AR-G2/AR 2000ex/AR 1500ex

Rheometers

Getting Started Guide

Revision R Issued January 2011

Notice

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
- TA Instruments Patents
- Other Trademarks
- TA Instruments End-User License Agreement
- TA Instruments Offices

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.

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

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

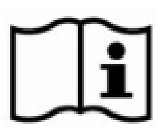
Do not attempt to service this instrument, as it contains no user-serviceable components.

Required Equipment

While operating this instrument, you must wear eye protection that either meets or exceeds ANSI Z87.1 standards. Additionally, wear protective clothing that has been approved for protection against the materials under test and the test temperatures.

Instrument Symbols

The following label is displayed on the instrument for your protection:

Symbol	**Explanation**
	This symbol on the AR-G2 indicates that you should read this Getting Started Guide for important safety information. This guide contains important warnings and cautions related to the installation, operation, and safety of the 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.
	This symbol indicates that you are advised to consult this manual for instructions.

Please heed the warning labels and take the necessary precautions when dealing with these areas. This *Getting Started Guide* contains cautions and warnings that must be followed for your own safety.

Warnings

WARNING: This equipment must not be mounted on a flammable surface if low flashpoint material is being analyzed.

WARNING: An extraction system may be required if the heating of materials could lead to liberation of hazardous gasses.

WARNING: It is recommended that this instrument be serviced by trained and skilled TA Instruments personnel at least once a year.

WARNING: The material used on the top surface of the Peltier Plate is hard, chrome-plated copper and the material used for the 'skirt' of the Peltier is stainless steel. Therefore, use an appropriate cleaning material when cleaning the Peltier Plate.

WARNING: The internal components of the ETC are all constructed from chemically resistant materials, and can therefore be cleaned with standard laboratory solvents. The only exception is the cladding for the thermocouples, which should not be immersed in a solvent for long periods. Use a small amount of solvent on a soft cloth and wipe the soiled area gently. This procedure should never be conducted at any temperature other than ambient.

WARNING: During the installation or reinstallation of the instrument, ensure that the external connecting cables (i.e., data, RS232 etc.) are placed separate from the mains power cables. Also, ensure that the external connecting cables and the mains power cables are placed away from any hot external parts of the instrument. Note: Ensure that the mains power cable is selected such that it is suitable for the instrument that is being installed or reinstalled, paying particular attention to the current rating of both the cable and the instrument.

WARNING: During operation, extreme hot or cold surfaces may be exposed. Take adequate precautions. Wear safety gloves before removing hot or cold geometries.

WARNING: Liquid nitrogen can cause rapid suffocation without warning. Store and use in an area with adequate ventilation. Do not vent liquid nitrogen in confined spaces. Do not enter confined spaces where nitrogen gas may be present unless the area is well ventilated. The warning above applies to the use of liquid nitrogen. Oxygen depletion sensors are sometimes utilized where liquid nitrogen is in use.

WARNING: The various surfaces and pipes of the ETC and the supply Dewar can get cold during use. These cold surfaces cause condensation and, in some cases, frost to build up. This condensation may drip to the floor. Provisions to keep the floor dry should be made. If any moisture does drip to the floor, be sure to clean it up promptly to prevent a slipping hazard.

WARNING: Always unplug the instrument before performing any maintenance.

WARNING: No user serviceable parts are contained in the rheometer. Maintenance and repair must be performed by TA Instruments or other qualified service personnel only.

WARNING: This instrument must be connected to an earthed (grounded) power supply. If this instrument is used with an extension lead, the earth (ground) continuity must be maintained.

WARNING: Take adequate precautions prior to heating of materials if it can lead to explosion, implosion or the release of toxic or flammable gases.

WARNING: The impeller is constructed from a rigid polymer composite material of density about 1.6 g cm-3. It he usual operating angular speed is 160 revolutions per minute, rpm, (16.76 radians per second). Under these conditions the unit is unlikely to provide a significant hazard to the user, and only the normal precautions observed when operating the rheometer need be taken.

The instrument software does permit operation of the rheometer at its maximum angular speed, without immersion of the impeller. Take reasonable precautions to avoid contact with the impeller when it is rotating at high angular speed. Ensure that clothing, jewelry, etc. does not become entangled in the impeller.

Electrical Safety

Always unplug the instrument before performing any maintenance.

Supply voltage: 110 to 230 VAC

Fuse type: 2 x T15A H250 V

Mains frequency: 50 to 60 Hz

Power: 1.4 kW

DANGER: Because of the high voltages in this instrument, maintenance and repair of internal parts must be performed by TA Instruments or other qualified service personnel only.

Liquid Nitrogen Safety

Potential Asphyxiant
WARNING: Liquid nitrogen can cause rapid suffocation without warning. Store and use in an area with adequate ventilation. Do not vent liquid nitrogen in confined spaces. Do not enter confined spaces where nitrogen gas may be present unless the area is well ventilated. The warning above applies to the use of liquid nitrogen. Oxygen depletion sensors are sometimes utilized where liquid nitrogen is in use.

Extremes of temperature
During operation, extreme hot or cold surfaces may be exposed. Take adequate precautions.
Wear safety gloves before removing hot or cold geometries.

Handling Liquid Nitrogen

The ETC uses the cryogenic (low-temperature) agent, liquid nitrogen, for cooling. Because of its low temperature [–195°C (–319°F)], liquid nitrogen will burn the skin. When you work with liquid nitrogen, use the following precautions:

- Liquid nitrogen evaporates rapidly at room temperature. Be certain that areas where liquid nitrogen is used are well ventilated to prevent displacement of oxygen in the air.
- Wear goggles or a face shield, gloves large enough to be removed easily, and a rubber apron. For extra protection, wear high-topped, sturdy shoes, and leave your trouser legs outside the tops.
- Transfer the liquid slowly to prevent thermal shock to the equipment. Use containers that have satisfactory low-temperature properties. Ensure that closed containers have vents to relieve pressure.
- The purity of liquid nitrogen decreases as the nitrogen evaporates. If much of the liquid in a container has evaporated, analyze the remaining liquid before using it for any purpose where high oxygen content could be dangerous.
- The oven inner doors have a trough around the bottom of the element assembly for collection of excess liquid nitrogen. Any excess fluid collected will drain out from the oven at the lower outer edge.

If a person is burned by liquid nitrogen:

1. IMMEDIATELY flood the area (skin or eyes) with large quantities of cool water, then apply cold compresses.
2. If the skin is blistered or if there is a chance of eye infection, take the person to a doctor IMMEDIATELY.

Chemical Safety

- Do not use hydrogen or any other explosive gas with the ETC.
- Use of chlorine gas will damage the instrument.
- If you are using samples that may emit harmful gases, vent the gases by placing the instrument near an exhaust.

Usage Instructions

Before connecting the rheometer to auxiliary equipment, you must ensure that you have read the relevant installation information. Safety of the rheometer may be impaired if the instrument:

- Shows visible damage
- Fails to perform the intended measurements
- Has been badly stored
- Has been flooded with water
- Has been subjected to severe transport stresses.

Maintenance and Repair

CAUTION: Adjustment, replacement of parts, maintenance and repair should be carried out by trained and skilled TA personnel only. The instrument should be disconnected from the mains before removal of the cover.

WARNING: The cover should only be removed by authorized personnel. Once the cover has been removed, live parts are accessible. Both live and neutral supplies are fused and therefore a failure of a single fuse could still leave some parts live. The instrument contains capacitors that may remain charged even after being disconnected from the supply.

This page is intentionally blank.

Table of Contents

This page is intentionally blank.

Chapter 1:

About the AR Series Rheometers

Overview

This chapter reviews the history of rheology, and traces the development of combined motor and transducer (CMT) rheometers. The AR-G2, AR 2000ex, and AR 1500ex are introduced, and brief descriptions of their main components and accessories are given. Please read this chapter carefully to familiarize yourself with the terminology used throughout this manual.

A Brief History of Rheology and the Development of CMT Rheometers

In 1929, Professor Eugene Bingham, a physical chemist working at Lafayette College in Pennsylvania, decided that the study of the deformation and flow of matter was important enough to merit its own title. On the advice of a Professor of Classics, he coined the term “rheology”, from the Greek rew (rheo) meaning flow. But the discipline of rheology is much older than the word. The first formal scientific description of a rheological phenomenon appeared in Isaac Newton's Principia Mathematica, published in 1687, where he suggested that “the resistance which arises from the lack of slipperiness of the parts of [a] liquid, other things being equal, is proportional to the velocity with which the parts of the liquid are separated from one another.” Today we would say that the shear stress is proportional to the shear rate, and we would call the constant of proportionality the viscosity of the liquid. As we now know, Newton's postulate applies only to a limited class of low molecular weight liquids, over finite ranges of shear rate or stress. Rheology is usually more concerned with materials whose behavior is non-Newtonian, in that their viscosity is a function of shear rate or stress. Such materials include polymers, paints, inks, creams, gels, shampoos, drilling fluids, adhesives, and many foodstuffs.

It seems that Newton conducted no experimental work on the viscosity of liquids, and it was not until the middle of the nineteenth century that work in that area was led by Poiseuille. The operating principle of most of the early viscometers, including Poiseuille's, was that the fluid was driven by pressure or gravity through a capillary or other constriction, and the rate of flow measured. Devices of this design are still in use today, but, although they may have the advantage of simplicity of construction and operation, they have the drawback that the sample can only be subjected to a finite strain.

However, a great step forward was made in the 1880's when the rotational viscometer was introduced by Couette and others. In this type of device, the sample is situated either in the annular gap between two concentric cylinders, as in Couette's original design, or in the gap between two concentric, horizontally mounted, parallel platens. One of the cylinders or platens (the stator) is fixed, the other (the rotor) is rotated, and provided that the rotation can be permanently maintained, there is no limit to the strain that the sample can be subjected to. In Couette's design, the outer cylinder was fixed, the inner was driven by a weight connected to it through a series of pulleys. The angular velocity of the rotating cylinder was calculated from the time taken for the weight to fall. This design is interesting for two reasons, one being that it was the stress that was controlled (through the weight) rather than the strain or strain rate, the other being that actuator and detector were mounted on the same axis. It happens that the first of these gave rise to the term used to describe the successors to this type of viscometer: “controlled stress”. They might alternatively have been described by the second as “combined motor and transducer” (CMT). This term is now preferred, since modern rheometers can operate in both controlled stress and controlled rate modes.

It was many years before an electrically driven version of Couette's CMT apparatus was developed. The next major advance in rheological instrumentation was introduced by Weissenberg in the 1940's. Weissenberg's intention was to investigate the viscoelasticity of polymer melts and solutions, but the viscometers that existed at the time were not suitable for this study. This led to the next advance in instrumentation.

The study of elasticity parallels closely the study of viscosity. The first scientific reference to elasticity was made by Robert Hooke, a correspondent and rival of Newton's, who published his famous anagram “CEIINOSSITTUU” in 1676, revealed as “ut tensio sic uis" (as the extension, so the force) in 1679. Hooke's Law, as it came to be called, was supported by experimental observation, but it was not until the work of Young in the early nineteenth century that it was realized that the law could be applied to material properties, rather than simply to extensive sample properties. In modern terminology, we would summarize Young's findings by saying that the strain is proportional to the stress, and we would refer to the “constant of proportionality” as the “modulus of the material.” Later in the nineteenth century, the work of Maxwell, Voigt, Kelvin, Boltzmann and others showed that the distinction between viscous liquids and elastic solids was not as clear as had previously been thought. Most of the materials listed above as non-Newtonian, are also viscoelastic, in that they exhibit aspects of both types of behavior. (The names of the scientists who contributed to the development of rheology reveal its importance: Einstein was also involved, and rheologists like to say that in their discipline Newton, Maxwell and Einstein did the easy bits.)

To conduct his investigation into polymer viscoelasticity, Weissenberg developed the first modern, electrically driven, rheometer during the early 1940s, the basis of which was a lathe turned on its end. As such it differed in two very significant ways from the Couette viscometers, firstly in that it was what later became called a controlled rate rheometer, and secondly in that the actuator and detector were mounted on separate axes. To adopt the principle of naming used above, this can be called the “separate motor and transducer” (SMT) design. The principle of operation was that one of the platens of the measuring system was rotated at a set angular speed, the torque transmitted by the sample being measured at the other platen. Weissenberg called his instrument a “Rheogoniometer”, since both the torque and the axial force could be measured, the latter being used to calculate the normal stress which results from the elasticity of the sample. In the late 1940s the rheogoniometer was commercialized, but its price was beyond the range of most materials testing laboratories. In 1970 Chris Macosko and Joe Starita formed the Rheometrics company (later renamed Rheometric Scientific) to produce a lower cost alternative, and launched the first of a long line of high quality SMT rheometers that led eventually to the modern ARES. Rheometric Scientific was acquired by TA Instruments in January 2003, and its products continue to be manufactured and developed.

In the meantime, interest revived in CMT instruments, partly because of a desire to perform creep tests, and partly because of the need to investigate the phenomenon of the yield stress in more detail, for which the available SMT rheometers lacked the sensitivity. To these ends, Jack Deer, who was employed as a technician at the London School of Pharmacy, designed a rotational rheometer based on the Couette viscometer, but with the weight replaced, originally by an air-turbine drive, and later by a drag cup motor (both shown in Figure 1). To reduce the friction in the instrument, an air bearing was introduced. Deer's first published description of the instrument appeared in 1968 [Davis, Deer and Warburton, J. Sci. Instr. 2, 933-936, 1968]. He began to commercialize it shortly afterwards. In the early 1980's the design was taken up by the Carri-Med company, at Deer's instigation, and that company launched its first rheometer, the CSR, in 1984 (show n in Figure 2).

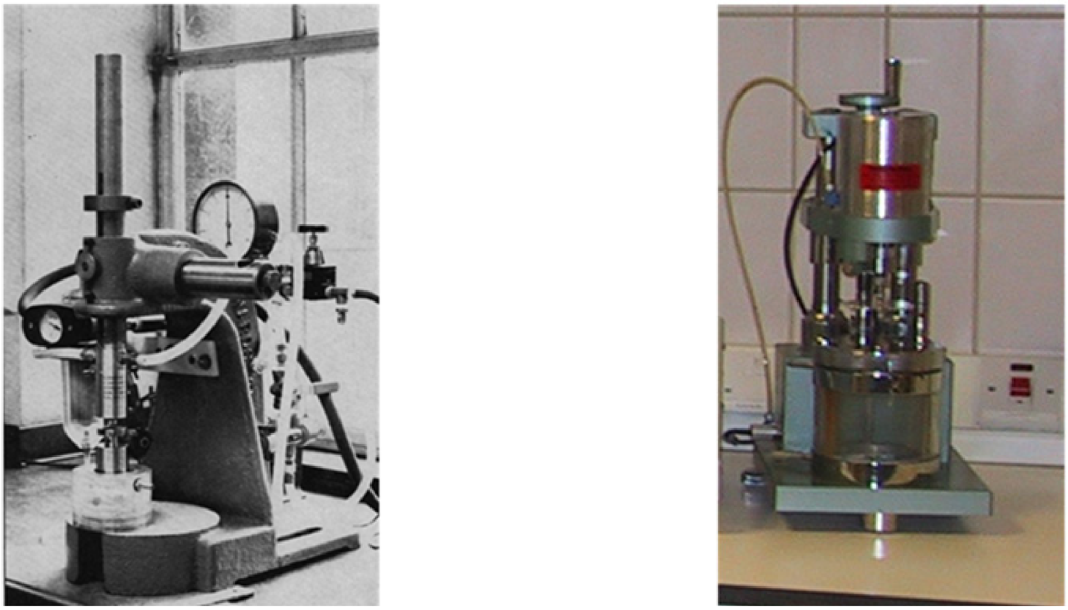


Figure 1 Jack Deer's Air Turbine Rheometer (left); Deer Rheometer (right).

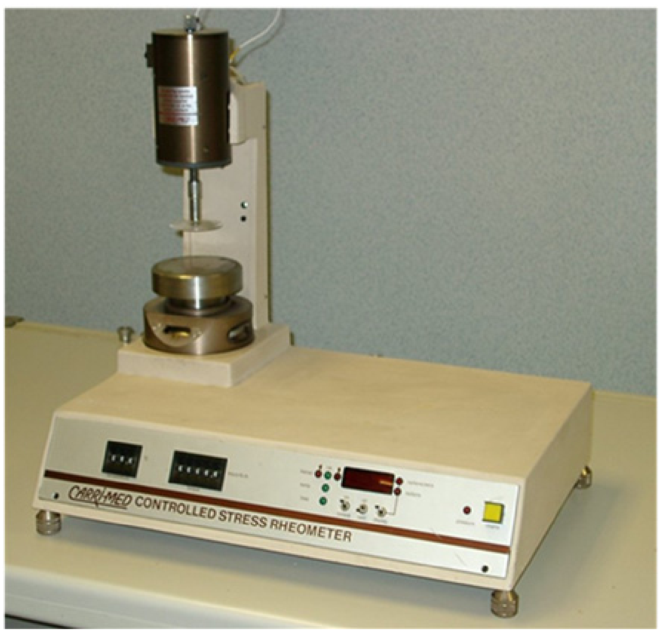


Figure 2 CSR.

Carri-Med acquired the rights to the Weissenberg rheogoniometer in 1990, but the mainstay of its business remained the CMT successors to the Deer, which included the CSL and CSL2 (shown in , until the company was purchased by TA Instruments in 1994. From that time on, progress in CMT technology has been remarkable, with the AR 1000 launched in 1996 and the AR 2000 in the year 2000 by TA Instruments. Both these instruments used air bearings, but the limits of that technology appear to have been reached, and for the AR-G2, launched in 2005, a magnetically levitated bearing was used. This and other developments by TA Instruments have advanced the instrumentation further. Developments, for example, in the drag cup motor and the electronics, have led to substantial improvements in the low torque, controlled rate, and transient performances of the instrument. TA Instruments' AR-G2 is now the world's most advanced CMT rheometer. Some of the improvements made in the electronics and other components of the rheometer have also been incorporated into the AR 2000 to form the AR 2000ex and AR 1500ex.

Figure 3 CSL^2.

The AR-G2, AR 2000ex, and AR 1500ex

The AR-G2, AR 2000ex, and AR 1500ex are the world's most advanced combined motor and transducer (CMT) rheometers. The instruments consist of a main unit and a separate control box containing the electronics. The interplay between the rheometer main unit and the electronics is described in "Key Rheometer Components" on page 22.

A schematic of the AR-G2 rheometer is given in the figure below. The AR 2000ex and AR 1500ex are similar.

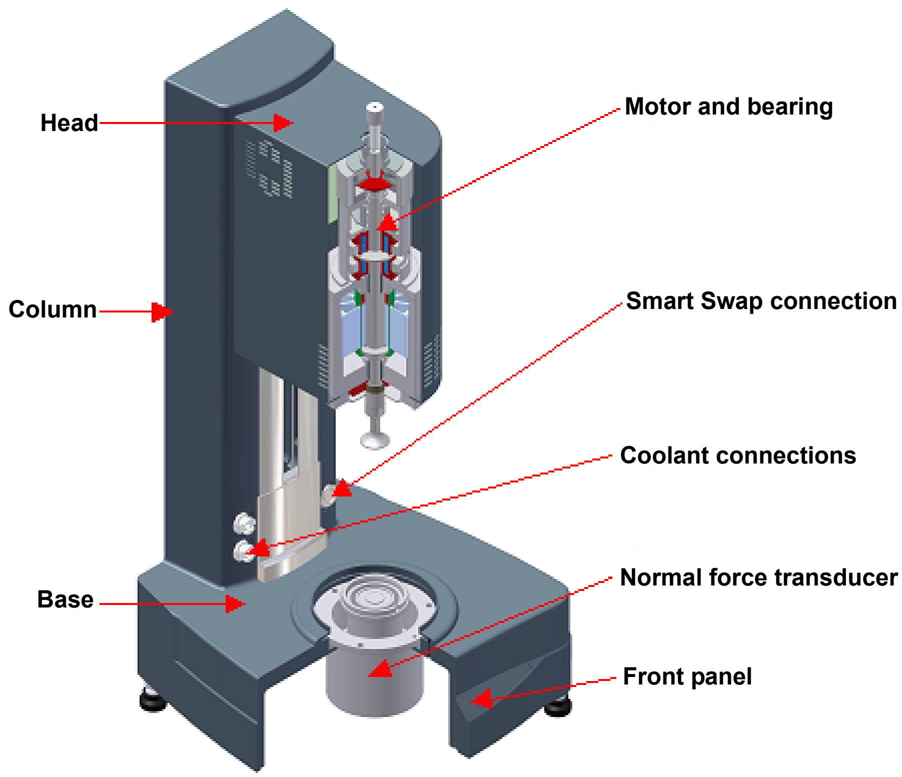


Figure 4 The AR-G2 Rheometer (AR 2000ex and AR 1500ex are similar).

Description

The body of the rheometer is a rigid, single-piece metal casting comprising a base and column.

The instrument head is attached to a ball-slide, which is mounted within the column. The vertical position of the head is controlled by driving the screw of the ball-slide. The head contains the following:

- The drag cup motor, with an armature that forms the rotating spindle of the rheometer.
- An air or magnetic thrust bearing that supports the spindle.
- An optical encoder that determines its angular position.

Each of these components is described in more detail in "Key Rheometer Components" on page 22.

Key Rheometer Components

The main components of the rheometer are described below. If you have a good understanding of the design and function of each component, it will make efficient use of the rheometer easier. This section describes, in detail, the design and functions of the:

- Casting
- Ball slide
- Air thrust bearing (AR 2000ex/AR 1500ex)
- Magnetically levitated thrust bearing (AR-G2)
- Radial air bearings
- Rotational mapping
- Motor
- Encoder
- Normal force transducer (AR-G2/AR 2000ex)
- Electronics
- Front panel
- Smart swap
- Auto GapSet Mechanism

Casting

The body of the rheometer is a single-piece aluminium casting, consisting of a base and column. The casting is an important component of the rheometer, as it needs to be rigid to axial and torsional stresses, robust, and capable of being machined to high precision and accuracy to ensure correct alignment of the other components of the instrument. Computer Numerical Control (CNC) machining is used to ensure concentricity, flatness and parallelism in the measuring system when attached.

Ball Slide

The instrument head assembly containing the motor, bearing and optical encoder is mounted on a stiff, linear motion, precision ball slide guide. The ball slide is mounted within the instrument column, and a motor and optical encoder are located in the base of the casting to drive the ball slide screw, moving the instrument head vertically, and to measure its position.

Magnetically-Levitated Bearing (AR-G2)

All CMT rheometers contain a bearing, and it is this component that largely controls the quality of data that can be obtained on the instrument. The design of a bearing is a compromise involving several properties such as friction, stiffness, air consumption and tolerance to contamination and misuse. To keep the friction low, non-contact bearings have always been used in the better quality rheometers. A thrust disc is mounted horizontally on the rotating spindle of the rheometer and, on traditional instruments, this disc is supported within a chamber by air introduced from below at high pressure. To prevent the spindle moving upwards, air is also introduced into the chamber from above, and to prevent it moving laterally, radial air-bearings are used.

On the AR-G2 rheometer, the thrust disc is retained, but it is levitated magnetically. The thrust disc is constructed from a magnetically susceptible material. Electromagnetic actuators are positioned above and below the disc, the strength of the magnetic field generated by each actuator is controlled through the current supplied to its coils. The stronger the field, the greater the attraction between the actuator and the thrust disc. The axial position and motion of the spindle are detected by sensors mounted above the upper actuator, and can be closely controlled by varying the supplied current to each actuator coil.

This arrangement has advantages over the traditional air-bearing in many respects. The gap between the thrust disc and the stationary components of the instrument can be much wider, of the order of millimeters rather than micrometers. This results in both the friction of the bearing being substantially lower, and increases the smoothness of rotation. The latter is particularly important, since it means that the variation in the bearing characteristics with angular position, that are inevitable for any real bearing, can be more easily allowed for by calibration (“mapping”). The axial stiffness of the bearing is increased, because of the tightness of the control loop governing the axial position (to prevent lateral movement of the shaft, radial air-bearings are retained on the AR-G2). The air consumption is reduced, and the wider gap and more durable materials used make the bearing more robust and less susceptible to contamination.

Air Bearing (AR 2000ex/AR 1500ex)

As its name suggests, an air bearing uses air as the lubricating medium. This allows virtually friction-free application of torque.

The design of an air bearing is a compromise between several characteristics such as air consumption, friction, stiffness, and tolerance to contamination and misuse. The amount of air consumed is related to the pressurized bearing clearance. To minimize air consumption, a small clearance (<10 µm) is needed. However, as air has a finite viscosity (0.0018 mPa.s), small gaps give rise to high shear rates and, correspondingly, the friction increases.

If large gaps are used, the shear rate is lowered and friction is reduced, but the stiffness of the air bearing is also reduced. Thus, a compromise in the design of an air bearing is needed for optimal performance.

The air bearing uses a mixture of proven bearing techniques with novel materials. The surfaces can be easily machined to tolerances of less than 1 µm, providing an extremely smooth finish.

A schematic of the air bearing and the other main components of the rheometer head is shown in the figure below. The bearing is designed to be virtually friction- free, so that it moves under the smallest of forces. Even extremely small manufacturing variations in the bearing can be sufficient to make it rotate. Therefore, to ensure that the bearing rotation is steady throughout a full 360°, a process called *Rotational Mapping*, which is explained in the next section, is carried out.

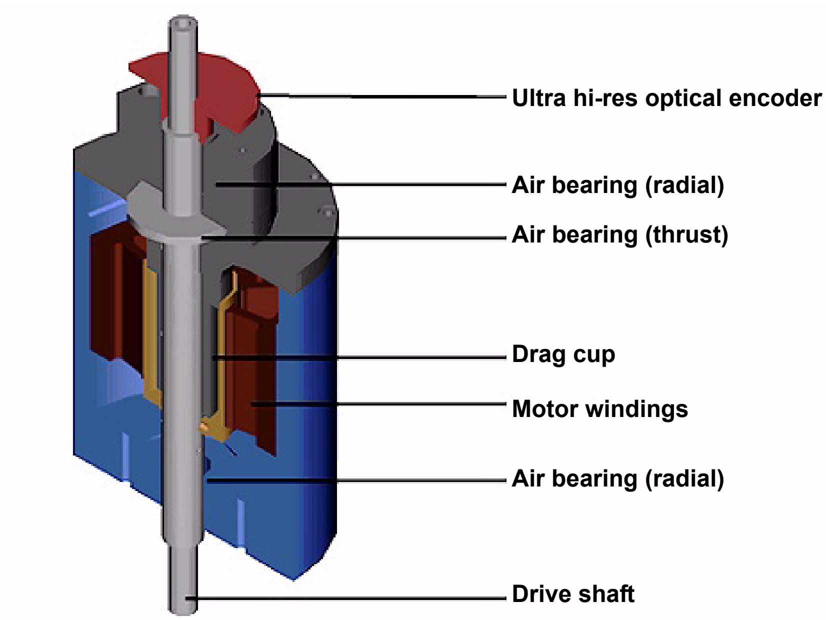


Figure 5 AR 2000ex Rheometer head.

Radial Air Bearings

Radial bearings provide stiffness and support in the radial direction. The AR-G2, AR 2000ex, and AR 1500ex are designed with two porous carbon radial bearings, located above and below the motor.

Rotational Mapping

The characteristics of any real bearing will vary with angular position. By combining absolute angular position data from the optical encoder with microprocessor control of the motor, these small variations can be mapped automatically, and the results stored. Unless changes to the bearing characteristics occur, the variations are stable over time.

The microprocessor can, therefore, allow for the variations by recovering the stored map and making the appropriate baseline correction to the applied torque. This results in a very wide bearing operating range, without operator intervention.

Instructions for performing the rotational mapping can be found in TRIOS Online Help. The figures below show examples of the AR-G2 performance before and after mapping.

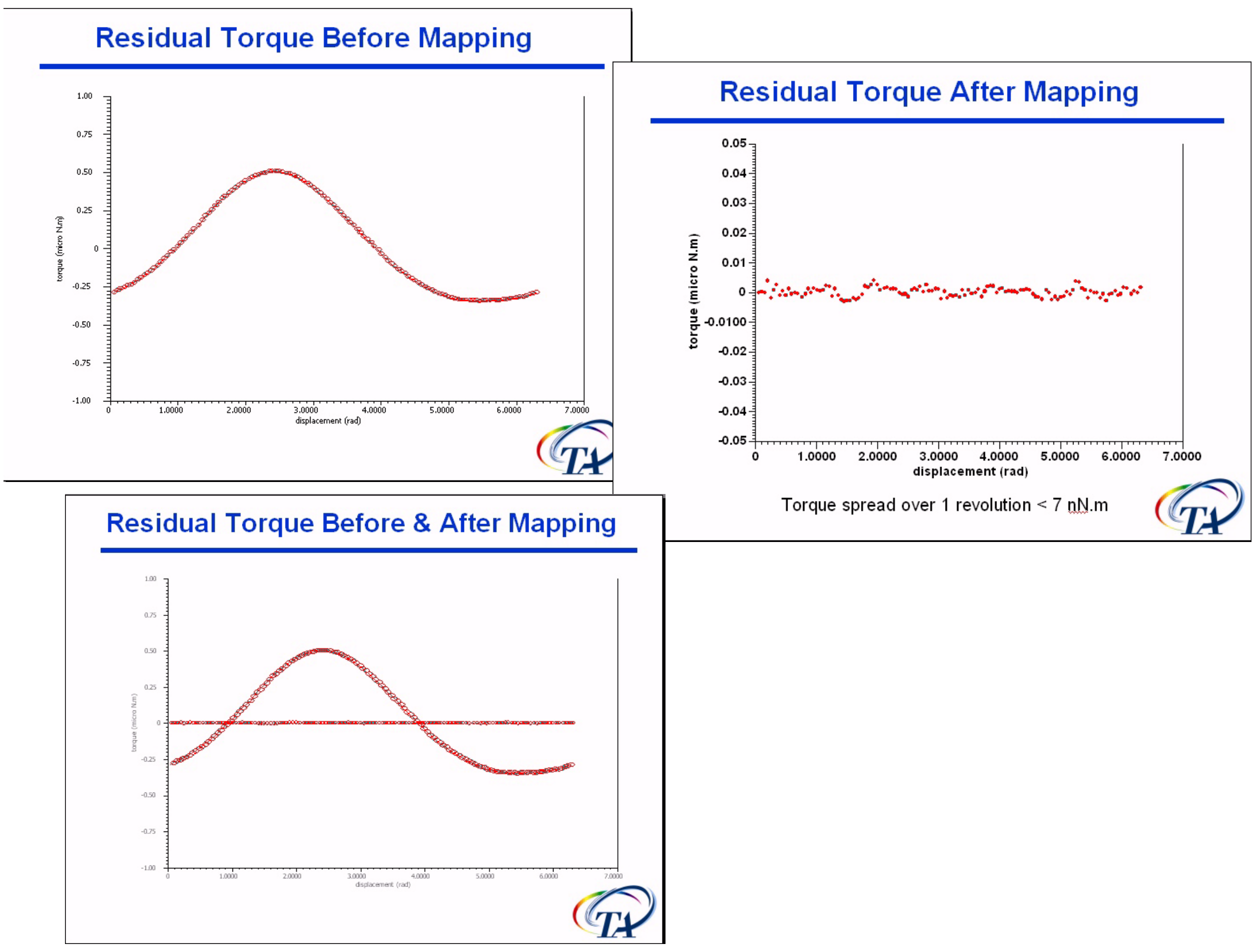


Figure 6 Rotational mapping examples.

Motor

The requirement that the bearing used on the rheometer should be low in friction applies equally to the motor. The AR rheometers use a non-contact "drag cup" motor. A thin-walled metal cup is mounted on the rotating spindle of the rheometer. A magnetic field rotating at thousands of revolutions per minute is generated by continuously varying the current supplied to stationary pole pieces surrounding the cup. This produces an eddy current in the cup, which generates a second magnetic field. The two fields oppose each other, in accordance with Lenz's law, and the cup field is forced to follow the rotating field. Hence, the cup is "dragged" round by the rotating field, and a torque is generated whether the cup moves or not.

Drag cup motors have many desirable characteristics besides their low friction. Since they have no fixed magnets, the torque produced is independent of the angular position. Futhermore, the torque is approximately proportional to the square of the current, which means that a wide torque range is produced by a relatively narrow current range. The rotating components of the motor can be very low in inertia—the limit is the thinness to which the cup walls can be machined. Low inertia is important whenever the angular velocity of the moving parts is changed, for example, during transient or dynamic experiments, or steady changes in torque.

The motor on the AR-G2 rheometer incorporates a patented drag cup temperature sensor. For the first time in any rheometer design, the temperature of the drag cup is measured, ensuring the most accurate possible torque output.

The low friction and inertia of the motor, together with sophisticated modern electronics allow close control of the motor, both in its native, controlled torque, mode, and through feedback in controlled displacement or angular velocity mode. Although designed according to the principles of traditional controlled-stress rheometers, the AR rheometers are better regarded as both controlled-stress and controlled-strain rheometers.

Optical Encoder

The transducer used to determine the angular position of the rotating spindle should have high resolution, low friction (*i.e.*, non-contact), low inertia, and a rapid linear response. These criteria are met by the optical encoder used on the AR rheometers. This consists of a non-contacting light source and photocell, arranged on either side of a transparent disc mounted on the rheometer spindle. At the edge of this disc are extremely fine, photographically etched radial lines, which form a diffraction grating. A stationary segment of a similar disc is also mounted between the light source and the photocell, and the diffraction pattern formed by the light transmitted through the gratings is detected by the photocell. As the spindle rotates, the diffraction pattern changes. The associated electronic circuitry interpolates and digitizes the resulting signal, to produce digital high resolution, angular position data.

The angular velocity of the rotating spindle is calculated from successive readings of the angular position, and since this is done at electronic processor speed, the encoder effectively has two outputs, the angular position and the angular velocity.

Normal Force Transducer (AR-G2 and AR 2000ex Only)

Normal force is detected on the static lower measuring geometry assembly using high sensitivity load cell technology. This results in a fast response, wide range signal, which is easy to calibrate, and has a genuine normal force measurement capability.

Both the AR-G2 and AR 2000ex rheometers have the ability to control the amount of normal force during an experiment, and make quantitative measurements of normal forces generated by a sample during a test.

CAUTION: During sample loading and measurement, the normal force transducer is protected from overload. However, take care when cleaning or attaching accessories to the lower plate that you do not exceed the maximum normal force.

When a viscoelastic liquid is sheared, a force can be generated along the axis of rotation of a cone or parallel plate geometry. For this to happen, the structure responsible for the elasticity must not be completely disrupted by steady shear.

For this reason, colloids, suspensions, etc., although elastic at rest, become effectively inelastic under steady shear and can show negative normal forces due to inertial effects. However, polymer solutions and melts, and products incorporating them, are typically elastic under shear because of the long lifetime of the molecular entanglements.

Normal force measurements are made with cone and plate or parallel plate geometries; therefore, it is important to use a method to detect the force that does not allow significant changes in the gap. This would result in the actual shear rate varying with normal force, due to deflections of the force-detecting component.

Front Panel

Some of the operation of the rheometers can be controlled through buttons on the front panel, as shown in the figure, as well as through the rheometer software.

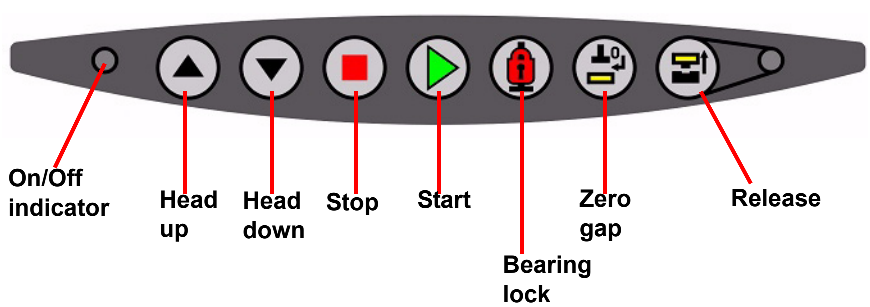


Figure 7 Front panel.

Explanation of the front panel from left to right:

- On/Off Indicator (red): Lights up when power to the instrument is on.
- Head Up: Used to raise the instrument head.
- Head Down: Used to lower the instrument head.
- Stop: Terminates whatever operation the instrument is performing, for example finding the gap zero, mapping the bearing or running an experimental procedure.
- Start: Used to start an experimental procedure. (AR-G2 only)
- Bearing Lock: Applies a software lock to bearing to prevent the instruments shaft from rotating. This lock will be over-ridden when the experimental procedure is started. (AR-G2 only)
- Zero Gap: Starts the automatic gap zero position finder.
- Release: Used as the Smart Swap release button.
- Smart Swap indicator light (green).

Smart Swap™

The AR rheometers' feature "Smart Swap" technology that automatically senses the temperature control system present and configures the rheometer operating software accordingly, loading all relevant calibration data. The use of this feature is covered in this manual.

Also available for use with the AR-G2 only are the Smart Swap™ geometries, which are an extension of the Smart Swap technology. These geometries can be automatically identified when installed on the AR-G2 rheometer. The magnetic coating on the head of each geometry provides the read/write technology that will uniquely identify it to the instrument.

Auto GapSet Mechanism

The auto GapSet facility has three major functions, as follows:

- Automatic setting of gaps via software
- Programmed gap closure
- Thermal gap compensation

These features of the GapSet mechanism are described in detail in the TRIOS Software Online Help.

Environmental Control Units

The following sections briefly describe the environmental control units for the AR Rheometers.

Peltier Plate

The Peltier Plate is the standard temperature control system for the rheometers. It uses the Peltier thermo-electric effect to control the temperature accurately, with rapid heating and cooling. The plate consists of a copper disc, with hard chrome plating on the upper surface. A Pt100 temperature probe is embedded in the disc, in thermal contact with it and close to the surface. Copper is used as the disc material for its very high thermal conductivity, ensuring negligible temperature gradients across the surface of the plate. The hard chrome plating prevents mechanical or chemical damage to the plate.

Refer to the Peltier Plate Getting Started Guide for additional information.

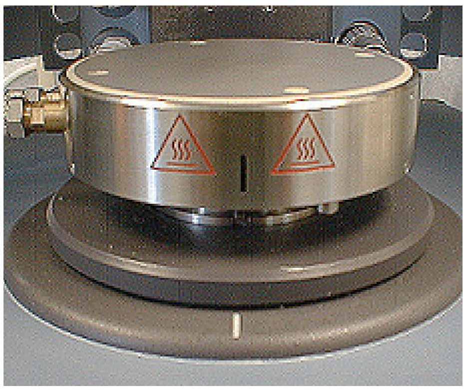


Figure 8 AR Series Peltier Plate.

Peltier Concentric Cylinders

The AR Series Peltier Concentric Cylinder Temperature System combines the convenience of Smart Swap™ and Peltier heating technology with a wide variety of cup and rotor geometries. Concentric cylinder geometries are commonly used for testing low viscosity fluids, dispersions or any liquids that are pourable into a cup. Examples of materials suitable for Concentric Cylinders include low concentration polymer solutions, solvents, oils, drilling mud, paint, varnish, inkjet ink, ceramic slurries, pharmaceutical suspensions such as cough medicine and baby formula, foams, food products such as juices, thickeners, dairy products such as milk and sour cream, salad dressings, and pasta sauce.

Refer to the Peltier Concentric Cylinder Getting Started Guide for additional information.

Figure 9 AR Series Peltier Concentric Cylinder.

Upper Heated Plate

Lower Peltier Plates have a maximum temperature of 200°C. However, vertical temperature gradients when heating from only the bottom can become significant at temperatures above 50°C, leading to errors in the absolute rheological data. The Upper Heated Plate (UHP) is compatible with all Peltier Plate models and provides upper plate temperature control. The UHP features 8, 25, and 40 mm diameter cones and plates and a maximum temperature of 150°C. The lower temperature can be extended using a variety of flexible liquid and gas cooling options.

NOTE: To extend the upper heater temperature range to 200°C, see electrically heated plates option).

Refer to the Upper Heated Plate Getting Started Guide for additional information.

Figure 10 AR Series Upper Heated Plate.

The Electrically Heated Plate (EHP)

The EHP provides active heating and cooling of parallel plate and cone and plate geometries. With standard and disposable systems it's ideal for rheological characterization of polymer melts and thermosetting materials up to a maximum temperature of 400°C. The optional gas Cooling Accessory extends the minimum temperature to –70°C. Standard features include 25-mm diameter parallel plate geometry, environmental cover, and heated purge gas. An optional clear cover is available for sample viewing and for use with the Camera Viewer option. The AR-G2 EHP offers Active Temperature Control (ATC), making it the only EHP system capable of direct temperature control of the upper and lower plates. The Upper EHP can be used with lower Peltier Plates for temperature control to 200°C and as temperature control to 150°C for UV curing options.

Refer to the Electrically Heated Plate Getting Started Guide for additional information.

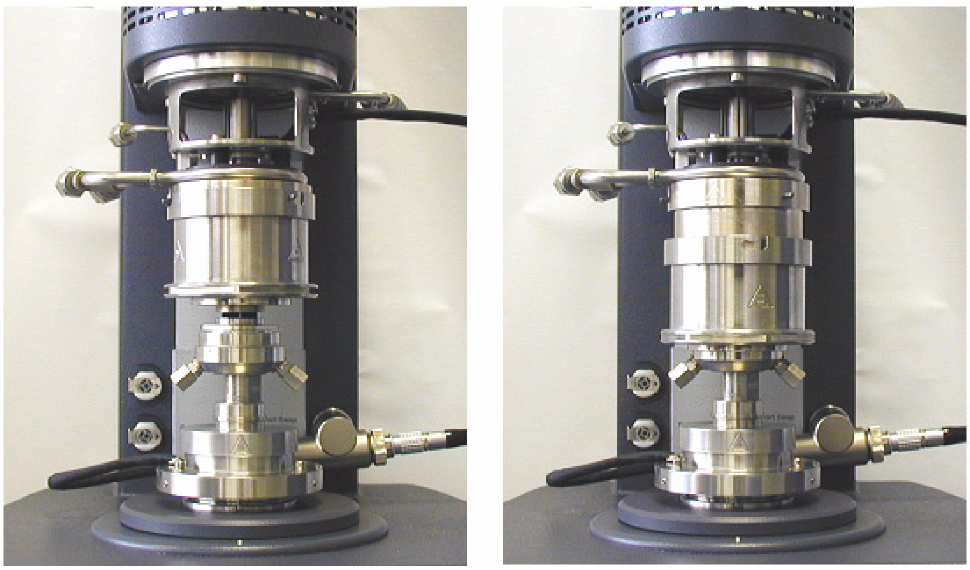


Figure 11 AR Series EHP.

The Pressure Cell

WARNING: TA Instruments' Pressure Cell is designed for use at temperatures up to 150°C and pressures up to 138 bar (2000 psi). At all times during the use of the cell, wear safety glasses and clothing that afford adequate protection against the sample under test, and the temperature and pressure used. At other than ambient temperature, the outer surfaces of the cell may become very hot or cold. When operating at these temperatures, wear gloves that afford adequate protection against the surface temperature of the pressure cell and its fittings.

The Pressure Cell is a sealed vessel that can be pressurized up to 138 bar (2000 PSI) over a temperature range of –10 to 150°C. It can be used either in self-pressurizing mode, in which the pressure is produced by the volatility of the sample, or by externally applying the pressurization, typically with a high pressure tank of air or nitrogen gas. All necessary plumbing and gauges are included as a manifold assembly. The Pressure Cell is ideal for studying the effect of pressure on rheological properties, as well as studying the materials that volatilize under atmospheric pressure. This option is available for the AR-G2 and AR 2000ex rheometers.

Refer to the Pressure Cell Getting Started Guide for additional information.

Figure 12 AR Series Pressure Cell.

The Starch Pasting Cell

The Starch Pasting Cell (SPC) is a Smart Swap™ accessory available on all AR Rheometers. The option provides a more accurate and powerful tool to characterize the gelatinization of raw and modified starch products as well as the properties of the starch gels. It can also be used for characterizing many other highly unstable materials. It uses an innovative impeller design for mixing, reduction of water loss, and control of sedimentation during testing. The actual sample temperature is measured and controlled in a temperature chamber with heating/cooling rates up to 30°C/min.

Refer to the Starch Pasting Cell Getting Started Guide for additional information.

Figure 13 AR Series Starch Pasting Cell.

Asphalt Submersion Cell

This temperature control system is specifically for the measurement of asphalt binders. Its operation is covered by the Asphalt Submersion Cell manual.

Refer to the Asphalt Submersion Cell Getting Started Guide for additional information.

The Environmental Test Chamber (ETC)

The ETC is a high temperature Smart Swap™ option available for the AR-G2 and AR 2000ex rheometers. It uses a controlled convection / radiant-heating concept and has a temperature range of –160 to 600°C with heating rates up to 60°C/min. The unique design of the ETC provides fast response and temperature stability over a continuous 760°C range as highlighted in the figure below with temperature steps of 20°C. The ETC is a very popular option for polymer applications and can be used with parallel plate, cone and plate, disposable plate, and rectangular torsion clamps for solids. Typical materials that can be tested include thermoplastics, thermosets, elastomers, caulks and adhesives, solid polymers, asphalt binder, and oils and greases.

Refer to the ETC Getting Started Guide for additional information.

Figure 14 AR Series ETC.

Accessories

The sections below briefly describe the AR Rheometer accessories.

Bicone Interfacial Accessory

The bicone interfacial accessory is mainly used to determine the viscosity of the interface between two liquid phases. The stator is a circular cup with removable lid, the geometry is a thin, biconical disc. For chemical inertness, and to reduce the meniscus effect, the cup and lid are constructed from poly (tetrafluoroethene), PTFE, and the geometry from stainless steel. It is important that the cup and disc are aligned concentrically, and the base with Smart Swap™ connector into which the cup sits has been designed to ensure this. Normally, the cup should be exactly half filled with the more dense sample fluid, and filled to the top with the less dense fluid. The disc is placed at the interface of the two fluids. A mark has been lightly inscribed on the inside of the cup to indicate when it is half full.

Figure 15 Bicone Interfacial Accessory.

The Interfacial Double Wall Ring (DWR)

The Interfacial Double Wall Ring (DWR) measuring system measures the viscous and linear viscoelastic properties of the interface between liquid-liquid and liquid-air. It consists of a thin, square-edged ring and a Delrin® trough with a circular channel. The ring and support legs are constructed from a platinum/ iridium (Pt/Ir) alloy, for chemical inertness, ease of cleaning, and wettability. The ring support is made of stainless steel. It is important that the ring and trough are perfectly aligned (concentricity), and the trough positioned on the Peltier Plate accurately leveled.

A non-return (check) valve is fitted to the trough below the level of the interface. Together with the supplied tubing and syringe, this can be used to adjust the lower fluid level, or to add an active ingredient.

NOTE: The fabrication process used for the DWR will result in more runout than our standard cones and plates. The total runout of the DWR is inspected using a 3D laser technique and has to be better than 0.5 mm to pass inspection. This value was determined from the influence on sample measurements taken during the development process. The human eye can generally perceive a total runout greater than 0.05 mm, so the DWR will always appear to “wobble” when rotating, even when within specification.

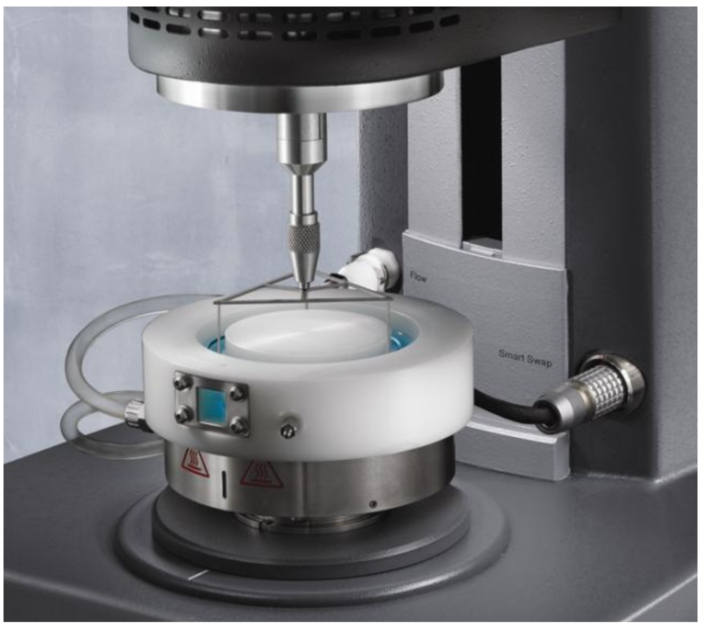


Figure 16 Interfacial DWR.

The ETC Viewer

WARNING: After ETC use, do not turn off the cooling air to the ETC Viewer until the unit has returned to room temperature. Doing so could damage the lens assembly and/or camera chip.

The ETC (Environmental Testing Chamber) Viewer is as an option that can be used with the rheometer for the following purposes:

- Viewing the edge of plates and cones and the torsion sample
- Providing streaming video on Status page and during tests
- Capturing images with data point (not fast sampling)
- Viewing point image in TRIOS Instrument Control Software

The software provided with the ETC Viewer works with any USB camera so a web cam can be easily used for Peltier tests. The viewer assembly is air cooled to allow it to perform over whole temperature range of the ETC (-160 to 600°C). The primary and secondary illumination, as well as the focusing aspects of the viewer, are all controlled from Rheology Advantage Instrument Control software for your convenience.

The UV Curing Accessory

UV-curable materials are widely used for coatings, adhesives, and inks. When these materials are exposed to UV radiation, a fast cross-linking reaction occurs, typically within less than a second to a few minutes.Two SmartSwap™ accessories for rheological characterization of these materials are available for the AR-G2 and AR 2000ex rheometers. Onc accessory uses a light guide and reflecting mirror assembly to transfer UV radiation from a high-pressure mercury light source. The second accessory uses self-contained light emitting diodes, LEd, arrays to deliver light to the sample. Accessories include 20 mm quartz plate, UV light shield, and nitrogen purge cover. Optional temperature control to a maximum of 150°C is available using AR Series Electrically Heated Plates (EHP) option. disposable plates are available for hard UV coatings which cannot be removed from the plates once cured.

Refer to the UV Curing Accessories Getting Started Guide for additional information.

Figure 17 AR Series Light Guide UV Curing Accessory.

Small Angle Light-Scattering (SALS) Accessory

The AR Series Small Angle Light Scattering System, AR-SALS, is an option for simultaneously obtaining rheological and structural information, such as particle size, shape, orientation and spatial distribution. The AR-SALS is available for the AR-G2 and AR 2000ex Rheometers. The option incorporates TA Instruments' Smart Swap™ technology bringing a new level of speed and simplicity for making simultaneous rheology and SALS measurements. The system can be installed, aligned, and ready for measurements in as little as five minutes. It features patented Peltier Plate temperature control and the scattering angle (θ) range over which measurements can be made is ~ 6° to 26.8°. The scattering vector range (q) is 1.38 μm^{-1} to 6.11 μm^{-1} and the length scale range is about 1.0 µm to ~ 4.6 µm.

Refer to the SALS Accessory Getting Started Guide for additional information.

Figure 18 SALS Accessory.

AR Rheometer Geometries

Standard geometries for the rheometers are constructed from stainless steel, hard anodized aluminium, titanium or acrylic (polymethyl methacrylate).

NOTE: This applies only to the face of the geometry in direct contact with the sample, the shaft may be constructed from other materials.

Other materials may be available on request, at additional charge. The geometry should be as low in density possible, to minimize its moment of inertia, it should be chemically resistant to the sample, and it should have a surface texture that provides adhesion to the sample, to eliminate slippage.

The available geometries are listed below. Refer to TRIOS Online Help for additional details.

- Cone and plate
- Parallel plate
- Concentric cylinders
- Double gap concentric cylinders
- Solid sample (rectangular)
- SER Universal Testing Platform

Smart Swap™ Geometries

The AR-G2 Smart Swap geometries have a larger diameter than those used on the AR2000ex and 1500ex. This is required to record sufficient data (36 bits) around the circumference. In addition, the geometries have a larger bore to allow a better location surface and easier cleaning.

Each geometry has a unique six-digit serial number for identification purposes. When the geometry is set up for the first time this number is encoded into the magnetic strip and a link is established to a geometry file in the instrument control software. The geometry then becomes “Smart”. When a Smart Swap Geometry is attached to the rheometer, a sensor registers the attachment and slowly spins the shaft to read the serial number from the magnetic strip. The geometry file associated with this serial number is then loaded by the software.

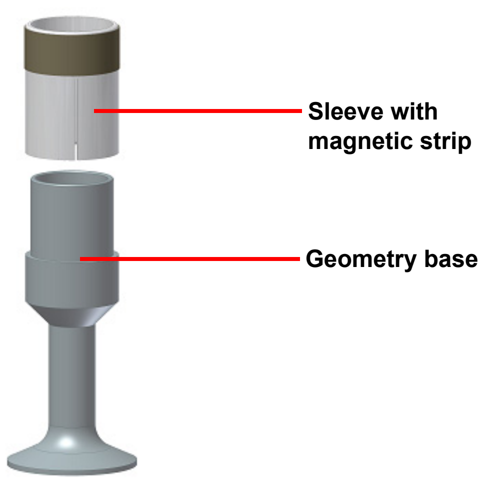


Figure 19 Smart Swap geometry.

Instrument Specifications

The table found below contains the technical specifications for the AR-G2/AR 2000ex/AR 1500ex Rheometer.

Table 1: AR-G2 Technical Specifications

Item/Area	Specifications
Accessory (Electronics Base)	
Width	7.25 in.(18.5 cm)
Height	14.75 in.(37.5 cm)
Depth	17.75 in.(45 cm)
Weight	38.1 lbs (17.3 kg)
Module (Instrument Base)	
Width	11.75 in.(30 cm)
Height	26.5 in.(67 cm)
Depth	12.5 in.(32 cm)
Weight	63.8 lbs (29 kg)
Minimum torque oscillation CR	0.003 µN.m
Minimum torque oscillation CS	0.003 µN.m
Minimum torque steady CR	0.01 µN.m
Minimum torque steady CS	0.01 µN.m
Maximum torque	200 mN.m
Torque resolution	0.1 nN.m[1]
Motor inertia	18 µN.m.s
Angular velocity range CS	0 to 300 rad/s
Angular velocity range	CR 1.4E^{-9} to 300 rad/s
Frequency range	7.5E^{-7} to 628 rad/s
Displacement resolution	25 nrad
Step change in velocity	7 ms
Step change in strain	30 ms
Direct strain control	Standard[2]
Thrust bearing	Magnetic
Normal/Axial Force range	0.005 to 50 N
Smart Swap™	Standard
Smart Swap geometry	Standard

CR: Controlled Rate Mode
CS: Controlled Stress Mode
[1] Internal Resolution for D to A converter at torque of 0.1 µN.m.
[2] Direct Strain Control provides single cycle oscillation and continuous oscillations during experiments.

Table 2: AR 2000ex/AR 1500ex Technical Specifications

Item/Area	Specifications
Accessory (Electronics Base)	
Width	7.25 in.(18.5 cm)
Height	14.75 in.(37.5 cm)
Depth	17.75 in.(45 cm)
Weight	38.1 lbs (17.3 kg)
Module (Instrument Base)	
Width	11.75 in.(30 cm)
Height	26.5 in.(67 cm)
Depth	12.5 in.(32 cm)
Weight	62.2 lbs(28.7 kg)
2000ex Specifications	
Minimum torque oscillation CR	0.03 µN.m
Minimum torque oscillation CS	0.1 µN.m
Minimum torque steady CR	0.05 µN.m
Minimum torque steady CS	0.1 µN.m
Maximum torque	200 mN.m
Torque resolution	1 nN.m[1]
Motor inertia	15 µN.m.s
Angular velocity range CS	0 to 300 rad/s
Angular velocity range CR	$1E^{-8}$ to 300 rad/s
Frequency range	$7.5E^{-7}$ to 628 rad/s
Displacement resolution	40 nrad
Step change in velocity	25 ms
Step change in strain	60 ms
Direct strain control	Standard[2]
Thrust bearing	Porous Carbon Air
Normal/Axial Force range	0.005 to 50 N
Smart Swap™	Standard
1500ex Specifications	
Minimum torque	0.1 µN.m
Maximum torque	150 mN.m
Torque resolution	1 nN.m[1]
Motor inertia	15 µN.m.s
Angular velocity range CS	0 to 300 rad/s
Angular velocity range CR	$1.00E^{-7}$ to 300 rad/s
Frequency range	$7.50E^{-7}$ to 628 rad/s
Displacement resolution	40 nrad
Step change in velocity	25ms
Step change in strain	60ms
Thrust air bearing	Porous Carbon
Smart Swap	Standard

CR: Controlled Rate Mode
CS: Controlled Stress Mode
[1] Internal Resolution for D to A converter at torque of 0.1 µN.m.
[2] Direct Strain Control provides single cycle oscillation and continuous oscillations during experiments.

Chapter 2:

Installing the Instrument

Overview

Normally the installation of your new system will be carried out by a member of the TA Instruments sales or service staff, or their appointed agents, and it will be ready for you to use. However, should you need to install or relocate the instrument, this chapter provides the necessary instructions.

Removing the Packaging and Preparing for Installation

If needed, the first step is to carefully remove all items from any and all packaging. We recommend that you retain all packaging materials in case the instrument has to be shipped back to TA Instruments at some point in the future (for example, in the case of some upgrades).

Installation Requirements

It is important to select a location for the instrument using the following guidelines.

Choose a location that is...

In

- An indoor area only (A clean environment).
- Altitude up to 2000 m.
- A temperature-controlled area (5°C to 40°C).
- An area where the maximum relative humidity is 80% for temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40°C.
- An area with ample working and ventilation space around the instrument, approximately 2 meters in length, with sufficient depth for a computer and its keyboard.

On

- A stable, vibration-free work surface.

Near

- A power outlet. (Mains supply voltage fluctuations not to exceed ±10% of the nominal voltage, installation category II.)
- Your computer for direct connection of serial or ethernet cable or a network port.
- Air Bearing Gas Pressure (air or nitrogen) must be clean, dry, oil-free compressed air at 345–690 kPa gauge (50–100 psig). The dew point should be –20°C or better. Flow rate should be 25 L/min. A 1/4 NPT female connection must be provided for the AR main air supply.

Away from

- Dusty environment (pollution degree 2).
- Exposure to direct sunlight.
- Poorly ventilated areas.

After you have decided on the location for your instrument, refer to the following sections to unpack and install the AR-G2/AR 2000ex/AR 1500ex Rheometer.

Connecting the System

Connecting the system together should present no problems, as long as you use instructions found in the following sections.

Connecting the Rheometer to the Electronics Control Box

The Electronics Control Box forms the link between the rheometer and the computer. All the required processing is done within the control box. The following steps should be followed to connect the two units together (refer to the figure below).

1 Push the female end of the power cable into the Power port on the back of the rheometer and the other end in the Power port on the back of the control box.

2 Push the D-type cable into the Signal port on the back of the rheometer and connect the other end to the Signal port on the back of the control box.

The AR-G2/AR 2000ex/AR 1500ex rheometers communicate with the control computer via an Ethernet link.

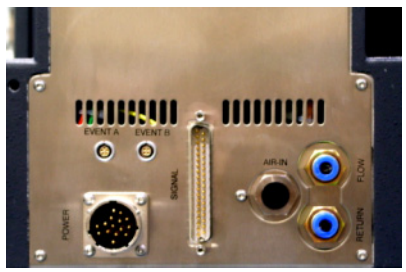


Figure 20 Cable connections.

Connecting the Computer to the Electronics Control Box Using Ethernet Communications

Ethernet communications can be setup in two ways. The electronics control box and computer can be connected directly via a single Ethernet cable, or both can be connected using separate cables to a Local Area Network [LAN]. Full details are provided in the software installation instructions.

Connecting Air and Water to the Rheometer

Refer to the figure on the previous page for information on the location of the relevant connections in the instructions below.

1 For Peltier-based temperature control options, connect a supply of cooling water to the flow and return connections at the rear of the rheometer

2 Connect the air supply (from the air regulator assembly) to the '**air in**' connection. Set the regulator to 2 bar (30 psi).

Leveling the Rheometer

Optimum performance depends upon the instrument being level and in a sturdy position to avoid the possibility of rocking. To check and see whether your instrument is level, simply place a bubble spirit level on the Smart Swap base, or installed temperature system (for example, Peltier Plate). If the instrument is not level, screw the adjustable feet (located at each corner of the instrument) either in or out, as necessary. Check the spirit level after each adjustment.

Once you have the instrument levelled correctly, press each corner of the instrument to check that all four feet are in contact with the laboratory bench. Any movement caused by pressing should be rectified by adjusting the feet, and then rechecking the level. An 'L'- shaped level with a bubble in each arm is most convenient type to use for this process.

Installing a Geometry

1 Switch on the air and remove the bearing clamp by turning the draw rod counterclockwise (anti-clockwise).

2 Push the geometry up the spindle and hold it while locating the draw rod in the screw thread of the geometry.

3 Screw the draw rod upwards (clockwise). It should be screwed finger tight but not forced.

To remove the geometry, perform this operation in reverse.

Chapter 3:

Use, Maintenance, and Diagnostics

Start-Up and Shut-Down Procedures

Starting Up the Rheometer

Follow the steps below to start the rheometer:

NOTE: This assumes that the rheometer has already been correctly installed.

1 Check that the air supply is turned on

2 Remove bearing clamp if fitted.

3 Turn on fluid circulation, if required for correct operation of the installed temperature system.

4 Turn on power to the rheometer.

5 Connect to rheometer via the software.

Shutting Down the Rheometer

Follow the steps below to shut down the rheometer:

1 Turn off the power to the rheometer.

2 Turn off any fluid circulation.

3 Fit the air bearing clamp if it is likely that the bearing will be disturbed while the air is off. In the case of the EHP, UHP, and ETC (doors closed), simply removing the draw rod should be sufficient to protect the bearing unless the instrument is going to be moved.

NOTE: It is recommended that the air be left on and that the bearing remain unclamped.

4 Turn off the air supply.

It is possible for the motor/bearing assembly on an AR2000ex\AR1500ex to slowly drop under its own weight when the power is off. This will not damage the rheometer, and will only result in the zero gap position being lost. To maintain the zero reference in such cases, follow the alternative shut-down procedure below:

1 Remove any temperature systems from the Smart Swap connector.

2 Remove upper geometry if fitted.

3 Lower the bearing\motor assembly to the bottom of its travel.

4 Turn off power to the rheometer.

5 Fit the bearing clamp, if bearing is likely to be disturbed while the air is off.

6 Turn off the air supply.

Maintenance and Repair

CAUTION: Adjustment, replacement of parts, maintenance and repair should be carried out by trained and skilled TA personnel only. The instrument should be disconnected from the mains before removal of the cover.

WARNING: The cover should only be removed by authorized personnel. Once the cover has been removed, live parts are accessible. Both live and neutral supplies are fused and therefore a failure of a single fuse could still leave some parts live. The instrument contains capacitors that may remain charged even after being disconnected from the supply.

Moving the Instrument

Please follow these recommendations when you move or lift the instrument and its accessories:

- Always remove the temperature control module from the rheometer before attempting to move it. Details on how to do this can be found in TRIOS Online Help.
- When moving the rheometer, the bearing clamp should always be in place, ensuring that the bearing cannot be moved.

1 Insert the draw rod into the top of the rheometer.

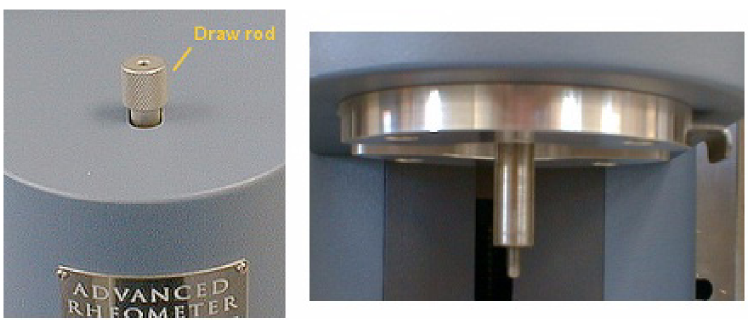


Figure 21 Inserting the draw rod.

2 Push the bearing clamp up onto the draw rod. Hold it in place while turning the knob at the top in a clockwise direction.

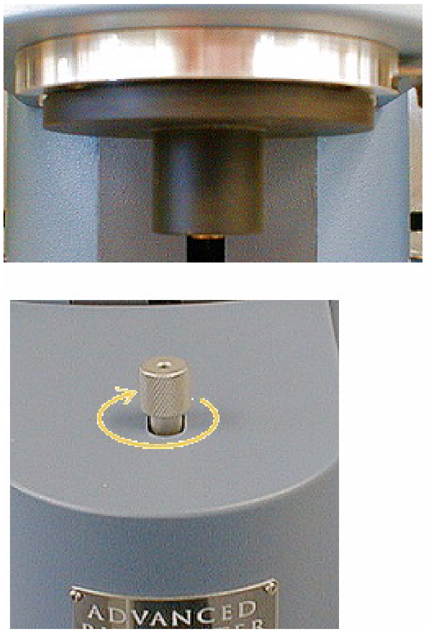


Figure 22 Performing step 2.

CAUTION: Always hold the clamp and turn the knob– never the other way round.

3 Treat the rheometer with the same degree of care you would take with any scientific laboratory instrument.

Error & LCD Display Messages

The LCD display on the front of the rheometer electronics box displays useful information and error messages.

Power On Messages

Immediately after power up of the rheometer, the display will show **'Initialising...'** After a few seconds this will change to **'AR-G2 8.xx xx/xx/xx' (x is version dependent)**. If it does not, there is a problem with the rheometer.

After a few more seconds, the display will either show **'System test Ok'** or **'System test failed Y,'** where Y is an error code as show below:

1	ROM checksum error	Either bad firmware or hardware fault	Try reloading firmware, otherwise call for service.
2	RAM error	Hardware fault	Call for service.
4	Dual port RAM error	Hardware fault	Call for service.
40	Battery failure	Low battery	Sometimes seen the first time the system is restarted after a firm-ware upgrade. Cycles power off then on
80	Backup RAM error	Hardware fault	Call for service.
400	Parameter block checksum error	Either corrupted internal system parameters or hardware fault	Call for service.

Initialising ...

During start up of the rheometer, the following items are shown as initializing:

- Electronics
- Power board
- Instrument

Bearing overspeed

Shown when the rheometer bearing rotation exceeds the specified maximum speed.

Bearing pressure too low

This is displayed if the air supply has been inadvertently switched off while the rheometer was on or if the supply pressure has dropped below the minimum operating pressure.

Encoder index not found

This message can be displayed if the air bearing is not free to move. This can occur if the air-bearing clamp is still attached or if the air bearing lock is on. Failing this, there may be a fault on the position encoder.

Nf gauge fault

This message is displayed if an excessive normal force was detected when attempting to zero the normal force reading. This could be caused by either an excessive force being applied by air bearing/sample/ mechanical interference with ETC or a gauge fault.

Nf temp sensor fault

This message is displayed if there are either faulty normal force temp sensors or, if you have for instance, frozen the instrument with excessive liquid nitrogen.

Operator stop event

This message is displayed when the Stop button was pressed while the Rheology Advantage software had the keypad locked. This usually indicates that a test run was in progress and the operator aborted it using the rheometer stop button.

Power cable fault

This indicates that the Power cable may not be plugged in firmly.

Signal cable fault

This message indicates that the signal cable may not be plugged in firmly.

Temp sys element fault

This message is displayed because the Peltier or heater element has developed a fault.

Temp system environment

There is a configuration problem with the installed temperature control module. *I.e.*, no water to the Peltier, etc. Re-read the manual to check you have set everything up correctly.

Temp system sensor fault

This message is likely caused by fault/damage to the Pt100 or thermocouple.

Other Messages

Other error messages may be displayed. These are usually indicative of problems with the rheometer that can only be fixed by a qualified TA Instruments representative.

This page is intentionally blank.

Index

L

M

N

O

P

V

W