Discovery Hybrid Rheometer

(DHR Series)

Getting Started Guide

Revision B **Issued April 2013**

Notice

The material contained in this manual, and in the online help for the software used to support this instrument, is believed adequate for the intended use of the instrument. If the instrument or procedures are used for purposes other than those specified herein, confirmation of their suitability must be obtained from TA Instruments. Otherwise, TA Instruments does not guarantee any results and assumes no obligation or liability. TA Instruments also reserves the right to revise this document and to make changes without 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
- 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.

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 DHR 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 to 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 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: 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 gasses.

WARNING: The Starch Pasting Cell (SPC) impeller is constructed from a rigid polymer composite material of density about 1.6 g cm-3. The usual operating angular speed is 160 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 high concentrations of 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 and gas 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 gasses 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.

WARNING: Use two people to lift and/or carry the instrument. The instrument is too heavy for one person to handle safely. Refer to Figure 26 for lift handle locations.

Table of Contents

Chapter 1:

About the Discovery Series Rheometers

Overview

This chapter reviews the history of rheology, and traces the development of combined motor and transducer (CMT) rheometers. The three models in the Discovery Series 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 (shown in Figure 2).

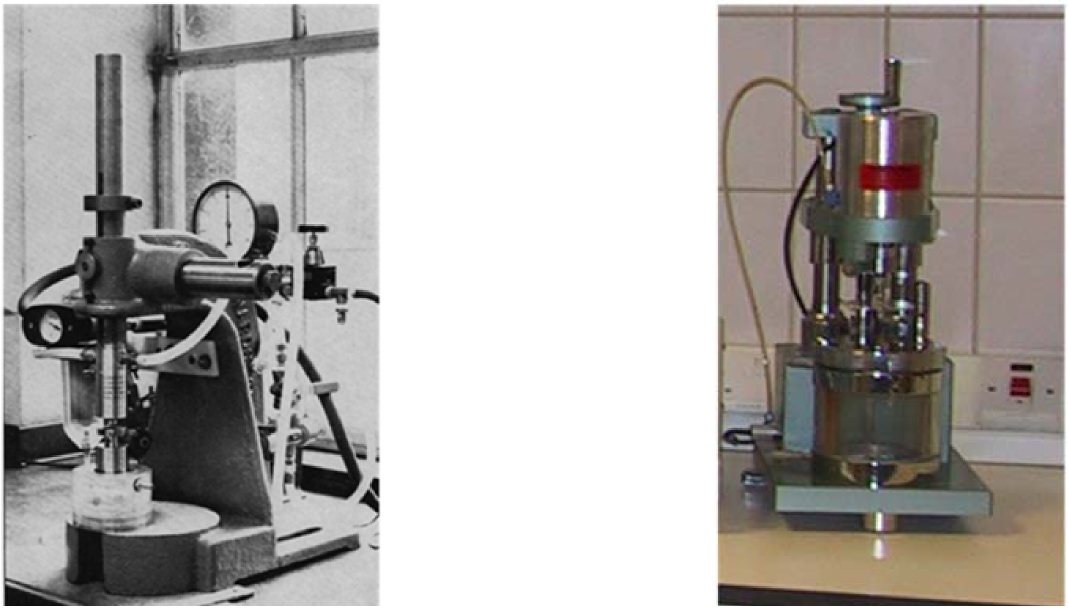


Figure 1 Jack Deer’s Air Turbine Rheometer (left); Deer Rheometer (right).

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 Figure 3), until the company was purchased by TA Instruments in 1993. 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 (Figure 4), 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.

Figure 3 CSL^2.

Figure 4 AR-G2.

The Discovery Hybrid Rheometer Series (DHR-3, DHR-2, and DHR-1) builds on the AR-G2 technology, with the DHR-3 setting the new standard for CMT rheometers.

Figure 5 DHR and electronics box.

The Discovery Hybrid Rheometer (DHR)

The Discovery Series rheometers (DHR-3, DHR-2, DHR-1) are the world's most advanced combined motor and transducer (CMT) rheometers. The systems consist of a main instrument and a separate electronics box. The interplay between the rheometer main unit and the electronics is described in "Key Rheometer Components" on page 19.

A schematic of the DHR is given in the figure below.

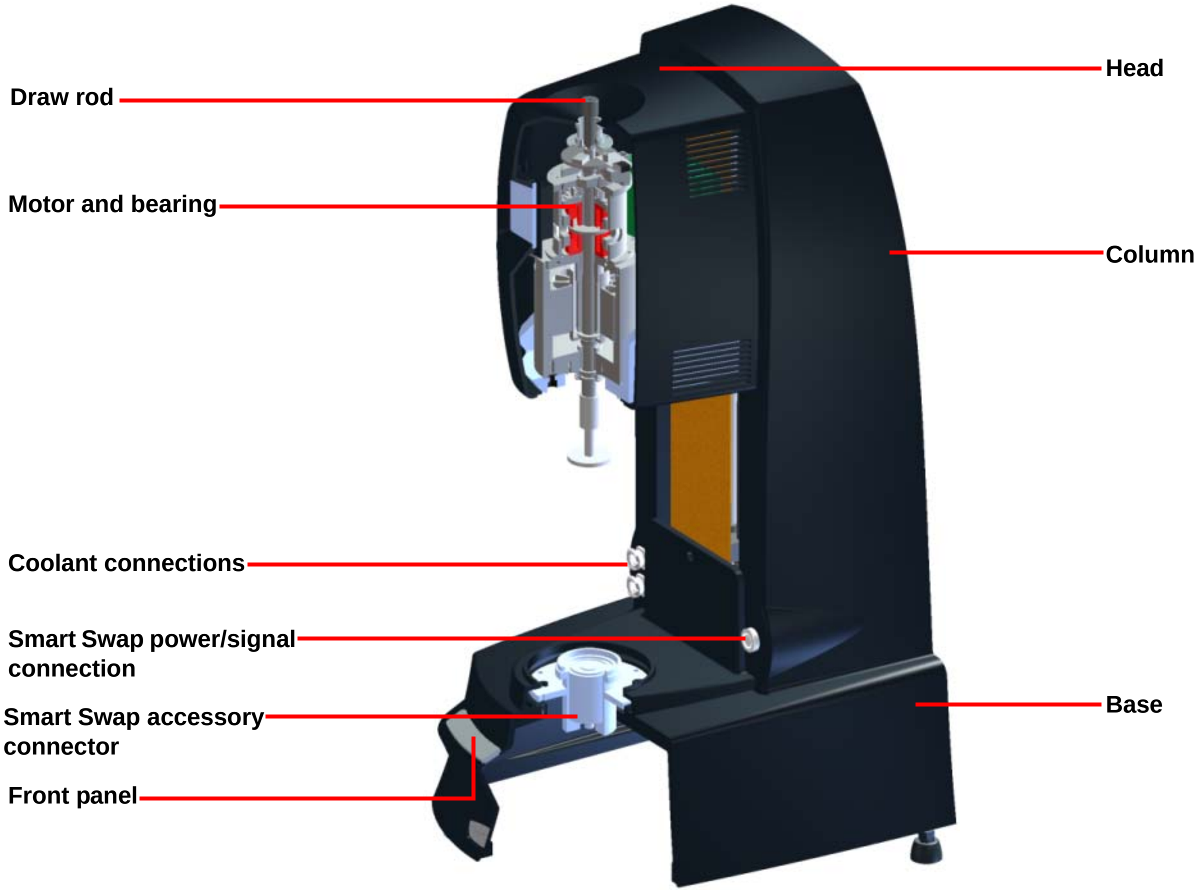


Figure 6 The DHR.

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.
- A magnetic thrust bearing that supports the drive shaft and two radial air bearings that align it.
- An optical encoder that determines its angular position.

Each of these components is described in more detail in "Key Rheometer Components" on page 19.

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
- Magnetically levitated thrust bearing
- Radial air bearings
- Motor
- Encoder
- Axial force transducer
- Electronics
- Front panel
- Smart swap
- Auto GapSet Mechanism
- Display

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. A motor located in the base of the casting drives the ball slide screw, moving the instrument head vertically. Its position is measured by a linear encoder mounted on the ball slide.

Magnetically-Levitated Bearing

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.

In the Discovery Series rheometers, 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 used). The air consumption is reduced, and the wider gap and more durable materials used make the bearing more robust and less susceptible to contamination.

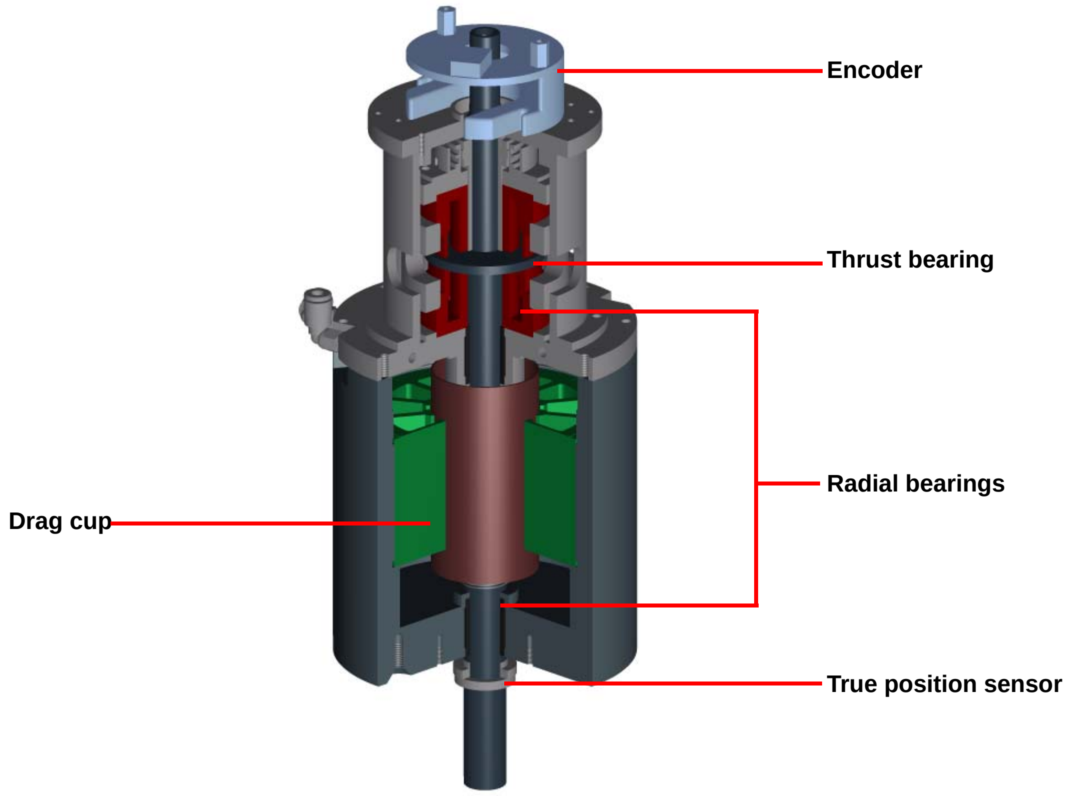


Figure 7 DHR motor bearing.

Radial Air Bearings

Radial bearings provide stiffness and support in the radial direction. The Discovery Series rheometers are designed with two porous carbon radial bearings, located above and below the motor.

Motor

The requirement that the bearing used on the rheometer should be low in friction applies equally to the motor. The Discovery Series 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 have a very low moment of 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.

Drag cup motors can get hot during use, and the torque output will vary with temperature. The motor incorporates a patented drag cup temperature sensor. The temperature of the drag cup is measured, and the input to the motor corrected, 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 Discovery Series 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 moment of inertia, and a rapid linear response. These criteria are met by an optical encoder. 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.

In the DHR-3, the performance of the encoder is enhanced by using a dual reader configuration. This patent pending design improves the basic resolution and noise level of the displacement signal as well as removing drift and improving phase resolution.

Axial Force Transducer

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.

Axial force control is also important for making measurements under tension or compression, and for loading delicate samples where it is important to retain their structure.

The DHR uses a Force Rebalance Transducer (FRT) to measure axial force. It provides the most accurate normal force measurements because the drive shaft is maintained in its vertical null position; it does not require a physical movement like capacitive sensors or strain gauges.

Front Panel

Some of the operation of the rheometers can be controlled through buttons on the front panel (shown in the figure below), as well as through the instrument control software (TRIOS Software).

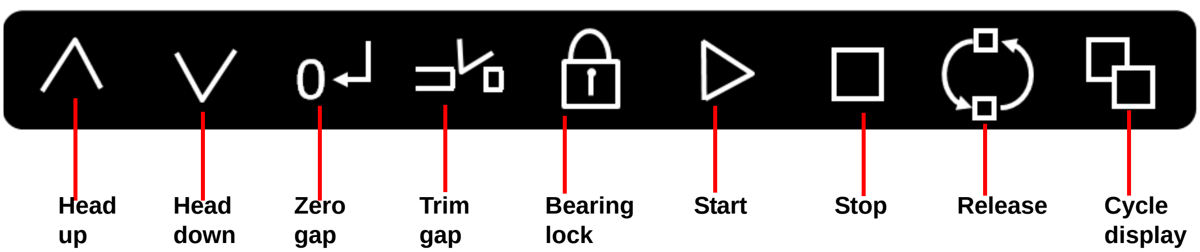


Figure 8 Front panel.

Explanation of the front panel from left to right:

- Head up: Used to raise the instrument head.
- Head down: Used to lower the instrument head.
- Zero gap: Starts the automatic gap zero position routine. A flashing red light on the button indicates that the routine is active.
- Trim gap: Used to lower the instrument head to the trim gap and set the final gap. The first time the button is pressed the light flashes red until the trim gap is reached, at which point it changes to a flashing green. The green light on the Start button is also illuminated. If the Start button is pressed, the gap closes to the geometry gap and the currently active experiment in TRIOS Software starts. If Trim gap is pressed again, then the gap closes to the geometry gap. During the closure, the light is a continuous red, changing to a continuous green when the geometry gap has been reached. The start button also illuminates green.

- Bearing lock: Applies a software lock to the bearing to prevent the instrument's shaft from rotating. This lock is over-ridden when the experimental procedure starts. A continuous red light indicates the bearing is locked. Pressing the button when the bearing is locked releases it. If the button is pressed for 3 seconds, the bearing rotates to its "home" position and then locks. This is indicated by a flashing red light. The "home" position is used when fitting a geometry.
- Start: Used to start an experimental procedure. When the button illuminates green, pressing it starts the current active experiment in TRIOS. If the geometry is not at the measurement gap, the gap automatically closes before starting the experiment.
- Stop: Terminates whatever operation the instrument is performing, for example finding the gap zero, mapping the bearing or running an experimental procedure. A flashing red light indicates that a measurement is in progress.
- Release: Used as the Smart Swap release button.
- Cycle display: Used to display alternative screens on the instrument's user interface.

Smart Swap™

The Discovery Series 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 standard across the entire range are Smart Swap™ geometries. These geometries can be automatically identified when installed on the 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 four major functions, as follows:

- Automatic setting of gaps via software
- Programmed gap closure
- Thermal gap compensation
- Axial force control (in conjunction with the axial force transducer)

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

True Position Sensor

No motor is 100% efficient, so there is always heat generated as a by-product of torque development. This can result in thermal expansion of components within the motor/bearing. An inductive linear position sensor located at the point the drive shaft exits the motor housing measures movement due to thermal expansion and makes a real-time adjustment to the geometry gap. The True Position Sensor is standard on all DHRs and is always active. It works with all geometries and environmental systems.

The performance of the True Position Sensor is enhanced by using the motor water cooling option. The water flows though a channel in the motor carriage casting before routing through the motor core. This provides a thermal break and is particularly effective when using environmental systems such as EHP and ETC.

NOTE: The water cooling is optional, but recommended during high-torque, long-lasting test procedures.

Environmental Control Units

The following sections briefly describe the environmental control units for the Discovery Series rheometers.

Peltier Plate

The standard Peltier Plate is the most widely-used temperature control system for the rheometers. It uses the Peltier thermoelectric 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.

The Dual Stage Peltier Plate (DSPP) is a system optimized for low temperature measurements using the standard four element array as a heat sink for a single Peltier element and top plate. This still has the same maximum temperature as the standard plate, but because the lower Peltier elements are the heat sink for the top element rather than a circulating fluid, low temperatures can be reached quickly, and without the use of expensive refrigerated fluid circulators.

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

Figure 9 Discovery Series Peltier Plate.

Peltier Concentric Cylinders

The Discovery 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 10 Discovery 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. The DHR offers Active Temperature Control (ATC), making it capable of direct temperature control of the upper and lower plates.

NOTE: To extend the upper heater temperature range to 150°C or above, use the Electrically Heated Plates option).

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

Figure 11 Discovery 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 DHR offers Active Temperature Control (ATC), making it 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 12 Discovery Series EHP.

The Starch Pasting Cell

The Starch Pasting Cell (SPC) is a Smart Swap™ accessory available on all Discovery Series 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.

Asphalt Submersion Cell

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

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

Figure 13 Discovery Series Asphalt Submersion Cell.

The Environmental Test Chamber (ETC)

The ETC is a high temperature Smart Swap™ option available for all Discovery Series 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. 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.

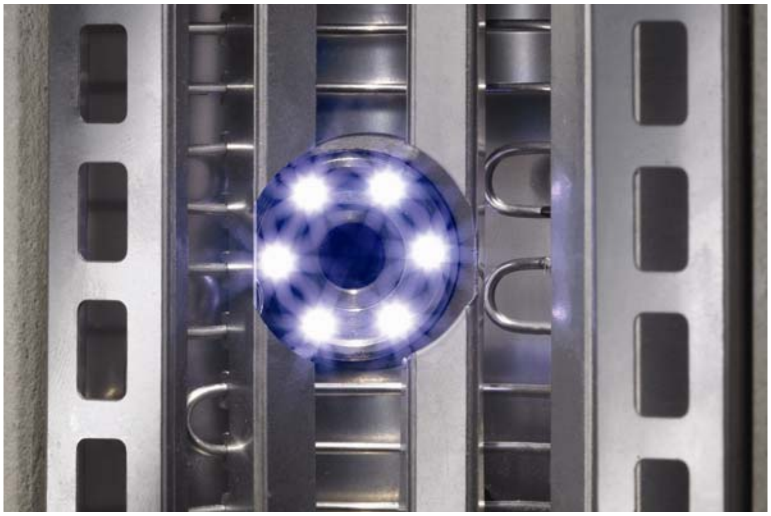


Figure 14 Discovery Series ETC and ETC viewer.

Accessories

The sections below briefly describe the Discovery Series 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 polytetraflouroethylene, PTFE, and the geometry from stainless steel.

The Interfacial Double Wall Ring (DWR)

The patented 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.

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.

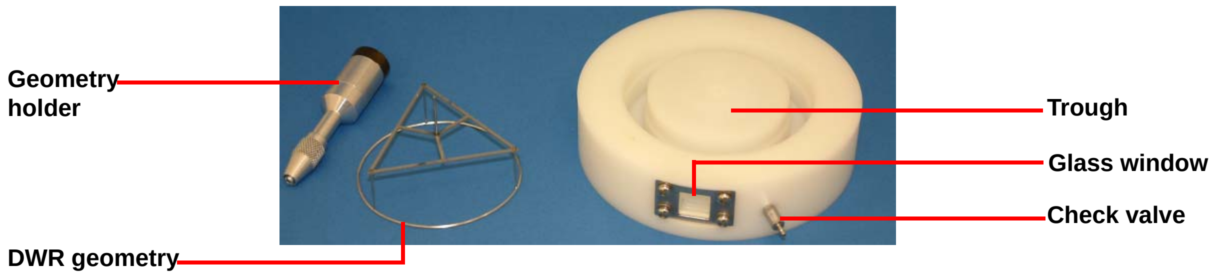


Figure 15 Interfacial DWR.

The Du Noüy Ring

The Du Noüy Ring measuring system is mainly used to determine the linear viscoelastic properties of the interface between liquid and air. It consists of a thin wire ring and a Duran glass dish. The ring is constructed from a platinum / iridium (Pt/Ir) alloy for chemical inertness, ease of cleaning, and wettability. It is important that the ring and dish are aligned concentrically, and a locating ring is provided that fits over the Peltier plate to ensure this. Two dishes are available; the outer diameter of the standard dish is 70 mm and the outer diameter of the small dish is 50 mm.

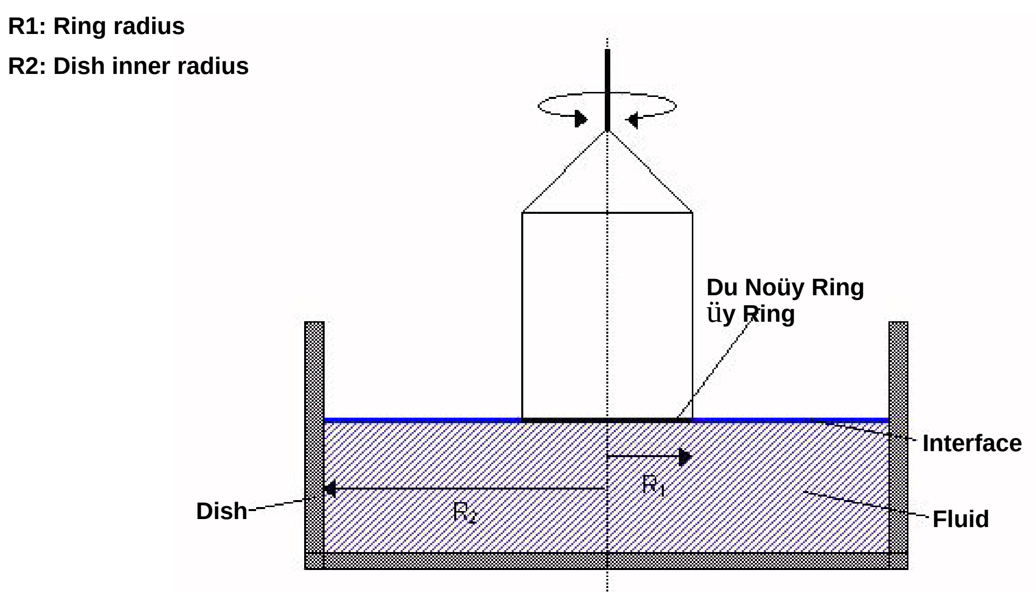


Figure 16 Du Noüy Ring measuring system schematic.

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 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 all Discovery Series Rheometers.

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

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
- Capturing images with data point (not fast sampling)
- Viewing point image in TRIOS results files

The viewer assembly is air cooled to allow it to perform over the 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 within TRIOS Software.

Refer to Figure 14 for an image of the ETC Viewer.

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 Smart Swap™ accessories for rheological characterization of these materials are available for the DHR-2 and DHR-3 rheometers. One 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 the Electrically Heated Plates (EHP) option. Disposable plates are available for hard UV coatings which cannot be removed from the plates once cured.

A blue light with a wavelength around 450 nm is also available. The blue light is most frequently used for curing highly-filled dental restoratives.

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

Small Angle Light-Scattering (SALS) Accessory

The Small Angle Light Scattering System, SALS, is an option for simultaneously obtaining rheological and structural information, such as particle size, shape, orientation and spatial distribution. The SALS is available for the DHR-2 and DHR-3 rheometers. This 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.

Discovery Series Rheometer Geometries

Standard geometries for the rheometers are constructed from stainless steel, hard anodized aluminium, or titanium.

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)
- SER2 Universal Testing Platform
- Interfacial
- Starch

Smart Swap™ Geometries

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.

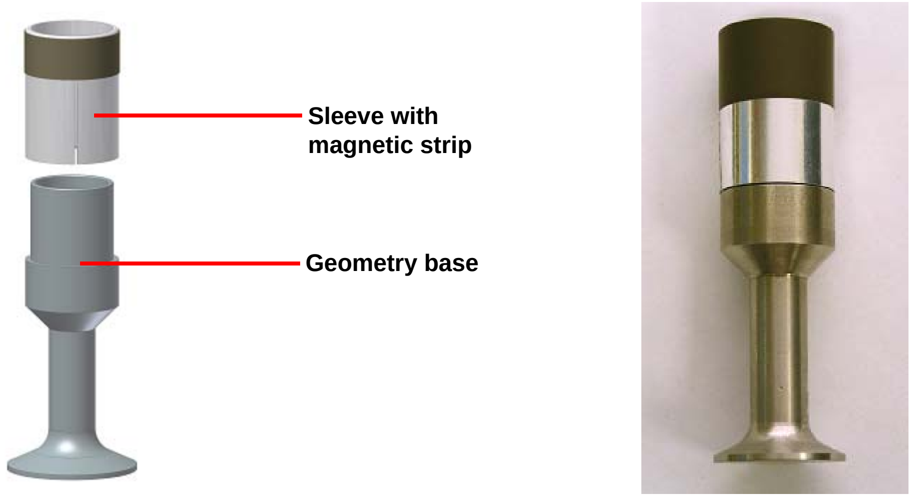


Figure 17 Smart Swap geometry.

Instrument Specifications

The tales below contains the technical specifications for the three tiers of Discovery Hybrid Rheometers.

Table 1: DHR-3 Technical Specifications

Item/Area	**Specifications**
Main Instrument	
Width	32 cm (12.5 in)
Height	76 cm (30 in)
Depth	42 cm (16.5 in)
Weight	32 kg (70.5 lbs)
Electronics Box	
Width	26 cm (10 in)
Height	48 cm (19 in)
Depth	44 cm (17 in)
Weight	14 kg (31 lbs)
Minimum torque oscillation	0.5 nN.m
Minimum torque steady shear	5 nN.m
Maximum torque	200 mN.m
Torque resolution	0.05 nN.m
Minimum frequency	1.0E-07 Hz
Maximum frequency	100 Hz
Minimum angular velocity[1]	0 rad/s
Maximum angular velocity	300 rad/s
Displacement resolution	2 nrad
Step time, strain[2]	15 ms
Step time, rate[2]	5 ms
Maximum normal force	50 N
Normal force sensitivity	0.005 N
Normal force resolution (mN)	0.5 mN

1. Zero in controlled stress mode. Controlled rate mode depends on duration of point being measured and sampling time.
2. Results at 99% of commanded value.

Table 2: DHR-2 Technical Specifications

Item/Area	Specifications
Main Instrument	
Width	32 cm (12.5 in)
Height	76 cm (30 in)
Depth	42 cm (16.5 in)
Weight	32 kg (70.5 lbs)
Electronics Box	
Width	26 cm (10 in)
Height	48 cm (19 in)
Depth	44 cm (17 in)
Weight	14 kg (31 lbs)
Minimum torque oscillation	2 nN.m
Minimum torque steady shear	10 nN.m
Maximum torque	200 mN.m
Torque resolution	0.1 nN.m
Minimum frequency	1.0E-07 Hz
Maximum frequency	100 Hz
Minimum angular velocity[1]	0 rad/s
Maximum angular velocity	300 rad/s
Displacement resolution	10 nrad
Step time, strain[2]	15 ms
Step time, rate[2]	5 ms
Maximum normal force	50 N
Normal force sensitivity	0.005 N
Normal force resolution (mN)	0.5 mN

1. Zero in controlled stress mode. Controlled rate mode depends on duration of point being measured and sampling time.
2. Results at 99% of commanded value.

Table 3: DHR-1 Technical Specifications

Item/Area	Specifications
Main Instrument	
Width	32 cm (12.5 in)
Height	76 cm (30 in)
Depth	42 cm (16.5 in)
Weight	32 kg (70.5 lbs)
Electronics Box	
Width	26 cm (10 in)
Height	48 cm (19 in)
Depth	44 cm (17 in)
Weight	14 kg (31 lbs)
Minimum torque oscillation	10 nN.m
Minimum torque steady shear	20 nN.m
Maximum torque	150 mN.m
Torque resolution	0.1 nN.m
Minimum frequency	1.0E-07 Hz
Maximum frequency	100 Hz
Minimum angular velocity[1]	0 rad/s
Maximum angular velocity	300 rad/s
Displacement resolution	10 nrad
Step time, strain[2]	15 ms
Step time, rate[2]	5 ms
Maximum normal force	50 N
Normal force sensitivity	0.01 N
Normal force resolution (mN)	1 mN

1. Zero in controlled stress mode. Controlled rate mode depends on duration of point being measured and sampling time.
2. Results at 99% of commanded value.

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 a Serial or network port.
- Air Bearing Gas Pressure (air or nitrogen) must be clean, dry, oil-free compressed gas 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 rheometer main gas 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 your Discovery Series 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 Box

The electronics box forms the link between the rheometer and the computer. All the required processing is done within the electronics box. The following steps should be followed to connect the two units together (refer to Figure 18 and Figure 19 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 electronics 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.

NOTE: Discovery rheometers communicate with the control computer via an Ethernet link, as described in the next section.

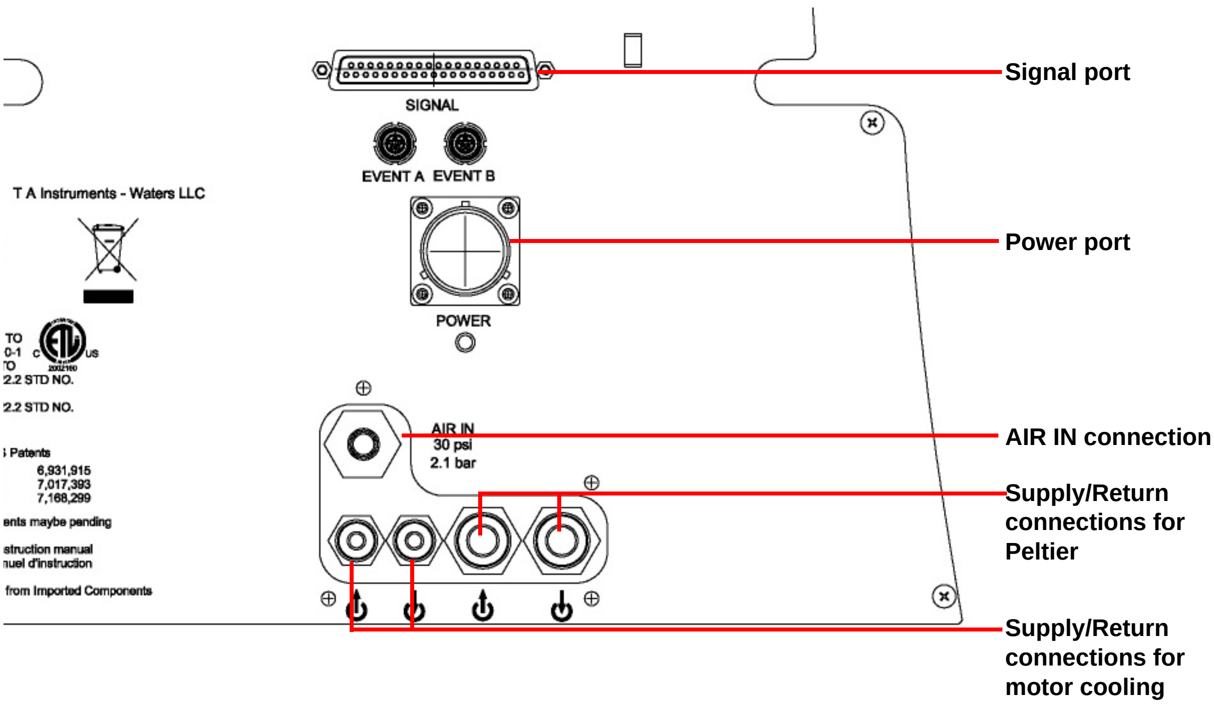


Figure 18 Cable connections to make on rheometer back panel.

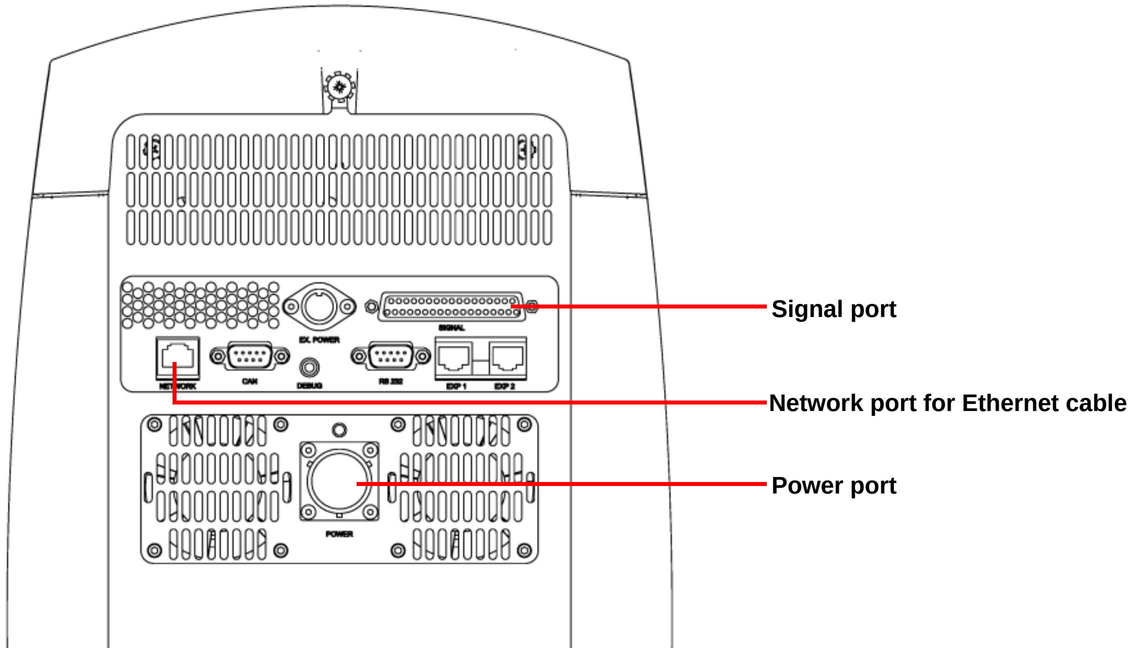


Figure 19 Cable connections to make on electronics box back panel.

Connecting the Computer to the Electronics Box Using Ethernet Communications

Ethernet communications can be setup in two ways. The electronics 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] or router. Full details are provided in the software installation instructions.

Connecting Air and Water to the Rheometer

Refer to Figure 18 on the previous page for the locations of the relevant connections in the instructions below.

1 For Peltier-based temperature control options, connect a supply of water to the supply 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).

Connecting the TA Air-Cooled Peltier Circulator

Refer to Figure 18 and Figure 19 for the locations of the relevant connections in the instructions below.

To connect the Peltier Circulator, connect the supply and return hoses to the flow supply and return connections on the rear of the rheometer.

NOTE: After the system has been started, recheck the level of water in the reservoir and refill to the inner rim, if necessary.

CAUTION: Do not put any liquid other than distilled water and TA Instruments' Conditioner in the circulator reservoir.

Connecting Motor Cooling

The Discovery Series rheometer will operate without motor cooling, but may shut down if operated at maximum torque for prolonged periods. Providing a source of cooling allows the rheometer to operate at maximum torque indefinitely. It also improves the performance of the True Position Sensor.

To avoid condensation within the instrument, use water close to ambient temperature. For best performance, allow time for the instrument to thermally stabilize before taking measurements.

Establishing Power to the System

To establish power to the electronics box and DHR, follow the instructions below.

1 Plug the AC power cord into the AC power socket on the lower back panel of the electronics box. Refer to Figure 20.

2 To power on the system, press the power switch on the electronics box to the On (**I**) position.

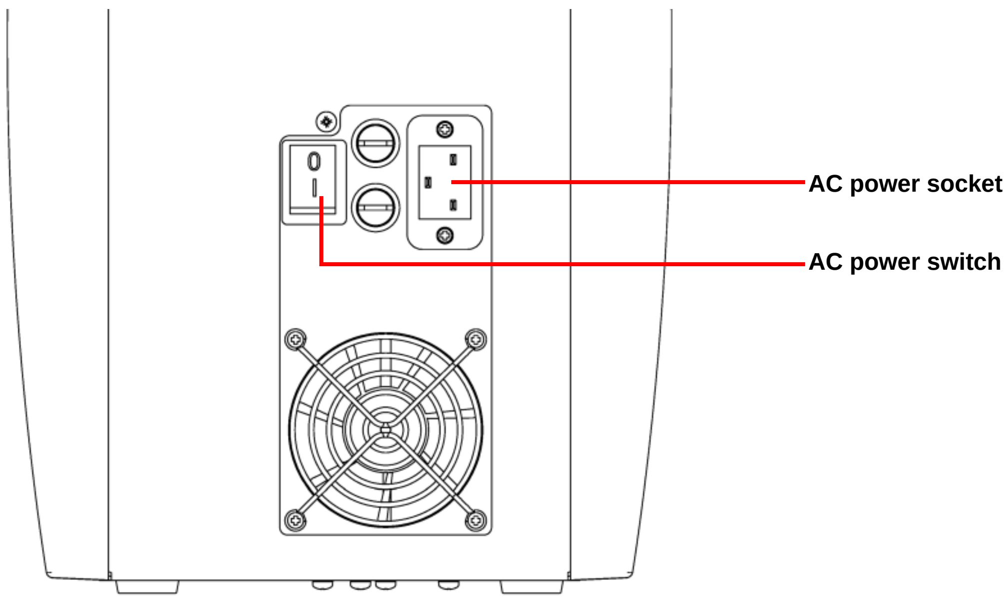


Figure 20 Lower back panel of electronics box.

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 levelled, 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 the most convenient type to use for this process.

Installing a Geometry

1. Turn on the compressed air supply to the instrument and remove the bearing clamp by turning the draw rod counterclockwise (anti-clockwise). Refer to Figure 6 for draw rod location, if necessary.
2. Power on the instrument and allow it to initialize (about 30 seconds to 1 minute).
3. Push the geometry up the spindle and hold it while locating the draw rod in the screw thread of the geometry.

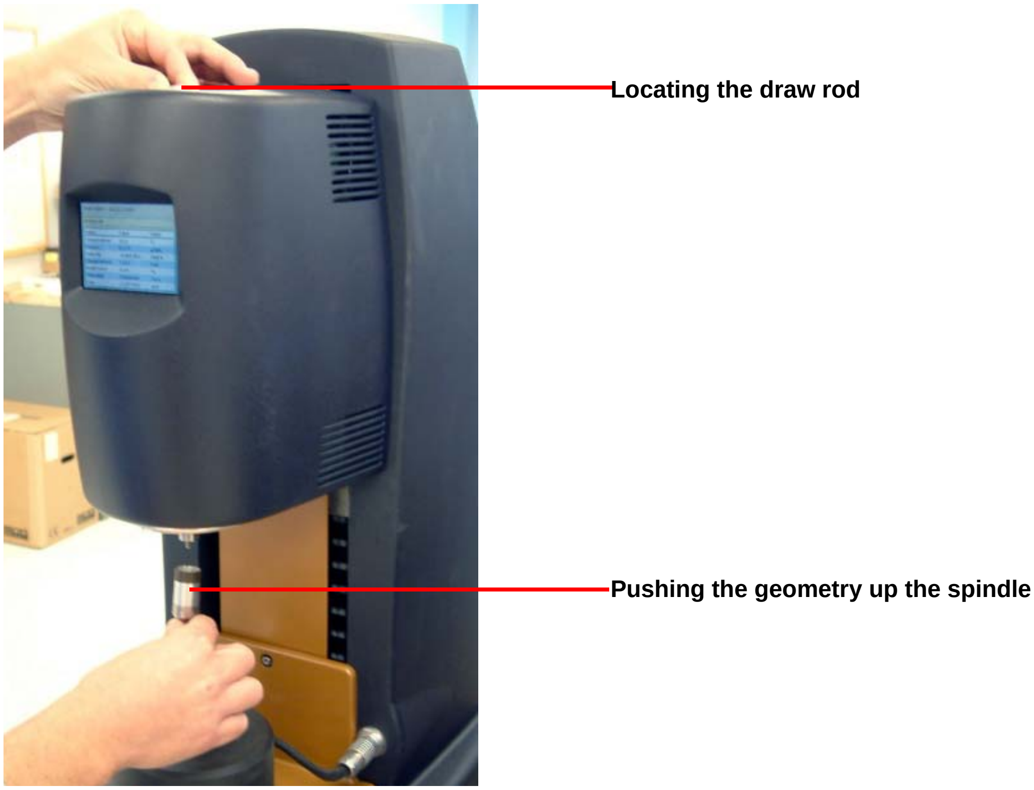


Figure 21 Installing the geometry.

4. Rotate the draw rod clockwise. The draw rod screw thread will pull the geometry upwards into position on the spindle. It should be screwed finger tight, but not forced.

NOTE: If Smart Swap is turned on, the geometry rotates a few seconds after it is fitted to enable identification.

NOTE: To remove the geometry, perform this operation in reverse.

To install the geometry so that it is in the same position each time:

1 Move the motor shaft to the home position by holding the Lock button for 3 seconds until you hear a short beep. Alternatively, click the **Go to Home Position** in TRIOS Software.

2 Align the notch on the Smart Swap geometry with the notch on the Smart Swap cover and screw in the draw rod.

NOTE: If Smart Swap is turned on, the geometry rotates a few seconds after it is fitted to enable identification.

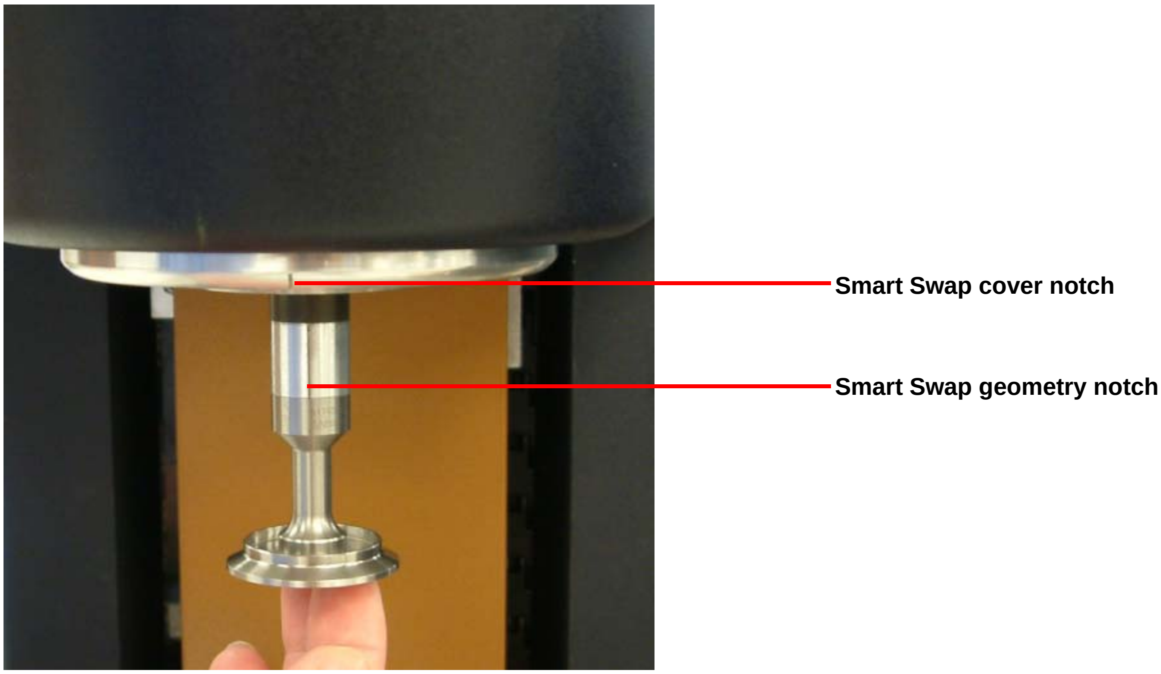


Figure 22 Aligning the Smart Swap geometry notch and Smart Swap cover notch.

Chapter 3:

Use, Maintenance, and Diagnostics

Startup and Shutdown 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 Power on the system by pressing the power switch on the electronics box to the On (**I**) position. Refer to Figure 20 for power switch location.

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 system by pressing the power switch on the electronics box to the Off (**0**) position. Refer to Figure 20 for power switch location.

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.

Adjusting Brightness of the LCD Display

The display brightness can be adjusted from the front panel.

1 Press the cycle display button until the network settings are displayed.

Figure 23 DHR front panel.

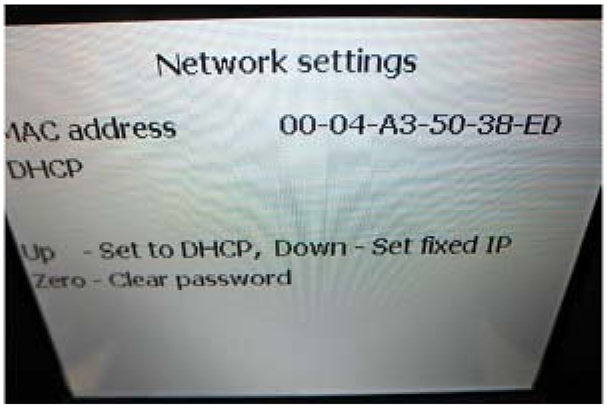


Figure 24 Network settings screen.

2 Press and hold down the cycle display button (do not lift your finger off the button). The display will cycle to the TA Logo view, and gradually the display will brighten. Release the button when the display brightness is sufficient.

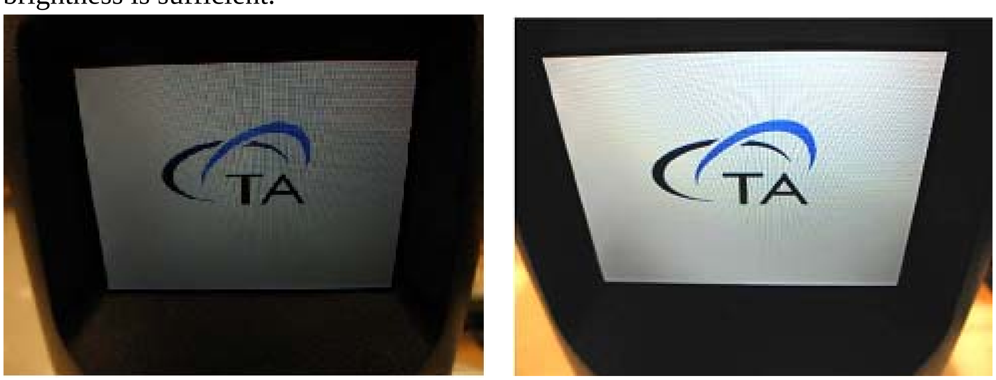


Figure 25 Dim display (left); Brightness adjusted (right).

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.

WARNING: Use two people to lift and/or carry the instrument. The instrument is too heavy for one person to handle safely. Refer to Figure 26 below for lift handle locations.

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.

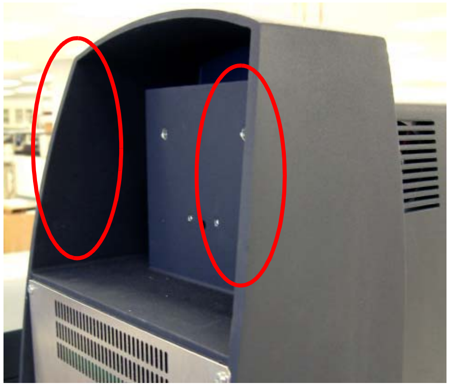
1 Ensure that the draw rod is installed.

2 Push the bearing clamp up onto the draw rod. Hold it in place and turn the knob at the top of the draw rod in a clockwise direction to engage the bearing clamp. Continue to turn the draw rod until it is finger tight.

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

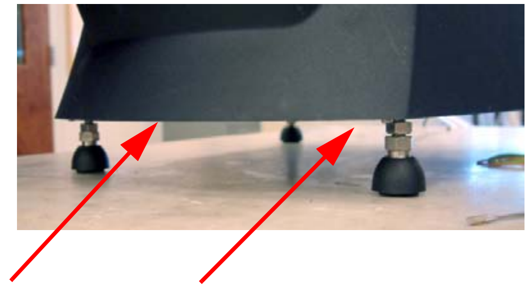
3 Lifting the instrument should always be done with two people. With each person standing on either side of the instrument, place hands in the locations shown below and lift upwards, keeping the instrument in an upright position. See the figure on the next page.

Rear of instrument



Each person grasps the DHR rear cover with one hand in the locations shown above.

Front of instrument



Each person places one hand underneath the front cover of the DHR.

Figure 26 DHR lift handle locations.

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

Startup Errors

The instrument has some power on self test (POST) routines.

If the electronics box issues groups of beep codes while flashing the TA logo in time with the sounder, then there is either a serious error which prevents the system from proceeding further, or there is a less serious error but no display is available to notify the user. Please see “System POST Error Codes” on page 52.

If it is a less serious error with no display available, the system should continue after 60 seconds but may not work correctly depending on the nature of the error.

If the electronics box issues a repeated sequence of three tones, then there is an error which should be listed on the display but there is no keypad available for the user to acknowledge the error. In this case the system should continue after a short period but may not work correctly depending on the nature of the error.

There are 3 error screens that may be displayed:

System Issues

Module name	Firmware status	Module status	Module POST

Firmware status can be: Not found, Unknown, Outdated, Current, Newer, Experimental

FPGA Version Issues

Module name	FPGA status	FPGA version

FPGA status can be: Not found, Unknown, Outdated

Power Drive Issues

Motor drive	Control mode	FPGA status

and/or

Gap set drive	Control mode

The display and keypad modules are marked as optional for the self test and so their absence should not in itself cause any errors.

If the display is blank (white) but cycles between bright and dim every 1 second, then there is a problem with the display graphics file data.

System POST Error Codes

Table 4: DHR Series POST Error Codes

Number of Beeps	Code (hex)	Description
1	1	Signal cable not fitted
2	2	Power cable not fitted
3	4	Instrument ±48V supply not activated
4	8	System controller communications failure
5	10	Heater drive communications failure
6	20	Display not present
7	40	Keypad not present
8	80	Sensor board magnetic bearing data communications failure
9	100	Sensor board encoder data communications failure
10	200	Magnetic bearing actuator fault
11	400	Motor drive activation failed
12	800	Gap set drive activation failed
13	1000	Module firmware version error
14	2000	Module status/POST error
15	4000	FPGA version error

Module Status Codes

Table 5: DHR Series Module Status Codes

Code (hex)	Description
1	Unexpected processor reset
2	Supply rail out of range
4	Temperature out of range
8	Sensor fault
10	Output fault
20	Power fail indicated
40	System heartbeat timeout
80	CAN rx overflow
100	CAN tx timeout
200	Module startup
400	CAN rx overrun

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