Grace
INSTRUMENT COMPANY

Model 3500 Viscometer
Instruction Manual

Part No. MENU3500001 Rev. B

NOTE
Grace Instrument reserves the right to make improvements in design, construction and appearance of our products without prior notice.

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Overview of M3500a and M3500pH Viscometers

The Grace Instrument Company Model 3500a and M3500pH viscometers are digital automatic instruments, which are used to measure the viscosity of Newtonian as well as non-Newtonian fluid. They can be operated both in stand-alone and PC software modes. M3500a viscometers take universal 50 Hz or 60 Hz 120-220 VAC electrical power. The heater cup is available for 120 VAC or 220 VAC.

M3500a viscometers are true Couette coaxial cylinder rotational viscometers since the test fluid is contained in the annular space (shear gap) between an outer cylinder and the bob. Viscosity measurements are made when the outer cylinder, rotating at a known velocity, causes a viscous dragging torque on the bob, which is digitized and measured. This system permits the true simulation of many significant flow process conditions encountered in industrial processing.

Viscosity as measured by a Couette type viscometer such as the Model 3500a is a measure of the shear stress caused by a given shear rate. For Newtonian Fluids, this relationship is a linear function; i.e. a plot of shear stress vs. shear rate is a straight line. In many instances, while the fluid of interest may not be Newtonian, its rheology is near enough to Newtonian that this viscometer can be used and the viscosity calculated as though it were Newtonian.

The fast response of M3500a also makes it a much better candidate than Brookfield viscometers in the food and paint industries.

M3500pH viscometers do real time pH measurements in addition to all the other great features of the model M3500a viscometers

Features include:

* One-touch absolute automated testing operation
* Single Board Computer controlled stand-alone operation
* Precision shear rate control with an extremely wide speed range from 0.01 rpm to 600 rpm continuously
* Temperature control and display capability
* Over temperature protection by thermostat
* Friendly LCD display and keypad user interface
* Automatically saves the last test result and test setups
* Complies with all API standards and maintains the same rotor and bob sizes as Fann[®] 35 and Chan 35
* Universal power supply 120-240VAC
* Automatic Gel Strength measurement
* Fast response measurement and real time monitoring capability
* FREE data acquisition and communication software Gracedaq, M3500Frac and M3500pH
* Microsoft Access[®] database engine
* Customized test reporting capability
* Real time graphing and data collecting
* Graph printing capability
* 9 different types of charting, includes shear stress vs. shear rate, viscosity vs. shear rate, viscosity vs. temperature, etc.
* Unlimited chart overlapping
* Online frequent asked questions technical support.

Two versions, 1 oz-in and 5 oz-in full range torque are available in order to broaden shear stress ranges and allows the measuring of viscosity in a wide variety of fluids.

For price and discount information, please visit our web site: ***http://www.graceinstrument.com*** or email to us: ***sales@graceinstrument.com***.

Chapter 1. General Information

1.1 Measurement Range

M3500a has the following measurement range:

Speed: 0.01~600 rpm continuously
Shear Rate: 0.0027~3254 sec^{-1}
Temperature: 0°F~212°F (-17°C~100°C)
Pressure: Atmospheric pressure
Viscosity: 0.5~5,000,000 Centipoise
Torque: 0~1*oz-in or 0~5 oz-in**
Shear Stress: 1~37,000 dyn/cm^2
Accuracy: ±0.5% of span

When placing an order, please follow the part number scheme as follows:

M3500a-1 or **M3500a-5**
Option: **M3500a-1** - 1oz-in full scale torque measurement (equivalent to a Fann$^{®}$ 35 viscometer with F0.2 spring resolution and 975° F0.2 spring full scale reading);
            M3500a-5 - 5oz-in full scale torque measurement (equivalent to a Fann$^{®}$ 35 viscometer F1 spring resolution and 975° F1 spring full-scale reading).

For example, a unit with a 5 oz-in torque full scale, with PC data acquisition software, the part number is M3500a-5.

*For R1B1 (Rotor 1 & Bob 1) combination, 1 oz-in represents a 182.9 degree reading on an Fann$^{®}$ 35 viscometer with a F1 spring installed. 1 oz-in torque is also corresponding to a shear stress of 934.6 dyn/cm^2 applied to the bob when the R1B1 is used for measurement. In another words, 1 oz-in version has about a Fann$^{®}$ 35 F0.2 spring resolution and 975° F0.2 spring full scale reading.

**For R1B1 (Rotor 1 & Bob 1) combination, 5 oz-in represents a 914.5 degree reading on an Fann$^{®}$ 35 viscometer with a F1 spring installed. 5 oz-in torque is also corresponding to a shear stress of 4673 dyn/cm^2 applied to the bob when the R1B1 is used for measurement. In another words, 5 oz-in version has about a Fann$^{®}$ 35 F1 spring resolution and 975° F1 spring full scale reading.

1.2 Hardware List

With your M3500a automatic viscometer shipment, the following should be included:
1. One M3500a viscometer per unit
2. One R1 sleeve per unit
3. One B1 bob per unit
4. One stainless steel cup per unit
5. One temperature sensor per unit
6. One CD-ROM copy of the software for the M3500a, including 3 programs of Gracedaq, M3500Frac and M3500pH.
7. One communication cable to connect your PC comport to M3500a

Depending on your order, you could also have the following options:
1. Plastic M3500 carrying case
2. Thermal cup with heating capability
3. Cooling cup with cooling capability
4. AC inverter which will change 12VDC to 120VAC power supply

5. R2, R3 sleeves
6. B2, B3, B4 bobs
7. Other material types for the rotor and bob is also available.
8. Small sample adapter.

1.3 Mechanical Specifications

Mechanical Specs are as followed:
a. 5" x 8" compact foot print
b. 16" tall
c. 20 lbs. total weight.

1.4 Electrical Specification

M3500a viscometer can be used with either 120V 60Hz VAC or 220V 50Hz VAC power supplies

The M3500a heater cup is available in two versions, 120 VAC or 230 VAC.

1.5 Recommended Operating Conditions

The recommended operation environments for M3500a are:
a. 10°C ~ 30 °C
b. Atmosphere pressure

The minimum requirements for the PC to install and run the **Gracedaq** data acquisition, **M3500Frac** and/or **M3500pH** software is:
- Pentium 120MHz;
- 16 Mb memory;
- At least one comport available;
- Windows operating system (Windows 95, 98, ME, NT, 2000 or XP).

Chapter 2. Hardware Setup

2.1 Test Preparation

The hardware setup of the M3500a automatic viscometer is simple. Just follow these steps:

Step 1:   Plug in the temperature probe to the socket located on the back of M3500a viscometer as shown in Pic 1.

Pic. 1 Plug in temperature probe

Step 2:   Plug in the thermal cup power outlet as shown in Pic 2, if heating control of the sample is desired.

Pic 2. Plug in thermal cup power outlet

Step 3:   Plug in the serial communication cable as shown in Pic 3.

Pic 3. Plug in serial cable

Pic 4. Put on dust shield (MACH3500057).

Step 4:   Remove the Sample Cup from the stage. Assemble the Dust Shield onto the Bob Shaft with the flange end up and hold it in place as shown in Pic 4.

Pic 5. Screw on bob.

Step 5:   Assemble the Bob onto the Bob Shaft by screwing it clockwise until it is tight against the Dust Shield.

WARNING
Never over tighten the bob. Over tightening the bob may incur damage to M3500a viscometers. After testing, it is recommended you take off the bob and clean it, in order to prevent the bob from sticking to the bob shaft.

Pic 6. Put on the sleeve.

Step 6:   As shown in Pic 6, with your left hand holding the rotor edge, assemble the sleeve onto the rotor by screwing it clockwise with your right hand. Make sure the threads in the Sleeve and on the Rotor are clean so the Sleeve will seat on the Rotor by hand tightening.

Pic 7. Put the cup assembly on stage.

Step 7: Put the stainless steel sample cup into thermal cup. Please notice that there are three stands at the bottom of the thermal cup as shown in Pic 7. Put the thermal cup on the stage (item 10 in Fig 1, in appendix B), matching those stands to the three holes on the stage.

Pic 8. Secure temperature probe

The stainless steel sample cup that is provided has a line scribed at the 350-ml test fluid level.

Step 8. Fill the Sample Cup to the scribed line with a recently agitated sample of the fluid to be tested. A scribed line on the sleeve indicates proper immersion depth. Refer to Fig. 1 at appendix B. Damage to the bob shaft bearings may occur if this immersion depth is exceeded. If other sample holders are used, the space between the bottom of the rotor and the bottom of the sample holder should be one-half inch (1.27cm) or greater. Clip the brass clip to the edge of the sample cup. Then gently place the temperature probe into the clip. If you are using a small sample adapter cup, just insert your small sample adapter cup directly into the thermal cup, and insert the temperature probe into the hole in the wall of adapter cup. DO NOT WORRY ABOUT THE GAP BETWEEN SMALL SAMPLE ADAPTER CUP AND THERMAL CUP. THE THERMAL CUP WALL DOES NOT GENERATE HEAT. **DO NOT INSERT SMALL SAMPLE ADPTER CUP INTO LARGE SAMPLE CUP WHILE HEATING UP. USE ONLY ONE CUP AT A TIME.**

Step 9. Plug the power cord of M3500a into an AC power outlet, and turn the switch on at the back of the unit.

WARNING
Make sure that no sample should be contacting the bob, when you power up your M3500a viscometer. Otherwise self-calibration of bearing drag will be incorrect.

When the M3500a is initially powered up the screen will display our company name and instrument information. The instrument will then go through a self warming-up and self-calibration of bearing drag.

When the self-calibration is finished the main LCD menu screen will be displayed and your M3500a is now ready for testing.

FEATURES

If during the self-calibration process, the M3500a senses a bearing drag that is more than 0.7% of full scale, it will display an error message recommending you to change the bearings.

If M3500a battery power is low, it will warn you to change the coin cell battery. However, you do not have to change the battery unless memorization of the previous test results and test setups need to be retained after powering down the instrument.

2.2 Cleaning

Pic 9. Taking off bob and dust shield.

Refer to Fig 1 in appendix B for parts described in the following procedure. The disassembly and cleaning procedures are provided as below.
Step 1. Loosen the thumbscrew (item 9 in Fig 1 appendix B); lower the stage (item 10 in Fig 1 appendix B) to the bottom position.
Step 2. Remove the cup and temperature probe for cleaning.
Step 3. Twist the sleeve counterclockwise while holding the rotor to take off the sleeve.
Step 4. While pulling down the bob very slightly, rotate the bob counterclockwise to loosen the bob, please be prepared that once the bob is taken off, the dust shield might fall down, as shown in Pic 9.

WARNING

**Turning the bob clockwise to loosen it when looking down from the top of the machine.
Never push the bob upward when loosening the bob.**

Chapter 3. M3500a Stand-alone Operation

3.1 M3500a Keypad LCD Interface Diagram

The M3500a has a keypad-LCD interface as shown below:
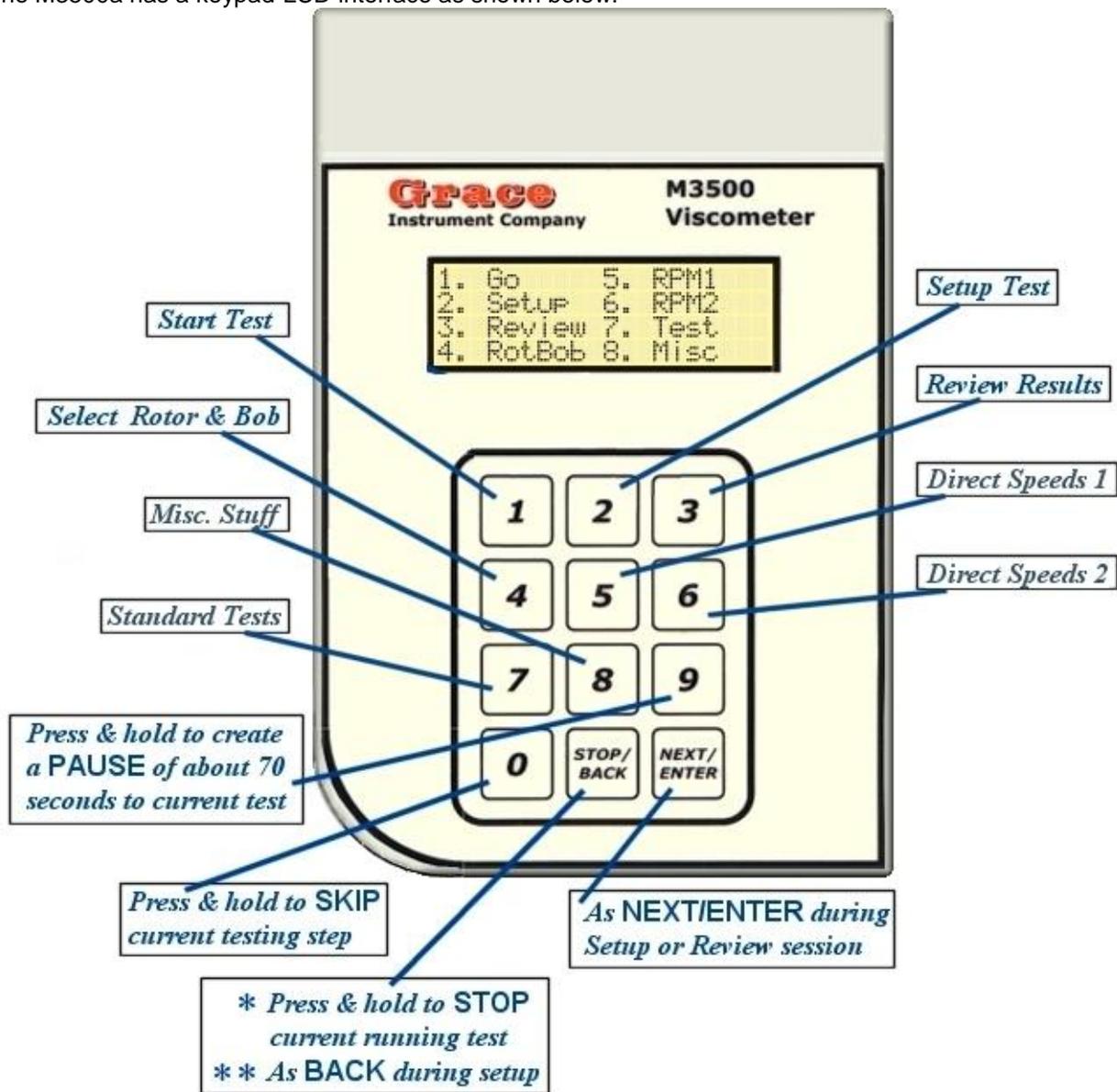
The user can run a test, setup test procedures, view test result and setup rotor/bob configuration through the keypad-LCD interface.

The Keypad-LCD user interface diagram for M3500a viscometers is shown as next page:

Initial Screen

```
GRACE INSTRUMENT
M3500A-1 VISCOMETER
   VISIT US @ WWW.
GRACEINSTRUMENT.COM
```

Warm-up Screen

```
Warming up & Self-
    Calibrating.
No fluid touching
   bob please.
```

Menu Screen

```
1. Go      5. RPM1
2. Setup   6. RPM2
3. Review  7. Test
4. RotBob  8. Misc
```

Press 1, 2, 3 or 4

Press 5, 6, 7 or 8

1. Testing Screen

```
Step###:########S ###F
    #####Cp    ###.##Rpm
Stress:  ####dyn/cm-2
Fann###deg Gel:######
```

2. Setup Screen

```
STEP#:   ##
TIME:######(SEC)
TEMP:###(F)
SPEED:#####(/100RPM)
```

3. Review Test Result Screen

```
Step###:########S ###F
    #####Cp    ###.##Rpm
Stress:  ####dyn/cm-2
Fann###deg Gel:######
```

4. Rotor & Bob Selecting Screen

```
1. R1B1    5. R1B5
2. R2B2    6. R1B4
3. R3B1
4. R1B2
```

5. Direct Speed Tests 1

```
1. 600   5. 6
2. 300   6. 3
3. 200   7. 2
4. 100   8. 1  9.Back
```

6. Direct Speed Tests 2

```
1. 60    5. 6
2. 30    6. 3
3. 20    7. 2
4. 10    8. 1  9.Back
```

7. One Touch Standard Tests

```
1. 120Api  5.
2. 150Api  6.
3.         7.
4.         9.  Back
```

8. Setup Average

```
1. Avg     5.
2. Release 6.
3.         7.
4.         9.  Back
```

3.2 Start & Stop Testing

Refer to Fig 1 in appendix B for parts described in the following procedure. Refer to Section 2.1 "Test Preparation" for how to prepare a test.

After preparing the test, first loosen the thumbscrew (item 9 in Fig 1 appendix B). Raise the stage so that the test fluid immures to the scribed line on the sleeve. Then tighten the thumbscrew to secure the stage elevation. You can preset the location of shaft collar (item 8 in Fig 1 appendix B) so that stage will stop at the right height every time.

Since the M3500a remembers your last test setup and test, it cannot be simpler to start a test if you have already setup the desired testing procedures. Make sure you are in the main menu screen (refer to Section 3.1), and press "1". The test will start and finish the whole test without your intervention.

During a test, **press & hold** the "Stop/Back" button to stop the current test.

We wish we could have even washed your cup automatically after the test, but the cost prevented us to do that!

The LCD display during the test is explained as follows:
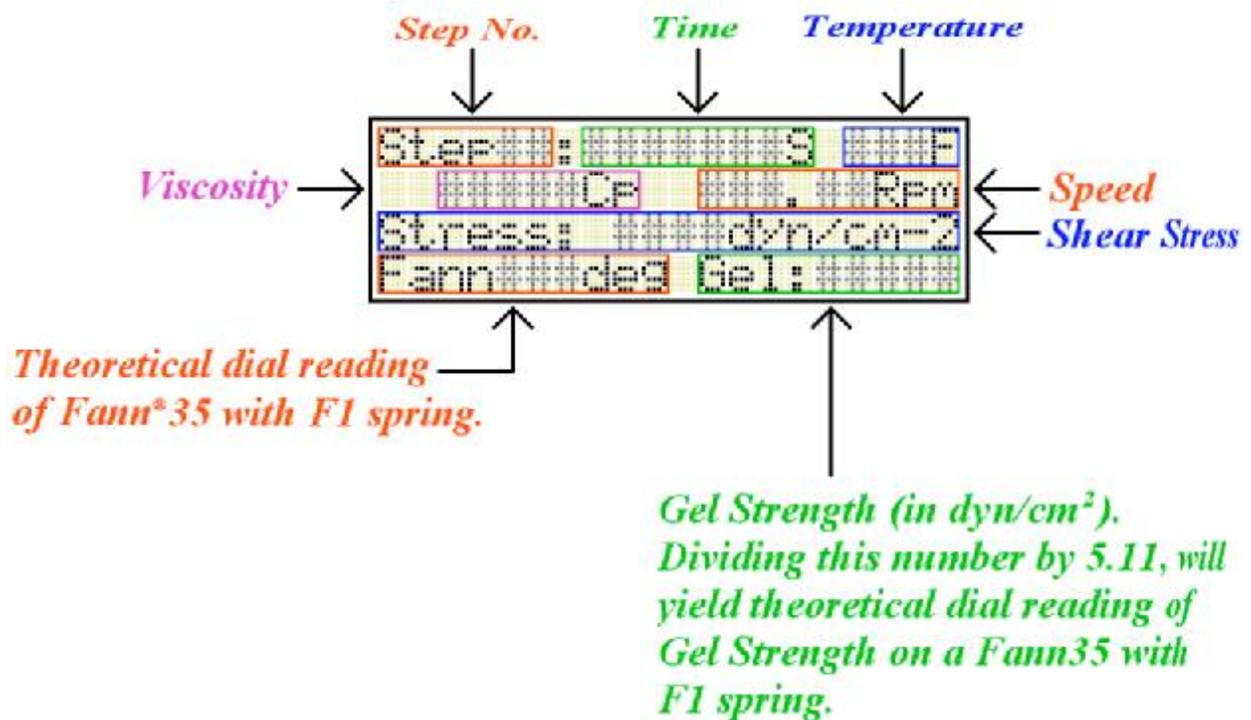
3.3 Setup Test Steps

At the main menu screen, press 2 and it will go to the setup screen. The current setup step number will be shown at the upper left-hand corner. Input time duration (in seconds), temperature (in °F), and speed (in rpm) information. If you made a mistake during entering one certain parameter, just keep on pressing any number key (0 to 9), and the blinking cursor will go back to the initial input position again.

After you have finished entering one parameter, go to the next parameter by pressing "Next/Enter" key. When you have finished all required parameters for one step, go to the next step by pressing "Next/Enter" key.

If you make a mistake on previous steps or previous parameters in your setup progress, you can press the "Stop/Back" key to go back to previous step.

When you finished entering all steps, pressing "Next/Enter" twice will return you to the main menu.

Up to 98 test steps can be setup and saved.

3.4 Review Test Result

If your M3500a has not been powered down since your last test or the battery in your M3500a still has power (the battery last around 4-6 years) it will store your last test setup and test results. To view the last test results press "3" at the main menu screen. View the next step by pressing the "Next/Enter" key. After all the test steps have been reviewed the program will return to the main menu automatically.

3.5 Setup Rotor Bob Information

The M3500a viscometer can use different rotor and bob combinations. To enter the rotor and bob selection screen press "4" from the main menu screen. You can enter the rotor & bob selection screen to select the rotor bob combination in your system. The default rotor bob combination is R1-B1.

Press 1 to select R1B1;
Press 2 to select R2B2;
Press 3 to select R3B1;
Press 4 to select R1B2;
Press 5 to select R1B5;
Press 6 to select R1B4;

3.6 RPM1 (Direct Speeds 1)

By pressing "5" in the main menu screen, a sub menu with most used test speeds will show up. By pressing 1-8, direct speed tests will start. Please note that a quick test started this way will not control the temperature and the unit will continue to run until the "Stop/Back" key is pressed.

3.7 RPM2 (Direct Speeds 2)

By pressing "6" in the main menu screen, a sub menu with less common test speeds will show up. By pressing 1-8, direct speed tests will start. Please note that a quick test started this way will not control the temperature and the unit will continue to run until the "Stop/Back" key is pressed.

3.8 TESTS (Standard Tests)

By pressing "6" in the main menu screen, a sub menu with standard API tests will show up. Currently only the standard API 120°F mud test, API 150°F mud test and API cement tests are offered.

120 °F API Mud setup:

Step No.	Step Time (Sec)	Step Temp (°F)	Step Speed (rpm)
1	600	120	300
2	20	120	600
3	20	120	300
4	20	120	200
5	20	120	100
6	20	120	6
7	20	120	3
8	20	120	600
9	20	120	0
10	20	120	3
11	20	120	600
12	600	120	0
13	20	120	3

150 °F API Mud setup:

Step No.	Step Time (Sec)	Step Temp (°F)	Step Speed (rpm)
1	600	150	300
2	20	150	600
3	20	150	300
4	20	150	200
5	20	150	100
6	20	150	6
7	20	150	3
8	20	150	600
9	20	150	0
10	20	150	3
11	20	150	600
12	600	150	0
13	20	150	3

API Cement test setup:

Step No.	Step Time (Sec)	Step Temp (°F)	Step Speed (rpm)
1	20	75	3
2	20	75	6
3	20	75	30
4	20	75	60
5	20	75	100
6	20	75	200
7	20	75	300
8	20	75	200
9	20	75	100
10	20	75	60
11	20	75	30
12	20	75	6
13	20	75	3
14	20	75	0
15	20	75	3
16	600	75	0
17	20	75	3

3.9 MISC (Misc. Stuff)

"8" in the main menu screen is for setting up miscellaneous stuff. In this sub menu, by pressing "1", the user can setup how many samples to be averaged for stand-alone test results. Please note that this will not interfere with your real-time (PC controlled) test results.   By pressing "2", the step motor driver will not apply holding torque to the sleeve.

3.10 Zeroing

The M3500a viscometer has been calibrated and inspected before shipment, and was designed so that it does not need to be calibrated for a long period of time.

Every time when you start a new test, the M3500a viscometer will automatically self-zero.

3.11 Pause Test & Jump to Next Step

During the middle of a test, press and hold the keypad button "9" and it will stop the motor for about 70 seconds. After 70 seconds, the test will assume.

During the middle of test, press and hold the keypad button "0" and it will jump to the next step.

Chapter 4. Gracedaq Data Acquisition Software

4.1 Gracedaq Installation

Gracedaq functions with the M3500a model. **It is strongly recommended that a new user review the training movie included on the CD-ROM.**

When you insert the M3500 software CD-ROM into your CD-ROM drive, an auto-run installation menu should show up automatically. On this menu, please click *Install Gracedaq* and follow the prompts to finish the installation. If your Windows feature '*Auto insert notification'* is disabled, or if for any other reason causes the AutoPlay/AutoRun menu not to start automatically, please use Windows Explorer to view the content of the CD-ROM and double click file "setup.exe" in the root directory of the CD-ROM then follow the instructions.

For latest update, download the updated M3500a.exe file from our web site: *http://www.graceinstrument.com*. Then overwrite your M3500a.exe file, which is normally located at c:\program files\M3500a, with your downloaded one.

4.2 Testing Setup

It is very straightforward to setup test procedures with Gracedaq. Just go to the "Setup" screen by clicking the "Setup" button on the main screen.

In the setup screen, the user can setup the following information:
a. Unit
   The user can select EI (English Unit) or SI (Metric Unit) by clicking on the corresponding selection.

b. Rb factor
   The user can select rotor bob factor (Rb factor) by selecting the right option in the drop-down option box.

c. Setup test steps and procedures
i. To open or select saved test sequence setups: On the Sequence Name Table located at the upper right corner of the setup screen, click the name of the sequence name that you want to view or download. The test steps will be shown on the Test Steps Table located at the bottom of the setup screen.
ii. To delete a saved test sequence: On the Sequence Name Table located at the upper right corner of the setup screen, click the name of the sequence name that you want to delete. Then click the "Delete" button located at the upper right side of the setup screen.
iii. To save a certain test sequence as a new name: On the Sequence Name Table located at the upper right corner of the setup screen, click the name of the sequence name that is to be copied. Then click the "Save As" button located at the upper right side of the setup screen. Assign the new sequence a new name, then a new sequence is generated.
vi. To Insert a step before a certain step: Click the step where you want to insert a new step in the Test Steps Table located at the bottom of the setup screen, then click the "Insert New Step" button located at the bottom of the setup screen. A small screen will come up and ask you to input the new step information.
v. To delete a certain test step: On the Test Steps Table located at the bottom of the setup screen, click the step that you want to delete. Then click the "Delete" button located at the bottom of the setup screen.

4.3 Upload Test Setup to M3500a

Uploading test setup procedures function is on the "Setup" screen. Once you have selected the right comport and the test steps that you want to download, just click the "Send to M3500a" button. The status bar at the bottom of Setup screen will show the progress of the download.

4.4 Download Test Result

After finishing a test, the test result is automatically saved in M3500a viscometer. The user can use Gracedaq to download the latest test results and save it to the database for future review.

To download data use the following guideline:
1. Go to the setup screen and setup the correct comport number
2. Return to the main screen
3. Click the "Get from M3500" button; (the bottom status bar shows the progress of the downloading process)
4. If the download is successful, the "Related Info" screen will appear. Input the related information about the test in the corresponding spaces.

The Gracedaq will automatically draw the graphic view of this test as well as save the test result to the database.

4.5 Report Generating & Exporting

The M3500a can generate a test report as well as export the test report to other formats. Once you have a test opened, click the "Report" button on the main screen. A report will show up. Then you can view the report. The user can export the results to different formats by clicking at the bottom second to the right button on the report screen.

4.6 Graphic View and Print of Test Result

At the main screen, when you already have a test opened, a graphic view of the test results can be seen. Move your cursor on any portion of the graph and right click on your mouse. A pop-up menu will appear through which you can maximize the graph or export the graph to a bitmap file for printing. You also can change the title of the graph, change the color and legend, as well as zoom in and out of the graph. Take a moment and experiment, **it is fun!**

On the right side of the graphic view, there is a pull down selection combo box. The following shows the 9 types of charts:

1. Shear stress vs. shear rate
2. Shear stress vs. speed
3. Viscosity vs. shear rate
4. Viscosity vs. speed
5. Shear stress vs. temperature
6. Viscosity vs. temperature
7. Shear stress vs. time
8. Temperature vs. time
9. Viscosity vs. time

Just select the chart type that you want. The chart will change automatically to that type.

To print a graph, just click the "Print Graph" button. A printing dialog window will show up. Just click "OK" after selecting correct printer.

4.7 Related Information

Normally there is some important information associated with the test result. Gracedaq provides a "Related Info" function to help users save as well as edit the important information.

After an old test result is opened, click the "Related Info" button on the main screen. The "Related Info" screen shall appear. You can edit the following information:

a. Test name (Can not be empty or duplicated with other tests)
b. Mud or Fluid ID (Can not be empty or duplicated with other tests)
c. Test time (Can not be empty)
d. Company name (Optional)
e. Comments (Optional)

After finishing the change, click "OK" button to save the change.

When you just finished downloading the test result from the M3500a, the related information input screen will shown up. If you do not enter the required information, the downloaded test results will not be saved to the database.

4.8 Real Time Measurement

By clicking the "Real Time" button on the main screen of Gracedaq, the "Real Time Testing" screen will show up. First, you have to send a sequence to M3500a at the setup screen before you can access the real time testing screen.

The following is a list and functions of those buttons on the "Real Time Testing" screen:
Start: Starts the real time test (You first need to go to the "Setup" screen to download the setup steps before your can start the M3500a.).
Stop: Interrupts and stops the current test.
Exit: Exits Real Time Testing screen and returns you to the main screen.
Save as: Saves the current test as a new name.

First of all, the user needs to click on "Save As" button to input the related information, such as test name and time, etc. Start the test by clicking on "Start" button. User can select different data storage interval "on the fly" by clicking on the corresponding option button in the "Sample Saving Rate" group box.

NOTE: IF YOU ARE RUNNING A LONG TEST, 1 DATA/SEC SAMPLING RATE CAN GENERATE A HUGE FILE QUICKLY. THAT WILL SLOW DOWN THE SYSTEM PERFORMANCE SUBSTANTIALLY.

After the test is finished, a message will appear on the screen telling you that the current test is finished.

4.9 Chart Overlapping

Gracedaq has unlimited chart overlapping capability. Just follow the following instructions to overlap the 9 types of charts (only limited by your computer memory).

1. At main screen, first open the base test to be compared with by clicking the "Open saved test" button.
2. Click the "Chart Type" combo box to select the chart type that you want to compare.

3. Click the "Overlap Chart" button, and then select the saved test that you want to overlap the chart on.
4. If more than two test results need to be compared, just repeat step 3

Chapter 5. M3500Frac Software

5.1 M3500Frac Installation

The M3500Frac program functions with the M3500a model. **It is strongly recommended that all new users review the *M3500Frac Training Course.*** It can be found on the M3500Frac software, at the beginning of the installation menu of the CD-ROM.

The M3500Frac requires some database components, which in turn needs MS Internet Explorer 4.01 or a later version. Please first install Internet Explorer 5.5 if your computer has an older version Internet Explorer than 4.01.

When you insert the M3500 software CD-ROM into your CD-ROM drive, an auto-run installation menu should show up automatically. On this menu, please click *Install M3500Frac* and follow the prompts to finish the installation. If your Windows feature '*Auto insert notification'* is disabled, or if for any other reason it causes the AutoPlay/AutoRun menu not to start automatically, please use Windows Explorer to view the contents of this CD-ROM and double click file "setup.exe" in the root directory of the CD-ROM, and follow the instructions.

After the M3500Frac installation, if an error message "Provider Not Found, it may not have been installed properly" occurs while running M3500Frac, please follow the ***In case of problem…*** option on the installation menu to solve this problem.

For the latest update, download the update M3500Frac.exe file from our web site at: <u>http://www.graceinstrument.com</u>. With the downloaded one, overwrite your M3500Frac.exe file, which is normally located at c:\program files\M3500Frac.

5.2 Setup

Click **Setup** button on the main window of M3500Frac program to open the setup window.

a.   Hardware and Misc. setup
By choosing ***Hardware and Misc. setup*** tab in the setup window, the user can setup unit and communication port information.
i.   Unit Selection
User can select CGS (Centimeter Gram Second system), EI (English unit) or SI (metric unit)
ii.   Commport Setup for M3500a
For proper communications with the M3500a viscometer a communication port setup has to be accomplished before using other features of this program. A unique and available RS232 comport (COM1 to COM8) has to be assigned to each working M3500a viscometer.

<div style="border:1px solid black; padding:4px;">

NEVER use the same port for more than one viscometer unit

</div>

.

b.   Test Sequence setup
By choosing ***Test Sequence Setup*** tab in the setup window, the user can setup his test sequence, ramp details within each sequence step, and other related parameters.
i.   To create a new test sequence: Click the button ***New*** and enter a sequence name. User can select the new sequence or any existing sequence listed in the ***Saved test sequences*** box by clicking on its name.
ii.   To delete an existing test sequence: Select the sequence by clicking its name in the ***Saved test sequences*** list box, then press the button ***Delete***.
iii.   To copy an existing sequence as a new one: Click a sequence name to be copied, press the button ***Copy As*** and give a new name in the next pop-up dialog box.

iv. **To Insert or delete a single sequence step:** To insert a single step, first click on an adjacent step, then click *Insert new step* button. A window will show up asking whether you want to insert before or after the selected step. Proceed with the necessary information. To delete a single step, first click on that step, then press *Delete current step* button.

v. **To setup a batch of steps at a time:** For more convenience, the user can generate a series of sequence steps by clicking on *Auto Step Builder* button. A few input boxes will show up. Please input the necessary parameters into those boxes, and click on *OK* button. You can edit individual steps later by simply clicking on any individual parameter and input your value, just like an Excel spreadsheet.

vi. **To define ramp steps for all sequence steps:** At the lower right corner of the setup screen, the user can define ramp steps for all sequence steps. Please keep in mind that this series of ramp steps with a different shear rate will be run by all sequence steps which is defined at the lower left corner of the setup screen. Click a sequence name in the list-box *Saved test sequences* to select it. Then input all necessary parameters. Refer to the below diagram for the definition of various parameters.
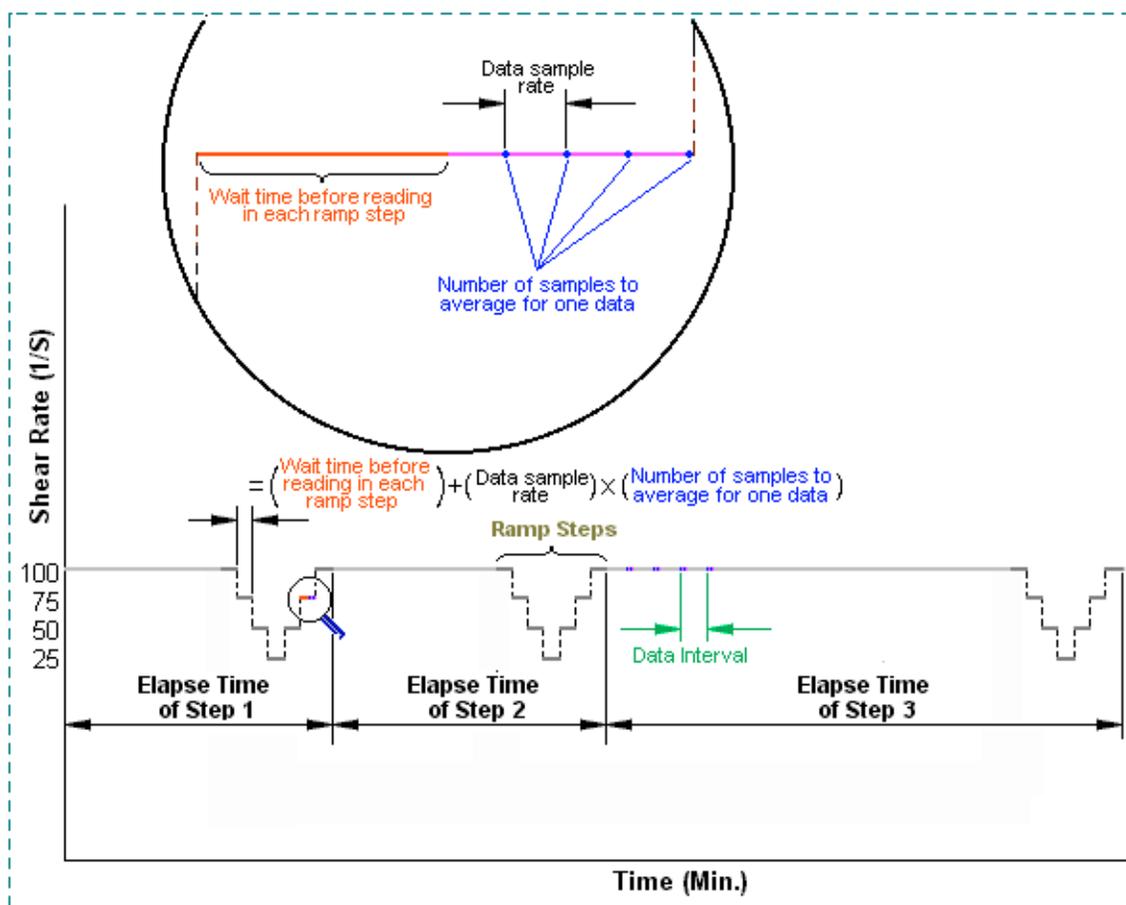
vii. **To define a test *Auto Shut Down* condition:** Please input two parameters in the frame *Auto Shut Down* so that when the viscosity falls below the defined value for more than the defined time the test will stop automatically.

viii. **To Save Change:** After you have made all the changes, make sure to save your changes by clicking the **Save Change** button before proceeding. Otherwise all your changes will be lost.

5.3 Real Time Test

By clicking the button **Real Time Test** on the main window of the M3500Frac the **M3500Frac Real Time Test & Monitoring** window will show up. Then on the upper left corner click **Add Instruments.** When the drop down menu appears click on which viscometer unit you are using to perform the test. Up to 8 units can be added to perform real time tests simultaneously. Upon adding one viscometer unit, the corresponding Real Time Test sub-window will appear.

The following list shows the functions of the buttons on the sub-window:

Select Sequence   Before starting a test, the user has to select a certain sequence, which is defined in **Test Sequence Setup**

Start/Stop   When starting the test a window will show up, and the user can input the related test information. Only test names are necessary. Please make sure to input the correct bob number. During testing the user can press **Stop** to halt the test at any time.

Exit   Exits the Real Time Test sub window

Because the control logic of M3500Frac is different from that of Gracedaq, M3500Frac will take over all controls of the M3500a viscometer. So the LCD display on the M3500a Viscometer may not respond as soon as the button **Start** is pressed. This is normal, because the test is controlled by M3500Frac software not by the M3500a Viscometer itself. **DO NOT WORRY** about the delay of communications between the M3500Frac program and the viscometer.

5.4 Result Data Analysis and Test Report

Result data analysis and test report features are located in the main window of M3500Frac. Click on **Open Saved Test button**, a list of saved tests will show up. Double click on your test name or input your test name in the input box and press **OK**. Then a graphic presentation of the selected test result will be displayed in the chart area on the main screen.

    i.   **Related Information:** After a saved result is opened, click the button **Edit Test Info** on the main window. The Test Related Information window will appear. You can review or modify the following information:
          a. **Test Name** (required and duplication with other tests are not allowed)
          b. **Fluid ID** (optional)
          c. **Researcher's Name** (optional)
          d. **Pre-Test pH** (optional)
          d. **Post-Test p**H (optional)
          e. **Description, Notes and Comments** (optional)
          f. **Additives** table (optional)
          After finishing the change, click "Save" button to save the change.
   ii.   **X Scale & Y Scale**: the user can change the current active chart to Log, semi-log or normal scales by checking the corresponding options of **X Scale** and **Y Scale** check boxes.
  iii. **Dim Scale**: By checking **2D** or **3D** option inside of the **Dim Scale** box, the user can select the dimension of the current active graph to be 2 dimensional or 3 dimensional. Also notice that 2 dimension and 3 dimensional modes have different groups of **Select Chart Type** options.
  iv. **Select Chart Type**: By clicking on the pull down combo box **Select Chart Type**, the user can select his desired chart type.
   v.   **Data Option**: For data presentation purposes, sometimes the user does not want the data during ramping (with different shear rates) to show up. Just check the option **No Ramp** inside of the **Data** check box. To show all of the data, check the option **All** inside of the **Data** check box.
  vi. **Other Options**: Right-click on the charting area and a pop-up menu will show up. It contains a lot of useful features, for example, **Include Data Labels** for 2D, **Rotation Animation** for 3D… Also you can zoom in to a 2D chart, just press and hold the mouse left button, then drag the mouse and release the mouse button.

vii.   **Report**: Buttons *Brief Report*, *Detail Report* and *Chart Print* are for test report purposes. Their functions are pretty straightforward. The user can export his raw data by first clicking *Detail Report* button, then export the raw data from the report.

viii.   **Chart Overlapping:** M3500Frac has unlimited chart overlapping capability. Chart overlapping is only active when the *2D* option is selected and one of following chart types is selected.

Chart overlapping is only active when *DIM Scale* is *2D* and *Chart Type* is one of the following types:

Shr. Stress	Vs.	Shr. Rate
Visc	Vs.	Sample Temp
Viscosity	Vs.	Shear Rate
Shr. Stress	Vs.	Time

First open a saved test, and then change the chart type to one of above four options. Then click the button *Overlap Charts*. Finally select the saved test that you want to overlap onto the existing one. Repeatedly click on the button *Overlap Charts* for more test data overlapping.

Chapter 6. M3500pH Software

The M3500pH software is very similar to M3500Frac software except in addition it contains pH information. Please refer to Chapter 5 for operation menu.

Chapter 7. Maintenance, Calibration & Repair

7.1 Repair and Replacement Policy

Grace Instrument Company Return Policy

For your protection, items being returned must be carefully packed to prevent damage in the shipment and insured against possible damage or loss. Grace Instrument will not be responsible for damage resulting from careless or insufficient packing.

Before returning items for any reason, authorization must be obtained from Grace Instrument Company. When applying for authorization, please include information regarding the reason the items are to be returned.

Repair

We provide repair service to all equipment manufactured by Grace Instrument Company.

7.2 Maintenance

Three kinds of maintenance should be performed periodically for M3500a viscometer.
1. Replacing the bob-shaft bearings. (Once every 6 months to 2 years, depending on the usage conditions.)
2. Replacing or cleaning the fan filtration media. (Once every 6 months to 2 years, depending on the working environment.)
3. Replacing the memory backup battery. (Once every 2 years to 4 years, depending on the usage.)

a. Replacing the bob-shaft bearings

Because of its superior design, the bob-shaft bearings are much less vulnerable to acid or other corrosive vapors. You can expect your M3500a viscometer bearings to last much longer than Fann[®] 35 viscometer bob-shaft bearings under the same working conditions and usage.

After some usage, the bob shaft bearings could start to generate a large dragging error. If the bearing drag at 600 rpm is more than 0.7% of the full scale reading the M3500a viscometer the LCD display will give you a warning to change the bob-shaft bearings as in the following figure. Periodically pay attention to the LCD display when the unit is just powered on and while self-calibration is in progress. If a warning sign shows up and recommends you to change the bob-shaft bearings follow the procedures below.

(However, if you are still satisfied with your current measuring accuracy, you can neglect the warning sign and keep on using the unit.)

Changing bob shaft bearings
1. Remove the sleeve, bob and dust shield as outlined in Section 3.2 "Start & Stop Testing".
2. Prepare a stand about 10"-12" high and put it at the right hand side of M3500a viscometer when looking at it from the front.
3. Take off the top cover by removing the 10 screws that secure the top cover to the frame.

4. Carefully take off the cover and put it on the stand as shown in Pic 10.

Pic 10. Take off top cover.

Pic 11. Pull out sensor arm pin.

5. Remove the sensor arm pin by first removing the set screw on the top of the bob shaft, then pull the pin out from the bob shaft as shown in Pic 11. **Note:** some of the older models may not have a screw on top of the bob shaft in this case the sensor arm pin is secured by a small drop of glue. Be sure to clean the glue off before you try to remove the pin.

Pic 12. Take off sensor mounting plate.

6. Carefully take off the mounting screws, which tighten the sensor to the main frame, as shown in Pic 12. Then lay the sensor assembly aside.

<u>Caution</u>
Please DO NOT unscrew the force sensor from the sensor mounting plate, because the sensor is extremely fragile and re-assembling it needs professional skill.

Pic 13. Take off sensor stop plate.

7. Remove the long screw that is threaded through the main frame that is the stop for the sensor arm pin. **Note how far it was screwed in before removing, it must be put back in as close as possible to original position to allow 2 to 5 degrees of free swing of the force arm.**
For older models:
Take off the sensor stop plate by taking off the two screws as shown in Pic 13.

Please note the positioning of the sensor stop plate before taking it off because it needs to be placed back in the correct position and direction after the maintenance procedure. The correct position will allow 2°~5° free swing of the force arm when the sensor keeps free of force.

Pic 14. Take off top snap ring.

8.Using a suitable pair of retainer ring pliers compress and remove the large retaining ring as shown in Pic 14. This ring secures the torsion assembly body.

9. As shown in Pic 15, remove the bob-shaft assembly by pushing upward on the torsion shaft from the bob end. It may be necessary to tap lightly on the end of the torsion shaft to free it.

Pic 15. Push up bob-shaft bearing assembly.

10. To change the bottom bob-shaft bearing, loosen the socket set screw in the lower bearing retainer and remove the retainer over the threaded end of the torsion shaft. Then remove the lower torsion bearing and replace it with a suitable lower bob-shaft bearing.

Pic 16. Bob-shaft assembly.

11. To change the top bob-shaft bearing, using retainer ring pliers, remove the small internal retaining ring from the torsion body as shown in Pic 16. Then remove the small copper retainer ring. Finally remove the top-shaft bearing and replace it with a suitable one.

> **NOTE**
> **The top and bottom bob-shaft bearings are different in a standard unit, even though they have same sizes. Please do not mix them.**

12. Using reversed steps as described above, put back bob-shaft assembly and sensor assembly. After tightening the sensor assembly to the main frame, as shown in Pic13, using your index finger push the sensor arm pin to make sure that the pin is pushing against the "V" shape edge on the sensor assembly. If the pin slips from the "V" shape edge, loosen the sensor mounting screws and adjust its position.
13. Perform a calibration on torque measurement as specified in Chapter 7.3 "Calibration".
14. Put the top cover back on and tighten all the screws. Please make sure than no connectors or cables get jammed beneath the cover.

B. Clean or changing the fan filtration media

At the back of the M3500a viscometer, there is a cooling fan, which constantly blows cool air into the unit when it is powered on. The fan filtration media filters the intake air and is located outside of the unit for easy access. If the filtration media starts to clog up with too much dust, follow the procedure below to clean or change it.
Use a small flat head screwdriver to pry off the plastic cover of fan filtration media as shown in Pic 17. Take out the filtration media. Clean it with water. Dry it and put it back. If the filtration media is broken, replace it with a new one.

Pic 17. Change or clean the fan filtration media

c. Changing the memory backup battery.

If you want the M3500a viscometer to remember the last setup and last test result after totally powering down, every 2-6 years the on board battery needs to be changed. The longer the M3500a viscometer is kept powered on the longer the memory backup battery lasts. So for a unit with a lot of usage the battery can last 4 years easily. **Please note if you do not power down the unit, the M3500a viscometer can always remember the last test result and setup.**

To change the memory backup battery,
1. Remove the sleeve, bob and dust shield as outlined in Section 3.2 "Start & Stop Testing".
2. Prepare a stand about 10"-12" high, put it at the right hand side of M3500a viscometer when looking at it from the front.
3. Take off the top cover by unscrewing the 10 screws that secure the top cover to the frame.
4. Carefully take off the cover and put it on the stand.
5. Carefully pull out the battery holder without breaking the wires by separating it from the bottom sticker.
6. Place a new battery in with correct polarity direction.
7. Secure the battery holder back to the original location by slightly pushing on it.
8. Put the top cover back on and tighten all screws. Please make sure than no connectors or cables are jammed beneath the cover.

7.3 Calibration

Before the new M3500a viscometers were shipped to you they were calibrated for both temperature measurement and torque measurement. You should find a sheet of the "Calibration report" supplied with a new unit.

Accuracy Check

An accuracy check should always be performed before any calibration. An accuracy check should only be done with Newtonian certified calibration fluids. Calibration Fluids are available in nominal 20, 50, 100, 200, and 500 cP. All are traceable to ASTM standards and each bottle of fluid is furnished with a viscosity temperature chart certifying that batch of fluid.

1.   The instrument being checked must be clean before immersing the rotor and bob into the calibration fluid. If necessary remove the rotor and thoroughly clean the bob, bob shaft, and rotor. Make sure the bob shaft and rotor are straight and have not been damaged.

> **CAUTION**
>
> **The batch number on the label of the calibration fluid must match the number on the viscosity/temperature chart.**

2.   Fill the sample cup to the scribed line with calibration fluid and place it on the instrument stage. Elevate the stage so that the rotor is immersed to the proper immersion depth.

3.   Place a thermometer into the sample until the bulb touches the bottom and secure it to the side of the viscometer to prevent breakage.

4.   Setup a test sequence, in which the first step operates the instrument at 300 rpm for three (3) minutes. This will equalize the temperature of the bob, rotor and the fluid.

5.   Then run 10 seconds for each step of 100 rpm, 200 rpm 300 rpm and 600 rpm. Review or download the results depending on what model you are using. Also record the temperature from the thermometer to the nearest 0.1° C, (0.15° F).

Compare the thermometer reading to the M3500a measurement, the difference should be within ± 2 °F. The viscosity from the temperature chart at the recorded thermometer temperature should be within ± 2 cP of the 300 rpm reading. Twice the cP viscosity from the chart should be within ± 3 of the 600 rpm reading. Please be careful that the readings of shear stress or "Fann® angle" have not reached the maximum reading. Plot the Shear Stress vs. Shear Rate chart, zero, 100 rpm, 200 rpm, 300 rpm and 600 rpm reading should be linear. If zero, 300 and 600 points do not fall in a straight line, possibly either the rotor, bob or bob shaft is bent or other eccentricity exists. Readings outside the specified limits are indications that the instrument should be either calibrated or repaired. After completion of the calibration check carefully wipe clean the rotor inner and outer surfaces, the bob, the thermometer, the sample cup, and work area.

Calibration

After a calibration check, if a calibration is necessary, follow the steps below:
1. Remove the sleeve, bob and dust shield as outlined in Section 3.2 "Start & Stop Testing".
2. Prepare a stand about 10"-12" high and put it at the right hand side of the M3500a viscometer when looking at if from the front.
3. Take off the top cover by unscrewing the 10 screws that secure the top cover to the frame.
4. Carefully take off the top cover and put it on the stand as shown in Pic 10.

> **WARNING**
> **After taking off the top cover, at power-on condition, exposed wire, connectors and components can contain high voltage. DO NOT TOUCH ANY PARTS WITH BARE HANDS.**

5. Power the unit on and wait until main screen on LCD shows up. Using a voltage meter, adjust the zero-offset by placing the positive probe to "**TP1**" on circuit board and place the negative probe onto the very
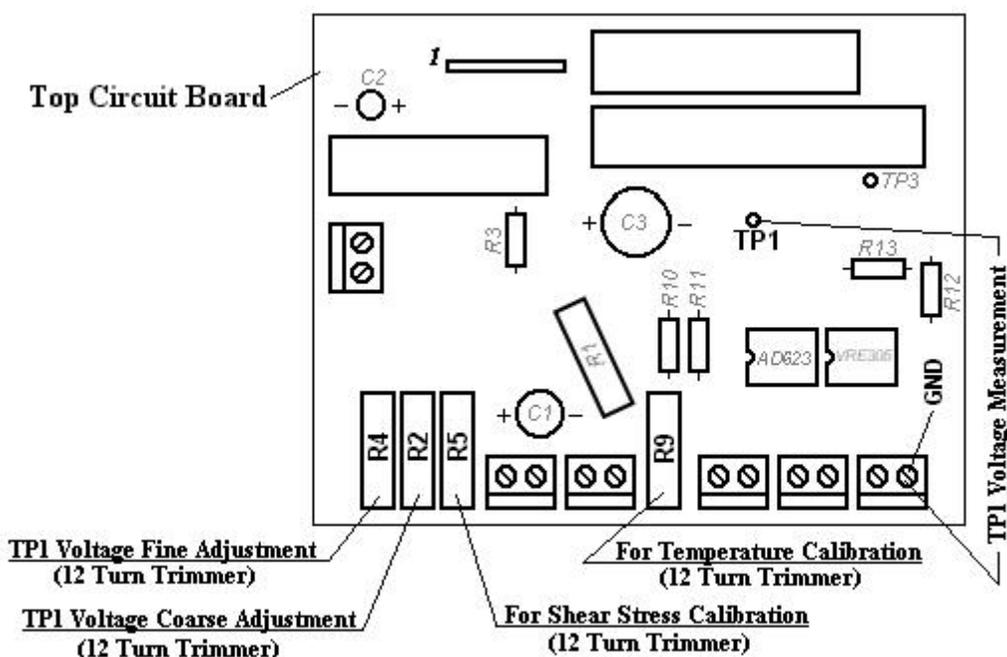
right terminal pin "**GND**" as shown in Pic 18 and Pic 20.

Pic 18. Coarse TP1 Voltage adjustment.   Pic 19. Fine TP1 Voltage adjustment.

Pic. 20

6. Adjust R4 until TP1 voltage reading is around 100 mv as shown in Pic 18. Adjust R2 until TP1 voltage reading is exactly 100 mv. R4 and R2 are all 12-turn resistance trimmers. Try to turn full-scale in both directions of R4 and R2 screws to adjust TP1 voltage.

For a M3500a-1 viscometer, continue from step 7 through step 10; for a M3500a-5 viscometer, skip down to step 13 through 21.

7. Setup a test sequence with only one test step for 2000 seconds, 40° F and 300 rpm.
8. Pour 100 cP calibration fluid into sample cup. Put on the dust shield, bob and sleeve. Raise the stage to the proper height.
9. Push keypad button "1" to start the test. Wait 3 minutes.
10. Use a thermometer to record the temperature to the nearest 0.1° C (0.15° F). Locate the correct viscosity of the calibration fluid at this temperature.

11. Turn the potentiometer R5 (shown on Pic 20), until the digital reading of the shear stress on the M3500a LCD display is as below:

$$\text{Shear stress reading} = \text{viscosity (cP)} \times 5.11$$

Also, R5 is a 12-turn resistance trimmer. Please try to turn full scale to calibrate shear stress.
12. If initially the shear stress reading before calibration is too far away from correct reading (>30 dyn/cm^2), power down the unit, then repeat step 5 to 6 and step 10 to 11.

(The following is for a M3500a-5 viscometer.)

13. Power the unit on and setup a test sequence with only one test step for 2000 seconds, 40° F and 300 rpm.
14. Pour 200 cP calibration fluid into sample cup. Put on shield, bob and sleeve. Raise the stage to be ready for a test. Refer to Section 2.1 "Test Preparation" and Section 3.2 "Start & Stop Test" for detailed description.
15. Push keypad button "1" to start the test. Wait 3 minutes.
16. Use a thermometer to record the temperature to the nearest 0.1° C, (0.15° F). Locate the correct viscosity of the calibration fluid at this temperature.
17. Turn the potentiometer R5 (shown on Pic 20), until the digital reading of the shear stress on the M3500a LCD display is as below:

$$\text{Shear stress reading} = \text{viscosity (cP)} \times 5.11$$

R5 is a 12-turn resistance trimmer. Please try to turn full scale to calibrate shear stress.
18. If initially the shear stress reading before calibration is too far away from correct reading (>30 dyn/cm^2), power down the unit, then repeat step 5 to 6 and step 15 to 17.

At last, turn off the power and put back the top cover, being sure that no connectors or cable are jammed underneath the top cover.

NOTE: For the best accuracy over the full range of the M3500 it is recommended to use 100 cp calibration fluid for the M3500a-1 model and 200 cp calibration fluid for M3500a-5 model.

Model M3500ph pH Calibration

To calibrate the pH you must use two standard pH buffer solutions each with a different pH value.
1.   From the main menu on the M3500ph viscometer LCD display, press 5 on the keypad.
2.   Place the probe in the pH buffer with the lower pH value.
3.   Using the keypad enter its pH value then press NEXT on the keypad.
4.   Wait for the next menu screen to appear (approx. 40 seconds).
5.   Remove and clean the probe thoroughly.
6.   Place the probe in the pH buffer with the higher pH value.
7.   Using the keypad enter its pH value the press "Next" on the keypad.
8.   When the calibration is complete it will return to the main menu.

When pH calibration is finished be sure to clean the probe before putting it into your sample.

Appendix

Appendix A. Trouble Shooting and Error Messages

A. Troubleshooting

Symptoms	Causes
Incorrect shear stress reading	1. Shear stress is larger than measurement range. Refer to Appendix C.
Erratic viscosity or shear stress reading	1. Contaminated bob shaft bearings 2. Bent bob shaft 3. Rotor out of alignment 4. Incorrectly adjusted main shaft
Out of calibration	1. Contaminated bob shaft 2. Bent bob shaft 3. Bent rotor 4. Friction in bob shaft bearings 5. Damaged or incorrectly installed force sensor
Excessive noise	1. Top cover loose, do not worry.
Excessive run-out of rotor	1. Damaged rotor 2. Contamination in main shaft recess
Takes too long to heat or does not heat up at all	1. Small sample adapter is insert into large sample cup. Only use one of them at a time. 2. Heater cup plug loose or not plugged in all the way
Sticking support legs	1. Corrosion/contamination within support legs 2. Legs out of adjustment

B. Gracedaq Error Messages

The possible error messages could appear during your use of Gracedaq and their solution are listed as below:

Message: Fail to open comport.
Solution: Go to "Setup" screen, change to a comport number which is available, and connecting to M3500a. If it still does not help, close the Gracedaq program and start again.

Message: No response from M3500a, please check connection.
Solution: Go to "Setup" screen, make sure the currently selected comport is correct, then check the cable connection to M3500a is secure.

Message: A chart can not overlap itself.
Solution: If you are trying to overlap a set of saved data to itself, this error will occur. Just overlap with a chart different from the one already opened.

Message: Duplicate test sequence name, please input again.
Solution: When you are trying to "Save As" a new test sequence or to create a new test sequence, you input a test sequence name which has already been used. Just do it again with another new name.

Message: At least one printer needs to be installed to perform report.
Solution: When you are trying to generate report of a saved test, at least one printer should be installed on your computer. You can install any printer, including Microsoft Fax. If you have no printer available then complete the following instructions.

Open folder **Printer** in *Windows Explorer* or *My Computer*, and then double click the **Add Printer** icon to start **Add Print Wizard**. On the wizard window, click button **Next** to install a printer, and then select **Local printer** on the next dialog window and click the button **Next** to continue. In the next new window select a printer manufacturer in the **Manufacturers** list, and then in the **Printers** list select a printer made by this manufacturer. For example, select <u>Canon</u> as manufacturer in the left list and select <u>Canon Bubble-Jet BJ-10e</u> as printer in the right list, then click button **Next** to go ahead. After a further dialog window appears, select a port in the list **Available ports**. Generally, **LTP1: ECP Printer Port** can be selected, and then click button **Next** once more. In the next window, give a name to the printer or use the default name by Windows and select **No** to reply **'… as the default printer?**' and then press button **Next** to move on to the last dialog window. There, select **No** to answer '**Would you like to test a print page?**' and press button **Finish**. Thus, Windows will install a printer for you. Accurately speaking, Windows will install a printer driver for you even though you have no printer.
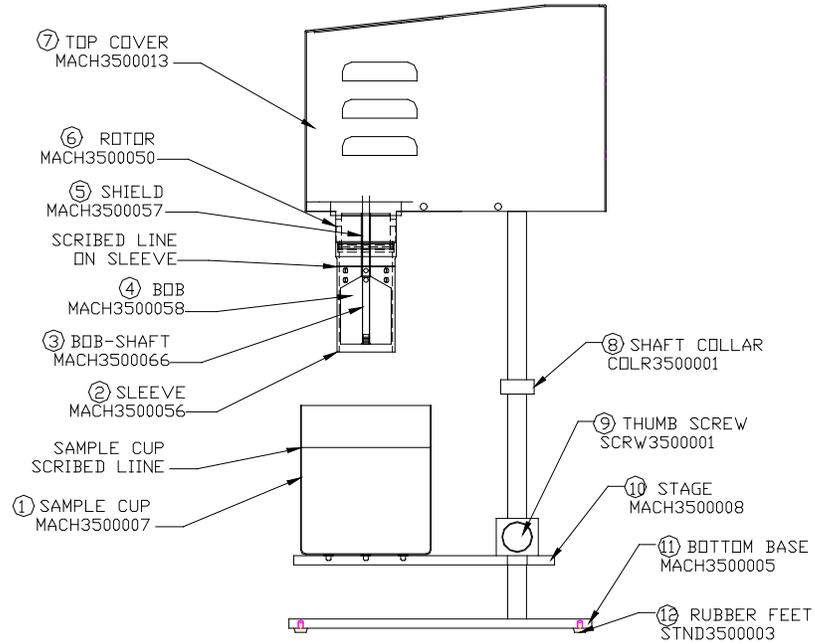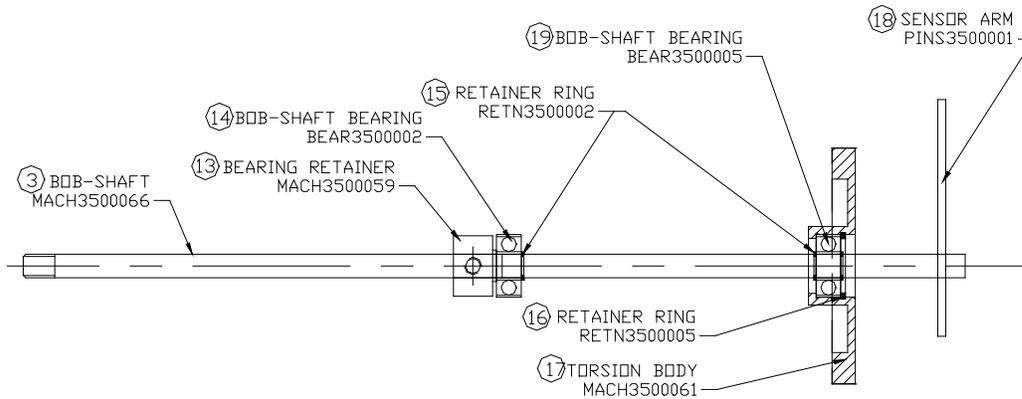
Appendix B. Drawings

⑦ TOP COVER
MACH3500013

⑥ ROTOR
MACH3500050

⑤ SHIELD
MACH3500057

SCRIBED LINE
ON SLEEVE

④ BOB
MACH3500058

③ BOB-SHAFT
MACH3500066

② SLEEVE
MACH3500056

SAMPLE CUP
SCRIBED LIINE

① SAMPLE CUP
MACH3500007

⑧ SHAFT COLLAR
COLR3500001

⑨ THUMB SCREW
SCRW3500001

⑩ STAGE
MACH3500008

⑪ BOTTOM BASE
MACH3500005

⑫ RUBBER FEET
STND3500003

Fig. 1 M3500a side view

⑱ SENSOR ARM
PINS3500001

⑲ BOB-SHAFT BEARING
BEAR3500005

⑮ RETAINER RING
RETN3500002

⑭ BOB-SHAFT BEARING
BEAR3500002

③ BOB-SHAFT
MACH3500066

⑬ BEARING RETAINER
MACH3500059

⑯ RETAINER RING
RETN3500005

⑰ TORSION BODY
MACH3500061

Fig. 2 Bob-Shaft Assembly

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APPENDIX C. MEASURING RANGE

Measuring Range for M3500a-1 & M3500a-5 Viscometers

ROTORϔBOB	R1 B1	R2 B1	R3 B1	R1 B2	R1 B5	R1 B4
BASIC DATA						
Rotor Radius (cm)	1.8415	1.7588	2.5866	1.8415	1.8415	1.8415
Bob Radius (cm)	1.7245	1.7245	1.7245	1.2276	1.5987	0.8622
Bob Height (cm)	3.800	3.800	3.800	3.800	3.800	1.900
Shear Gap in Annulus (cm)	0.1170	0.0343	0.8621	0.6139	0.2428	0.9793
Radii Ratio, R_1/R_0	0.9365	0.9805	0.667	0.666	0.8682	0.468
Maximum Use Temperature (°C)	93	93	93	93	93	93
Minimum Use Temperature (°C)	0	0	0	0	0	0
SHEAR STRESS RANGE						
Shear Stress Range (dynes/cm^2)						
For Model M3500a-1	1~1,000	1~1,000	1~1,000	2~1,793	1~1,163	8~8,000
For Model M3500a-5	5~5,000	5~5,000	5~5,000	10~9,864	5~5,815	40~40,000
SHEAR RATE RANGE						
For Both M3500a-1 & M3500a-5						
Shear Rate Constant k_3, sec^{-1} per rpm	1.7023	5.4225	0.377	0.377	0.85115	0.268
Shear Rate Range, sec^{-1} $\gamma = k_3 N$						
N = 0.01 rpm	0.017	0.054	0.0038	0.0038	0.0085	0.0027
N = 0.1 rpm	0.17	0.54	0.038	0.038	0.085	0.027
N = 1 rpm	1.7	5.42	0.38	0.38	0.85	0.27
N = 10 rpm	17	54.2	3.8	3.8	8.5	2.7
N = 10 rpm	170	542	37.7	37.7	85.1	26.8
N = 600 rpm	1,021	3,254	226	226	510.7	161
VISCOSITY RANGE IN CENTIPOISE						
Minimum Viscosity						
For Model M3500a-1	0.098	0.031	0.38	0.0088	0.2	5.0
For Model M3500a-5	0.49	0.15	1.9	0.044	1	24.8
Maximum Viscosity						
For Model M3500a-1	5,882,353	1,851,852	26,315,789	47,184,211	141,829	2,962,962,963
For Model M3500a-5	29,411,765	9,259,259	131,578,947	259,578,947	709,146	14,814,814,815
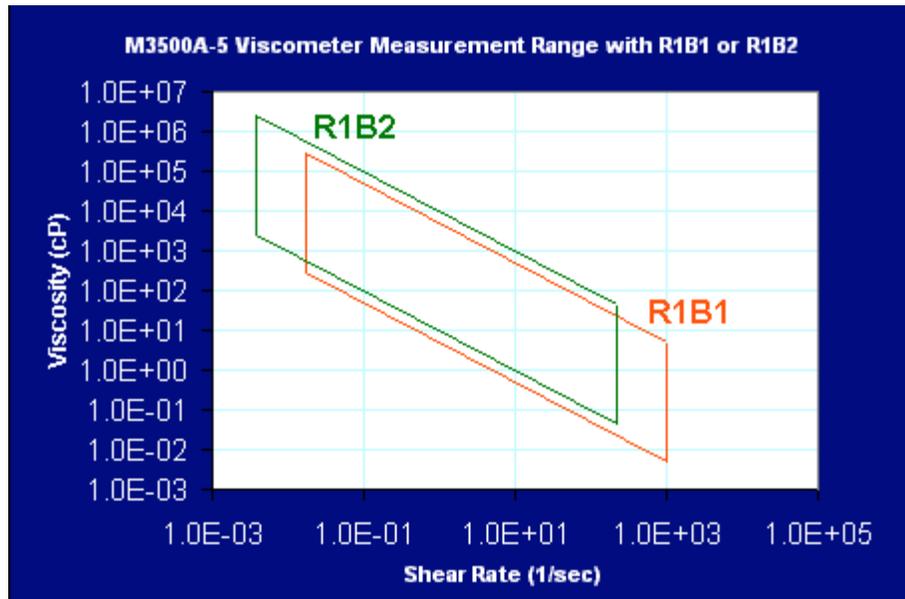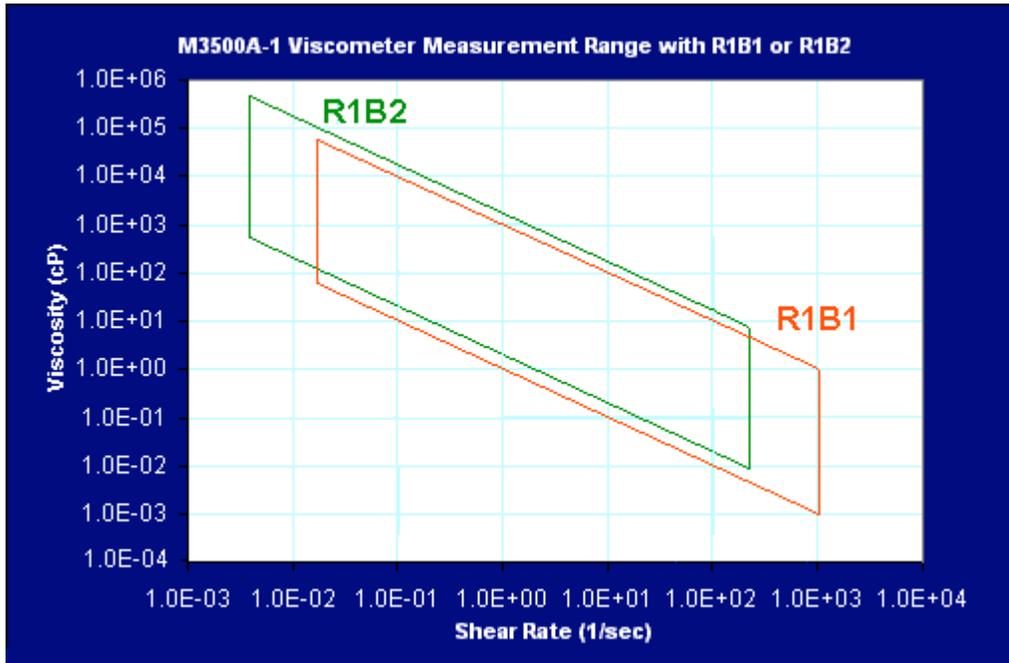
Warranty

Limited Warranty

Grace Instrument Company warrants to the original purchaser that this product is free of defects in material and workmanship for a period of 12 months from the date of product shipment to customer. If defective, the product must be returned to us, prepaid, to the address shown below and it will be replaced, by us, at no charge. Any product which malfunctions and is returned to us within the warranty period will be repaired or replaced (our option) at no charge, provided it has not been subjected to abuse and has been installed with reasonable care.

Advertising claims made by us represent our honest opinion of the qualities and features offered by the products described. However, we must leave to the purchaser the responsibility to determine whether the product ordered will fulfill his needs. We therefore disclaim any warranties expressed or implied, including warranties of merchantability and fitness for a particular purpose, except as provided herein.

No person is authorized to make any verbal or written representations concerning this product and we disclaim any responsibility for any such representations.

In no event shall Grace Instrument Company be liable for consequential damages of any kind, unless specifically excluded by law. It is up to the purchaser to determine the suitability and reliability of this product for his particular application. Grace Instrument Company shall not be liable for consequential, incidental, or special charges.

Grace Instrument Company assumes no liability for customer assistance, infringements of patents or copyrights arising from the use of this product. Grace Instrument Company does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, or other intellectual property right of Grace Instrument Company relating to this product or process of manufacture.

Any product which is not covered by the above warranties will be repaired at a cost commiserate with the work required. Repair charges shall not exceed $500.00 without prior approval.

This warranty gives you specific legal rights and you may also have other rights that vary from state to state.

All sales are made subject to the terms stated above. If these terms are not acceptable to the purchaser, then he should return this product in the original packaging. Retention of this product by the customer shall constitute an agreement that he has read and accepts the terms of this Limited Warranty.

Return of Items

For your protection, items being returned must be carefully packed to prevent damage in shipment and insured against possible damage or loss. Grace Instrument Company will not be responsible for damage resulting from careless or insufficient packing.

Before returning items for any reason, authorization must be obtained from Grace Instrument Company. When applying for authorization, please include information regarding the reason the items are to be returned.

Contact and shipping address is:

Grace Instrument Company
888 W. Sam Houston Pkwy S. Suite 125
Houston, Texas 77042
U.S.A.
Telephone: (713) 783-1560
FAX: (713) 974-7144
E-mail: *sales @graceinstrument.com*

http://www.graceinstrument.com

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