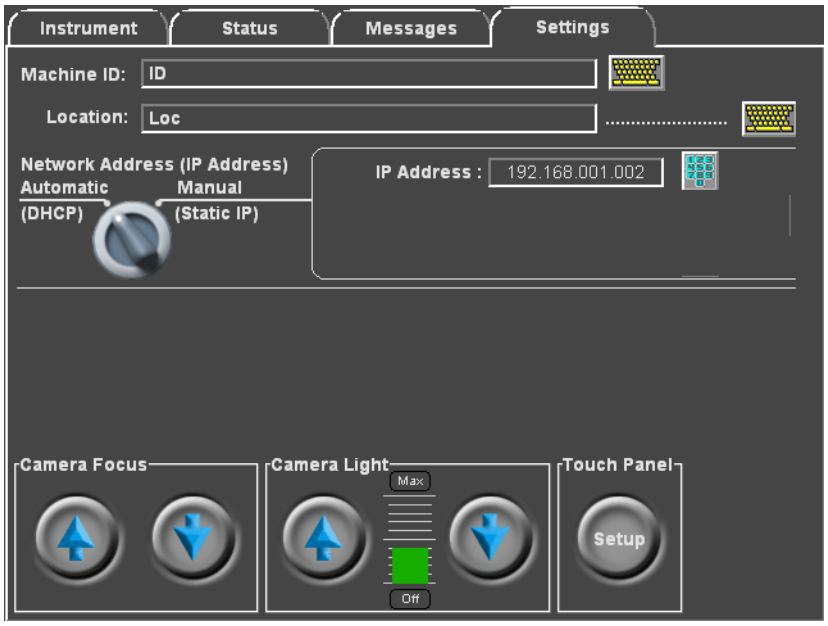

Figure 6 RSA-G2 Settings touch screen.

Linear Transducer

The RSA-G2 utilizes a Force Rebalance Transducer (FRT), shown below, to measure axial force generated by the sample.

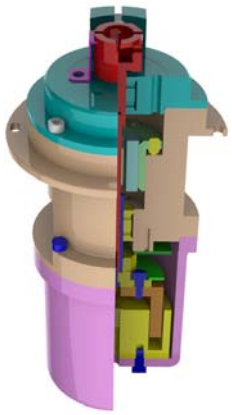

Figure 7 RSA-G2 linear transducer.

CAUTION: Force Rebalance Transducers contain a precision air bearing that is equipped with a bearing lock, which prevents movement of the air bearing when no air is applied. To avoid damaging your transducer, familiarize yourself with the operation of the bearing lock, and read the instructions carefully.

MISE EN GARDE: Les transducteurs de rééquilibrage de force contiennent un palier à air de précision équipé d'un verrou de palier qui empêchent le mouvement du palier à air lorsque l'air n'est pas appliqué. Pour éviter d'endommager le transducteur, familiarisez-vous avec l'utilisation du verrou de palier et lisez attentivement les instructions.

The FRT consists of an axial (normal force) servo control system. This system utilizes position feedback to maintain the axial FRT shaft in a null position all the time. When an axial force is applied to the FRT shaft, the servo control system responds by driving the required current through the axial force motor coil to maintain the shaft null position. The electrical current required to maintain this null position is proportional to the amount of axial force applied to the shaft. The current is converted to a voltage through a precision current sense resistor, and the voltage is measured and scaled to provide a force value. Selection and control of the force range is performed using the TRIOS software. Note that the maximum force measurable by the transducer is 3500 grams.

For axial force, full-scale measurements can be made in both the upward and downward directions. The weight of the shaft and tool does not reduce the measurement range in the downward direction.

The actuators (motor and transducer) contain a precision air bearing that is equipped with a bearing lock, which prevents movement of the air bearing when no air is applied. To avoid damaging your motor or transducer, familiarize yourself with the operation of the bearing lock and observe the following cautions:

- Do not unlock the bearing unless air is applied to the actuators.
- If the instrument will be moved or the air supply removed for an extended period of time, lock the actuators prior to removing air.
- If the air supply is interrupted while the actuators are unlocked, do not touch the anvil until air is restored.
- Maintain airflow to the actuators at all times to prevent contamination of the air bearing.

Failure to observe these cautions will result in damage to the actuators.

Linear Air Bearing Motor

The linear air bearing motor, also referred to as the *actuator*, deforms the sample by applying an axial strain to the sample. The motor combined with the step motor can be operated in dynamic (sinusoidal) mode or step strain and creep-recovery tests.

Figure 8 RSA-G2 linear air bearing motor.

Motor position is recorded using an LVDT feedback servo system. Frequency range is to 100 Hz, amplitude range to ±1.5 mm.

Bearing Lock

The motor and transducer each are equipped with a bearing lock to protect the delicate air bearings during shipping, and any other times when air cannot be supplied to the instrument. Retain the locks in case the test station needs to be moved, or in the event that the air supply will be removed for an extended period of time. Note that the motor cover must be removed to expose the threaded hole that is used to install the motor bearing lock.

Modular Power Supplies

The RSA-G2 uses a separate box that houses the instrument power supplies, controller, and a self-diagnostic display.

These stackable units are designed to sit on the floor, under your lab bench, leaving more room on the top of the bench for other uses.

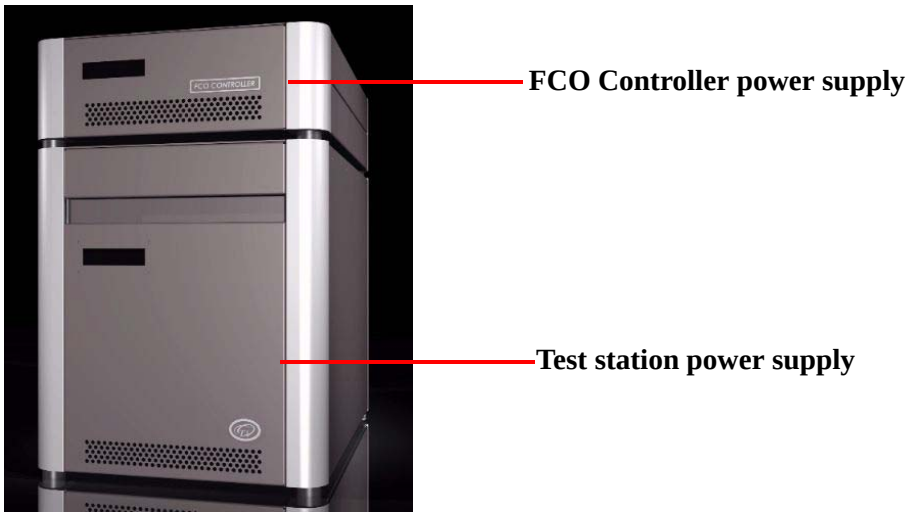

Figure 9 Stackable power supplies.

Environmental Control Unit

The FCO is the only environmental system available for use with the RSA-G2. There are two optional subambient controllers for use with the FCO: LN2 Controller and Gas Chiller.

Refer to the following sections for basic information regarding each specific environmental option. For more details, refer to the online help available in the TRIOS software.

NOTE: See TRIOS Help for installation information regarding all of the environmental control units.

Forced Convection Oven (FCO)

NOTE: For FCO installation instructions, refer to TRIOS software Help.

DANGER: Do not remove the outer or inner covers of the oven, as high voltage (200 VAC) exists inside the oven when the oven is on.

DANGER: Ne déposez pas les couvercles externes ou internes du four, en raison de la présence d'une tension élevée (200 VCA) dans le four lorsqu'il est allumé.

DANGER: Do not touch the outer cover when the oven is running, as the outer covers can get very hot. Only touch the FCO handle, if necessary.

When opening the oven to load samples, the heaters and the gas flowing through the heaters shut off. However, the geometries remain hot, as does the air around the sample area. Therefore, show care when loading and trimming your sample.

DANGER: Ne touchez pas le couvercle extérieur lorsque le four est en marche, car les couvercles extérieurs peuvent devenir très chauds. Ne touchez le manche du FCO que si c'est nécessaire.

Lorsque vous ouvrez le four pour la mise en place des échantillons, les réchauffeurs et le gaz qui s'écoule à travers les réchauffeurs s'arrêtent. Cependant, les géométries restent chaudes de même que l'air autour de la zone de l'échantillon. Par conséquent, soyez prudent lors de la mise en place et de l'ajustage de votre échantillon.

When running the oven above 450°C, make sure the special heat shield is installed on the transducer frame.

Lorsque le four fonctionne à plus de 450° C, assurez-vous que l'écran thermique spécial est installé sur le châssis du transducteur.

NOTE: Geometry baffles prevent heat from entering the transducer and motor areas. For optimum performance when running the FCO above 250°C, place the upper and lower geometry baffles outside the outer top and bottom covers of the oven, as shown below. Refer to TRIOS Help for additional information.

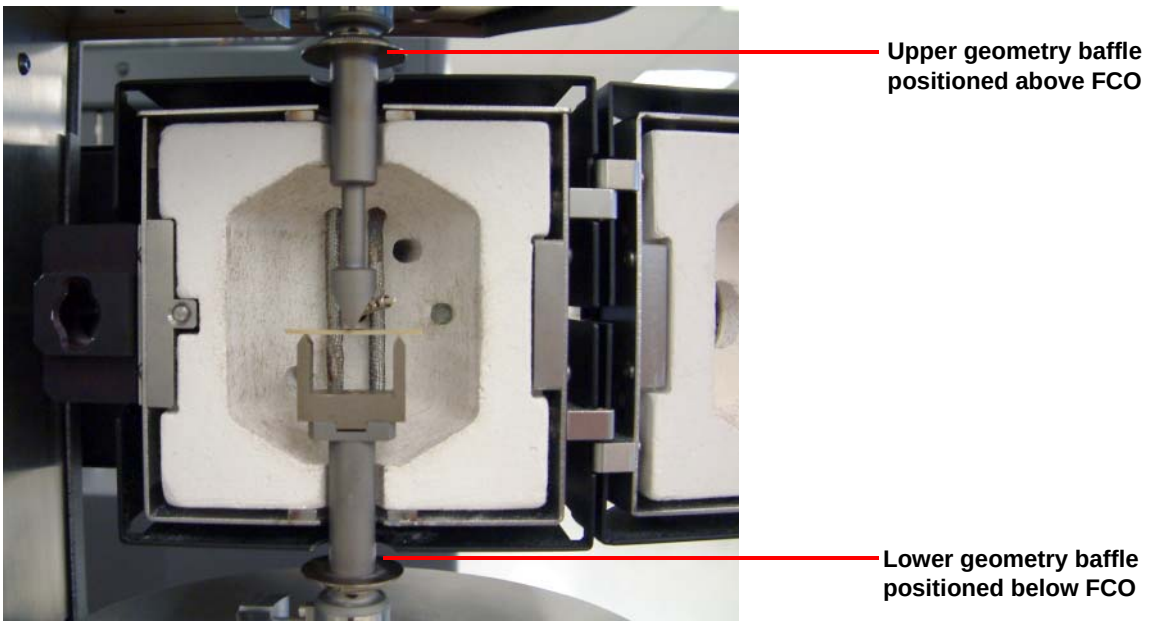

Figure 10 RSA-G2 geometry baffles positioned properly above and below FCO, with sample loaded.

CAUTION: Make sure the purge air is flowing when the oven is on. Failure to do so could cause damage to components inside the oven. The purge line connects to the back of the RSA-G2, to the port labeled OVEN PURGE.

MISE EN GARDE: Assurez-vous que l'air de drainage circule lorsque le four est en marche. Le non respect de cette précaution pourrait provoquer des dégâts sur les composants du four. La conduite de drainage se raccorde à l'arrière de l'RSA-G2, au port étiqueté DRAINAGE DU FOUR.

The oven is a forced convection environmental chamber that encloses the sample. Mounted in the oven are two resistive heaters, which are used to control the temperature of the gas flowing through them. During testing at or above ambient temperature, either air or nitrogen gas may be input to the heaters. If test temperatures must be extended to below ambient, the input to the heaters must be evaporated liquid nitrogen (LN2) supplied by the optional cryogenic LN2 Controller (or very cold gas supplied by the optional Chiller).

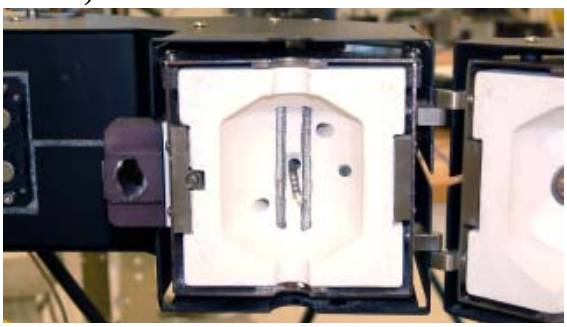

Figure 11 RSA-G2 Forced Convection Oven (FCO).

Table 1: FCO Specifications

Temperature range **with LN2 Controller** **with Chiller** **with ACS-3**	Ambient to 500°C without subambient controllers –150°C to 500°C* –50°C to 500°C* –100°C to 600°C
Heating rate	up to 60°C/min
Precision	±0.05°C
Stability	±0.1°C
Geometry compatibility	Oven is compatible with all RSA-G2 and RSA III geometries (except RSA III immersion geometry)
Optional accessories	LN2 Controller, Chiller, Camera

*The 500°C temperature testing is limited to two hours. Transducer may shut down if run for a longer time period.

The FCO has two forced gas gun heaters with counter-rotating air flow for a wide temperature range (ambient to 500°C) and maximum temperature stability. If you will be running at temperatures below ambient, either the optional LN2 Controller (operation to –150°C) or the ACS-3 chiller (operation to –100°C) can be used to extend the operational range of the oven. The FCO is recommended for measuring materials' viscoelastic properties changes with respect to frequency or temperature in either bending or tension/compression modes.

Oven Temperature Control

Oven temperature is maintained by a control loop that is closed around three platinum resistance thermometer (PRT) sensors located in the oven. The FCO may use up to three PRT sensors in order to control the temperature. These are:

- Mid-oven air PRT (used with solid-sample geometries)
- Upper air PRT (used for fast-response temperature control)
- Lower air PRT (used for fast-response temperature control)

Using the default system settings, the RSA-G2 reports and controls the measured temperatures using the mid-oven air PRT temperature.

Measured oven temperatures from all PRTs are compared to the set point temperature in the FCO controller, and heater power is changed to minimize the difference between the set point and measured temperatures. The oven uses faster responding air temperature measurements to stabilize rapid temperature changes in the oven, and uses the geometry or mid-oven air temperature measurements to precisely adjust the final oven temperature.

Subambient Controllers (Optional)

There are two optional subambient controllers for use with the FCO: LN2 Controller and Air Chiller.

LN2 Controller

CAUTION: The bulk tank must be a low pressure (22 psi/1.5 bars) source, as a high pressure tank will damage the LN2 Controller.

MISE EN GARDE: Le réservoir en vrac doit être une source de basse pression (22 psi / 1,5 bar), vu qu'un réservoir haute pression endommagerait le régulateur LN2.

NOTE: For LN2 Controller installation instructions, refer to TRIOS software Help.

The LN2 Controller uses liquid nitrogen to extend the lower range of the FCO to –150°C. The LN2 Controller is connected between an external liquid nitrogen source and the RSA-G2 test station. Controlled by the oven supply enclosure through the software, the LN2 Controller consists of a Dewar flask, a solenoid valve to control liquid nitrogen flow into the Dewar, and hardware to control the boiling of the liquid nitrogen to produce cold nitrogen gas within the flask. A second solenoid valve controls the flow of the nitrogen gas out of the Dewar flask for use by the test station, and a third solenoid valve provides for venting of the flask while it is filling and while in standby mode when there is no gas flowing through the FCO heaters.

Figure 12 LN2 Controller.

Table 2: LN2 Controller Specifications

Dimensions	28 cm (11 in) W x 24.1 cm (9.5 in) D x 55.9 cm (22 in) H
Weight	17.3 kg (38 lbs)
Temperature range	Extends lower range of oven to –150°C

Dewar Flask

A Dewar flask is a container specifically designed to efficiently store liquid nitrogen. Dewar flasks help prevent evaporation due to their double-wall construction. Within the Dewar flask, a heater immersed in the LN2 provides controlled boiling. The Dewar is equipped with two pressure relief valves to allow excess nitrogen gas to vent when the LN2 Controller is turned off.

ACS-3 and Chiller Panel

NOTE: For installation instructions, refer to the ACS-3 Getting Started Guide.

The ACS-3 is a unique three-stage air chiller system for subambient temperature control and general cooling of select instrumentation from TA. Supported instruments and environmental systems include the DMA Q800 with standard furnace (-100°C), Discovery Hybrid Rheometer models with Environmental Test Chamber (-85°C), and ARES-G2/ RSA-G2 with Forced Convection Oven (-100°C). The ACS-3 features low-noise durable compressors (approx. 55 dB), small footprint, uninterrupted operation, CFC-free, and for specified temperature ranges, eliminates the recurring cost and safety concerns associated with handling and use of liquid nitrogen. The ACS-3 requires an air supply at pressure of 7 bar (100 psi), flow rate of 300 l/min (4.6 cfm), and dew point of -40°C (-40°F), and appropriate instrument-specific Chiller Panel.

Figure 13 ACS-3.

The Chiller Panel is mounted to the side of the ACS-3. The Chiller Panel assembly contains all of the pneumatic and electronic components needed to filter, regulate, and control the compressed gas (air or nitrogen) that is supplied to the FCO.

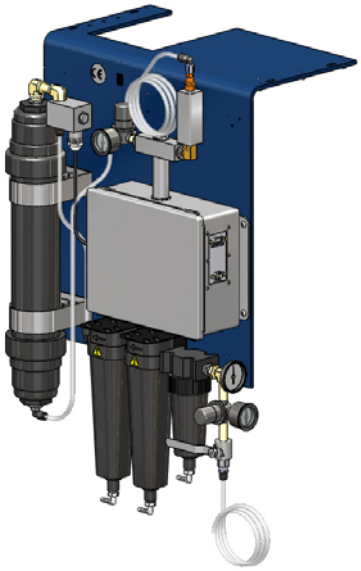

Figure 14 FCO Chiller Panel assembly before being mounted on Air Chiller.

Table 3: ACS-3 and Chiller Panel Specifications

Dimensions of Air Chiller (H x W x D): Without Chiller Panel With Chiller Panel	 112 cm (44 in) x 37 cm (14.5 in) x 56 cm (22 in) 112 cm (44 in) x 52 cm (20.5 in) x 56 cm (22 in)
Weight of Air Chiller Without Chiller Panel With Chiller Panel	 118 kg (260 lbs) 134 kg (295 lbs)
Dimensions of Chiller Panel	Height: 86.4 cm (34 in) Width: 48.3 cm (19 in) Depth:38.1 cm (15 in)
Weight of Chiller Panel	18.2 kg (40 lbs)
Lowest Temperature	ARES-G2/ RSA-G2 FCO: -100°C

RSA-G2 Accessories

The Camera (for use with an FCO only) allows for viewing of the sample at any point during an experiment. For additional information, refer to TRIOS Help.

Camera Accessory

CAUTION: To avoid potential damage to the camera, be sure that the air inlet tube and all electrical connections are properly connected.

MISE EN GARDE: Pour éviter des dégâts potentiels à la camera, assurez-vous que le tuyau d'arrivée d'air et tous les raccordements électriques sont correctement effectués.

NOTE: For Camera accessory installation instructions, refer to TRIOS software Help.

The FCO can be optionally equipped with a camera viewer with remote illumination and focusing. Used in conjunction with streaming video and image capture software, the camera displays real-time images in the software; an image is stored with each data point for viewing during or after a test. The FCO Camera viewer is an ideal tool for data validation.

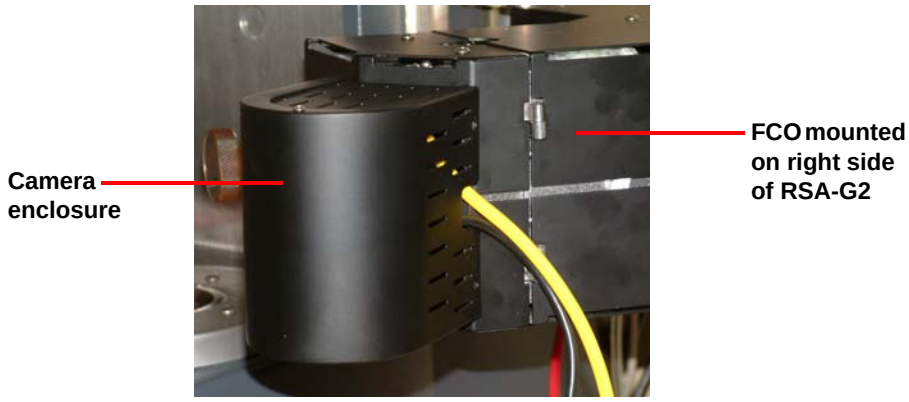

Figure 15 Camera accessory installed on FCO.

RSA-G2 Geometries

The test geometries are an important part of the sample testing procedure.

Although the physical properties of the sample generally dictate appropriate test geometry, it is sometimes possible to test a given sample using more than one geometry. Ideally, the test results should be identical in the different geometries. However, there exist experimental limitations that may make testing in one geometry preferable to testing in another. Additionally, factors such as anisotropy and differences in strain dependence may yield inconsistent results for different geometries.

Available Geometries

The following is a list of the geometries that can be used with the RSA-G2. Details for each geometry can be found in TRIOS software Online Help.

- Linear tension (rectangular/cylindrical)
- Compression (rectangular/cylindrical)
- Three-point bending
- Clamped bending (single cantilever, dual cantilever)
- Mixed bending (single, dual)
- Shear sandwich (rectangular/cylindrical)
- Immersion (tension, compression, three-point bending)
- Contact lens

For additional information regarding RSA-G2 geometries, refer to “Selecting and Installing a Geometry” on page 59.

Instrument Specifications

The table found below contains the technical specifications for the RSA-G2.

Table 4: RSA-G2 Technical Specifications

Item/Area	Specifications
Test station Power supply enclosure Oven supply enclosure	Depth 56 cm (22 in.) Width 46 cm (18 in.) Height 104 cm (39.37 in.) Depth 48 cm (19 in.) Width 32 cm (12.5 in.) Height 34 cm (13.5 in.) Depth 48 cm (19 in.) Width 32 cm (12.5 in.) Height 11 cm (4.5 in.)
Weight: Test station Power supply enclosure Oven supply enclosure	 104.5 kg (< 230 lbs) 12.7 kg (28 lbs) 6.8 kg (15 lbs)
Power: Test station Power supply enclosure Oven supply enclosure	 From power supply: 90 – 264 VAC, 16 amps max 180 – 264 VAC, 47 – 63 Hz, 13 amp max
Operating environmental conditions	Temperature: 15–30°C Relative humidity: 5–80% (non-condensing) Installation Category II Pollution degree 2 Maximum altitude: 2000 m (6560 ft) Minimum clearances of six inches from top and all sides, and eight inches from temperature control options.
TEMPERATURE SYSTEMS	
Forced Convection Oven (FCO)	–150 to 500°C (lower limit dependent on cooling device)
FCO Camera Viewer	Optional
Precision	±0.05°C
Stability	±0.1°C

Chapter: 2

Installing the RSA-G2

Unpacking/Repacking the RSA-G2

The instructions needed to unpack and repack the instrument are found as separate unpacking instructions in the shipping box and in the online documentation associated with the instrument control software. You may wish to retain all of the shipping hardware, the pallet, and boxes from the instrument in the event you wish to repack and ship your instrument.

Preparing the System

Before shipment, the RSA-G2 DMA is inspected both electrically and mechanically so that it is ready for operation upon proper installation. Only limited instructions are given in this manual; consult the online documentation for additional information. Installation involves the following procedures:

- Inspecting the system for shipping damage and missing parts.
- Choosing a suitable location.
- Connecting the RSA-G2 to a suitable air supply.
- Connecting all cables and lines.
- Connecting the RSA-G2 to the customer line voltage outlet.
- Connecting the RSA-G2 to the controller computer and network.

CAUTION: It is recommended that you have your RSA-G2 unpacked and installed by a TA Instruments Service Representative. Call for an installation appointment when you receive your instrument.

MISE EN GARDE: Il est recommandé que le dépotage et l'installation de votre RSA-G2 soient assurés par un représentant du service d'entretien de TA Instruments. Appelez pour prendre rendez-vous en vue d'une installation à la réception de votre instrument.

Inspecting the System

When you receive your RSA-G2, look over the instrument and shipping container carefully for signs of shipping damage, and check the parts received against the enclosed shipping list.

- If the instrument is damaged, notify the carrier and TA Instruments immediately.
- If the instrument is intact but parts are missing, contact TA Instruments.

Lifting/Moving the Instrument

The RSA-G2 is a very heavy instrument. Use three people to lift and/or carry the instrument. The instrument is too heavy for one person to handle safely. In order to avoid injury, particularly to the back, please follow the advice below.

1 Prepare the instrument for relocation as follows:

- **a** Remove all samples and geometries, as well as the Forced Convection Oven (if installed).
- **b** Turn off the power and all power cords and cables to the power supply.
- **c** Lock the motor and transducer.
- **d** Turn off the air/gas supply and disconnect all lines.

2 Remove the four corner plugs by pulling them straight out, as shown below. Retain the plugs for use after the instrument is moved.

3 Install the four carrying handles by screwing them into the threaded holes on all four corners, as shown below.

4 Follow the instructions on the next page, depending upon the method you are using to move the instrument, with a cart (recommended) or without a cart. If you are using a cart, you can move the instrument with two people. If you are not using a cart, three people are needed to move it.

Moving the RSA-G2 Using a Cart (Highly Recommended)

1 Obtain a cart that is wide enough to accommodate the instrument and able to support at least 250 lbs (114 kg). If possible, raise the cart until the top surface is level with your lab bench.

2 Position one person on the lighter side of the instrument (to the left as you face the instrument), and two people on the heavy side of the instrument (to the right as you face the instrument). Carefully slide the RSA-G2 onto the cart.

3 Wheel the cart to the desired location, slide the instrument onto the bench top, and remove the lifting handles.

Moving the RSA-G2 Without a Cart

When moving the RSA-G2 without a cart, you must have three people to perform the following procedure:

1 The handling points on the instrument are shown. Grasp the instrument at those points.

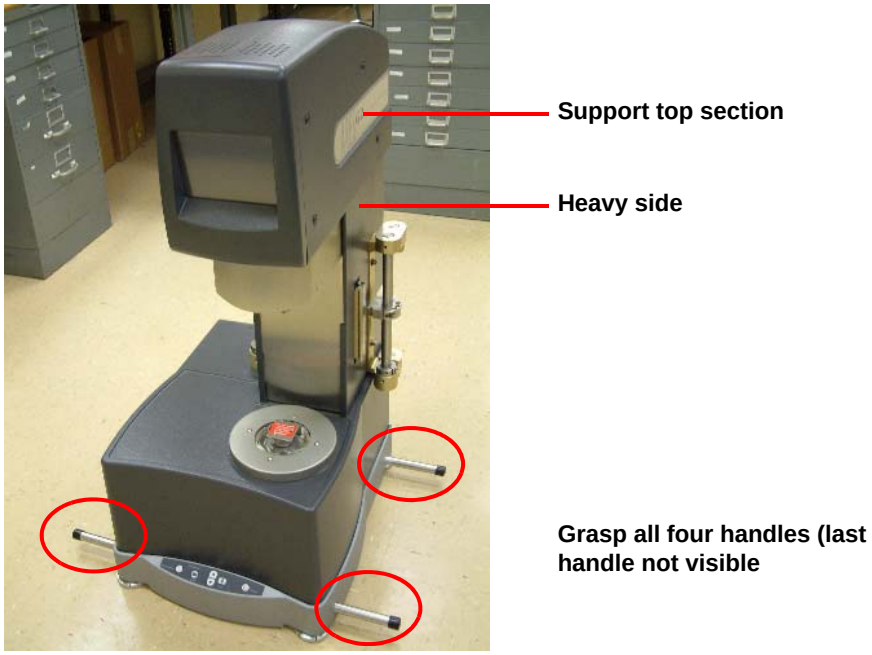

Figure 16 Instrument handling points (ARES-G2 shown).

2 Position one person on the lighter side of the instrument (to the left as you face the instrument), and two people on the heavy side of the instrument (to the right as you face the instrument).

3 Grasp the instrument as follows.

Light side: One person holds both lifting handles.

Heavy side: Each person holds one handle and puts free hand on the top section to support it.

4 Using proper lifting technique, lift and carry the instrument to the desired location.

5 When you have positioned the instrument at the desired location, remove the lifting handles and replace the corner plugs.

Choosing a Location

It is important to choose a location for the instrument using the following guidelines. The RSA-G2 should be:

In

- A temperature- and humidity-controlled area. Temperatures should be in range of 20 to 30°C.
- A clean, vibration-free environment, preferably on the ground floor in the building. It should be located away from pumps, motors, or other devices which produce vibrations.
- An area with ample working and ventilation space.
- An area that allows at least six inches of clearance on all sides of the equipment, and that allows a minimum of eight inches from the open and closed positions of all heated environment control systems.
- An area that does not restrict airflow to cooling fans on the rear of the power control box, or the option controllers.

On

- A stable work surface. **A marble table is recommended**. Isolation mounts on a standard lab bench are not recommended.

Near

- A power outlet. An RSA-G2 with an oven requires 180 to 264 VAC/50 or 60 Hz with a 20 amp outlet.
- Your TA Instruments TRIOS Instrument Control Software.
- Compressed lab air and purge gas supplies with suitable regulators and filters.

Away from

- Dusty environments.
- Exposure to direct sunlight.
- Direct air drafts (fans, room air ducts).
- Poorly ventilated areas.
- Noisy or mechanical vibrations.
- High traffic areas, where constant movements from passing personnel could create air currents or mechanical disturbances.

WARNING: Make sure there is no power going to the power supply unit while making the connections described in the sections below. If necessary, turn the power switch to the off position.

AVERTISSEMENT: Assurez-vous que le bloc d'alimentation électrique n'est pas alimenté en courant pendant le réglage des connexions décrites dans les sections ci-dessous. Si nécessaire, placez l'interrupteur d'alimentation sur la position d'arrêt.

TA Instruments recommends that you schedule a service technician to unpack and install your instrument. The instructions given here are provided for reference, if needed.

Connecting the Air Dryer

CAUTION: Read the installation, operating, and maintenance instructions that were supplied with your air dryer. Failure to properly operate and maintain your air dryer will result in extensive damage to this instrument.

MISE EN GARDE: Lisez les instructions d'installation, d'utilisation et de maintenance fournies avec votre déshydrateur d'air. L'utilisation et la maintenance inappropriées du déshydrateur d'air entraînent d'immenses dégâts sur l'instrument.

CAUTION: Excessive moisture in the air supply may damage the test station.

MISE EN GARDE: L'excès de moisissure dans l'alimentation en air peut endommager la station d'essai.

The dew point of the supplied air should be 10°C or lower. We highly recommend installing the optional air dryer/filter between the test station and the air supply. If your air supply has excessive moisture levels that result in immediate condensation, a pre-air dryer system is required. An oil-less compressor system is recommended as well.

The air source going into the dryer should have a minimum pressure of 80 psi (0.55 MPa). Follow the instructions below to install the air dryer.

1 Mount the air dryer to a wall in close proximity to the RSA-G2, allowing the lines to reach the back of the instrument. See the figure below.

Figure 17 Air dryer.

2 Connect the line from the filter to your air source.

3 Connect the outlet line from the regulator to the test station at the **Air** inlet port (see Figure 20 for its location). This is an input line to the test station that is used to supply air to the oven, motor, transducer air bearings, and throughout the test station.

4 Set the purge rate adjuster knob (shown below) to the setting number **2**.

Figure 18 Purge rate adjuster knob.

5 Turn on the air supply and use the pressure regulator knob to set the supply pressure to 80 to 90 psi (0.55 to 0.62 MPa).

Figure 19

Connecting the Test Station Ports

The ports and connections on the rear of the RSA-G2 are used to connect various components of the system to the instrument. This section describes these ports. All instructions are based on viewing the instrument from the rear. Refer to the Figure 20 as you make the connections.

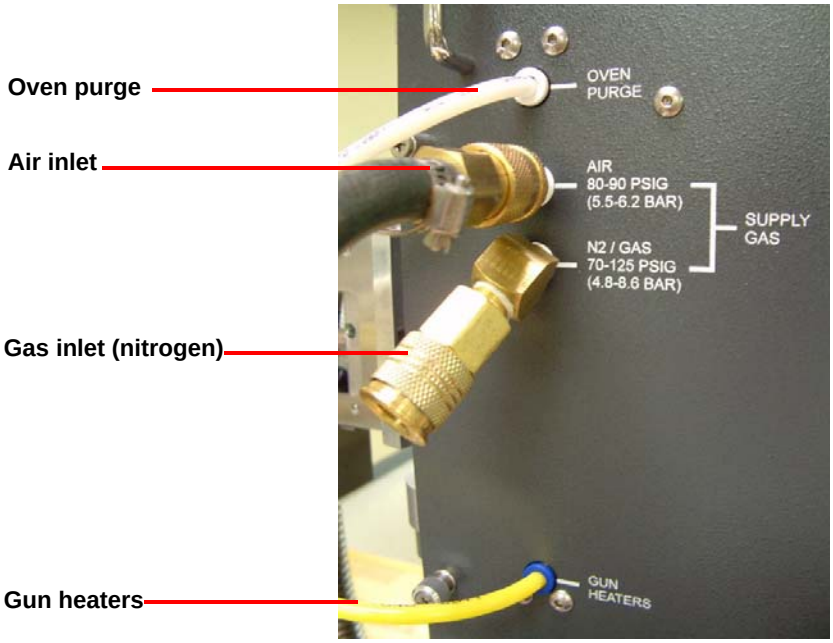

Figure 20 Gas ports on rear of RSA-G2.

- ***OVEN PURGE***: Provides dry gas input to the oven. The gas is circulated throughout the oven in order to maintain positive pressure and minimize frost when using the LN2 Controller.
- ***AIR inlet***: Connected to the (external) air dryer. This port is used to supply dry air to the oven, motor, transducer air bearings, and throughout the test station. The air supply pressure should be 80 to 90 psi (0.55 to 0.6 MPa).
- ***N2 / GAS inlet***: Connected to an external nitrogen (or other) inert gas supply. This port supplies nitrogen or another inert gas to the oven, thus allowing the gas to be used as the heating medium. Inert gas is used to keep a polymer sample from oxidizing and degrading. The gas supply pressure should be 70 to 125 psi (0.48 to 0.86 MPa).
- ***GUN HEATERS***: This is connected to the oven to provide pneumatic output from the test station to the oven. This port supplies the oven with air or N2 gas.

Gas Pressure Specifications

Air should be supplied to the RSA-G2 at 283.2 L/min (10 scfm) at a pressure of 80 to 90 psi (0.55 to 0.6 MPa). Gas connected through the **N2/GAS** port should be supplied at 70 to 125 psi (0.48 to 0.86 MPa) with a flow rate of 100 L/min.

Pressure to the various components should be preset to:

- Transducer: 40 psi (0.28 MPa)
- Motor: 40 psi (0.28 MPa)
- FCO heater air: 40 psi (0.28 MPa) with oven on.

Air Quality

It is critical that high quality, clean, dry air be supplied to the test station at all times. Any particles present in the air must be smaller than 5 microns. Since the motor and transducer use air bearings, larger particles in the air can easily damage the delicate high-precision bearing surfaces of these components. Damage to the bearing surfaces may result in faulty measurements, and if significant enough, the damage may require the replacement of the entire motor or transducer.

The dew point of the supplied air should be 10°C or lower. We highly recommend installing the optional air dryer/filter between the test station and the air supply. If your air supply has excessive moisture levels that result in the immediate condensation into water, a pre-air dryer system will be required. With air dryer installed the dew point drops to below –10°C.

Because of the critical nature of the air supplied to the instrument, and the potential for expensive damage through mishandling, we highly recommend that you inform your laboratory manager, or compressor maintenance personnel, of your instrument requirements in detail. You should also ask to be informed before any air supply interruption, or compressor maintenance, so that you can properly shut down and protect the test station. Typically after any compressor maintenance, there will be some residual particulates and moisture present in the supply lines. You should disconnect the air from the test station input (or air dryer) and purge the lines, before re-powering your instrument.

To quickly determine if there is an interruption in the air supply, we have found that it is helpful to install a pressure gauge before the air dryer. An oil-less compressor system is recommended as well.

Making the Test Station Purge Connections

Follow these instructions to connect the oven and the RSA-G2 test station. Refer to Figure 20 if necessary.

1 Locate the purge line going into the oven. Push this fitting into the port labeled **OVEN PURGE**. This is an output line from the test station that provides purge air to the oven.

2 Locate the line going to the oven's gun heaters. Connect this to the port labeled **GUN HEATERS**. This is an outlet line from the test station to supply the oven with air or N2 gas.

3 Connect your laboratory air dryer to the test station at the **AIR** inlet port. This is an input line to the test station that is used to supply air to the oven, motor, transducer air bearings, and throughout the test station. Make sure the supply pressure is set at 80 to 90 psi (0.55 to 0.6 MPa).

Connecting the Signal Panel

The signal panel is the input/output interface for electrical signals entering and leaving the RSA-G2 test station.

Upper Set of Signal Connections

Figure 21 displays the upper set of signal connections on the back of the RSA-G2.

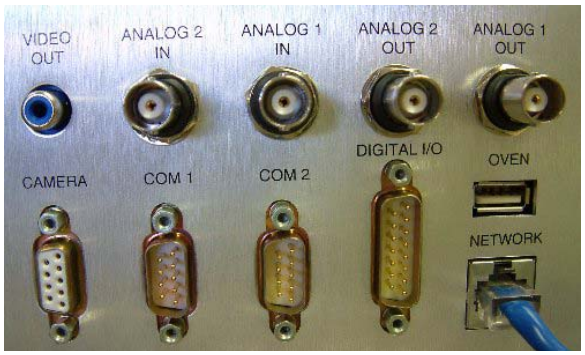

Figure 21 RSA-G2 upper signal panel.

The table below contains information regarding the upper set of signal panel connectors.

Table 5: Upper Signal Panel Connector Descriptions

Connector	Purpose
VIDEO OUT	Outputs the video signal from the RSA-G2 camera option to the controller computer for display.
ANALOG 1 IN	Accepts a ±10 VDC signal that can be sampled and stored in the experiment data file. This input is defined through TRIOS software.
ANALOG 2 IN	Accepts a ±10 VDC signal that can be sampled and stored in the experiment data file. This input signal is defined using TRIOS software.
ANALOG 1 OUT	A ±10 VDC signal that is defined using TRIOS software.
ANALOG 2 OUT	A ±10 VDC signal that is defined using TRIOS software.
CAMERA	Connection for the cable between the RSA-G2 test station and the camera located inside the FCO. This includes power, camera control signals, and camera output.
COM 1	A serial port output from the system CPU. This port is used for communication to an external circulator.
COM 2	A serial port output from the CPU. (For future use.)
OVEN	CAN bus connection to the FCO option.
DIGITAL I/O	TTL-compatible input and output signals and relay contact closures. They are defined using the TRIOS software.
NETWORK	Connection for communication between the RSA-G2 and the system network. (See "Connecting Cables and Lines" on page 41).

Lower Signal Panel Connections

The lower signal panel labels (shown below) are common between the ARES-G2 and RSA-G2. For the connections with two labels, the first label is applicable to the ARES-G2 and the second label is applicable to the RSA-G2.

The figure below identifies the lower set of connections on the ARES-G2/RSA-G2 signal panel.

Figure 22 RSA-G2 lower signal panel.

The table below contains information regarding the RSA-G2 lower signal panel connectors.

Table 6: Lower Signal Panel Connector Descriptions

Connector	Purpose
EXT USER IN	An external user input that can be connected to the internal strain measurement channel instead of the motor strain signal. (User selectable.) Input scaling is ±5 VDC
NORMAL IN	An external user input that can be connected to the internal normal measurement channel instead of the transducer normal signal. (User selectable.) Input scaling is ±5 VDC
HIGH V ENABLE	A relay contact closure that is used to enable the high voltage amplifier of the ER Accessory.
SPARE	Unused connection.
STRAIN OUT	Outputs a DC voltage that is proportional to motor strain. Scaling is ±5.0 VDC = ± Full Scale Strain
NORMAL OUT	Outputs a DC voltage that is proportional to motor strain. Scaling is ±5.0 VDC = ± Full Scale Force
COMMAND STRAIN	Outputs a DC voltage that is proportional to the actual motor defection. Scaling is ±10.0 VDC = ± Full Scale Command
DSP DAC	A general purpose ±10-volt analog output for future use that is derived from a digital-to-analog converter on the DSP board.

Connecting Cables and Lines

WARNING: Protect power and communications cable paths. Do not create tripping hazards by laying the cables across access ways.

AVERTISSEMENT: Protégez les chemins de câble électriques et de câbles de télécommunication. Ne créez pas de risques de déclenchement en posant des câbles sur les voies d'accès.

To connect the cables and gas lines, you will need access to the RSA-G2 rear panel. All directional descriptions are written on the assumption that you are facing the back of the instrument.

CAUTION: Connect all cables before connecting the power cords to outlets. Tighten the thumbscrews on all computer cables. Whenever plugging or unplugging power cords, handle them by the plugs, not by the cords.

MISE EN GARDE: Raccordez tous les câbles avant de connecter les cordons d'alimentation aux prises. Serrez les vis à serrage à main sur tous les câbles d'ordinateur. Chaque fois que vous branchez ou débranchez les cordons d'alimentation, tenez-les par les fiches et non par les cordons.

Connecting the Modular Power Supplies

Stackable power supplies are used with the RSA-G2 to house various printed circuit boards and electrical components. They provide power and communication with the instrument. Follow these instructions to connect the power supplies to the instrument and accessories.

Test Station (Lower) Power Controller

To connect the power supply, follow these steps:

1 Using the grip holds to move the test station power supply, place it on the floor close to the RSA-G2. Make sure you have access to the rear of the power supply and the RSA-G2. See the figure below. (The connections are already made in the figure.)

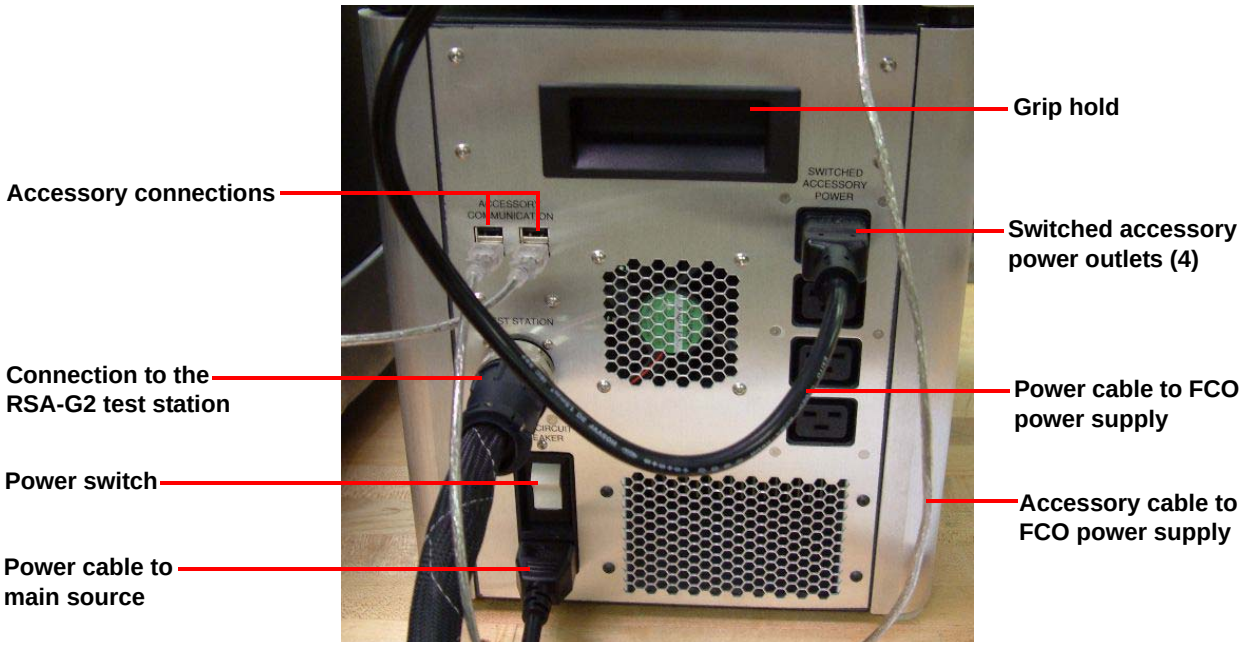

Figure 23 Test station power supply.

2 Obtain the accessory cable(s) from the accessory kit(s). Connect each cable to any of the four accessory connections. These will be connected to the upper power supplies (up to four upper power supplies can be connected).

3 Connect one end of the large multi-pin cable to the test station connector. The other end will be connected to the RSA-G2 test station later in this manual.

4 Plug in up to four accessory power cables to any of the switched accessory power outlets. These will be connected to the upper power supplies (from one to four upper power supplies can be connected).

5 Connect a power cable to the connector below the power switch, but do not connect this cable to the main power supply at this point.

6 Install any optional upper power supply units, such as the FCO or environmental control power supplies.

FCO Controller Power Supply

To connect the FCO power supply, follow these steps:

1 Place the FCO controller power supply on top of the test station (lower) power supply or on top of a previously installed environmental control power supply within the limit of the cable length. Make sure you have access to the rear of the power supply and the RSA-G2. See the figure below.

2 Obtain the loose end of one of the accessory cables that has already been connected to the lower power supply (see step 2 on the previous page), and insert it into the accessory port on the FCO power supply.

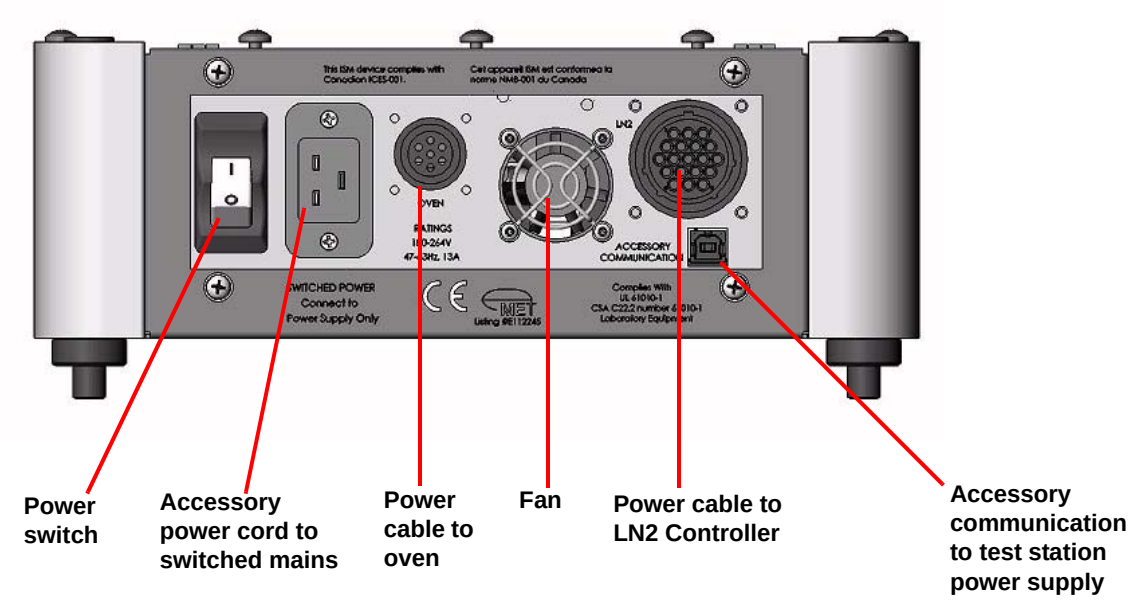

Figure 24 FCO controller power supply.

3 *Oven*: Connect the power cable from the oven to the connector to the left of the fan.

4 Obtain the loose end of one of the power cables that are already connected to a switched accessory power outlet on the lower power supply (step 4 in the previous section). Connect this to the power inlet next to the power switch on the FCO power supply.

5 Using the grip handles, position the power supplies as desired. (They may be placed on the floor or on the table top.)

6 Proceed to the next sections to connect the LN2 accessory and/or another power supply box, if applicable. **DO NOT switch on the power supply at this point.**

LN2 Controller Connection (optional)

1 Obtain the LN2 flex line from the LN2 accessory kit and connect between the LN2 Controller and a liquid nitrogen supply source (bulk tank). Bulk tank needs to be a low pressure (22 psi) source.

2 Obtain the LN2 transfer line.

3 Connect the elbowed end of the transfer line to the LN2 Controller.

4 Connect the opposite end of the transfer line to the FCO LN2 supply connection.

5 Connect the power cable from the LN2 Controller to the connector on the right side, above the communications port.

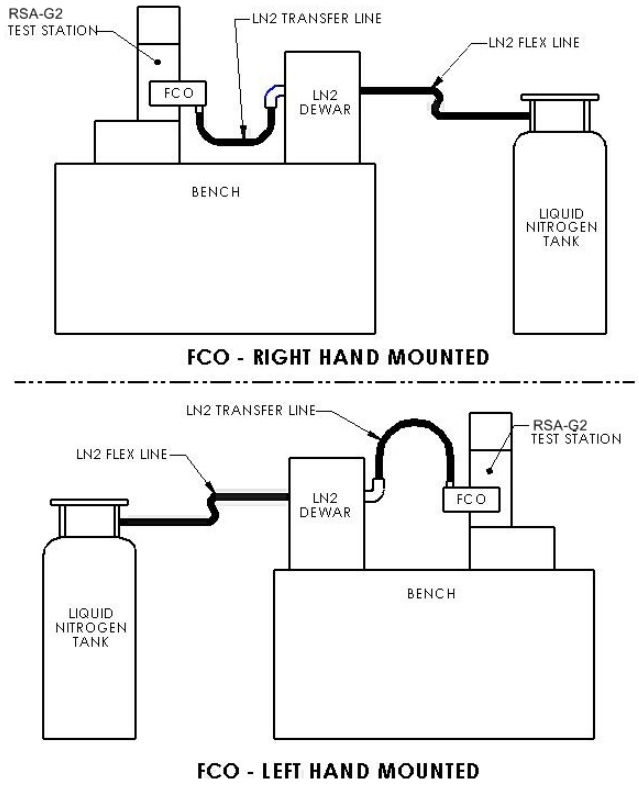

Figure 25 FCO left- and right-hand configurations.

Setting Up System Communication

The instrument and controller (computer) will be connected to a router. Make the cable connections described below to set up the router.

This section also covers how to connect the system to a LAN.

Figure 26 Router.

1. On the RSA-G2 touch screen display, press the **Display Settings** tab and ensure that the software knob is set for **DHCP**.
2. Using keyboard icons, enter the **Machine ID** and **Location**.
3. Power down the RSA-G2.
4. Make sure the host computer LAN is set for DHCP.
5. Ensure that TRIOS Instrument Control Software is installed on the controller computer.
6. Connect Ethernet cables to two of the router LAN ports. For this configuration, no connection is made to the routers WAN port.

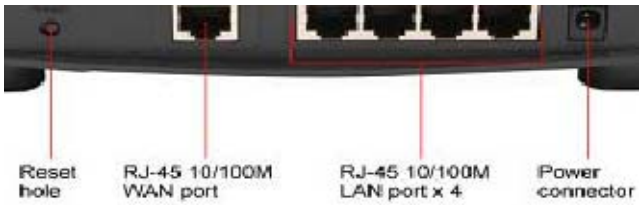

Figure 27 Router ports.

   a Connect one Ethernet cable to the RSA-G2 **NETWORK** port.

Figure 28 Ethernet connection.

   b Connect the other Ethernet cable to the host computer Ethernet port.

7 Connect the 12 V output from the router transformer into the router power port.

8 Connect the input from the router transformer into an AC outlet (100 to 240 VAC 50/60 Hz).

9 Power on the RSA-G2.

10 The power and two of the Ethernet LEDs light up on the Router.

11 Double-click on the TA Explorer icon on your controller desktop.

12 The RSA-G2 is recognized based on the Instrument ID.

13 Click on the instrument icon to establish communication between TRIOS software and the RSA-G2.

Connecting the Computer to LAN

If you wish to also connect the computer to a LAN, you will need to have already installed a network interface card.

1 Locate the second Ethernet port on the back of the computer.

2 Plug on end of the Ethernet cable into the company's Ethernet port.

3 Plug the other end of the Ethernet cable into the LAN.

4 Check the Ethernet port on the rear of the computer. If communication between the computer and the LAN has been properly established, a solid green light and flashing yellow lights will appear at the port.

Connecting Accessories

Follow the instructions in the associated manual or online help for instructions on connecting any accessories to the RSA-G2.

To install the various geometries, refer to TRIOS software Help.

Connecting the Test Station Power Cable

CAUTION: Before plugging the power cable into the wall outlet, make sure the instrument is compatible with the line voltage. Check the label on the back of the unit to verify the voltage.

MISE EN GARDE: Avant de brancher le câble d'alimentation dans la prise murale, assurez-vous que l'instrument est compatible avec la tension de la ligne. Consultez l'étiquette au dos de l'appareil pour vérifier la tension.

Once all cables and lines have been connected to the modular power supplies and the RSA-G2 test station, you can connect the power cable.

Install the power cable as follows:

1 Make sure the power switch on the lower power supply module is in the Off (O) position.

2 Plug the large, multi-pin cable from the lower power supply to the appropriate connection on the rear of the RSA-G2 test station, as shown in Figure 29.

3 Connect the grounding wire to the cabinet as shown in Figure 29.

4 Plug the power cord from the lower power supply module into the wall outlet.

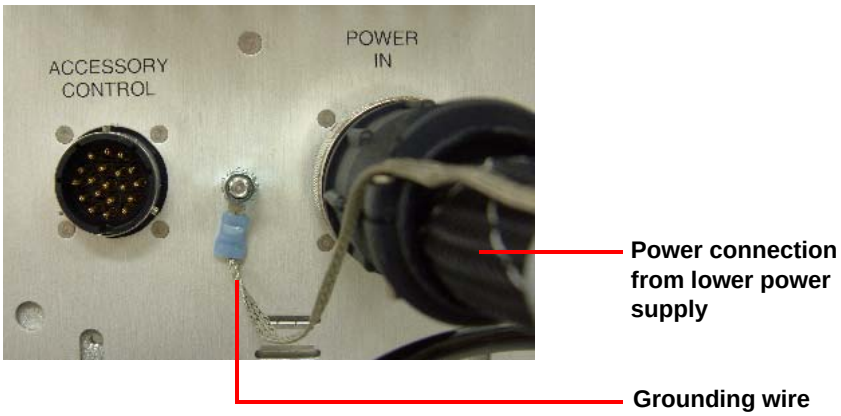

Figure 29 Power connection on the rear of the RSA-G2 test station.

Leveling the RSA-G2

The RSA-G2 is leveled using the feet, or levelers (shown below), located on each corner. Note that the right-rear leveler is fixed in position; **do not attempt to adjust this leveler**.

Clockwise rotation of the leveler extends it, raising the instrument at its location.

Counterclockwise rotation of the leveler retracts it, lowering the instrument at its location.

Figure 30 RSA-G2 leveler.

Follow the instructions below to perform this procedure.

1 Make sure that the air is on and the motor is unlocked.

2 Place the supplied bull's eye level on top of the motor mount.

Figure 31 Bull's eye level placed on lower geometry.

3 Retract all three (3) levelers by turning them counterclockwise until the instrument is lowered as far as possible.

4 **Left-to-right adjustment**: Viewing the level from the front of the instrument, extend the left-rear leveler until the level's air bubble aligns (left to right) with the circle on the glass face of the level.

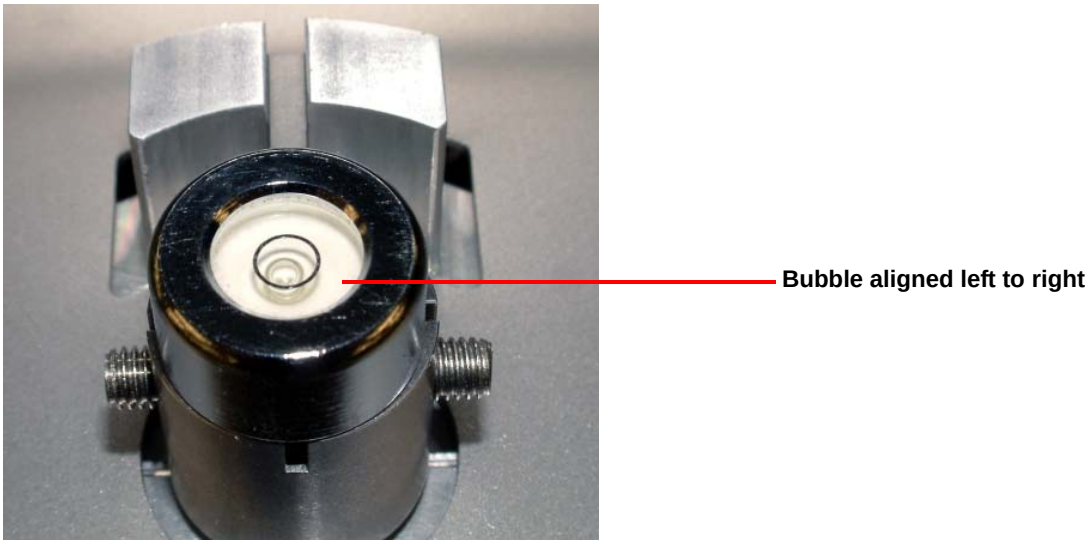

Figure 32 Air bubble left-to-right aligned.

NOTE: If left-to-right leveling is not possible due to the fixed right-rear foot on the instrument being below level, it is necessary to either shim the table to level or shim the instrument's fixed right back foot.

5 **Front-to-back adjustment**: If necessary, extend both front levelers until they just touch the table top.

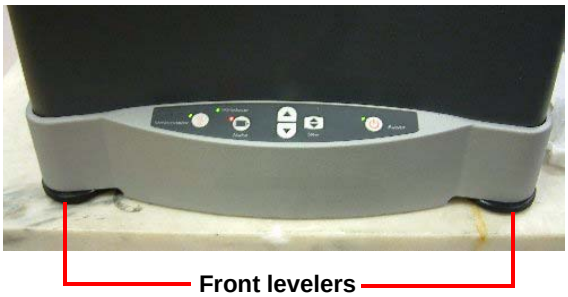

Figure 33 RSA-G2 front levelers.

6 **Front-to-back adjustment**: Turn the left-front leveler in either direction until the bubble is centered within the circle. Viewing the level from the left or right side of the instrument, extend both front levelers equally until the level's air bubble aligns (front to back) with the circle on the glass face of the level.

Figure 34 Air bubble front-to-back aligned.

NOTE: By extending both levelers in equal amounts, the left-to-right leveling that was performed in step 4 will not be disturbed.

7 Check both the left-to-right and front-to-back leveling. Repeat step 4 through step 6, if necessary.

Starting the RSA-G2

When all of the connections have been made between the test station, oven, power supplies, network, and any environmental system accessory; and the transducer and motor are unlocked, you can turn the power on.

NOTE: Ensure that the router is on first before powering on the RSA-G2; this is so an IP address can be generated for the RSA-G2.

1 If necessary, plug the power cord from the lower power supply module into the power source for the room.

2 Turn the power switch on the back of the lower power supply module to the On position (|). After this is done, the LED near the **Standby** button on the keypad should be solid red.

3 Press the standby button on the test station front panel (shown in the figure below). The instrument power status light blinks until the instrument comes up to full power. The light shows a steady green when the instrument is ready to be used. When the instrument is powered up, the motor becomes energized and automatically moves to its zero position. Do not impede its movement while this is happening.

See Chapter 3 for basic information on using the RSA-G2. For additional details, refer to TRIOS software Help.

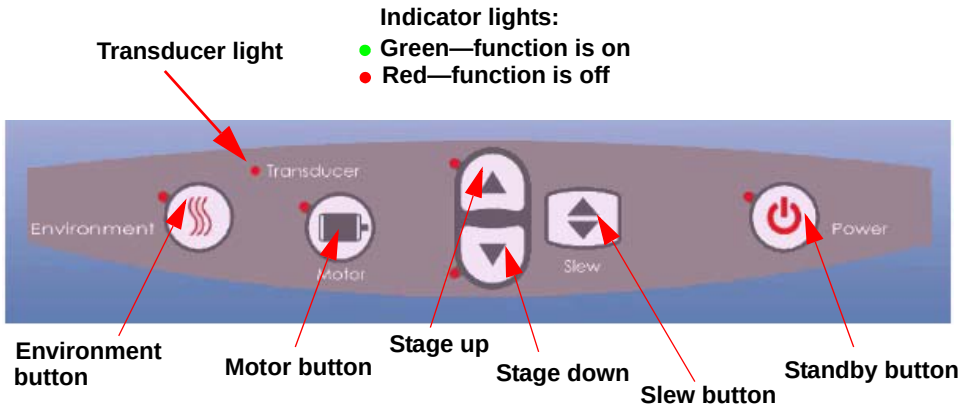

Figure 35 RSA-G2 keypad.

Shutting Down the RSA-G2

To shut down the RSA-G2, simply press and release the standby button on the front panel. This will safely power down the instrument as soon as the oven comes down to a safe operating temperature. At that point, the power shuts down and the power light turns red, indicating that the instrument is now in the standby state. Press and hold the standby button to cause the instrument to immediately go into the standby state.

Before switching the system to the standby state, all test sample materials should be removed from test fixtures, and the transducer should be moved into a position where the upper test fixture is not in contact with the lower test fixture. (When power is restored, the motor performs a calibration operation that requires free motor shaft displacement.)

If an error occurs that causes the instrument to not switch into the standby state, the standby button can be pressed continuously for 10 seconds to force an unconditional shutdown.

Powering "Off" the RSA-G2

If the instrument is expected to be disassembled for maintenance, disconnected from its compressed air source, or is being moved, then it is necessary to turn the power to the system completely off. Please follow these guidelines:

- A rocker switch/ circuit-breaker located on the lower part of the rear panel on the power controller removes all power from all components plugged into the power controller.
- Please make every effort to put the instrument into the "Standby" state before disconnecting power. Switching off the power while the system is operating may damage electronics or mechanical systems.
- Removing power from the system will cause some settings (specifically the Gap-Zero measurement) to be lost. It will be necessary to re-zero the test fixture after power is restored.
- Power should be turned off and the system unplugged from the mains-power-source if there is a reasonable expectation of a large electrical disturbance on the mains power source. (Severe weather, anticipated power outage, utility work, or anticipated extraordinary power-line transients.)
- Removing power from the system is not recommended as a daily practice; it is preferable to leave the system in its "Standby" state unless there is a specific reason to completely remove power.

Chapter: 3

Use, Maintenance, & Diagnostics

Using the RSA-G2

All of your RSA-G2 experiments will have the following general outline. In some cases, not all of these steps are performed. The majority of these steps are performed using the TRIOS Instrument Control Software. The instructions needed to perform these actions can be found in TRIOS online help; therefore, they will not all be covered in detail here.

- Calibrating the instrument.
- Selecting and preparing the sample.
- Selecting and installing the appropriate geometry for the desired test and sample.
- Creating or choosing the test procedure and entering sample and instrument information through the TRIOS Instrument Control Software.
- Loading the prepared sample.
- Starting the experiment.
- Displaying and analyzing results.

To obtain accurate results, follow all instructions carefully. For detailed information, refer to the online help through the TRIOS software.

DANGER: HIGH VOLTAGE is used in this instrument. DEATH ON CONTACT may result if operating personnel fail to observe safety precautions.

DANGER: Des tensions élevées sont utilisées dans cet instrument. Si le personnel d'exploitation ne respecte pas les précautions d'utilisation, il peut en résulter la MORT AU CONTACT de cet instrument.

Before You Begin

Before you set up an experiment, ensure that the RSA-G2, the environmental unit, and TRIOS software are installed properly. Make sure you have:

- Made all necessary cable connections from the RSA-G2 to the computer and to the modular power supplies.
- Connected all gas lines (air bearing and air cool).
- Connected your environmental units.
- Powered up the unit.
- Become familiar with the TRIOS software.
- Calibrated the RSA-G2, if necessary.
- Selected and installed a geometry.

Calibrating the RSA-G2

DANGER: Learn the areas of high voltage connections, and exercise care not to contact these areas when performing instrument calibration.

DANGER: Familiarisez-vous avec les zones des raccordements haute tension et faites preuve de prudence pour ne pas toucher ces zones lors de l'étalonnage de cet instrument.

To obtain accurate experimental results, calibrate the RSA-G2 upon initial installation. For the best results, you should recalibrate periodically. The calibration procedures that you need to perform vary. See the table below for a general guide to types of calibration. **For details on how to perform that calibration, refer to the online documentation accessed through the TRIOS software.**

The table below lists required tasks and the recommended interval for each task.

Table 7: Tasks and Recommended Intervals

Task	Interval
Geometry mass	Mandatory: During geometry creation (is a part of geometry configuration)
Phase angle and modulus check	Suggested: Monthly Mandatory: Following actuator or transducer replacement.
Force calibration	Suggested: Monthly Mandatory: Following transducer replacement

This section provides a brief description of each type of calibration. For the procedures needed to perform the calibration, refer to the online help accessed through the TRIOS software.

Geometry Mass

Geometry mass (weight) is an important parameter that enables the RSA-G2 to account for the effects of test geometry inertia at higher frequencies. The mass of the geometries are entered when configuring a geometry in TRIOS software. Some of the geometries' mass are listed in Table . For special or unknown geometries, obtain the mass through direct weighing with the RSA-G2 transducer, or perform the **Upper Fixture Mass Calibration** in TRIOS software. Refer to TRIOS Help for additional information.

Table 8: RSA-G2 Geometry Mass

Size (mm)	Type	Position	Mass (mg)	Compliance (mrad/N*m)
	3-pt bending	top	69	0
10	3-pt bending	bottom	84	0
15	3-pt bending	bottom	90	0
20	3-pt bending	bottom	97	0
	Cantilever bending	top	83	0
30	Cantilever bending	bottom	119	0
	Tension (film/fiber)	top	98	0
	Tension (film/fiber)	bottom	79	0
8	Compression (parallel plate)	top/bottom	82	0
15	Compression (parallel plate)	top/bottom	90	0
25	Compression (parallel plate)	top/bottom	92	0
2	Shear sandwich	top	77	0
1	Shear sandwich	top	79	0
0.5	Shear sandwich	top	82	0
	Shear sandwich	bottom	88	0
	Contact lens geometry	top	79	0
	Contact lens geometry	bottom	83	0

Phase Angle Check

To check the phase angle using the RSA-G2, perform a **Phase Angle and Modulus Check** in TRIOS software (refer to TRIOS Help for additional information).

The phase angle correction compensates for possible phase shifts that may be added to force and strain due to instrument electronics. Once the correction is determined, it should remain constant for the life of the system. The phase angle correction is computed and entered at the factory before the instrument is shipped, and should not have to be adjusted under normal operating conditions.

Phase angle is checked at the time of installation and is recommended to be rechecked once a year during a scheduled preventative maintenance visit. A 40-mm three-point bending geometry is required if you wish to periodically check the phase angle or perform a phase angle calibration outside of a scheduled preventative maintenance visit.

Recall that a purely elastic sample has a phase angle of zero degrees. The phase angle of steel is near zero. If the values obtained from this test are abnormal, please contact Technical Services for further assistance.

Force Calibration

Perform a **Force Calibration** using TRIOS software. Refer to TRIOS Help for additional information.

The force calibration ensures that the signal output by the transducer is properly scaled to normal force. Recall that the actual transducer output is a voltage that is proportional to the applied normal force. In order to correctly obtain a value for normal force, the software must convert from voltage to force using a conversion factor (calibration coefficient). The calibration coefficient is determined by observing the transducer output voltage while applying a controlled known force, and calculating the correct conversion factor to report the applied force. The calibration coefficient is then used by the software to compute true normal force during regular sample testing.

The calibration involves hanging precision weights on a calibration fixture, which is mounted on the transducer during calibration. The applied normal force is the amount of weight applied to the calibration fixture. For example, hanging a 2000 gram weight applies a normal force of 2000 gmf.

Selecting and Installing a Geometry

The sections below detail recommendations for selecting geometries, as well as procedures for installation.

General Recommendations

Although the physical properties of the sample generally dictate the appropriate sample geometry, it is sometimes possible to test a given sample using more than one geometry.

Ideally, the test results should be identical in the different geometries. However, there exist experimental limitations that may make testing in one geometry preferable to testing in another. Additionally, factors such as anisotropy and differences in strain dependence may yield inconsistent results for different geometries.

Recommendations for selection of a geometry based upon sample type are as follows:

- **Thin films**: Test thin films (such as magnetic recording tape) using the linear tension geometry.
- **Fibers**: Test fibers using the linear tension geometry.
- **Rubbers and other elastomers**: Below the glass transition, these samples are best tested using the clamped bending geometry. Above the glass transition, these samples can be tested in either compression using the compression (parallel plate) geometry, or in shear using the shear sandwich geometry.
- **Solid polymer bars**: These materials can be tested using either the clamped bending or three-point bending geometry for samples that are up to 4 mm in thickness and up to 12 mm in width.
- **Polymer melts**: Melts can be tested using the shear sandwich geometry or parallel plates, provided that the sample viscosity is high enough to prevent the material from flowing out of the tool.
- **High performance composites, ceramics, and metal bars**: These materials are best tested in a three-point bending geometry.
- **Foams**: Foams are best tested in either compression using the compression (parallel plate) geometry, or shear using the shear sandwich geometry.

Testing Limits and Compliance

The following factors limit the sample size that can be tested on the RSA-G2:

- Motor/transducer force and displacement ranges
- Sample compliance and stiffness
- Size of the test geometry

Transducer compliance and sample stiffness play a major role in the selection of sample size that can be accurately tested on the RSA-G2.

Definition of Compliance and Stiffness

For this discussion, we define *compliance* as displacement, in microns, per kilogram of applied force. Both transducer and sample exhibit compliance. *Stiffness* is the reciprocal of compliance.

Transducer compliance is the transducer shaft displacement resulting from force applied to the transducer. Shaft displacement is measured by a position sensor on the transducer shaft.

Sample compliance is sample displacement resulting from force applied to the sample. Sample stiffness denotes the force (kg) generated by displacement of the sample during deformation, per micron of sample displacement.

The RSA-G2 measures sample deformation (strain) by taking the difference between the motor and transducer displacement signals. The measurement is sensitive to limits in strain resolution, as well as variations in motor, and transducer, calibration and linearity. Under “ideal” conditions, the sample deformation is relatively large, and as such, the transducer displacement is much smaller than the motor displacement. The difference between the two (used to obtain sample displacement) is therefore a large number, and the relative error associated with the measurement is small. However, this error becomes significant when very stiff samples (low sample compliance) are tested, and the transducer displacement becomes close to the motor displacement. In this case, the difference between the two displacements is small, and the relative error is large, and of similar magnitude as the measurement.

This condition is indicated by the measured strain value being significantly smaller than the commanded strain value. **As a practical guideline, actual strain should be greater than 10 percent of the commanded strain.** If actual strain is much lower, the sample needs to be made less stiff by lengthening it and making it narrower and/or thinner. If necessary, change the geometry.

Sample compliance, or stiffness, is related to both the modulus and geometry of the sample. Since the modulus is, for the most part, fixed, the sample geometry is normally adjusted to obtain the desired sample compliance. It is critical that the sample compliance be within the operational range of the instrument otherwise inconsistent or incorrect results will be obtained.

Maximum and Minimum Sample Compliance

The sample geometry must be chosen such that, at the lowest temperatures (where the sample modulus is the greatest and the force generated the highest), the limitations of the transducer are not exceeded. Therefore, you should have a cursory knowledge of the range of both the modulus and the sample stiffness over the temperature range during testing.

The following guidelines offer recommended sample testing limits in terms of sample compliance.

- The minimum sample compliance that provides reasonably accurate data is 10 µm/kg. Below this value, the measured sample strain is subject to significant errors due to limits in the hardware transducer compliance correction.
- The recommended minimum sample compliance is 20 µm/kg, above which point the transducer compliance correction is sufficiently accurate to provide accurate strain measurements.
- The maximum sample compliance that can be accurately tested is (1500 µm) / (0.0001 kg) = 1.5e6 µm/ kg. This is based on the sample generating a force of 0.1 gm (the lower limit of the transducer measurement range) with a motor displacement of ± 1.5 mm in specs (the maximum dynamic strain amplitude).
- The recommended maximum sample compliance is 2e5 µm/kg.
- The key to selecting sample size is to ensure that, under all test conditions, sample compliance is greater than transducer compliance.

Table 9: Recommended Sample Sizes (Based on Geometries Used with an FCO)

Geometry	**Recommended Dimensions** (based upon physical limitations of test geometries)
Fiber monofilament Linear tension (cylindrical)	Length: up to 55 mm[1] (optimal length = 35–40 mm) Diameter: up to 0.5 mm
Film Linear tension (rectangular)	Length: up to 55 mm[1] (optimal length = 35–40 mm) Width: up to 12.7 mm (optimal width = 3–6 mm) Thickness: up to 0.8 mm
Clamped bending	Length: up to 50 mm Width: up to 12.7 mm Thickness: dependent upon complex modulus *E**
Compression (parallel plate)	Diameter: up to 25 mm Height: up to 25 mm
Shear sandwich	Length: up to 12.75 mm Width: up to 15.95 mm Thickness: 0.5, 1.0, or 2.0 mm
Three-point bending	Length: up to 40 mm Width: up to 12.7 mm Thickness: dependent upon complex modulus *E**

[1] 55 mm refers to the maximum actual length of the sample. This maximum sample length includes clamping of the sample, plus space in the FCO cavity to allow for a minimum amount of auto-tension to occur.

Basic Instructions for Geometry Installation

The following instructions provide general information for installing a geometry on the RSA-G2. Refer to TRIOS online help for further information.

General Guidelines

Following geometry installation, be certain to:

- Place the lower geometry on the motor shaft and tighten the set screws.
- Place the upper geometry on the transducer shaft, and tighten the set screws.
- Perform a geometry mass calibration following the instructions found in "Calibrating the RSA-G2" on page 56 or directly enter the mass when selecting or setting up the geometry in TRIOS software. The geometry mass calibration must be performed or entered the first time a new geometry is used. The software will store the geometries' mass for future use.
  NOTE: This calibration applies only to the geometry on the transducer shaft.
- Perform zero fixture before loading the sample. Refer to your specific geometry's TRIOS Help topic for additional information.

Follow these guidelines:

- When mounting the geometries, orient them so that the sample will be accessible to the sample PRT (mid-oven). For the most accurate sample temperature, the sample PRT should be moved to near the sample.
- Make sure that the sample PRT does not actually touch the sample (or geometry). Close the oven carefully until you are sure the sample PRT is adjusted properly. The alignment pins allow the geometries to be rotated in 90 degree increments. Often, rotating the geometry 90 degrees will place the sample in a position where the PRT can be placed close to the sample and not the geometry itself.
- While loading the sample onto the geometry, ensure that the sample is centered between the geometry mounting surfaces. Off-center loading may cause misalignment of the transducer/motor shafts, resulting in the appearance of an overload signal. Additionally, misalignment may also affect the accuracy of the data. If misalignment does occur, the sample should be removed from the geometry and carefully reloaded.
- When testing at temperatures below ambient temperature (or the temperature at which the sample was loaded), the clamps may loosen as they cool. This is due to difference in the thermal expansion coefficients of the sample and that of the geometries. Immediately prior to initiating testing at the lowest test temperature, you may wish to open the oven door and verify that the screws securing the clamps are tight, taking care not to touch any surface of the oven or geometries which may be at dangerous cryogenic temperatures. Axial force control should be used to maintain the integrity of clamped samples.

Installing the Upper Geometry

To install an upper geometry follow these steps:

1 Loosen the set screws on the transducer mount using the Allen wrench supplied in the geometry kit.

2 Obtain the desired geometry. Make sure there is no dirt or dust at the location surfaces for parallel and concentric alignment. Holding the geometry by the shaft, align the notch on the geometry with the slot on the transducer mount and insert the geometry into the transducer mount. Refer to Figure 36 for notch and slot locations. Hold the geometry in place.

3 While holding the geometry in place, tighten both set screws. The set screw head will move inward to hold the geometry in place. See the figure below.

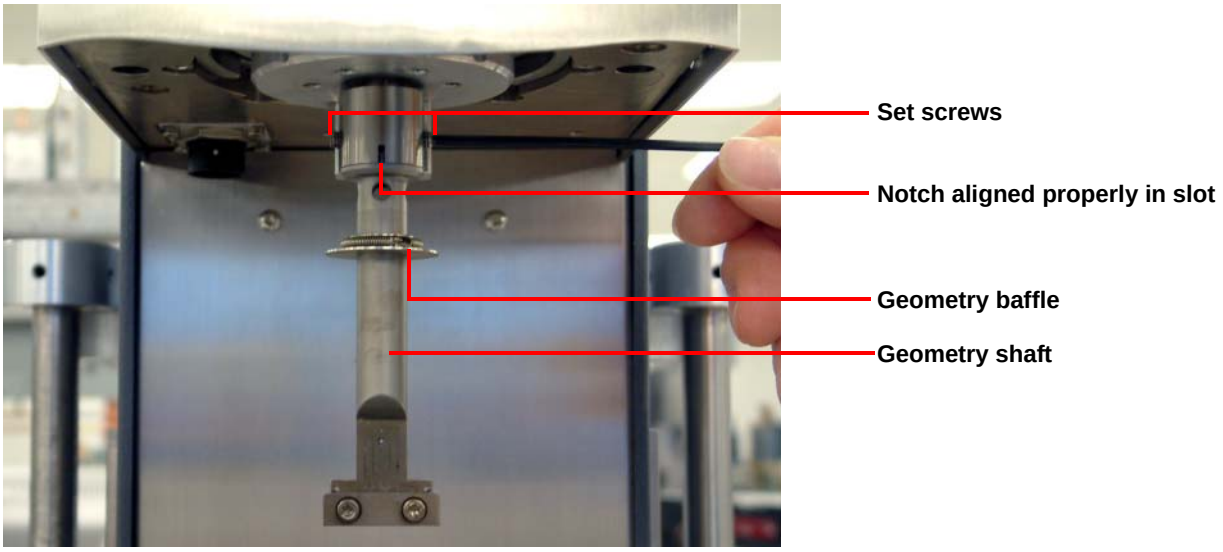

Figure 36 Upper geometry installed on RSA-G2.

Installing the Lower Geometry

Follow the directions below to install the lower geometry on the motor.

1 Loosen the set screws on the transducer mount using the Allen wrench supplied in the geometry kit.

2 Obtain the desired geometry. Make sure there is no dirt or dust at the location surfaces for parallel and concentric alignment. Holding the geometry by the shaft, align the notch on the geometry with the slot on the motor mount and insert the geometry into the motor mount. Refer to Figure 37 for notch and slot locations.

3 Tighten both set screws. The set screw head will move inward to hold the geometry in place. See the figure below.

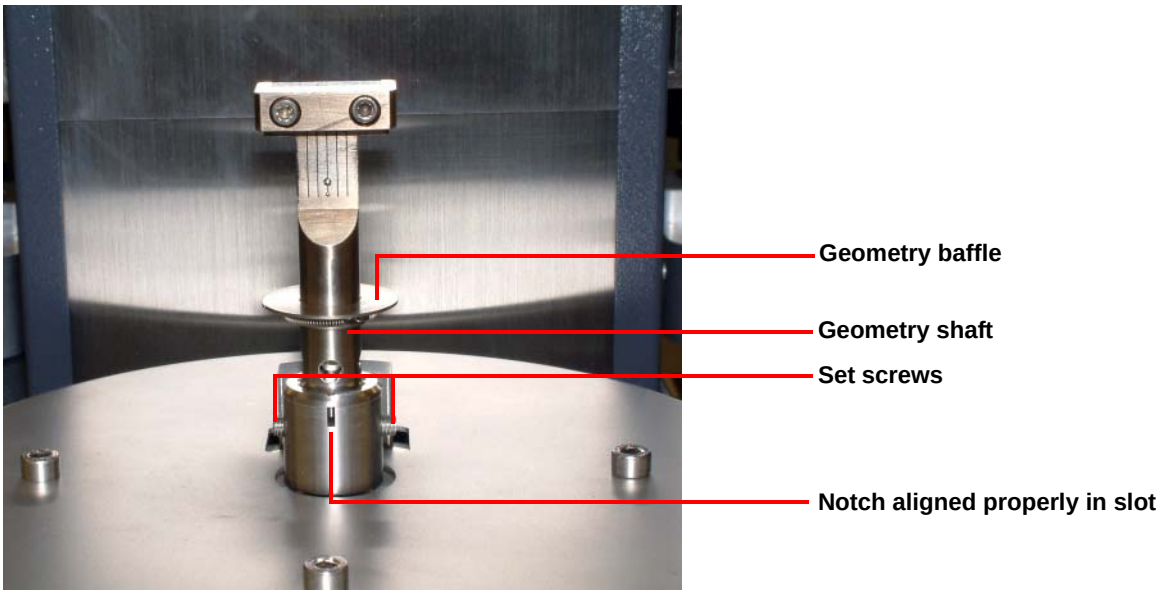

Figure 37 Lower geometry installed on RSA-G2.

Creating a Procedure

The RSA-G2 is capable of performing oscillation and step tests. These tests are organized under the following test types categories. (For detailed information, please consult the help available through TRIOS.)

- **Oscillation**: In oscillation experiments, the material is subjected to a sinusoidal shear deformation. The material functions that are obtained are dependent on frequency.
- **Step (Transient)**: A step test increments to a target value of stress (creep), strain (stress relaxation), or strain rate, and measures the response as a function of time.
- **Other**
    - **Axial**: Includes the linear/exponential motion of the stage or constant force on the sample for compressive or tensile testing on a sample.
    - **Arbitrary Waveform**: Allows defining the strain history used to deform the sample by supplying one or more analytical equations for strain, as a function of time.
    - **Temperature Ramp IsoForce**
    - **Temperature Ramp IsoStrain**

Running an Experiment

Once you have chosen and installed a geometry and loaded the sample into the RSA-G2, you will need to set up and run your experiment. This section provides basic instructions; for details on the steps involved, see the online help accessed through TRIOS software.

1 Select and install the appropriate geometry. If testing is to be done at temperatures other than ambient, install the geometry and then adjust the temperature to the desired initial value. Allow the geometry to reach thermal equilibrium.

2 Enter the desired sample information using TRIOS software.

3 Configure the selected geometry and create the desired experimental procedure.

4 Zero the gap between upper and lower test geometries.

5 Load the sample. The sample loading procedure depends upon geometry type being used; consult TRIOS Help for additional information.

6 If necessary, use Axial Force control to adjust the temperature, or wait for the sample to reach an equilibrium state.

7 Start the test.

Maintaining the Instrument

This section provides some basic maintenance procedures that you may need to use for your RSA-G2 instrument.

Cleaning Geometries

After you have finished testing your sample, open the oven (if used), raise the upper geometry and brush or wipe off the sample. Remove the geometry, if needed.

Routine Maintenance

A few maintenance procedures should be done on a regular basis to keep your instrument running safely and accurately.

Cable and Hose Inspection

Damage to the AC power cords can cause a safety hazard. Periodically inspect these items as follows.

AC Power Cords Inspection

Remove AC power to the instrument as follows:

1 Turn the power switch on the lower power supply module to the Off (O) position.

2 Remove the power cable leading to lower power supply module from the wall outlet.

3 Inspect all the cords for frayed insulation or exposed bare copper wire, especially in the immediate vicinity of the plugs on either end. If any damage is found, notify TA Instruments Service.

4 Apply AC power to the instrument as follows:

- **a** Ensure that the power switch on the lower power supply module is in the Off (O) position.
- **b** Plug the power cable from the lower power supply module into the wall outlet.
- **c** Turn the power switch on the lower power supply module to the On (|) position.

Air Hose Inspection

Remove AC power to the instrument as follows:

1 Turn the power switch on the lower power supply module to the Off (O) position.

2 Remove the power cable leading to lower power supply module from the wall outlet.

3 Lock the transducer and motor.

4 Remove air supply to instrument.

5 Inspect the air hoses for cracks and other damage that could result in leaks, especially in the vicinity of the bend radii. If any damage is found, notify TA Instruments for service.

If no leaks are found, apply AC power to the instrument as follows:

1. Establish airflow through the air dryer, but do not connect the air output to the test station. Allow the air to purge for 3 to 5 minutes.
2. Connect the air supply to the test station.
3. Unlock the transducer and motor.
4. Plug the power cable from the lower power supply module into the wall outlet.
5. Turn the power switch on the lower power supply module to the On (|) position.
6. Verify that the air pressure to the motor, transducer, and oven are correct.

NOTE: To verify the proper pressure setting for the FCO (**FCO Heater Air**), the FCO must be turned on. If the pressure is too low, the FCO turns off within a few seconds of being turned on, and the system displays a “low pressure” error message.

Internal Filter Inspection

There are also internal filters inside the test station that should be inspected and serviced on an approximately six month to a year basis. Only qualified service personal should perform this maintenance.

Air Dryer Inspection

Inspect and service the air dryer according to its manual. The two external filter cartridges mounted with the air dryer can be checked and changed. Make sure the moisture indicator is green. If it turns red, disconnect the air line, drain the filter bowls, and change the filter cartridges. Make sure the air dryer is set to **2**.

Power Supply Maintenance

The only maintenance procedure that you can perform for the power supply units is to use a vacuum to remove dust and debris from the fans on the rear of the units. Call TA Instruments if any other service is required.

LN2 and FCO Maintenance

There is a filter (P/N 613.02001) associated in the LN2 Controller hose that connects into the input of the controller. This filter removes any particle contaminants that may be introduced from the LN2 supply source. Unless there is a slow filling problem that could be attributed to a blocked or restricted inlet, it is usually not necessary to perform any periodic service on this filter, but periodic inspection is recommended.

To maintain LN2 Controller transfer line effectiveness, the LN2 controller should be run at cryogenic temperatures for at least one hour per month to ensure optimal performance. This maintains the level of vacuum in the transfer line which prevents the N2 gas from absorbing heat. Failure to do so will most likely result in the FCO losing its capacity to operate at the lower temperature limit.

Call TA Instruments if service is required.

Cleaning the Instrument

If the exterior plastic or metallic surfaces of the instrument require cleaning, use only a solution consisting of a non-abrasive household dish detergent and water.

Clean as follows:

1. Remove AC power to the instrument as follows:
   - **a** Turn the power switch on the lower power supply module to the Off (O) position.
   - **b** Remove the power cable leading to lower power supply module from the wall outlet.
2. Apply some cleaning solution onto a cotton cloth, then wring out the cloth to discharge excess water; the cloth must be damp, but not wet.
3. While ensuring that excess fluid from the cloth does not enter any crevice of the instrument, use the cloth to gently clean the desired external surfaces.
4. Ensure that all surfaces of the instrument are dry.
5. Apply AC power to the instrument as follows:
   - **a** Plug the power cable from the lower power supply module into the wall outlet.
   - **b** Turn the power switch on the lower power supply module to the On (|) position.

Cleaning the Touch Screen

Clean the touch screen as often as desired. Clean the touch screen with a household liquid glass cleaner and soft cloth. Wet the cloth (not the touch screen) with the glass cleaner, and then wipe off the touch screen and surrounding surfaces.

CAUTION: Do not use harsh chemicals, abrasive cleansers, steel wool, or any rough materials to clean the touch screen, as you may scratch the surface and degrade its properties.

MISE EN GARDE: N'utilisez pas de produits chimiques agressifs, de nettoyants abrasifs, de la laine d'acier ou tout autre matériau rugueux pour nettoyer l'armoire [écran tactile], car vous pourriez égratigner sa surface et dégrader ses propriétés.

Troubleshooting

See the online help accessed through TRIOS software for information on solving any problems that may develop.

Other than the routine maintenance listed in the previous section, there are no other repairs or service that you, as the customer, can perform. There are no customer-replaceable fuses in the RSA-G2.

Contact TA Instruments regarding service or repairs, as well as the availability of service contracts and plans.

Replacement Parts

Replacement parts for the RSA-G2 are listed below. Refer to the table below when ordering parts.

Table 10: RSA-G2 Replacement Parts

Part Number	Description
Replacement coalescing filter element	613.06404
Replacement particle filter element	613.06406
90-micron Nupro filter element	613.02001

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