INSTRUCTION MANUAL
MODEL 3530 Viscometer

Revision U – May 2025
P/N: 3530-1050
(Original Instructions)

S/N: ____________

CHANDLER ENGINEERING®

AMETEK®

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General Information

Introduction

This manual contains installation, operation and maintenance instructions for the Chandler Engineering Model 3530 Viscometer.

Purpose and Use

The Chandler Engineering Model 3530 Viscometer is a fully automated concentric cylinder viscometer designed to measure the rheological properties of test fluids by measuring shear stress at specific shear rates. This viscometer is the standard instrument referred to in the industry standards API Spec 10 (well cements), API RP 13B (drilling fluids) and API RP 39 (fracturing fluids).

Description

The Chandler Engineering Model 3530 Viscometer is an automated version of the versatile Model 3500 and 3500LS instruments that have been used in research laboratories, field and mobile labs, and onsite QC testing.

The viscometer can be equipped with a variety of bobs, rotors, and springs. This provides the user with a wide measurement range in addition to providing different gap sizes depending upon the fluid being tested. When operated manually, the 3530 has a low-end RPM of 0.1, enabling a measurement at 0.17 sec^{-1} when equipped with the R1, B1 configuration. When operated via the Rheo 3000 PC Interface, rotor speeds as low as 0.01 RPM can be achieved.

The measurement fluid is contained within the annular space or shear gap between the rotor and bob. The rotor is rotated at known velocities (shear rates) and the viscous drag exerted by the test fluid creates torque on the bob. This torque is transmitted to a precision torsion spring, and its deflection is measured and related to shear stress. The equations used to calculate the fluid viscosity are presented later in the manual (*Viscosity Calculations* in *Section 2 – Operating Instructions*).

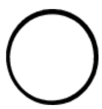
Features and Benefits

- Fully automated viscometer for control and data acquisition.
- Easy to set-up, easy to operate, easy to clean and maintain.
- Broad range of sensitivity/scalability through the use of different springs and rotor/bob combinations to accommodate a wide variety of fluid types.
- Use of a DC controlled motor allows the Model 3530 to be used in a 50Hz or 60Hz environment while maintaining the proper RPM readings.
- Manual preset speeds include 0.1, 0.2, 0.3, 0.6, 1, 2, 3, 6, 10, 20, 30, 60, 100, 200, 300 and 600 RPM. The Rheo3000 software can command any speed from 0.01 – 1000 RPM.
- Precision machining of the rotor, the bob, and support pieces allow perfect alignment each time the instrument is used.
- Stainless steel sample cup comes scribed for 350ml sample size.

Specifications

Operating Conditions:	41°F - 104°F (5°C - 40°C)
Voltage Rating:	100 – 240 VAC
Current Rating:	2 Amps
Frequency Rating:	50/60 Hz
Voltage Fluctuations:	120 VAC ± 5%; 220 VAC ± 5%
Environmental:	Indoor Use Only
Pollution Degree:	2
Installation:	Category II
Altitude:	2000m
Humidity:	10 – 80% non-condensing
Dimensions:	18.2” (46cm) high x 7” (18cm) wide x 12” (31cm) deep
Shipping Dimensions:	20” (51cm) high x 13” (33cm) wide x 25” (64cm) deep
Instrument Weight:	17 lbs (7 kg)
Shipping Weight:	50 lbs (23 kg)
Sample Container Volume:	350mL
Shear Rate Accuracy:	+/- 0.01 RPM
Torque Accuracy:	+/- 0.5 dial reading from 1 to 260 degrees
Operating Speeds:	0.01 – 1000 RPM when PC controlled

Symbols Used

Symbol	Meaning
	Protective Conductor Terminal
	On (Supply)
	Off (Supply)
	Warning, Potential Hazard
	Note, Important Information

Rheology Equations

The following equations are used to calculate the values for Shear Stress, Shear Rate, and Viscosity in the 3530 Viscometer:

$$Angular\ Velocity, \omega = RPM \frac{2\pi}{60}\ , sec^{-1}$$

$$Shear\ Rate,\quad \gamma = 2\omega \frac{{R_o}^2}{{R_o}^2 - {R_i}^2}\ , sec^{-1}$$

$$Shear\ Stress, \tau = \frac{M}{2\pi {R_i}^2 L}\ , \frac{dyne}{cm^2}$$

$$Viscosity, \mu = \frac{\tau}{\gamma}\ , \frac{dyne - sec}{cm^2}, Poise$$

$$Dial\ Reading, \theta = \frac{\tau 2\pi {R_i}^2 L}{F}, cPoise$$

$$Plastic\ Viscosity\ = \theta_{600} - \theta_{300}\ , cPoise$$

$$Yield\ Point = \theta_{300} - Plastic\ Viscosity\ , lbf/100ft^2$$

$$Apparent\ Viscosity = \frac{\theta_{600}}{2}, cPoise$$

Where,

RPM	= Motor Speed (Revolutions Per Minute)
R_o	= Rotor Radius, cm
R_i	= Bob Radius, cm
M	= Torque on Bob shaft (dyne-cm)
L	= Bob Height, cm
F	= 386 (F1 Spring Constant)

The Plastic Viscosity and Yield Point equations above require Dial Readings at the specified motor RPM. If those speeds are used, PV and YP are calculated as above. Otherwise, they are calculated from the Model.

Rheological Models

The Rheo 3000 software automatically calculates values for the following rheological models:

Bingham Plastic Model

The Bingham Plastic Model is expressed as:

$$\tau = YP + PV(\gamma)$$

Where: τ = Shear Stress

YP = Yield Point

PV = Plastic Viscosity

γ = Shear Rate

For these calculations, the Rheo 3000 software automatically collects data at a rate of one sample per second for each desired schedule step. The average of this data is calculated for each schedule step and applied to the following formula:

$$PV = ((\Sigma\gamma_{avg} * \Sigma\tau_{avg}) - (N * \Sigma\gamma_{avg}\tau_{avg})) / ((\Sigma\gamma_{avg})^2 - (N * \Sigma\gamma_{avg}^2))$$

$$YP = ((\Sigma\gamma_{avg}\tau_{avg} * \Sigma\gamma_{avg}) - (\Sigma\tau_{avg} * \Sigma\gamma_{avg}^2))/((\Sigma\gamma_{avg})^2 - (N * \Sigma\gamma_{avg}^2))$$

Where: τ_{avg} = Average Shear Stress for an individual schedule step during the data collection period.

γ_{avg} = Average Shear Rate for an individual schedule step

N = Number of schedule steps

The accuracy of the model is expressed as:

$$R^2 = 1 - (\Sigma\varepsilon_i^2/(\Sigma\gamma_{avg}^2 - (\Sigma\gamma_{avg})^2 / N)$$

Where ε_i represents the difference between the measured shear stress and the calculated shear stress using the Bingham Plastic equation $\tau = YP + PV(\gamma)$ for schedule step i.

For a perfect model, $R^2 = 1$.

API RP 13D defines "simplified" calculations that use the Dial Reading at 300 and 600 RPM. If these speeds exist in the schedule, the simplified calculations are used for Yield Point and Plastic Viscosity. Otherwise, the model described above is used. The R^2 value is always calculated as described above.

Power Law Model

The Power Law Model is expressed as:

$$\tau = K * \gamma^n$$

Where: τ = Shear Stress

K = Consistency

n = Power Law Exponent

γ = Shear Rate

For these calculations, the Rheo 3000 software automatically collects data at a rate of one sample per second for each desired schedule step. The average of this data is calculated for each schedule step and applied to the following formula:

$$n = ((\Sigma Log_{10}(\gamma_{avg}) * \Sigma Log_{10}(\tau_{avg})) - (N * \Sigma Log_{10}(\gamma_{avg})Log_{10}(\tau_{avg}))) / ((\Sigma Log_{10}(\gamma_{avg}))^2 - (N * \Sigma Log_{10}(\gamma_{avg})^2))$$

$$K = 10\hat{}((\Sigma Log_{10}(\gamma_{avg})Log_{10}(\tau_{avg}) * \Sigma Log_{10}(\gamma_{avg})) - (\Sigma Log_{10}(\tau_{avg}) * \Sigma Log_{10}(\gamma_{avg})^2))/((\Sigma Log_{10}(\gamma_{avg}))^2 - (N * \Sigma Log_{10}(\gamma_{avg})^2))$$

Where: τ_{avg} = Average Shear Stress for an individual schedule step during the data collection period.

γ_{avg} = Average Shear Rate for an individual schedule step

N = Number of schedule steps

The accuracy of the model is expressed as:

$$R^2 = 1 - (\Sigma\varepsilon_i^2/(\Sigma Log_{10}(\gamma_{avg})^2 - (\Sigma Log_{10}(\gamma_{avg}))^2 / N)$$

Where ε_i represents the difference between the base-10 logarithm of measured shear stress and the calculated shear stress using the Power Law equation $\tau = K * \gamma^n$ for schedule step i.

For a perfect model, $R^2 = 1$.

Herschel-Bulkley Model

The Herschel-Bulkley Model is expressed as:

$$\tau = YP + K * \gamma^n$$

Where τ = Shear Stress

YP = Yield Point

K = Consistency

n = Power Law Exponent

γ = Shear Rate

For these calculations, the Rheo software automatically collects data at a rate of 1 sample per second for each desired schedule step. The average of this data is calculated for each schedule step and applied to a nonlinear least-squares regression analysis to arrive at the model described above.

Casson Model

The Casson Model is expressed as:

$$F^{1/2} = k_0 + k_1 D^{1/2}$$

Where F = Shear Stress

k_0 = Yield Stress

k_1 = Plastic Viscosity

D = Shear Rate

For these calculations, the Rheo software automatically collects data at a rate of 1 sample per second for each desired schedule step. The average of this data is calculated for each schedule step and applied to formulas similar as used in the Bingham Plastic model except the square root of Shear Stress and Shear Rate are used.

The Casson model allows for "simplified" calculations that use the Dial Reading at 100 and 600 RPM. If these speeds exist in the schedule, the simplified calculations are used for Yield Point and Plastic Viscosity. Otherwise, the model described above is used. The R^2 value is always calculated as described above.

Shear Rate Range: $Sec^{-1} = k_3N$ Where: N = RPM, k_3 = Shear Rate Constant
(k_3 values are listed in the Calculation Section of the manual)

Rotor/Bob Configuration	Shear Rate for Specified RPM (sec^{-1})					
	R1 B1	R2 B1	R3 B1	R1 B2	R1 B3	R1 B4
N = 0.1 RPM	0.17	0.54	0.04	0.04	0.03	0.03
N = 0.2 RPM	0.34	1.08	0.08	0.08	0.05	0.05
N = 0.3 RPM	0.51	1.63	0.11	0.11	0.08	0.08
N = 0.6 RPM	1.02	3.25	0.23	0.23	0.16	0.16
N = 1.0 RPM	1.70	5.42	0.38	0.38	0.27	0.27
N = 2.0 RPM	3.40	10.84	0.75	0.75	0.54	0.54
N = 3.0 RPM	5.11	16.27	1.13	1.13	0.80	0.80
N = 6.0 RPM	10.2	32.5	2.26	2.26	1.61	1.61
N = 10 RPM	17.0	54.2	3.77	3.77	2.68	2.68
N = 20 RPM	34.0	108.5	7.54	7.54	5.36	5.36
N = 30 RPM	51.1	162.7	11.3	11.3	8.04	8.04
N = 60 RPM	102	325.4	22.6	22.6	16.1	16.1
N = 100 RPM	170	542	38	38	26.8	26.8
N = 200 RPM	340	1085	75	75	53.6	53.6
N = 300 RPM	511	1627	113	113	80.4	80.4
N = 600 RPM	1021	3254	226	226	161	161
N = 1000 RPM	1702	5423	377	377	268	268

Shear Stress Range

Shear Stress Range, dynes/cm^2						
Rotor/Bob Configuration	**R1B1**	**R2B1**	**R3B1**	**R1B2**	**R1B3**	**R1B4**
F 0.2 $\theta = 1^{o}$	1.02	1.02	1.02	2.01	4.1	8.2
F 0.2 $\theta = 300^{o}$	307	307	307	605	1225	2450
F 0.5 $\theta = 1^{o}$	2.56	2.56	2.56	5.04	10.2	20.4
F 0.5 $\theta = 300^{o}$	766	766	766	1510	3060	6140
F1 $\theta = 1^{o}$	5.11	5.11	5.11	10.1	20.4	40.9
F1 $\theta = 300^{o}$	1533	1533	1533	3022	6125	12,300
F2 $\theta = 1^{o}$	10.22	10.22	10.22	20.1	40.8	81.8
F2 $\theta = 300^{o}$	3066	3066	3066	6044	12,250	24,500
F3 $\theta = 1^{o}$	15.3	15.3	15.3	30.2	61.3	123
F3 $\theta = 300^{o}$	4600	4600	4600	9067	18,400	36,800
F4 $\theta = 1^{o}$	20.4	20.4	20.4	40.3	81.7	164
F4 $\theta = 300^{o}$	6132	6132	6132	12,090	24,500	49,100
F5 $\theta = 1^{o}$	25.6	25.6	25.6	50.4	102	205
F5 $\theta = 300^{o}$	7665	7665	7665	15,100	30,600	61,400
F10 $\theta = 1^{o}$	51.1	51.1	51.1	100.7	204	409
F10 $\theta = 300^{o}$	15330	15330	15330	30,200	61,200	123,000

For the bob and rotor dimensions referenced in the above shear rate and shear stress tables, see the Dimensions and Constants Table in the Operation Section of this manual.

Optional Accessories

35-175 **Kit, Calibration:** Used to calibrate the torque measuring system on the Chandler Model 3530 Viscometer. Kit includes a supporting bracket, 1.00 cm radius spool for bob shaft, five metric weights, and case.

Safety Requirements

READ BEFORE ATTEMPTING OPERATION OF INSTRUMENT

If this equipment is not used in a manner consistent with the manufacturer's specifications the protection provided by the equipment may be impaired.

Warning: Read before attempting operation of this instrument. This instrument is capable of high temperatures and pressures and must always be operated with CAUTION. The instrument is designed for operator safety. To ensure that safety, it is essential the general instructions outlined below are followed. This instrument should only be operated by trained personnel that have completed the appropriate safety training.

Warning: High Temperatures
During a test, the instrument can become hot and cause injury if touched. Allow the cylinder to cool to below 95°F / 35°C prior to touching.

The following safety procedures are advisable:

- Use appropriate Personal Protective Equipment such as safety glasses, latex gloves, etc.
- This is a bench top device; place the instrument on a suitable, level, and stable surface.
- Locate the instrument in a low traffic area. Allow a minimum of 12 in. / 305mm unobstructed clearance around side, back and top faces to provide for adequate ventilation. Position the back of the instrument to allow access to disconnect cords in the event of an emergency.
- Use the lifting handle and latching knob to move the heater bath.
- Never exceed the instrument maximum pressure and temperature ratings. The particular safety requirements associated with the handling and use of the medium to be tested, especially the additional requirements associated with handling potentially flammable liquids or otherwise hazardous agents are the responsibility of the customer – proper precautions must be taken to reduce the risk of fire or explosion.
- Always disconnect main power to the instrument before attempting any repair.
- Keep hands and clothing away from rotating components.
- Operate equipment with safety shields properly installed.
- Have the safety officer at your location review the safety aspects of the instrument and this manual and approve the operational and installation procedures.
- Observe and follow the warning labels on the instrument and observe caution notes!

Do not use bearings that have been dropped or have been allowed to touch the magnets. Accurate measurements cannot be made with bearings that have been dropped or slightly magnetized.

Before attempting to operate the instrument, the operator should read and understand this manual.

Where to Find Help

In the event of problems, contact your local sales representative or Chandler Engineering:

- Telephone: 918-250-7200
- Fax: 918-459-0165
- E-mail: chandler.sales@ametek.com
- Website: www.chandlereng.com

Instrument training classes are also available.

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Section 1 – Installation

Unpacking the Instrument

Remove the instrument from the packing crate carefully. The unit comes fully equipped with all the necessary components and ordered spare parts. Make sure that no parts are lost when discarding the packing materials. Place the instrument on a firm table, close to the required electrical outlets.

After the instrument is removed from the shipping crate, the equipment and spare parts should be checked against the packing list to ensure that all parts have been received and none are damaged.

File an insurance claim with your freight carrier if damage has occurred during shipping. Verify all parts shown on the enclosed packing list have been received. If items are missing, immediately notify Chandler Engineering.

Utilities Required

100 - 240 VAC
50/60 Hz

Tools/Equipment Required

Small flat-head screwdriver

Setting up the Instrument

1. Check and ensure the locking nut (35-0112) is finger tight to prevent the stage (35-0101) from slipping before starting the instrument. *Caution: Failure to do so may cause the stage and sample cup to slip and potentially spill the sample.*
2. Plug the power cord into the rear of the instrument.
3. Plug the power cord into a properly rated electrical outlet.
4. Attach the bob and rotor.
5. Attach the serial cable to the back of the instrument labeled “Data”.
6. Attach the other end of the serial cable to the computer.
7. Install the Rheo 3000 software on the computer (see complete software installation instructions below).
8. Perform a software calibration on the instrument (the instrument is tested and calibrated at the factory before shipment but must still be automatically calibrated to the software). See the Maintenance Section of this manual for complete calibration instructions.

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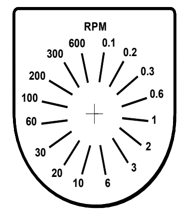
Section 2 – Operating Instructions

Accurate measurements are dependent upon having a clean and well-maintained instrument. Always remove the rotor and bob for cleaning after each use of the instrument, and protect them from dents, scratches, abrasions, and other damage.

Operation

Test Preparation

1. Fill the sample cup with the fluid to be tested up to the 350mL scribed line.
2. Place the sample cup on the sample cup stage and rotate the cup until the three feet on the cup are engaged in the holes.
3. Raise the sample cup and stage until the fluid level meets the scribed line on the rotor. Tighten the locking nut on the sample cup table.



Manual Instrument Operation

1. Operate the motor at one of the 16 preset speeds. Turn the rotary dial to the desired speed. Initially, running at high speed may be beneficial to quickly fill the annular space between the rotor and bob. This is especially beneficial for high viscosity fluids.
2. Observe the reading from the dial in the instrument by viewing through the illuminated lens. The pointer will indicate the dial reading. Allow the reading to stabilize before recording the result. Record the observation as a dial reading at the selected RPM (shear rate).
3. A schedule of increasing motor speeds (shear rates) is recommended to study “un-sheared” fluid viscosity. Alternately, a schedule of decreasing motor speeds is used to study “sheared” viscosity behavior. Consult the industry standard for a recommended schedule of test speeds.
4. Use the Rotation Inhibit switch (manual switch located behind the Sample Cup holder) to stop motion. This switch is primarily used for Gel Strength tests where the motor must be stopped and then started. When power is first applied to the motor, the internal magnets must be aligned. This realignment causes the motor to “jerk” and this jerk can invalidate a Gel Strength Test. The Inhibit switch stops motion while keeping power applied to the motor maintaining magnet alignment. When the motor must be stopped during a test, toggle the Inhibit switch to the “ON” position to stop motion. To start motion again (at the speed selected by the rotary dial), toggle the Inhibit switch to the “OFF” position. This switch has no effect when the instrument is operated via the Rheo3000 software unless Rotor Control is set to “Dial (Manual)”.

Automated Instrument Operation

This section is intended to provide a brief overview of how to start an automated test. The complete functionality of the software is described in the Software Operation section below.

1. Attach the serial cable from the back of the instrument to the computer.
2. Launch the Rheo 3000 software and create a new instrument or open a previously created instrument.
3. If necessary, Calibrate the instrument (see Software Calibration).
4. On the Preferences tab, set the desired settings for the test (Units, Viscosity Stabilization Criteria, etc.).
5. On the Schedule tab, create or load the desired schedule.
6. On the Main tab, in the “Log File” section, enter the desired Log Intervals.
7. Verify that the sample is in place and ready for measurement.
8. Zero the Dial Reading measurement by clicking the “Tare” button.
9. On the main screen, choose PC (automatic) under “Rotor Control”. Click the “Start Schedule” button.
10. A dialog will appear asking to start the data logger. If “Yes” is selected, another dialog will appear asking for the file name and location.
11. Depending on Preferences, a dialog may appear asking for log file header information.
12. Allow the test to run. The test data may be displayed on the screen during test by selecting the “Plot” tab and selecting the desired plot from the “Plot” menu.

In case of power loss or mechanical failure, when power is restored, the 3530 will NOT automatically restart.

Test Completion and Clean-up

1. Clean the instrument thoroughly upon completion. Use water only for the outside of the instrument.
2. Remove the rotor by holding the top portion of the rotor shaft and unscrewing the rotor nut clockwise. Avoid hitting the bob as the rotor is removed since it may damage the bob shaft. The machined surfaces of the rotor that fit into the rotor shaft must be kept clean and without scratches to preserve the accurate alignment of the rotor.
3. Remove the bob by turning counterclockwise until the rotation is impeded by the mechanical stop. Twist the bob while gently pulling downward. Always clean the bob and remove any debris from the tapered hole. It is very important to keep the mounting surface in the bob very clean for proper mechanical alignment of the bob.
4. To replace the bob, push gently upward and twist counterclockwise to lock the bob to the bob shaft.

Software Operation

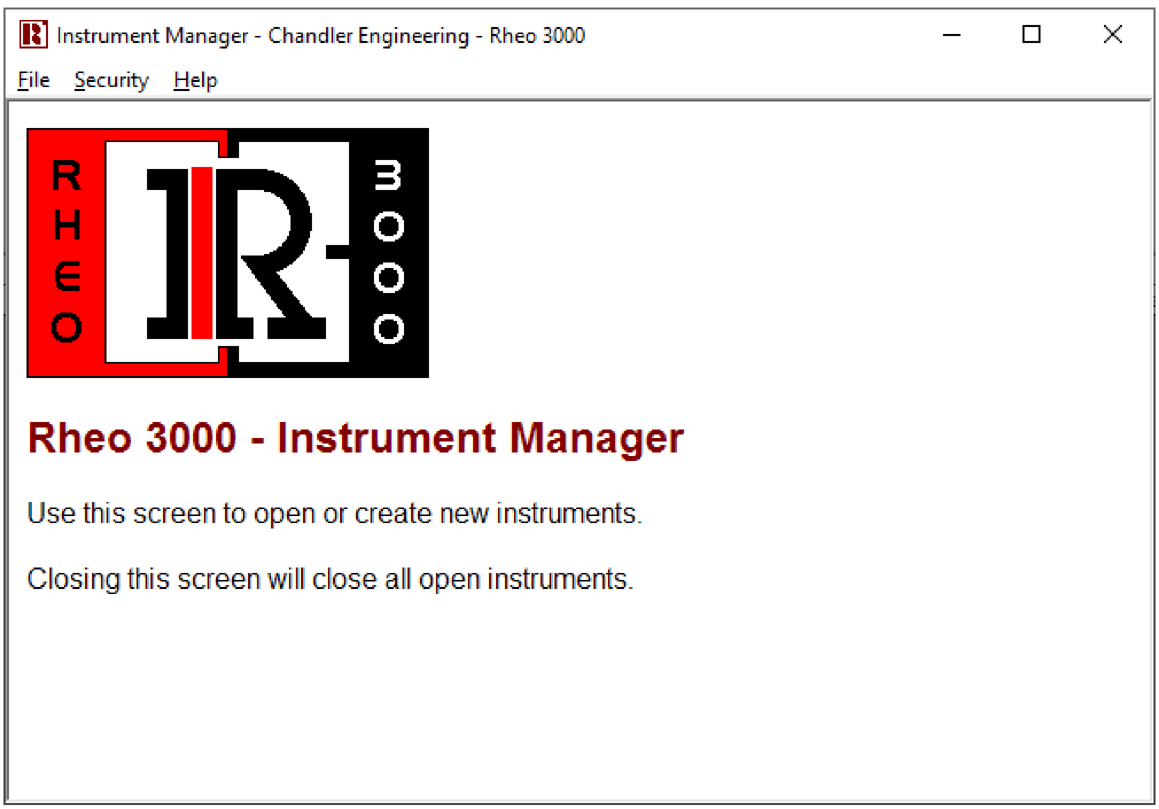
The Model 3530 viscometer can be operated remotely via PC serial interface, using the supplied Rheo 3000 software. This section provides detail on each of the software functions. Online documentation is also available under the Help menu.

Major Features of Rheo 3000

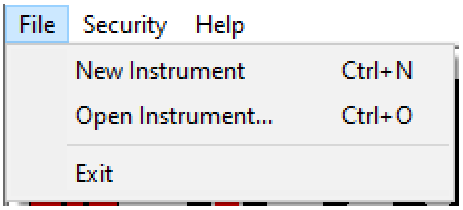
- Remote control of a stepping motor system to provide rotor speeds (step changes, linear ramps, constant speed)
- Automatic calibration of torque transducer using a Newtonian calibration oil
- Data storage in an Excel compatible file (*.CSV)
- Automatic calculation of Bingham Plastic, Power Law, Herschel-Bulkley and Casson Parameters.

Instrument Manager Window

The Rheo 3000 software is cable of running multiple independent instruments. These instruments are opened from the Instrument Manager window.

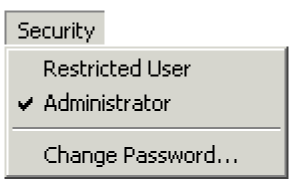


File Menu



- **New Instrument** – starts the process of defining a new Instrument. The software will ask for:
    - Instrument Type: Normal Operation or Simulation Mode
    - Is a 3500-04 Temperature Controller installed
    - Instrument Name
    - After entering the above information, a new Instrument window will appear.
- **Open Instrument** - Opens an existing instrument file, effectively connecting the software to the rheometer.
- **Exit** – Exits the Rheo 3000 software. If any Instrument windows are open, any running tests will be stopped (the user will be prompted to confirm) and the software will exit.

Security Menu



The security menu allows creation of different user access levels. If enabled, an Administrator password is required for the creation of custom schedules.
To prevent a user from entering custom schedules, the Restricted User setting must be selected. When selecting Administrator, a password prompt will appear, unless no Administrator password has been specified.

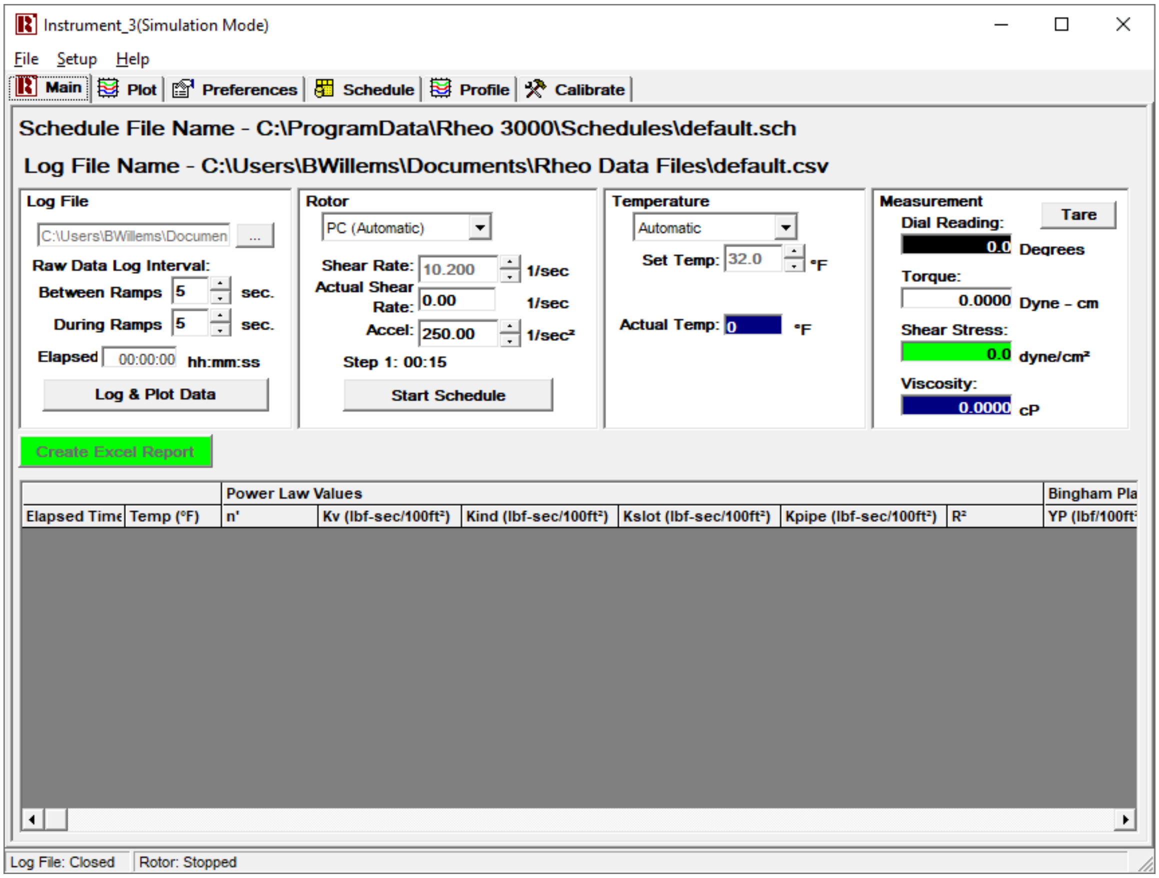
To specify an Administrator password, select Change Password. To disable the administrator password protection, simply enter the Administrator password in the Old Password entry box and leave the New Password and Confirm entries blank.

Help Menu

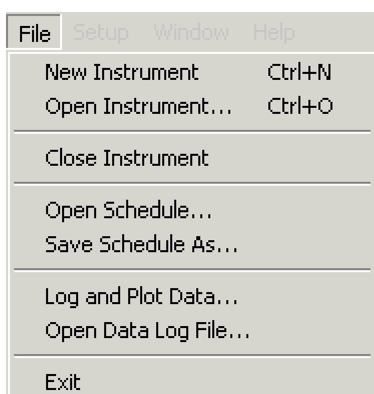
The Help menu provides access to the online help system (Contents and Index). About displays the About dialog showing software version number, contact information, etc.

Instrument Window

The Instrument Window provides all displays and indicators to operate a single 3530 Rheometer. Multiple Instrument Windows can be open and operated independently.



File Menu



- **Open Instrument** - Opens an existing instrument file, effectively connecting the software to the rheometer.

- **Close Instrument** - Closes an open instrument file, effectively disconnecting the software from the rheometer.

- **Open Schedule** - Used to open an existing test schedule that is stored on the disk drive. Test schedules use a proprietary binary file format that is only recognizable by the Rheo software.

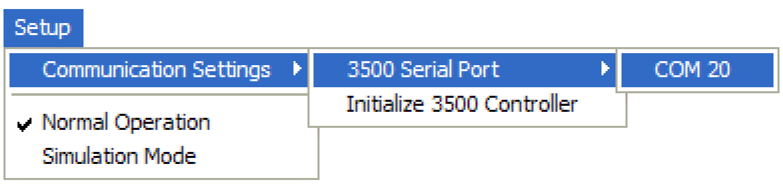
- **Save Schedule As** - Used to save an open schedule file to a new file name.

- **Log and Plot Data** - Starts logging data to a ".csv" file and resets the data plot. The ".csv" file extension is recognized by Microsoft Excel. Thus, a log file may be opened by double-clicking on its icon from within Windows, or from within Excel. Raw data is logged to the specified file, as well as Bingham Plastic and Power Law calculations.

- **Open Data Log File** - Opens an existing data log file, displaying its contents in the data plot and in the calculation grid.

- **Exit** - Exits the program.

Setup Menu



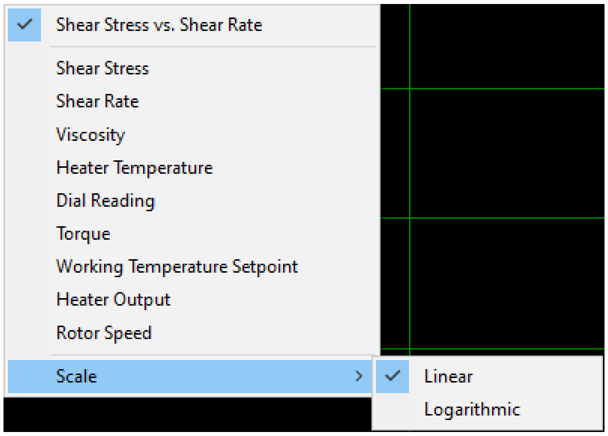
- **Communication Settings** - The communication settings sub-menu allows assignment of a specific PC serial port to the Model 3530 Instrument.

- **Initialize 3500 Controller** - This menu selection allows the Motor Controller to be reinitialized to factory default settings, effectively reloading the program stored in its electronic memory. Selecting this option will bring up the Controller Initialization Prompt. This operation should only be done under the direction of Chandler Engineering.

- **Normal Operation** - When selected, this option allows the software to communicate with the instrument.

- **Simulation Mode** - When selected, this option allows the software to operate without the presence of an instrument. If an instrument is connected, it will be ignored in simulation mode, and no rheological tests can be performed without first selecting **Normal Operation**.

Plot Menu



The plot menu is only visible when the Plot Tab is selected. The same menu can be shown by right-clicking anywhere in the Plot area on the Plot Tab. This menu shows a list of available channels for display.

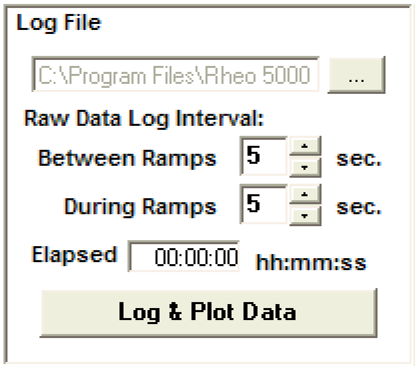
Help Menu

The Help menu provides access to the online help system (Contents and Index). About displays the About dialog showing software version number, contact information, etc.

Main Software Tab

The Main Tab provides feedback and allows the user to control a test. It is divided into the following sections:

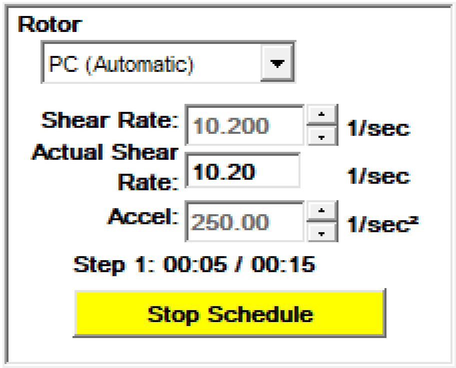
Log File



Allows a user to specify the following parameters for data logging and trending:

- The **Raw Data Log Interval** parameters define how often a data point for each measurement is written to the log file.
    - Between Ramps - Defines the log interval for manual operation, or for schedule steps where the raw data checkbox is selected but the model data checkbox is not selected.
    - During Ramps - Defines the raw data log interval for schedule steps where the raw data and model data checkboxes are selected.
- **Elapsed Time** displays the elapsed time in hours, minutes and seconds since an active log file was started.
- **Log & Plot Data** allows the user to start and stop Data Logging. Starting Data Logging will clear the Plot.

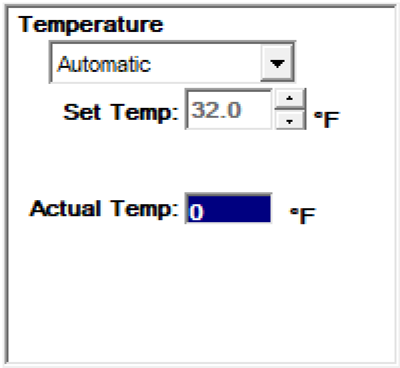
Rotor Control



Allows a user to start and stop a schedule, or control the rotor manually using the following parameters:

- Control Mode
  - **PC (Manual)** - the rotor may be controlled manually through the software. In this mode, any parameters specified in the loaded schedule are ignored.
  - **PC (Automatic)** - the rotor is controlled via the current schedule.
  - **Dial (Manual)** - the rotor is controlled via the built-in speed control dial on the instrument.
- **Shear Rate or Rotor Speed -** allows the user to manually enter a desired rotor speed, when Manual Mode is selected. When Automatic mode is selected, the shear rate from the current schedule stage is displayed. Units are defined on the Preferences Tab.
- **Actual Shear Rate or Rotor Speed -** displays the current rotor speed. Units are defined on the Preferences Tab
- **Accel -** allows the user to prescribe an acceleration/deceleration rate. If the motor stalls during a run, the acceleration rate should be decreased to 250 or lower.
- **Step Indicator -** shows the run time of the current step vs the total run time of the current step.
- **Start / Stop Schedule -** allows the user to start and stop the currently loaded schedule.

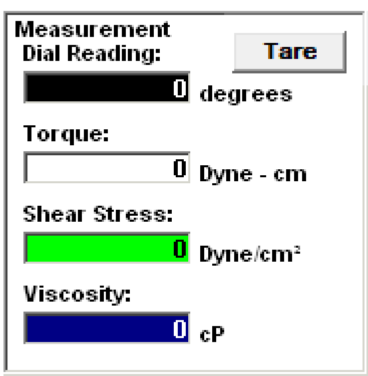
Temperature



Allows the user to start and stop Temperature control. This section is only visible if the 3500-04 Temperature Control option was selected when creating a new instrument.

- **Control Mode**
  - **Automatic** - Temperature is controlled via the current schedule.
  - **Manual** - Temperature may be controlled manually through the software. In this mode, any parameters specified in the loaded schedule are ignored.
- **Set Temp -** Displays the current set point. When **Control Mode** is **Automatic**, the set point is updated automatically by the software. When **Control Mode** is **Manual**, the user may enter the Set Point.
- **Actual Temp -** Displays the current Temperature as read from the controller. Units are defined on the Preferences Tab.

Calculations



Displays values for the following measured and calculated values:

- **Dial Reading (Degrees)** - Measured directly from the dial. Zero this reading by clicking the **Tare** button.
- **Torque (Dyne - cm)** - Based on the lookup table generated during instrument calibration.

- **Shear Stress (Dyne/cm^2)** - Based on the following formula:

$$\tau = \frac{Torque(Dyne \cdot cm)}{2\pi \cdot BobRadius(cm)^2 \cdot BobLength(cm)}$$

- **Viscosity (cP)** - Apparent Viscosity, based on the following formula:

$$\mu = \frac{ShearStress\left(\frac{Dynes}{cm^2}\right)}{ShearRate\left(Sec^{-1}\right)}$$

Calculation Grid

Elapsed Time	n'	Kv (cP)	Kind (cP)	Kslot (cP)	R²	YP (dyne/cm²)	PV (cP)	R²
00:07:04	0.956790	121.1515	120.816	122.5556	0.999032	4.398339	94.56212	0.998403

The Calculation Grid displays a list of automatically generated Model calculations. By default, only the Model results are shown. Right-click on the Grid and check or uncheck "Show Details" to show or hide the individual Model Data points

Model Calculations

The Rheo 3000 Software provides automated calculation of several rheological models. These values are logged to a data file if the logger is enabled during a test.

To generate these calculations the following steps are performed:

1. The user must define a schedule that includes a series of contiguous checked boxes in the "Log Model Data" column.

2. The schedule is executed by pressing the "Start Schedule" button on the Main Tab.

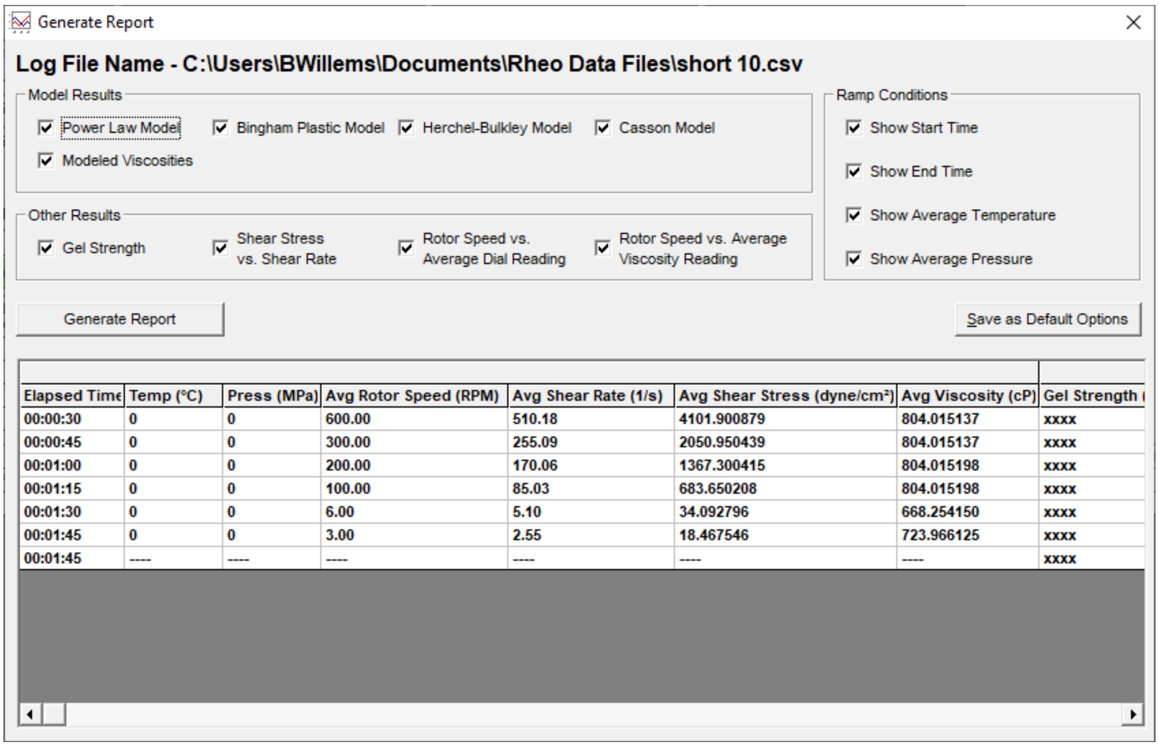
3. For each schedule step with the check box selected in the "Log Model Data" column, a data point depicting shear stress vs. shear rate is collected. Each data point is generated by averaging data (1 sample per second) over a specific time window (Viscosity Stabilization Criteria on the Preferences Tab). The window ends when the next step in a schedule is encountered. For example, if the user has entered 15 seconds for the Viscosity Stabilization value and a schedule step has a duration of 20 seconds, data will be collected once per second over the last 15 seconds of the schedule step and the average will become a single data point for Model calculation.

4. When either a schedule step with an unchecked box in the "Log Model Data" column is encountered, or the end of a schedule is encountered, the series of data points are used to calculate a set of Model values.

5. Each valid calculation is recorded in the data log file and displayed on the Calculation Grid of the Main Tab.

Generate Report Window

The Generate Report Window is opened when the user clicks the “Create Excel Report” button on the Main tab of the Instrument Window. This window will send a report directly to Excel. Microsoft Excel must be installed.



Model Results: Select the desired Model(s) to include in the generated report. Each Model is a separate page. If **Modeled Viscosities** is checked, a Modeled Viscosities section will be added to each selected Model.

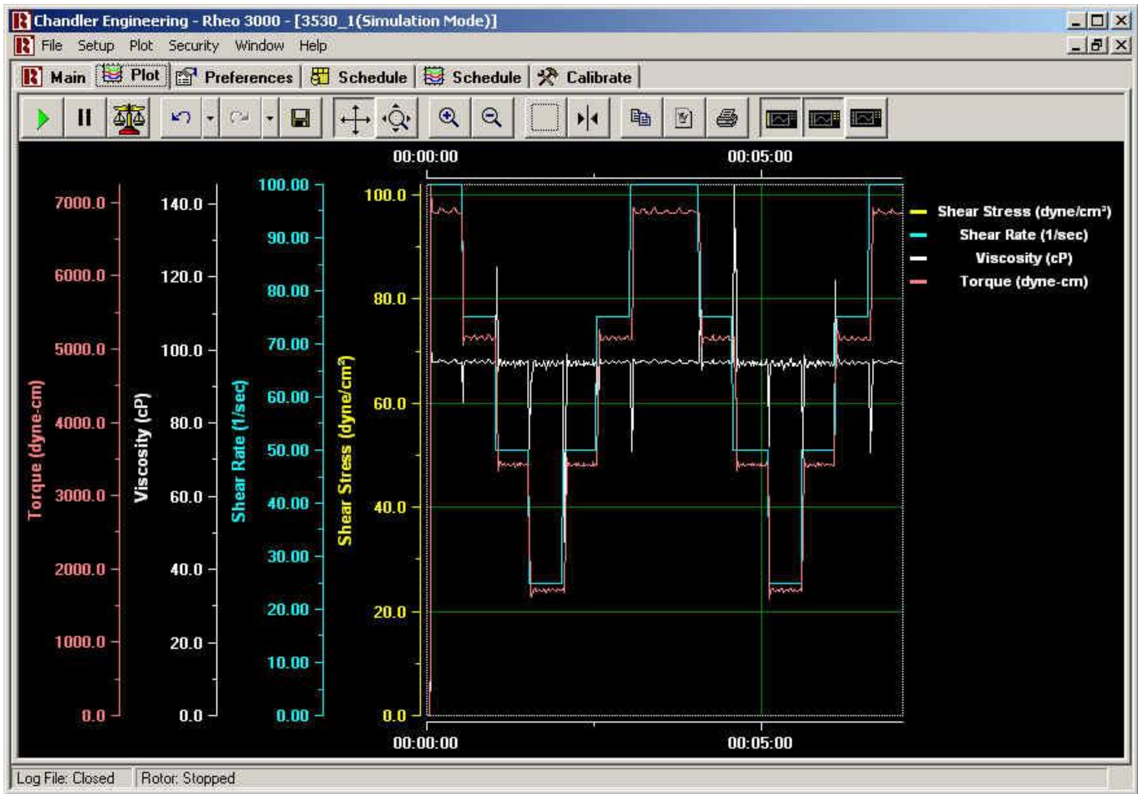
Ramp Conditions: Select the desired Ramp Conditions to be shown with each Model Calculation.

Other Results: If any of these options are selected a table with the appropriate Ramp Conditions vs “Other Results” is added to the last page of the Generated Report.

Generate Report: starts the Report Generation process. A new Excel window will open and the Report will be created.

Save as Default Options: Saves the current state of all check boxes for the next time the Generate Report window is opened.

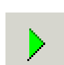
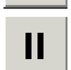
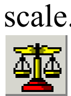
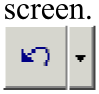
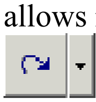
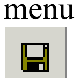
Plot Tab

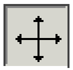
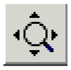
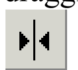
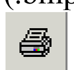
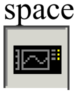


Once per second, all readings are sent to the Plot. Data from channels that are not currently visible are still saved to the Plot. At the start of a test, the Plot is cleared. The Plot can store about 24 hours of data.

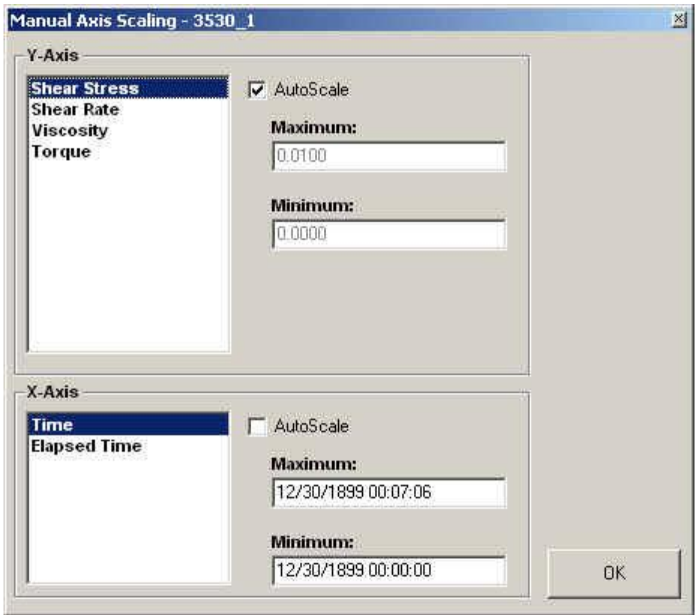
Plot Toolbar

The Plot Toolbar provides flexibility in manipulating the displayed contents of the chart. The following selections are provided.

-  **Enable X-Axis Tracking** - Causes the X-Axis to automatically adjust its scale.
-  **Disable X-Axis Tracking** - Causes the X-Axis to stop automatically adjusting its scale.
-  **Manual Axis Scaling** - Pressing this button displays the manual axis scaling screen.
-  **Undo** - Restores the plot settings, ignoring the last action. A drop-down menu allows multiple undo operations with a single mouse click.
-  **Redo** - Restores the plot settings, ignoring the last undo action. A drop-down menu allows multiple redo operations with a single mouse click.
-  **Save as Default Setting** - Saves the current plot configuration to the instrument file.

-  **Scroll (Axes)** - Selecting this button allows scrolling of the X and Y axes by clicking and dragging the desired axis scale.
-  **Zoom (Axes)** - Selecting this button allows zooming of the X and Y axes by clicking and dragging the desired axis scale.
-  **Zoom In** - Zooms in toward the center of the chart.
-  **Zoom Out** - Zooms out from the center of the chart.
-  **Zoom Box** - Zooms in on the chart around a window that is drawn by clicking and dragging.
-  **Cursor** - Displays or hides the **data cursor**. Note: Selecting a data cursor effectively disables X-Axis Tracking. To re-enable X-Axis Tracking, press the **Enable X-Axis Tracking** button.
-  **Copy to Clipboard** - Copies the displayed chart contents to the windows clipboard for pasting into other applications as a bitmap image.
-  **Save as Image** - Allows the displayed chart contents to be saved to a bitmap (.bmp), JPEG (.jpg) or enhanced metafile (.emf) file.
-  **Print** - Automatically rescales and prints the displayed chart contents on the default printer. The **Test File Name** is printed at the bottom of the page, and the **Log File Header** contents are printed at the top of the page.
-  **Show/Hide Y-Axis Titles** - Allows the user to hide Y-Axis titles to reserve more screen space for plot data.
-  **Show/Hide Legend** - Allows the user to hide the legend to reserve more screen space for plot data.
-  **Show/Hide Y Values in Legend** - Allows the user to display or hide current Y Values for each visible plot in the legend (if visible).

Manual Axis Scaling Screen

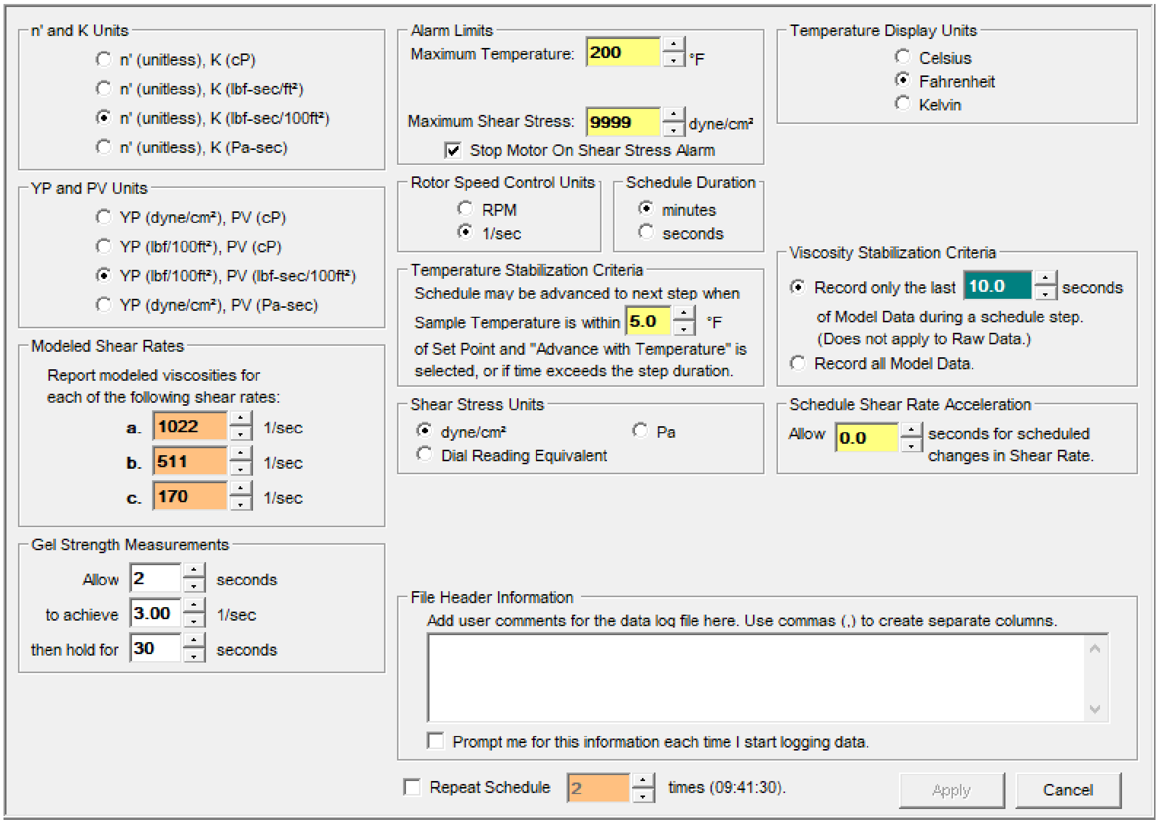


The Manual Axis Scaling Screen provides precise manual control over the displayed range of each plot.

- **Y-Axis** - Allows selection of individual plots in a list. By clicking on a plot title, auto-scale may be selected or deselected. If auto-scale is not selected, a maximum and minimum displayed scale value may be entered for the selected plot.

- **X-Axis** - Allows manual or auto-scaling of the X-Axes.

Preferences Tab



The Preferences Tab provides the following adjustable User Parameters.

- **n' and K Units** - Defines the units to display the Power Law Model results, both on the Main Tab and in the Data Log File.
- **YP and PV Units** - Defines the units to display the Bingham Plastic Model results, both on the Main Tab and in the Data Log File.
- **Modeled Shear Rates** - The modeled viscosity at each of these shear rates is logged to the Data Log File for each Rheological Model.
- **Gel Strength Measurements -** Defines the parameters used when adding Gel Strength tests to the Schedule.
- **Alarm Limits –** an Alarm will be displayed on the Main tab and the software will "beep" if the defined alarm limit is reached.
  - **Maximum Temperature** - Defines the temperature at which the "Over Temperature" alarm will display on the main screen. This value also represents the maximum allowable temperature entry value for a schedule or manual temperature control. The schedule is NOT automatically stopped if the Maximum Temperature is exceeded. This Alarm is only available if the 3500-04 Temperature Controller is enabled.
  - Maximum Shear Stress – Shear Stress is calculated from a lookup table generated during Instrument Calibration

  - Stop Motor on Shear Stress Alarm – defines if the schedule will be automatically stopped if the Shear Stress Alarm occurs.

  - To acknowledge an Alarm, click the Alarm Indicator on the Main tab. The Alarm will still be displayed if it is still active but the software will stop beeping.

- **Rotor Speed Control Units** - Allows rotor speed to be controlled as RPM or 1/sec.

- **Schedule Duration** – defines if each schedule Step Duration is in Minutes or Seconds.

- **Temperature Stabilization Criteria** – When "Advance with Temperature" is selected within a schedule, and the measured sample temperature reaches a value within this specified tolerance (increasing or decreasing temperature), the schedule execution will advance to the next schedule step. This option is only available if the 3500-04 Temperature Controller is enabled.

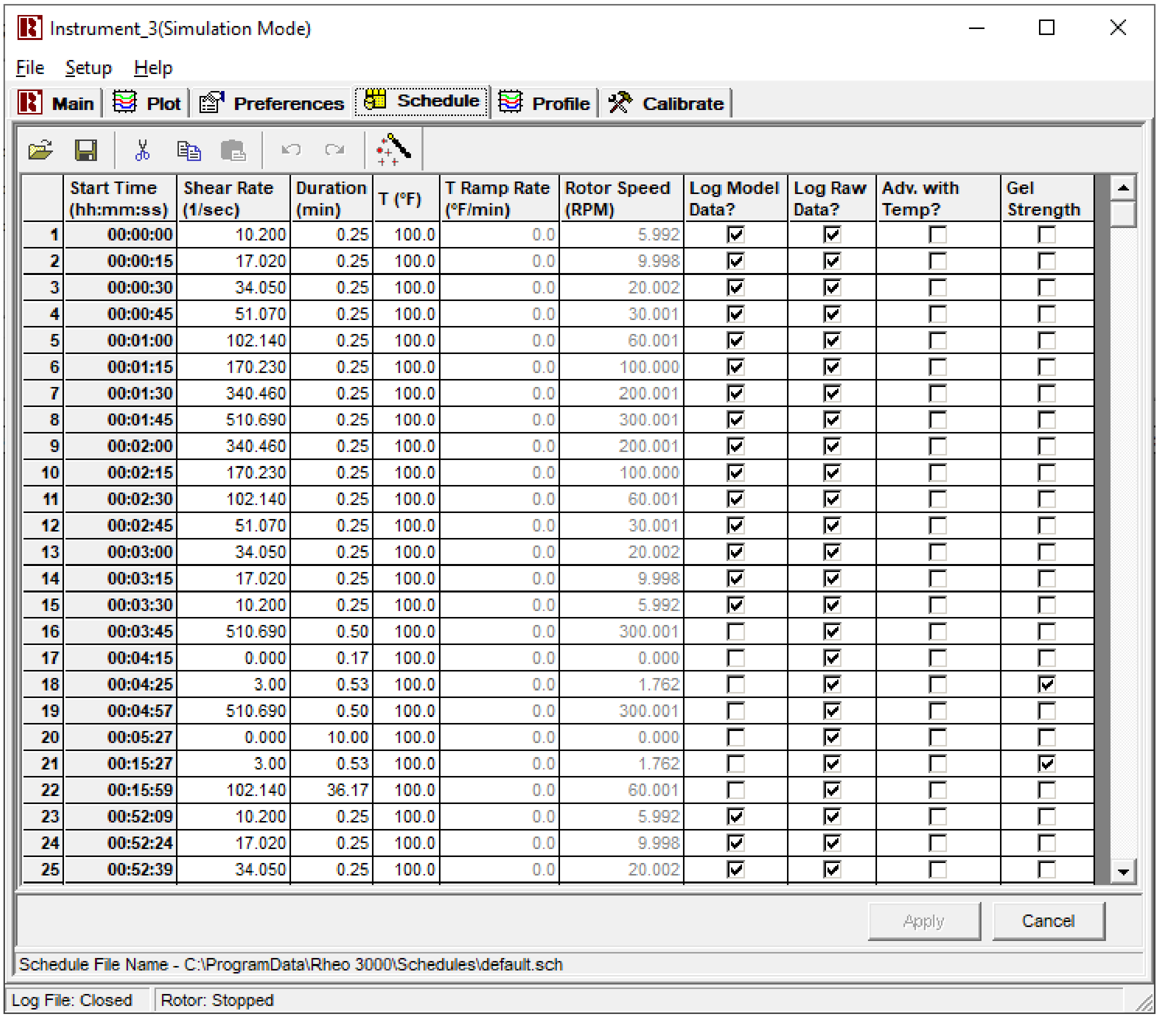
- **Temperature Display Units** - Allows the selection of degrees Fahrenheit, Celsius or Kelvin. This selection applies to the log file, as well as the schedule, alarm limits and any other place that temperature is displayed. Temperature display units may not be changed while data is being logged to a file. This promotes concurrency between the units advertised at the top of each column and the units for any data being logged. This option is only available if the 3500-04 Temperature Controller is enabled.

- **Viscosity Stabilization Criteria** - Viscosity stabilization refers to the stabilization of measured Shear Stress that occurs after a change in Shear Rate. See Bingham Plastic and Power Law Calculations for more information on how this feature is used. The length of the stabilization period is defined by the user.

- **Schedule Shear Rate Acceleration** - When this value is set to zero, it is overridden by the Accel field on the Main Tab. If a higher value is selected, each shear rate change within a schedule will utilize the specified period to provide a smooth, linear change in rotor speed. The initial acceleration (acceleration to the rotor speed prescribed by the first schedule step) always uses the acceleration value specified in the Accel field of the Main Tab.

- **File Header Information** - Information to be included at the top of each data log file is entered here.

Schedule Entry Tab



	Start Time (hh:mm:ss)	Shear Rate (1/sec)	Duration (min)	T (°F)	T Ramp Rate (°F/min)	Rotor Speed (RPM)	Log Model Data?	Log Raw Data?	Adv. with Temp?	Gel Strength
1	00:00:00	10.200	0.25	100.0	0.0	5.992	☑	☑	☐	☐
2	00:00:15	17.020	0.25	100.0	0.0	9.998	☑	☑	☐	☐
3	00:00:30	34.050	0.25	100.0	0.0	20.002	☑	☑	☐	☐
4	00:00:45	51.070	0.25	100.0	0.0	30.001	☑	☑	☐	☐
5	00:01:00	102.140	0.25	100.0	0.0	60.001	☑	☑	☐	☐
6	00:01:15	170.230	0.25	100.0	0.0	100.000	☑	☑	☐	☐
7	00:01:30	340.460	0.25	100.0	0.0	200.001	☑	☑	☐	☐
8	00:01:45	510.690	0.25	100.0	0.0	300.001	☑	☑	☐	☐
9	00:02:00	340.460	0.25	100.0	0.0	200.001	☑	☑	☐	☐
10	00:02:15	170.230	0.25	100.0	0.0	100.000	☑	☑	☐	☐
11	00:02:30	102.140	0.25	100.0	0.0	60.001	☑	☑	☐	☐
12	00:02:45	51.070	0.25	100.0	0.0	30.001	☑	☑	☐	☐
13	00:03:00	34.050	0.25	100.0	0.0	20.002	☑	☑	☐	☐
14	00:03:15	17.020	0.25	100.0	0.0	9.998	☑	☑	☐	☐
15	00:03:30	10.200	0.25	100.0	0.0	5.992	☑	☑	☐	☐
16	00:03:45	510.690	0.50	100.0	0.0	300.001	☐	☑	☐	☐
17	00:04:15	0.000	0.17	100.0	0.0	0.000	☐	☑	☐	☐
18	00:04:25	3.00	0.53	100.0	0.0	1.762	☐	☑	☐	☑
19	00:04:57	510.690	0.50	100.0	0.0	300.001	☐	☑	☐	☐
20	00:05:27	0.000	10.00	100.0	0.0	0.000	☐	☑	☐	☐
21	00:15:27	3.00	0.53	100.0	0.0	1.762	☐	☑	☐	☑
22	00:15:59	102.140	36.17	100.0	0.0	60.001	☐	☑	☐	☐
23	00:52:09	10.200	0.25	100.0	0.0	5.992	☑	☑	☐	☐
24	00:52:24	17.020	0.25	100.0	0.0	9.998	☑	☑	☐	☐
25	00:52:39	34.050	0.25	100.0	0.0	20.002	☑	☑	☐	☐

The Rheo software system allows user-defined schedules for automatic test control. Schedules are created and edited using the Schedule section of the Setup screen. Cells may be edited individually. Entire rows and groups of rows may be cut, copied and pasted.

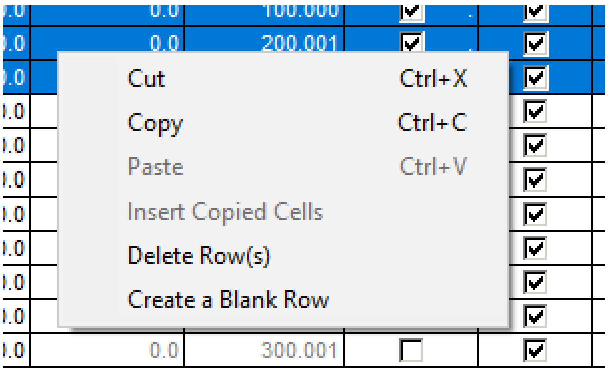
A toolbar at the top of the schedule grid provides the following selections:

- **Open Schedule File** - Opens a previously defined schedule file.
- **Save Schedule As** - Creates a copy of the current schedule with a new filename.
- **Cut** - Makes a copy of the current selection, then deletes the selection. This operation is also available on the Schedule Right-Click menu.
- **Copy** - Makes a copy of the current selection. This operation is also available on the Schedule Right-Click menu.
- **Paste** - Pastes the copied selection onto the selected location. This operation is also available on the Schedule Right-Click menu.
- **Undo** - Restores the schedule to a previous state.

- **Redo** - Reverses the Undo action
- **Schedule Setup Wizard** - Opens the Schedule Setup Wizard Screen.

The Apply button in the lower-right corner of this screen will save the current schedule to disk and apply the changes to the working schedule. A schedule may be edited as it is executed.

A popup menu appears when the user presses the right mouse button over the schedule grid area.



In addition to the same actions that are available on the Schedule Toolbar, the following actions are available:

- **Delete Row(s)** - Removes the selected rows from the schedule.
- **Create a Blank Row** - Adds a blank row to the schedule at the currently selected point.

A schedule may also be verified visually as it is being edited via the Profile Tab.

Each step of a schedule contains the following information:

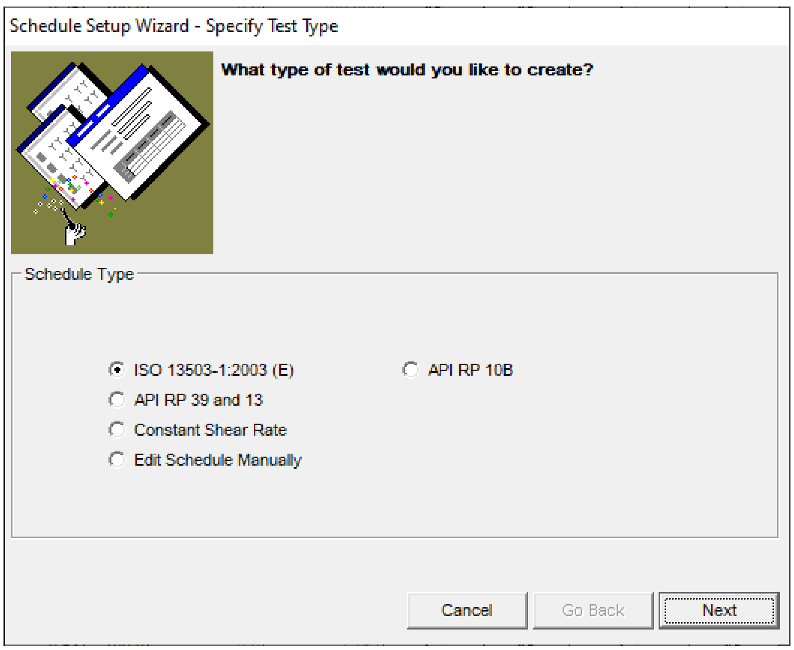
- **Start Time** - The relative time from the beginning of the schedule that a step will begin. This parameter is automatically calculated and updated by the Rheo program.
- **Shear Rate** - Defines the shear rate for a given schedule step.
- **Duration** - Defines the duration of a given schedule step in minutes.
- **T** - Defines the Temperature at the start of the current step. The software will ramp Temperature from the current step to the next step. This column is only available if the 3500-04 Temperature Controller is defined.
- **T Ramp Rate** - Displays the temperature ramp rate for a given schedule step. This parameter is calculated and updated automatically by the Rheo software. This column is only available if the 3500-04 Temperature Controller is defined.
- **Rotor Speed** - Displays the rotor speed in RPM, based on the desired shear rate.
- **Log Model Data** - Allows the user to specify which schedule steps are used for Model calculations. When an UNchecked Log Model Data step is encountered, the previous set of Log Model Data steps will be used to calculate the Models.

- **Log Raw Data** – Allows the user to specify whether if Raw Data will be logged during the given step. Data during this step will still be plotted.

- **Adv. with Temp? –** Determines if the given step will advance to the next step when the defined Temperature (T) is within the Temperature Stabilization Criteria defined on the Preferences Tab. This column is only available if the 3500-04 Temperature Controller is enabled.

- **Gel Strength –** Allows the user to specify that this step is a Gel Strength Measurement and that Gel Strength calculations will be added to the Model Data. **Shear Rate**, **Rotor Speed** and **Duration** will be changed to match the **Gel Strength Measurement** parameters defined on the Preferences Tab.

Schedule Setup Wizard



The Schedule Setup Wizard provides a simple way to set up a standard test. To start the wizard as an Administrator, select the rightmost button of the toolbar on the Schedule Entry Tab. If Restricted User is selected from the Security Menu, the wizard screen will appear automatically when the Schedule Entry Tab is selected.

To create a schedule using the wizard, simply follow the on-screen instructions. The following schedule types are provided.

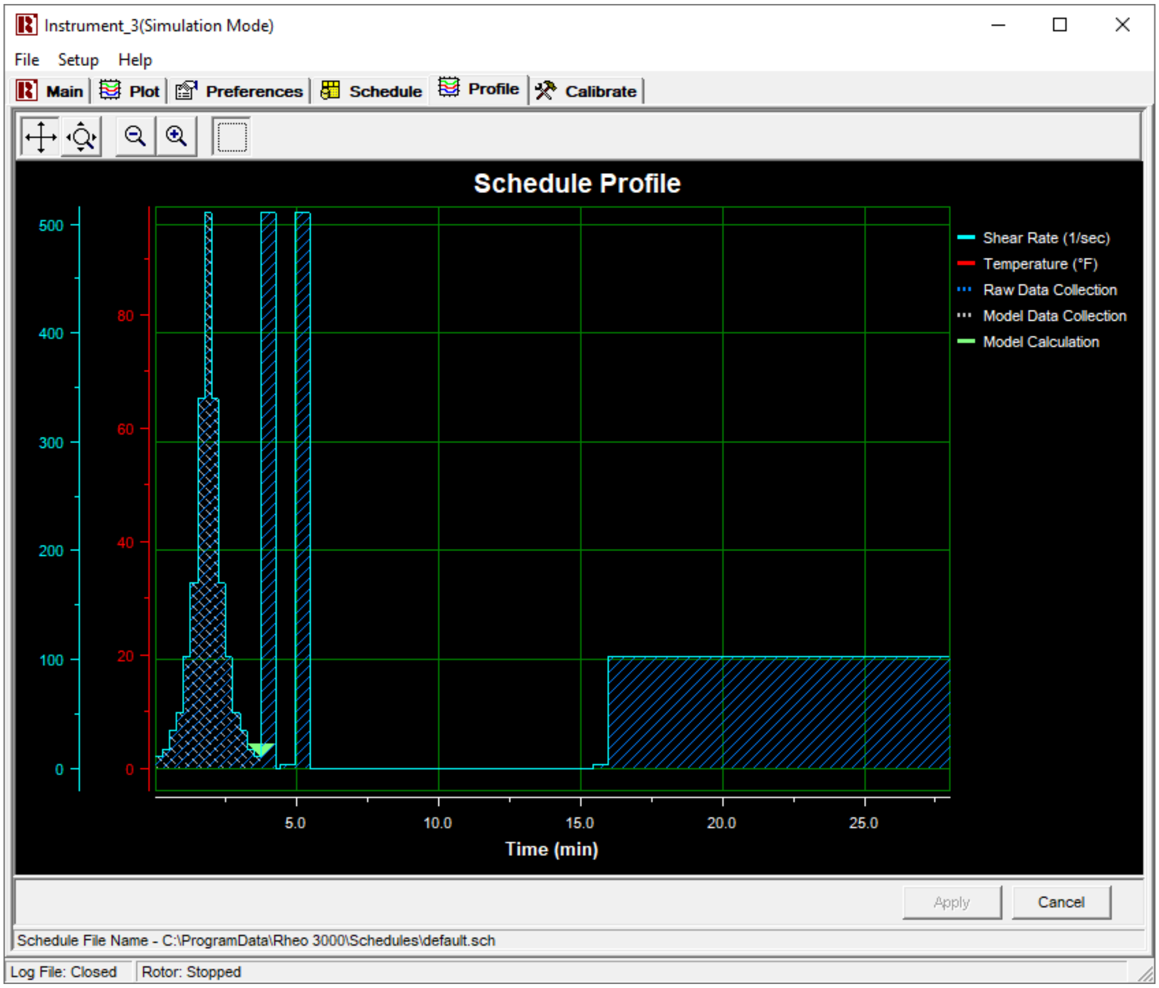
- **ISO 13503-1:2003 (E)** - Allows a schedule of user-defined duration to be created with either increasing or decreasing shear rate ramps. Any test duration may be selected. Ramp schedules are determined according to the ISO standard (100, 75, 50, 25 sec^{-1} in increasing or decreasing order).

- **API RP 39 and 13** - Provides an implementation of the API standard. Shear rate ramps are performed from 100 1/sec to 75, 50, 25, 50, 75 and 100 1/sec. Any test duration may be selected.

- **Constant Shear Rate** - Any constant shear rate and duration may be specified.

- **Edit Schedule Manually** - Closes the wizard and opens the Schedule Entry Tab. (Requires Administrator password if Restricted User is selected from the Security Menu.)

Profile Tab



A schedule may be verified visually via the Plot Schedule Tab. The shear rate or rotor speed set point is displayed over time. The shaded areas in the plot represent data collection windows for raw data and model data.

Calibrate Tab

The Calibrate Tab is discussed in the next section.

Manual Viscosity Calculations

Viscosity, by definition, is shear stress divided by shear rate. There are three different methods of calculating viscosity using the Model 3530. Each method requires different constants to be used in the calculations. The constants are outlined below, followed by a detailed explanation of the three methods used for viscosity calculation. Additionally, some common oilfield viscosity computations are provided for reference.

Dimensions and Constants for Viscosity Calculations

Rotor/Bob Configuration	R1 B1	R2 B1	R3 B1	R1 B2	R1 B3	R1 B4
Rotor Radius, R_o, cm	1.8415	1.7588	2.5866	1.8415	1.8415	1.8415
Bob Radius, R_j, cm	1.7245	1.7245	1.7245	1.2276	0.8622	0.8622
Bob Height, L, cm	3.800	3.800	3.800	3.800	3.800	1.900
Shear Gap, in Annulus, cm	0.1170	0.0343	0.8261	0.6139	0.9793	0.9793
Radii Ratio, R_j / R_o	0.9365	0.9805	0.667	0.666	0.468	0.468
Overall Instrument Constant, K	300.0	94.18	1355	2672	7620	15,200
Shear Stress Constant for Effective Bob Surface k_2, cm^{-3}	0.01323	0.01323	0.01323	0.0261	0.0529	0.106
Shear Rate Constant k_3, sec^{-1} per rpm	1.7023	5.4225	0.377	0.377	0.268	0.268
Standard F1 Torsion Spring $\eta = Kf\theta/N$						

Model 3530 TORSION SPRING CONSTANTS			
TORSION SPRING ASSEMBLY	**TORSION SPRING CONSTANT k_1**	**TORSION SPRING FACTOR f**	**MAXIMUM SHEAR STRESS WITH B1 BOB**
F0.2	77.2	0.2	307
F0.5	193.0	0.5	766
F1	386.0	1.0	1533
F2	772.0	2.0	3066
F3	1158.0	3.0	4600
F4	1544.0	4.0	6132
F5	1930.0	5.0	7665
F10	3860.0	10.0	15330

Method 1: Viscosity Calculation in Terms of an Overall Instrument Constant

Viscosity (cP) = K * f * (θ/N)

Where: K = overall instrument constant (units of dyne * sec * RPM per cm^2 * degree of deflection)
f = torsion spring factor (see Spring Constants Table above)
θ = Model 3530 dial reading
N = rate of revolution of the outer cylinder, RPM

Method 2: Viscosity Calculation in Terms of Three Instrument Constants

This method calculates the viscosity based on instrument constants for torsion spring, bob surface, and shear gap.

$$\text{Viscosity (cP)} = \left(\frac{k_1 * k_2}{k_3}\right) * 100 * \left(\frac{\theta}{N}\right)$$

Where: k_1 = torsion spring constant (see Spring Constants Table above), dyne-cm/degree
k_2 = shear stress constant for effective bob surface, cm^{-3}
k_3 = shear rate constant, sec^{-1}/RPM
θ = Model 3530 dial reading
N = rate of revolution of the outer cylinder, RPM

Method 3: Viscosity Calculation in Terms of Shear Stress Divided by Shear Rate

Shear stress (dynes/cm^2) = $k_1 * k_2 * \theta$

Shear rate (sec^{-1}) = $k_3 * N$

$$\text{Viscosity (cP)} = \frac{\text{Shear stress}}{\text{Shear rate}} * 100$$

Common Oilfield Computations

Note: These computations are valid only with the standard R1/B1 configuration. A spring other than F1 may be used if the dial readings are multiplied by the proper "f" factor.

Apparent Viscosity (cP)
$AV = \theta_{600\ RPM} / 2$

Plastic Viscosity (cP)
$PV = \theta_{600\ RPM} - \theta_{300\ RPM}$

Yield Point - approximate value (lb/ft^2)
$YP = \theta_{300\ RPM} - PV$

Yield Point – exact value (lb/ft^2)
$YP = 1.065 * (\theta_{300\ RPM} - PV)$

Section 3 – Maintenance

Tools Required

Standard mechanics tool set

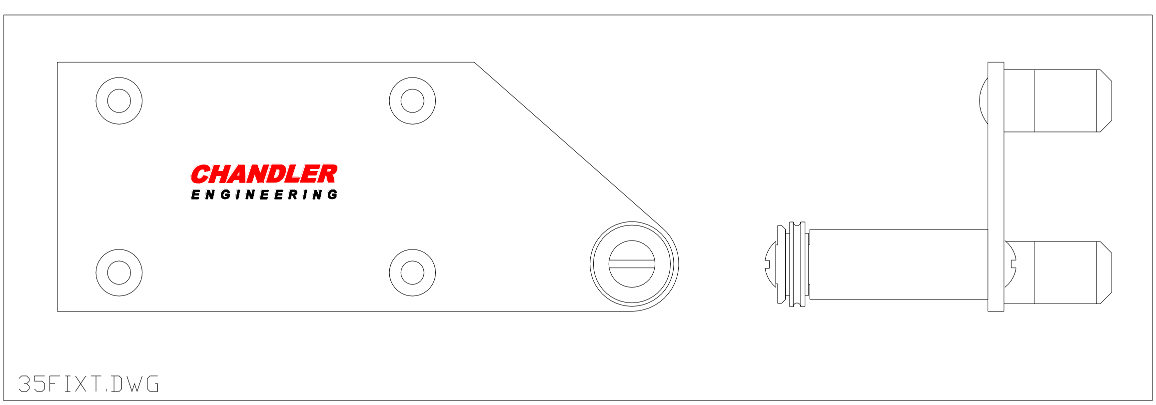
Cleaning and Service Tips

- The rotor and bob should be thoroughly cleaned after each test. Care should be taken to ensure that the bob shaft does not become bent.
- Never replace the power cord with an inadequately rated power cord (see section 5 – Replacement Parts for the Chandler Engineering part number).
- Maintenance should only be performed by qualified personnel.

Manual Calibration Procedure

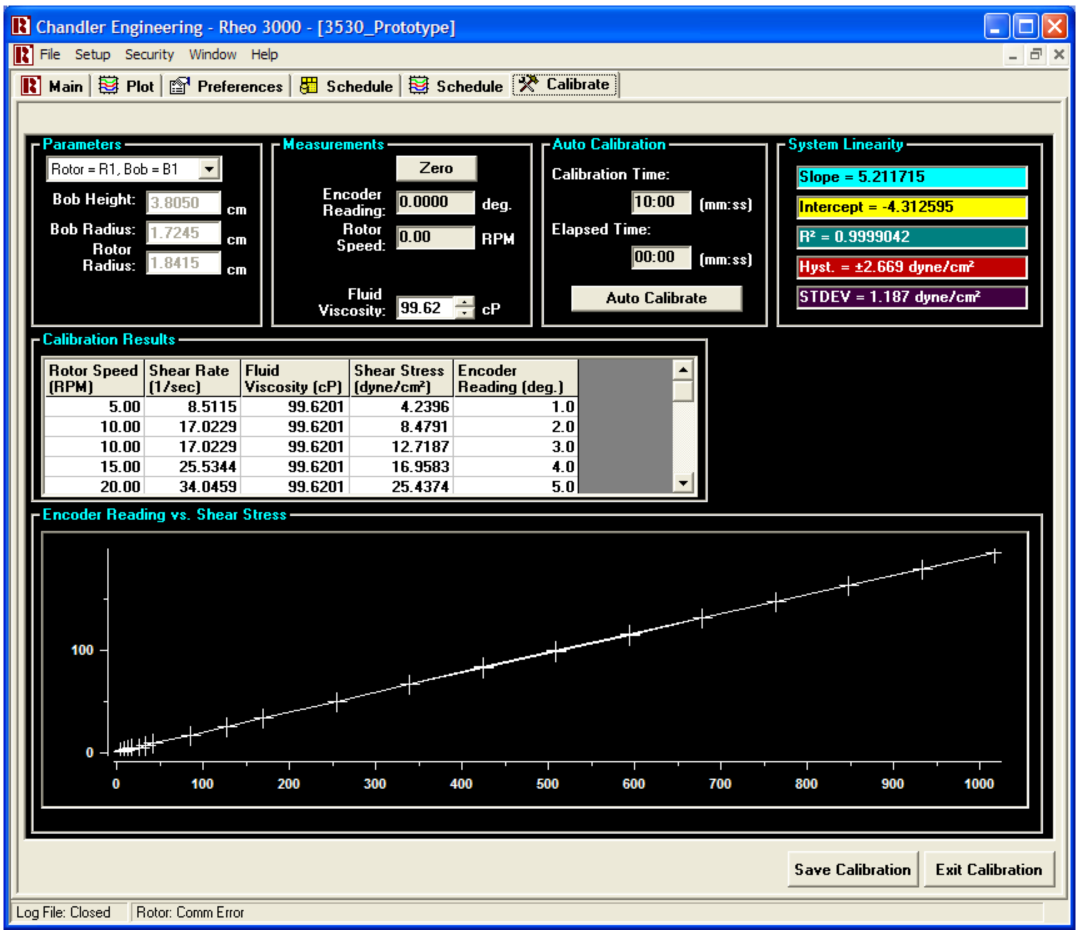
Note: The spring zero and span should be adjusted after any maintenance is performed on the Model 3530. The spring zero and span should be adjusted BEFORE the automatic calibration is performed using the software.

1. The spring zero and span must be adjusted using a calibration fixture or known viscosity fluid.
2. Verify the spring calibration by attaching the pulley frame from the calibration kit to the posts on the viscometer.
3. Attach the calibration disc and thread to the tapered end of the bob shaft and hang the 10-gram weight over the pulley with the anchor on the string attached to the disc.
4. Adjust the height of the frame on the vertical support shafts until the string is horizontal between the disc and the pulley.
5. Record the dial reading.
6. Repeat the process using the 20 gram, 50 gram, 100 gram weights and with all weights removed.
7. Refer to the table on the following page for the dial reading limits during spring calibration.
8. If the dial reading does not fall within the allowable tolerances, a calibration adjustment must be made. See the *Calibration Adjustment* section below.



Spring Tolerances for Calibration (Dial Reading)				
Weight (grams)	0.2 Spring	0.5 Spring	1.0 Spring	2.0 Spring
0	0 ± 0.5	0 ± 0.5	0 ± 0.5	0 ± 0.5
10	127 ± 2	51 ± 1	25 ± 1	12.5 ± 1
20	254 ± 2	102 ± 2	51 ± 1	25 ± 1
50		254 ± 2	127 ± 2	64 ± 1
100			254 ± 2	127 ± 2

Software Calibration



Calibration Overview

The Model 3530 Viscometer uses an automated software calibration procedure, which relates angular bob shaft deflection to shear stress. Measurements made at a variety of rotor speeds comprise a lookup table for the software to use when measuring shear stress. A pre-defined schedule takes the instrument from low speed to high speed, and back to low speed, waiting for a user-defined period seconds at each of 40 pre-defined speeds (20 increasing and 20 decreasing) to allow for measurement stabilization and data averaging. The result is a curve from which system linearity and hysteresis can be inferred.

Since this curve provides a reasonable impression of the instrument performance, a system of metrics has been established to compare what can be construed as a "good" calibration to a "bad" one. These metrics include linearity, slope, intercept, hysteresis standard deviation and maximum hysteresis.

System Linearity

The linearity of a calibration curve is noted by the value of R^2, which is an indication of how precisely a straight line can be plotted against the calibration data using the linear least-squares method. In general, an R^2 value of 1 indicates perfect linearity. An R^2 value of slightly less than one (0.99 or better) is generally expected.

While the linearity can provide clues to the performance of the instrument, analyzing the R^2 value of a given calibration only makes it possible to detect gross errors, such as frozen bearings, etc.

Slope

Since a good calibration result is reasonably linear, the slope of the same line generated by the least-squares method to produce R^2 provides an estimate of the spring constant in dyne/cm² per degree. In turn, this constant can be used to predict the maximum measurable shear stress by the formula τ_{max} = slope (dyne/cm²) * 300 degrees.

Intercept

The intercept of the line generated by the least-squares method provides an indication of sensor offset. Although any effects of a non-zero intercept are compensated for by the calibration, the intercept should typically be near zero, because "re-zeroing" the sensor can have an adverse effect on the effectiveness of a given calibration, otherwise. If the offset is near zero, the sensor can be "re-zeroed" or "tared" without the need for recalibration.

Hysteresis

Hysteresis provides an indication of overall friction in the system. When increasing the bob shaft torque to a given value, the resultant angular deflection may be less than that observed by approaching the same torque from a higher value. This is typically assumed to be the result of friction, although other factors can influence the reported hysteresis.

To characterize the hysteresis from a given calibration, each data point is compared with the lookup table generated by the calibration procedure itself. Since the calibration routine includes 1 data point for increasing shear rate and 1 data point for decreasing shear rate at each pre-defined speed, each lookup table entry is determined by the average of two bob shaft deflection measurements and the average of two shear stresses.

Standard Deviation

During and after calibration, the deviation of each data point (in dyne/cm²) from the lookup table (shear stress vs. angular deflection) is recorded. Standard deviation is calculated based on the data set containing these points. The formula for standard deviation is defined as:

$$\sigma = \sqrt{\frac{\sum(X-M)^2}{(N-1)}}$$

, where M is the mean and N = the number of data points.

Since each pair of data points is generated by comparison to their averages, M=0.

Maximum Hysteresis

Maximum Hysteresis is defined as the largest deviation found in the calibration data set from the calibration table. Whereas standard deviation provides a normalized indication of the overall bearing friction, maximum hysteresis provides a meaningful measurement of worst-case hysteresis.

Software Calibration Summary

Each of the parameters listed above are reported by the Rheo 3000 software. In addition to reporting each of these values on-screen, they are also recorded, along with all other calibration data and parameters, near the top of each individual log file. Analysis of the maximum hysteresis, hysteresis standard deviation, R^2, slope and intercept can provide a quick and easy verification of the state of an instrument, upon recalibration.

- **Parameters** - allows the user to select from a list of standard Rotor / Bob combinations. Bob Height, Bob Radius and Rotor Radius are automatically populated. If “Custom Geometry” is selected, Bob Height, Bob Radius and Rotor Radius are editable.

- **Measurements**
  - **Encoder Reading –** displays the current Encoder reading in degrees.
  - **Rotor Speed –** displays the current Rotor Speed
  - **Fluid Temp –** displays the current Fluid Temperature. This value is only visible if the 3500-04 Temperature Controller is enabled.
  - **Fluid Viscosity -** The known viscosity value of the calibration fluid. If the 3500-04 Temperature Controller is selected, this value is calculated from the entered **Calibration Fluid** data. Working Viscosity reference values are generated via linear interpolation within the defined Calibration Fluid table.

- **Auto Calibration**
  - **Calibration Time -** displays the total time required to Calibrate during an Auto Calibrate Sequence.

  - **Elapsed Time -** displays the elapsed time of an Auto Calibrate Sequence.
  - **Auto Calibrate** - Starts the auto-calibration sequence (see below).

- **Calibration Fluid** - The Viscosity of the Calibration Fluid at known temperatures are entered from the Calibration Certificate supplied with the Calibration Fluid. Use the New, Open and Save buttons to define a New Calibration Fluid, Open a previously saved Calibration Fluid or Save the currently defined Calibration Fluid. This table is only visible if the 3500-04 Temperature Controller is enabled.

- **Save Calibration** - Saves the calibration data. The Rheo 5000 software will begin using the new values.

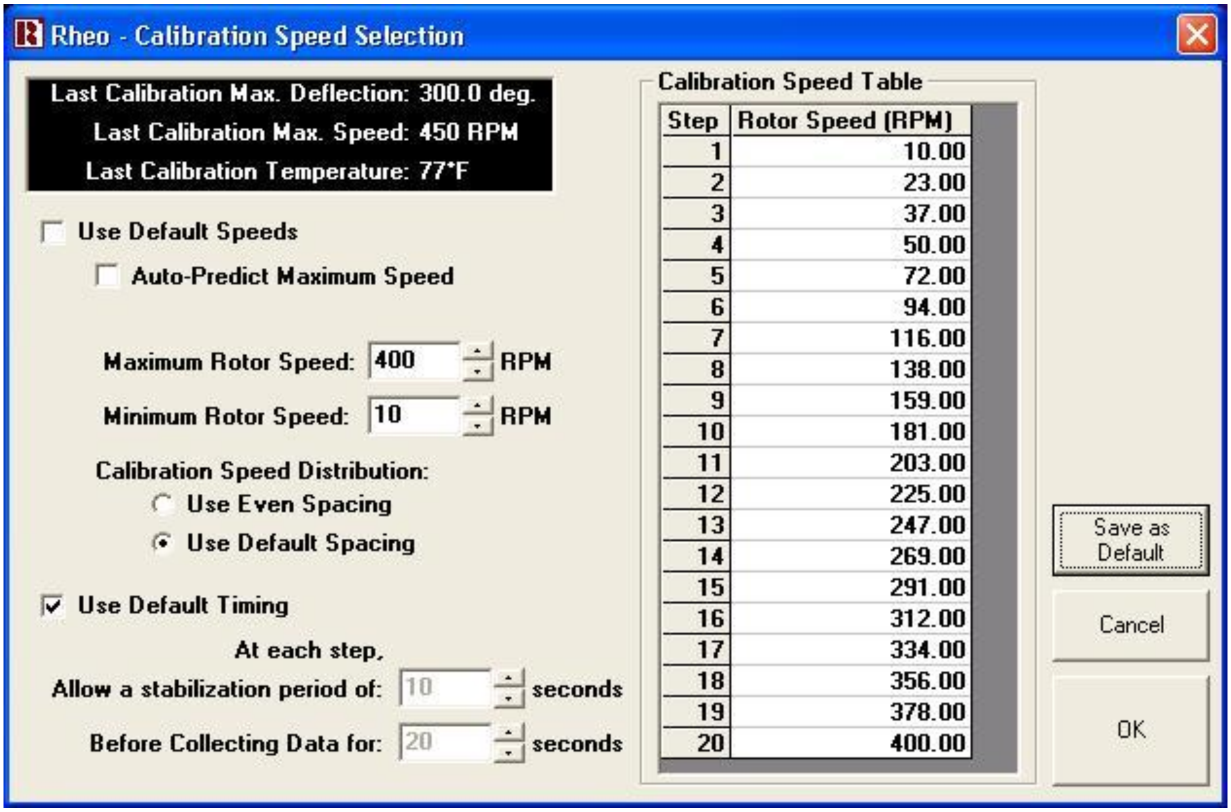
- **Tare Button -** Zeros the **Encoder Reading**.

- **System Linearity –** displays the Linearity calculations (discussed above). These values are updated during calibration. It is normal for them to display out-of-tolerance values while an Auto-Calibration Sequence is in progress.

- **Encoder Reading vs Shear Stress (Plot)** is a graphical representation of the Calibration Data. This should be a very straight, increasing line. It is normal for this line to have several "corners" while an Auto-Calibration Sequence is in progress.

It is highly recommended that a manual dial calibration be completed before a software calibration is performed.

Auto Calibration



- **Use Default Speeds** – Uses default rotor speeds for calibration.
- **Auto-Predict Maximum Speed** – Using previous calibration data for the same nominal viscosity calibration fluid, Rheo 3000 automatically determines the maximum rotor speed without exceeding the target spring deflection. The maximum speed should never exceed 600 rpm, and if so, manually change the speed to 600 rpm.
- **Target** – Maximum deflection of the spring. Maximum value is 300 degrees.
- **Maximum Rotor Speed** – Maximum rotor speed at which to determine a calibration value. This value should never exceed 600 rpm.
- **Minimum Rotor Speed** – Minimum rotor speed at which to determine a calibration value. Generally, this is set between 10 and 20 rpm.
- **Use Even Spacing** – Evenly disperses the tabular calibration rotor speeds.
- **Use Default Spacing** – Uses the default tabular calibration rotor speeds, the lower speeds are more narrowly spaced.
- **Use Default Timing** – Default durations for the stabilization period and data averaging period.
- **Allow a stabilization period of:** – Specify a duration, in seconds, for stabilization of the shear stress value before collecting data.
- **Before Collecting Data for:** – Specify a duration, in seconds, during which shear stress data is collected and averaged.

Serviceable Parts

Fuse Replacement

The main power fuse at the rear of the instrument may occasionally need to be replaced.

1. Unplug the power cord.

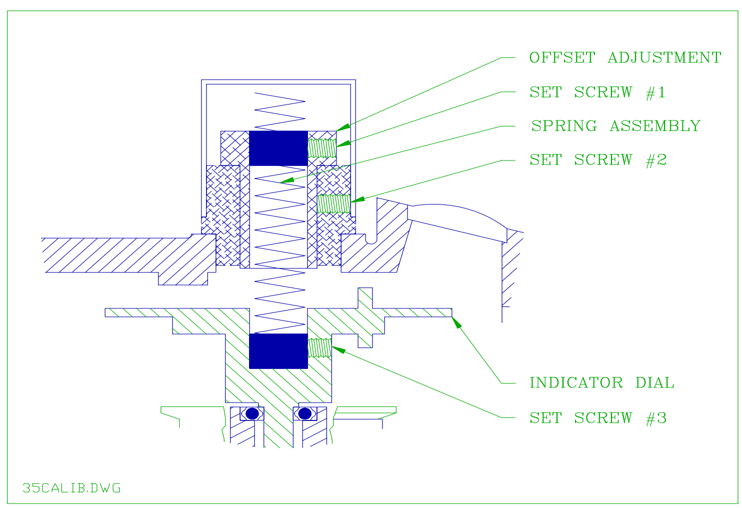
Power must be disconnected to prevent injury.

2. Verify that power to the instrument is OFF and unplug the instrument from the electrical outlet before proceeding.
3. Using a small flat-head screwdriver, pry open the top of the main power switch.
4. Remove the fuse-holder.
5. Remove the old fuse and replace with a new fuse, part number C11037 (see Section 5 – Replacement Parts for fuse rating and characteristic.)
6. Plug power cord into the power entry module located on the back of the instrument.
7. Turn on the instrument and verify the bob rotates.

Spring Assembly Replacement

1. Unplug power cord.

Power must be disconnected to prevent injury.



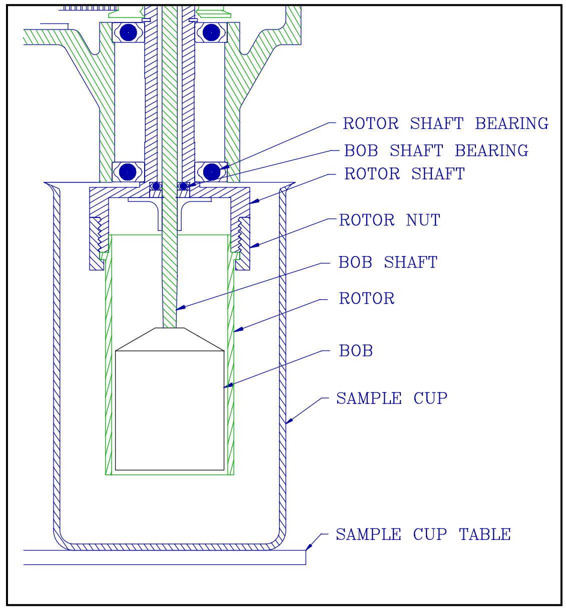
2. Screw in the #4-40 x 3 inch screw shipped with the instrument.
3. Loosen set screw #3. This set screw is accessed by removing the silver plug on the front of the instrument. The dial indicator must be rotated until the set screw aligns with the hole in the casting.
4. Carefully pull the spring assembly out of the instrument.
5. Insert new spring assembly.
6. Tighten set screw #3.
7. Plug power cord into the power entry module located on the back of the instrument.
8. Calibrate the instrument with the new spring following the instructions in the *Manual Calibration Adjustment* section.

Bob Shaft Bearing Replacement

1. Unplug power cord.

Power must be disconnected to prevent injury.

2. Remove the silver plug from the front of the instrument.
3. Loosen set screw #3 in the bushing.
4. Remove the torsion spring cap.
5. Loosen set screw #1 in the zero adjust sleeve.
6. Remove the 6 top cover screws.
7. Remove the spring assembly taking care not to stretch the spring.
8. Raise the gear box cover up and carefully lay it over the side of the gear box. The instrument can be laid on its side to simplify this process and to minimize the chance of damage to the attached wiring.
9. Remove the rotor.
10. Remove the bob.
11. Remove the 2 screws from the stand-offs and carefully slide the brown optical encoder away from the optical disc.
12. Remove the bearing splash guard by sliding it straight down and off of the bob shaft.



13. Remove the bob shaft snap ring by laying the instrument on its side and using a pointed tool to remove the snap ring.
14. Remove the bob bearing shield.
15. Pull the dial and bob shaft assembly straight up out of the bearings. DO NOT bend the shaft.
16. Carefully remove the bob shaft bearings.
17. Replace the bearings with new (or cleaned) bearings. DO NOT use oil or grease in the bearings.
18. Reverse the procedure for re-assembly. Use great care to ensure the cleanliness of the bearings and related components to prevent dial oscillations due to bearing drag.
19. Calibrate the instrument in the *Manual Calibration Adjustment* section.

Manual Calibration Adjustment

If the dial readings from the Manual Calibration are beyond the limits, an adjustment to the calibration must be made as follows.

1. Refer to the diagram of set screws on the following page as the adjustments are made.
2. Remove the spring cap and loosen set screw #1 using a 1/16 inch hex wrench on the zero adjust sleeve.
3. This loosens the upper spring clamp on the torsion spring assembly and allows the effective spring length to be varied by raising or lowering the mandrel inside the spring.
4. If readings are too high, move the spring mandrel down by turning it clockwise. If readings are too low, move the spring mandrel up by turning it counterclockwise.
5. Tighten set screw #1.
6. If the instrument ZERO must be adjusted, remove the spring cap and use a 1/16 inch hex wrench to loosen set screw #2.
7. Remove all weights from the calibration fixture.
8. Rotate the knurled bushing until the dial reading is 0. Tighten set screw #2.
9. Repeat the calibration procedure with the weights.
10. If the instrument will not calibrate properly, check the bob shaft bearings and refer to other potential problems listed in the Troubleshooting Guide.

Calibration may require repetitive adjustments of the Span and Zero since they are interrelated. Once the dial readings fall within the acceptable limits, tighten all the set screws securely and replace the torsion spring cap.

11. Operate the instrument at 300 RPM with a 200cP fluid in the sample cup. The dial oscillations should be less than 1 dial reading to verify the instrument is operating properly. If not, clean or replace the bob shaft bearings.

Dial oscillations can also be caused by a bent bob shaft or a damaged rotor assembly. Additionally, a rotor shaft belt pulley that does not slide freely vertically on the rotor shaft and key can cause bob bearing distortion.

Maintenance Schedule

MAINTENANCE SCHEDULE INSTRUMENT NAME					
COMPONENT	EACH TEST	MONTHLY	3 MONTHS	6 MONTHS	ANNUAL
Rotor	Clean				
Bob	Clean				
Bob Shaft Bearing		Inspect **			
Bob Shaft		Inspect **			
Torsion Spring		Inspect **			
Timing Belt				Inspect **	
Instrument Calibration		Check calibration			

This maintenance schedule applies to normal usage of two tests per day. Detailed procedures for these operations are contained in your manual.

● Per API Specifications

* Where Applicable

** Replace as needed

Section 4 – Troubleshooting Guide

Problem	Solution
Unsteady Dial Reading	• The bob shaft bearings may be dirty. Replace the bearings. • The rotor and bob may not be concentric. Remove both the rotor and bob, clean all mounting surfaces, replace the rotor and bob. • The spring may be worn, replace. • The bob shaft may be bent. Replace the shaft assembly.
Belt Makes Noises	• The drive belt is too tight, adjust the belt tensioner.
Motor Operates At Wrong Speeds.	• The wiring from the RPM selector switch may be damaged. Repair the wiring.
Instrument Does Not Operate When Power Switch Is ON.	• Inhibit switch in Inhibit ON position. Change switch position and try again. • Check fuses and replace if necessary. • The power switch may be defective, replace the switch and connector assembly if necessary. • The motor controller may be defective. Replace if necessary.

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Section 5 - Replacement Parts

Part Number	Description
35-0101	Stage
35-0111	Spacer
35-0112	Nut
35-0118	Bob (Type B1) Assembly
35-0125	Shield
35-0131	Sleeve, Zero Adjust
35-0132	Guard, Splash
35-0133	Idler Arm
35-0134	Spacer, Short Shaft
35-0136	Timing Belt Pulley, Modified
3530-CUP	Sample Cup
35-0191	Rotor
35-0228	Shaft, Rotor
35-0285	Label, Speed Control
3506-F1	Torsion Spring Assembly (F1)
3530-1011	Bob Shaft Assembly
3530-1031	Speed Selection Circuitry
3530-1032	Wiring Kit
3530-1062	Programmed Stepper Controller And Encoder Module
3530-1100	Cover, Base
3530-1105	Tube Support
3530-1106	Tube Support, Modified
3530-1108	Gear Box
3530-1109	Gear Box Cover
3530-1111	Timing Belt Pulley with Set Screw
3530-1112	Encoder Bracket
3530-1113	Motor Controller Bracket
3530-1114	Base
C07560	Standoff
C09848	LED
C09906	Cap, Torsion Spring
C10029	Stepper Motor
C10075	Collar, Clamp-on Shaft .5 x 1.13 x .40
C10533	Encoder Module
C10534	Encoder Disk
C10557	Timing Belt
C10582	Allen Nut, 7/16-20
C11037	Fuse, 2.000A, 250V, 5X20 Time Delay
C13673	Power Supply, 110/220VAC
C15723	Power Entry Module, 250V, 2A, 5x20
P-0066	O-Ring (Bumper)
P-1233	Foot, Rubber
P-2441	Power Cord,18AWG,1250W/10A

Part Number	Description
P-2931	Bearing, Main
P-2932	Bearing, Bob Shaft
P-2933	Bearing, Idler
P-2945	Plug, Hole
P-2948	Knob, Selector
P-3002	Knob, Locking
OPTIONAL ITEMS:	
35-0246	R2 Rotor
35-0261	B2 Bob Assembly
35-0262	B3 Bob Assembly
35-0263	R3 Rotor Nut
35-0264	R3 Rotor

To ensure correct part replacement, always specify Model and Serial Number of instrument when ordering or corresponding.

Section 6 - Drawings and Schematics

Drawing Number	Description
3530-1000	Assembly, Model 3530
3530-1030	Schematic, Model 3530

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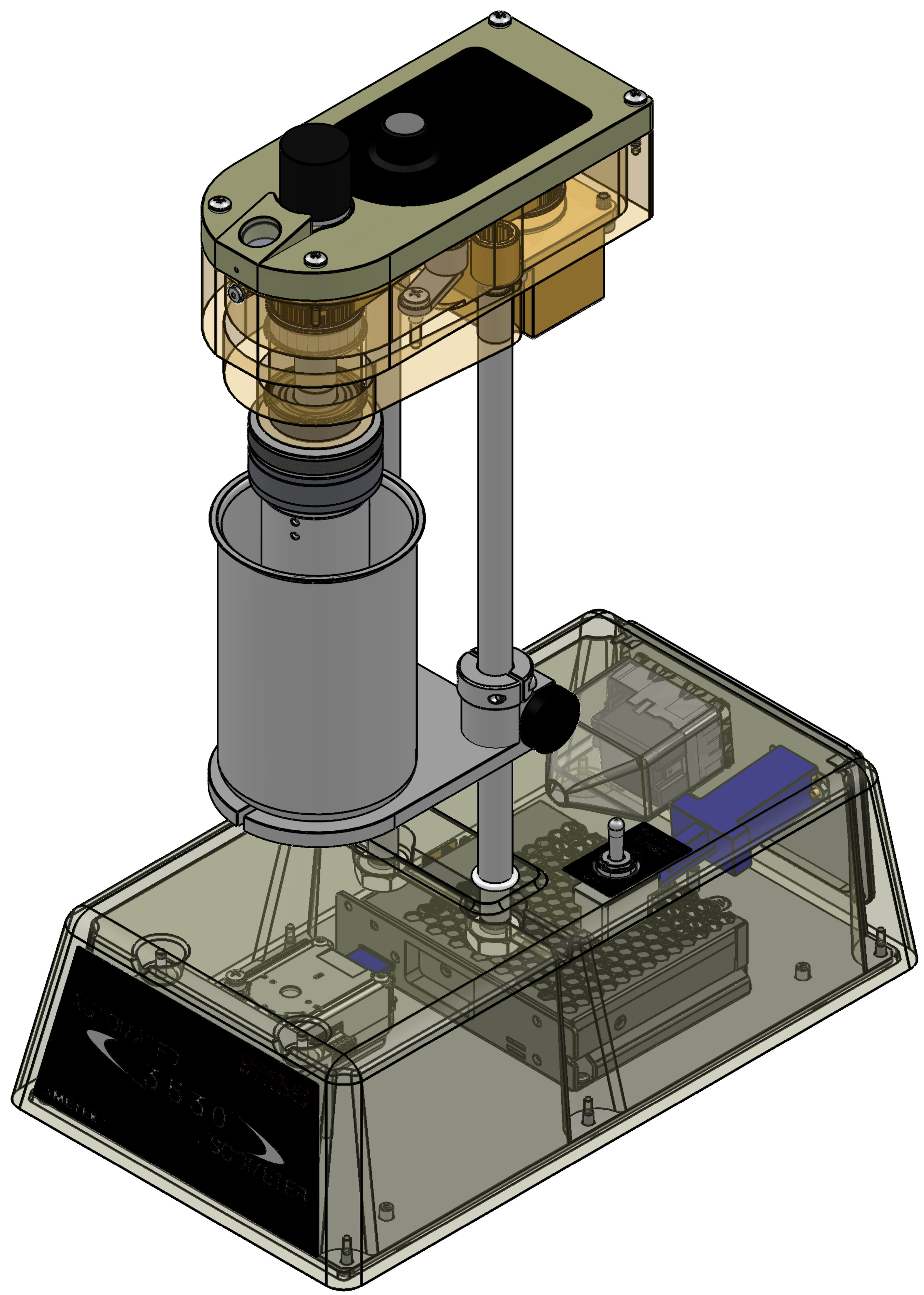
REV	DESCRIPTION	DATE	APPROVED
U	ECN T9000; ADDED P-2950	9/2/2020	JS
T	ECN T8975; REDRAWN IN SOLIDWORKS	8/4/2020	DLR
V	ECN T9346; REMOVED SLOTS ON 3530-1100 COVER	11/2/2021	JS



ITEM	PART NUMBER	DESCRIPTION	QTY	UoM
1	3530-1114	BASE,MODIFIED	1	
2	C18608	POWER SUPPLY,85-264VAC,48V,2.3A,ENCLOSED	1	
3	3530-1100	COVER,BASE	1	
4	3530-1101	COVER,BASE,REAR	1	
5	C11614	MODULE,PWR ENTRY,250V,4A,FLTR	1	
6	P-1233	FOOT,RUBBER,0.9687OD	4	
7	3530-1105	TUBE SUPPORT	1	
8	3530-1106	TUBE SUPPORT, MODIFIED	1	
9	3530-1108	GEAR,BOX,3530	1	
10	P-2931	BRG,BALL,RAD,0.625X1.375X0.344	2	
11	35-0228	SHAFT,ROTOR	1	
12	P-2932	BRG,BALL,RAD,0.187X0.500X0.150	2	
13	35-0125	SHIELD	1	
14	35-0132	SPLASH GUARD	1	
15	35-0191	ROTOR-R1	1	
16	35-0245	NUT, COUPLING, ROTOR	1	
17	3530-1109	COVER,GEAR BOX,3530	1	
18	3530-1040	PCA,ASSEMBLY,3530 SPEED SELECT,MFORCE	1	
19	35-0153	LIGHT PIPE	1	
20	35-0317	RETAINER,LIGHT PIPE	1	
21	P-2948	KNOB,SKIRTED,W/PTR,1/4"SHAFT	1	
22	35-0101	STAGE	1	
23	3506-CUP	SAMPLE CUP	1	
24	3530-1115	LABEL,FRONT,3530	1	
25	P-0407	SWITCH,TGLE,PNL,DPST,ON/XX/OFF	1	
26	3530-1119	LABEL,INHIBIT SWITCH	1	
27	3530-1113	CONTROLLER BRACKET	1	
28	3530-1062	PROGRAMMED STEPPER CONTROLLER	1	
29	C11613	BOOT,REAR COVER,PLASTIC	1	
30	3530-1033	ASSY,CABLE,CONTROLLER,MODEL 3530	1	
31	C11037	FUSE,2.000A,250V,5X20,TIMEDELAY	2	
32	3530-1034	ASSY,CABLE,MOTOR,MODEL 3530	1	
33	3530-1035	ASSY,CABLE,COMMS,MODEL 3530	1	
34	3530-1112	ENCODER BRACKET MODEL 3530	1	
35	C10533	OPTICAL ENCODER, 2048 CPR	1	
36	C10534	ENCODER DISK,2"OD,0.75" HUB	1	
37	35-0136	PULLEY,MODIFICATION	1	
38	35-0300	BUSHING	1	
39	35-0115	CLAMP - SPRING	2	
40	35-0131	SLEEVE	1	
41	C10029	MOTOR,STEP,NEMA23	1	
42	3530-1011	BOB SHAFT ASSEMBLY	1	
43	C09906	CAP,.980"ID,1"H INSIDE,VINYL	1	
44	3530-1111	PULLEY WITH ADDED SET SCREW	1	
45	C10557	BELT,TIME,.3125W,155T,5/16P	1	
46	35-0133	IDLER ARM	1	
47	P-2933	BRG,BALL,RAD,0.250X0.625X0.562	1	
48	H-25-017	SCREW,BHMS,SS,1/4-20X0.750,PHI	1	
49	H-10-011	SCREW,BHMS,SS,10-24X0.375,PHIL	1	
50	P-2929	LENS, PCX, 16MM X 40MM F.L.	1	
51	35-0166	TORSION SPRING ASSEMBLY,F1	1	
52	35-0140	POINTER	1	
53	P-2945	PLUG,SS,1/4,HOLE,NP	1	
54	C10116	RING,RET,INT,1.375,BASIC	2	
55	C09992	WSHR,WAVE SPRG,.648X.866X.012	1	
56	P-3595	RING,RET,EXT,0.625,INVERTED	1	
57	35-0118	BOB (30844)	1	
58	P-0065	ORING,BUNA,AS112-70	2	
59	P-3014	NUT,HEX,SS,7/16-20,JAM	2	
60	C11015	COLLAR,SHAFT,.5ID 1.25OD,SS	1	
61	35-0112	NUT,LOCKING STAGE	1	
62	35-0111	SPACER	1	
63	P-3002	KNOB,CLAMP,SEMI-GLOSS,.250-20	1	
64	C10582	ALLEN NUT,7/16-20,ALLOY STEEL	2	
65	P-3006	RING,SNAP	1	
66	P-3181	RIVET,POP,AL,0.187X0.250L	4	
67	H-6013	SCREW,BHMS,SS,6-32X0.312,PHIL	6	
68	H-6001	WSHR,LOCK,SS,#6	6	
69	H-4104	SCREW,BHMS,SS,4-40X0.187,PHIL	4	
70	H-4001	WSHR,LOCK,SS,#4	8	
71	H-6019	SCREW,BHMS,SS,6-32X0.500,PHIL	4	
72	H-4108	SCREW,PHMS,SS,4-40X0.375,PHIL	2	
73	H-3010	SCREW,RHMS,3-48X0.50,18-8,PHIL	2	
74	H-10-124	SCREW,SHCS,SS,10-32X0.375,ALN	4	
75	C12096	SCREW,THMS,SS,6-32X0.875,PHIL	4	
76	C09845	WSHR,NYLON,0.140X0.313X0.062THK	4	
77	35-0285	LABEL,TOP,16 SPEED,3500LS	1	
78	C12468	CONV,COMM,RS232-RS422	1	
79	C09285	STDF,HEX,ZN,0.18X0.31,4-40,M/F	2	
80	H-4101	NUT,HEX,SS,4-40	2	
81	C10722	CONN,AMP,5-PIN LOCKING	1	
82	C10723	CONN,PIN,AMP,24 AWG	4	
83	C11615	FUSE DRAWER,2-POLE,FINGERGRIP	1	
84	70607-80	JUMPER,BARRIER,2 POSITION	1	
85	C15936	CAP PLUG	1	
86	35-0174	LABEL,BASE COVER	1	
87	3530-1104	LABEL,BACK COVER,200-240 VAC	1	
88	Q5-C-1043	SCREW,PHMS,SS,4-40X0.250,PHIL	2	
89	3530-1060	PROC,ASSEMBLY,3530	REF	
90	3530-1030	DIAGRAM,WIRING,3530	REF	
91	P-2950	BOOT,SWITCH	1	

BREAK EDGES, DEBURR
UON DIMS ARE IN INCHES
1 PLC ±0.030 2 PLC ±0.010
3 PLC ±0.005 ANGL ±1/2°
SURFACE FINISH 63 RMS
THIRD ANGLE PROJECTION

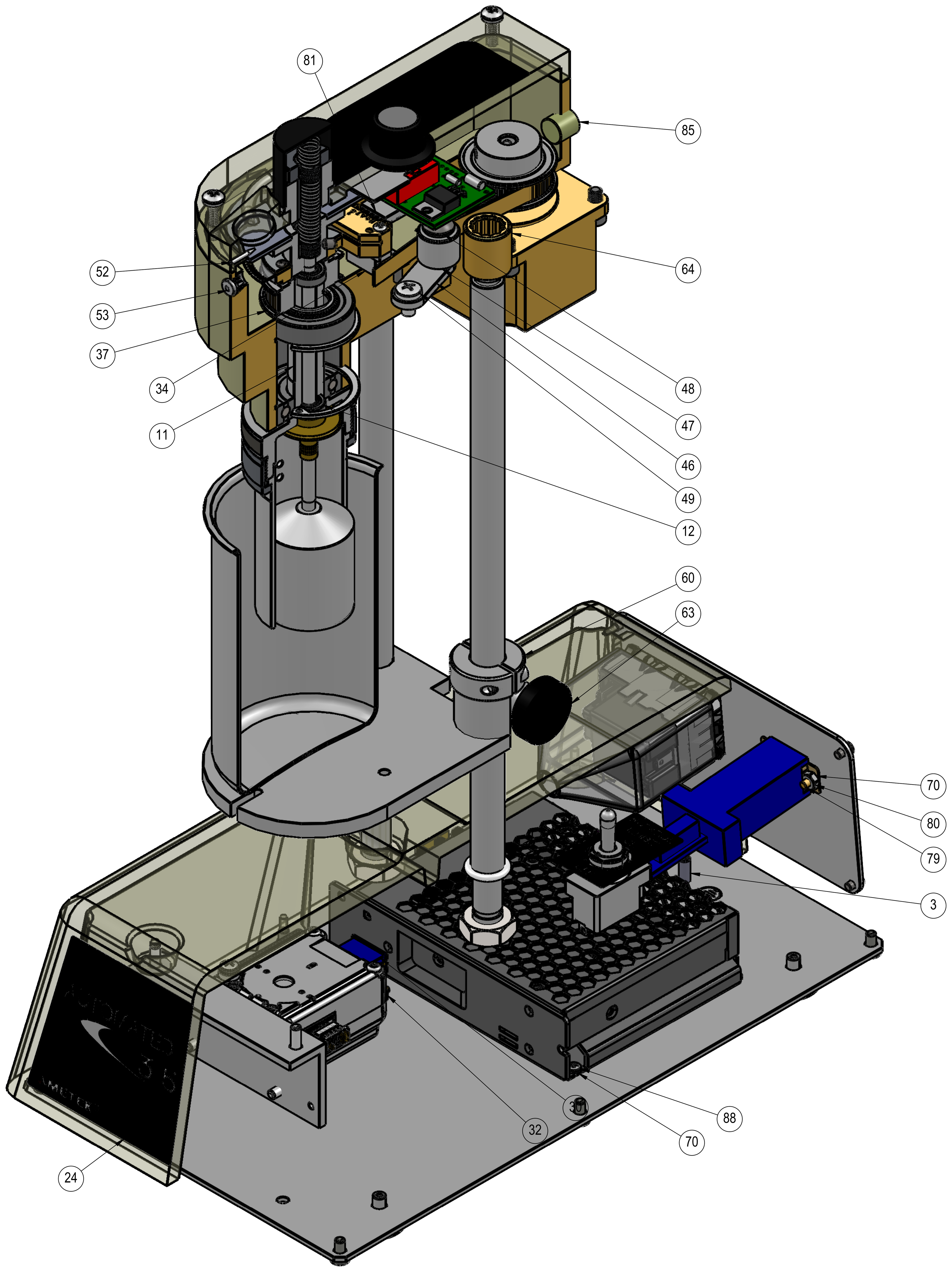
DRAWN: DLR 8/4/2020
MFG: -- 07-24-20
ENGR: -- 07-24-20
TYPE:
STRUCT:

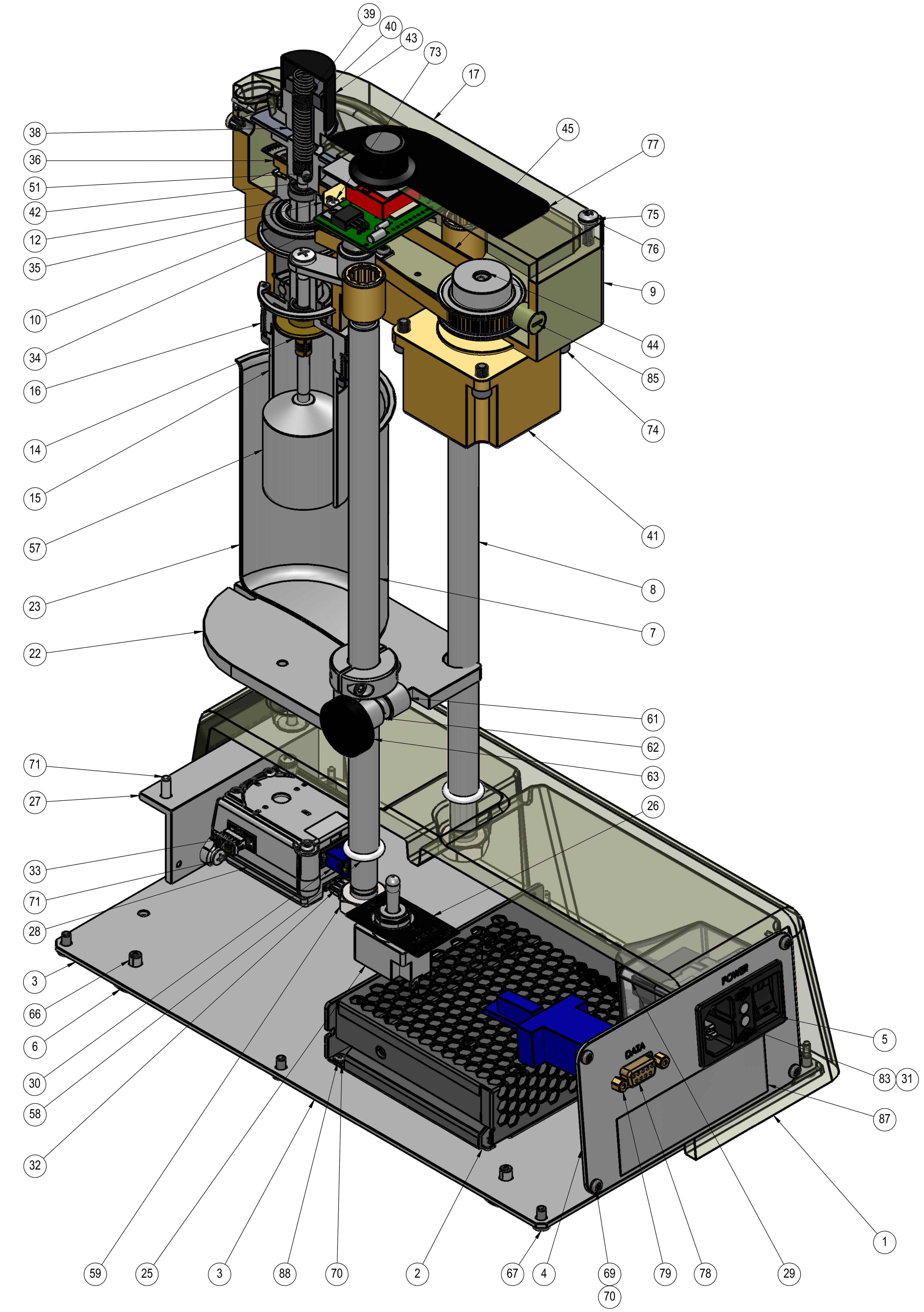
CHANDLER ENGINEERING

VISCOMETER ASSEMBLY

PN: 3530-1000
PROJ: 3530
REV V
SIZE D
SHEET 1 OF 4

TITLE BLOCK REV 3





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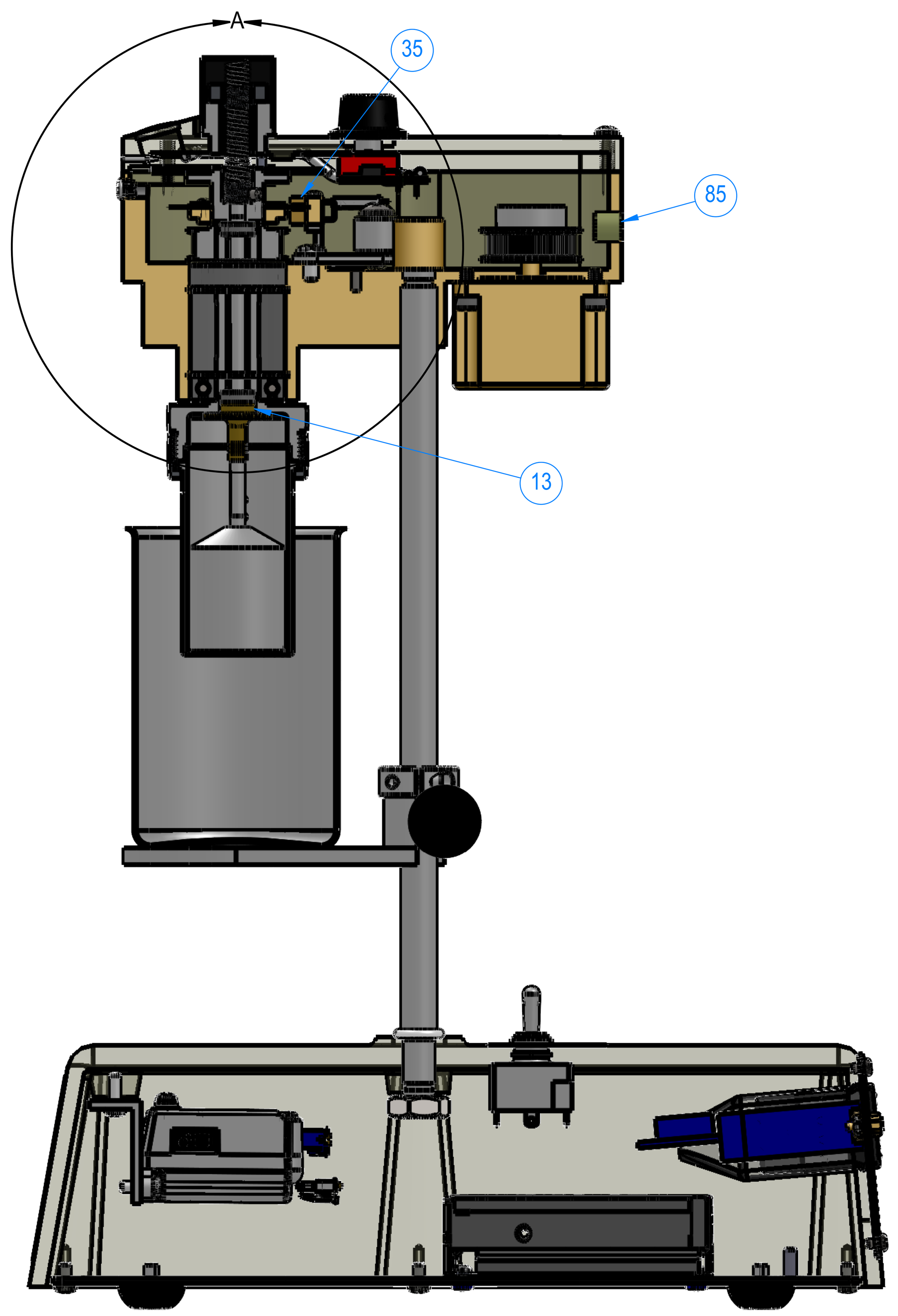
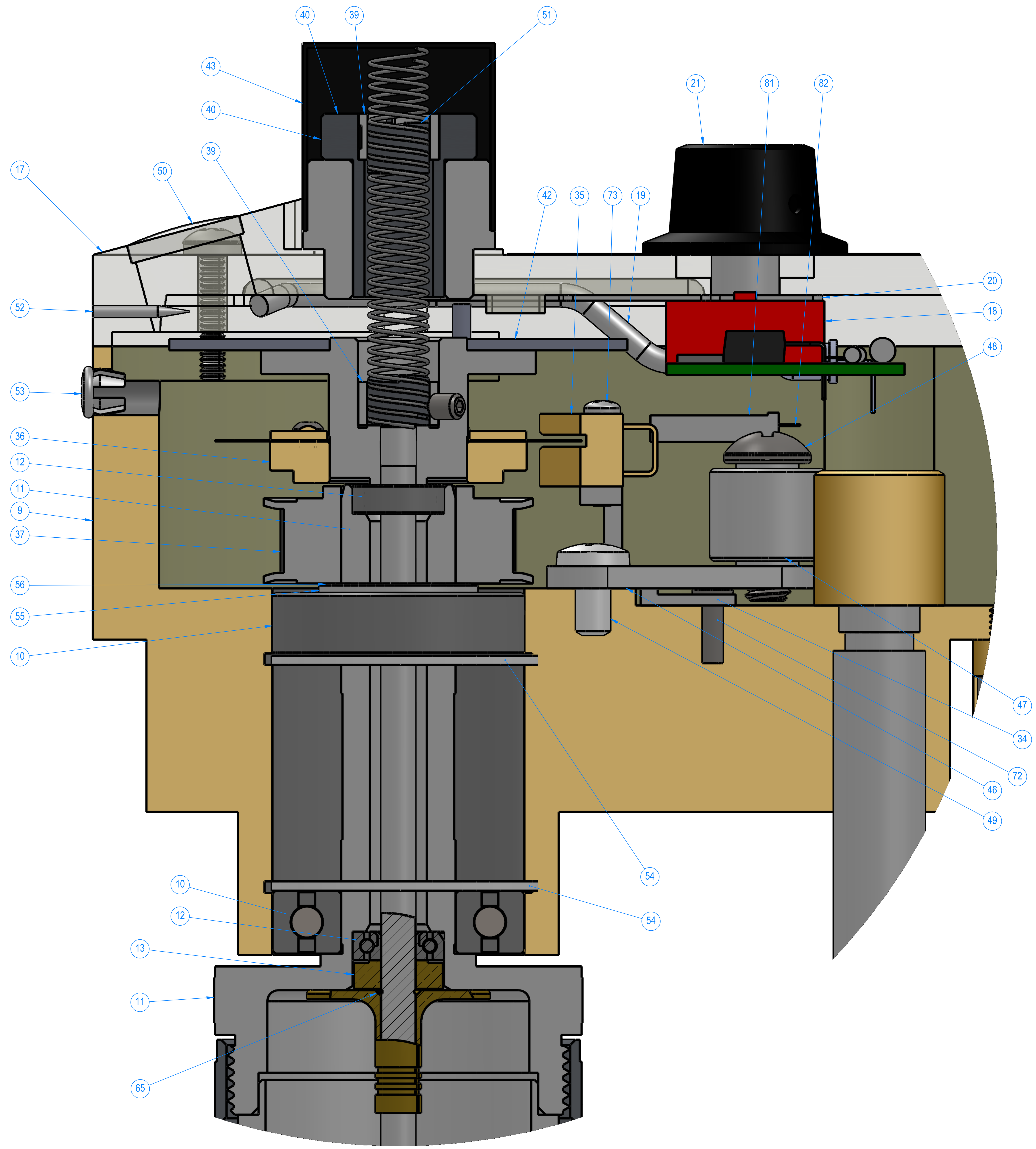
TITLE BLOCK REV 3



BELT NOT SHOWN



DETAIL A

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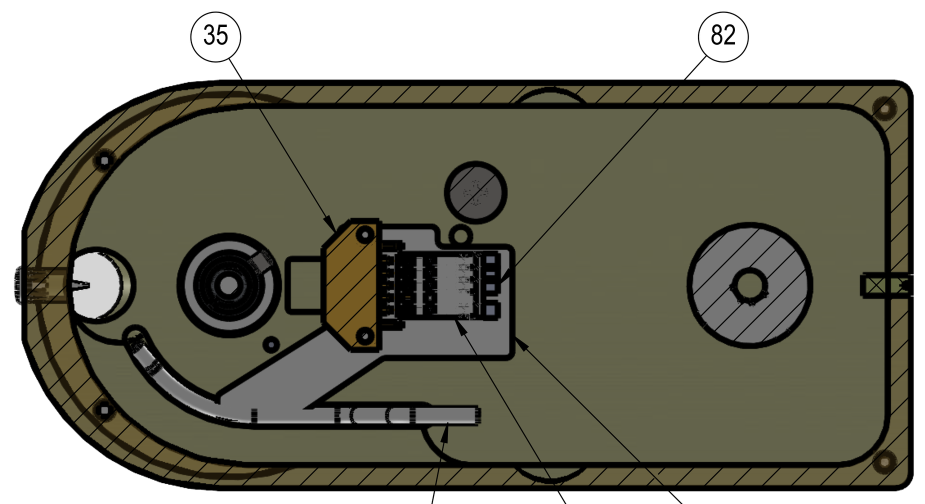
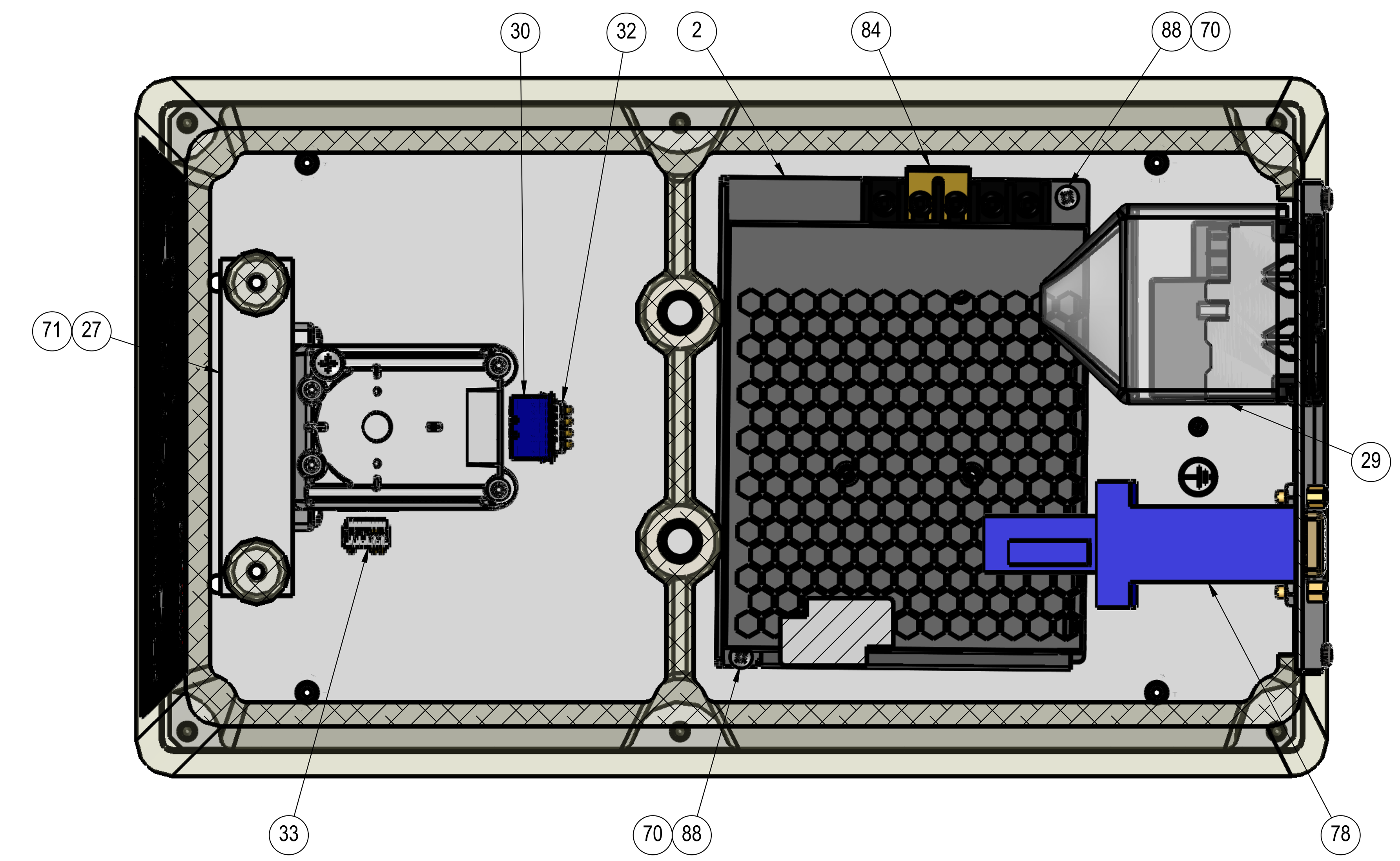
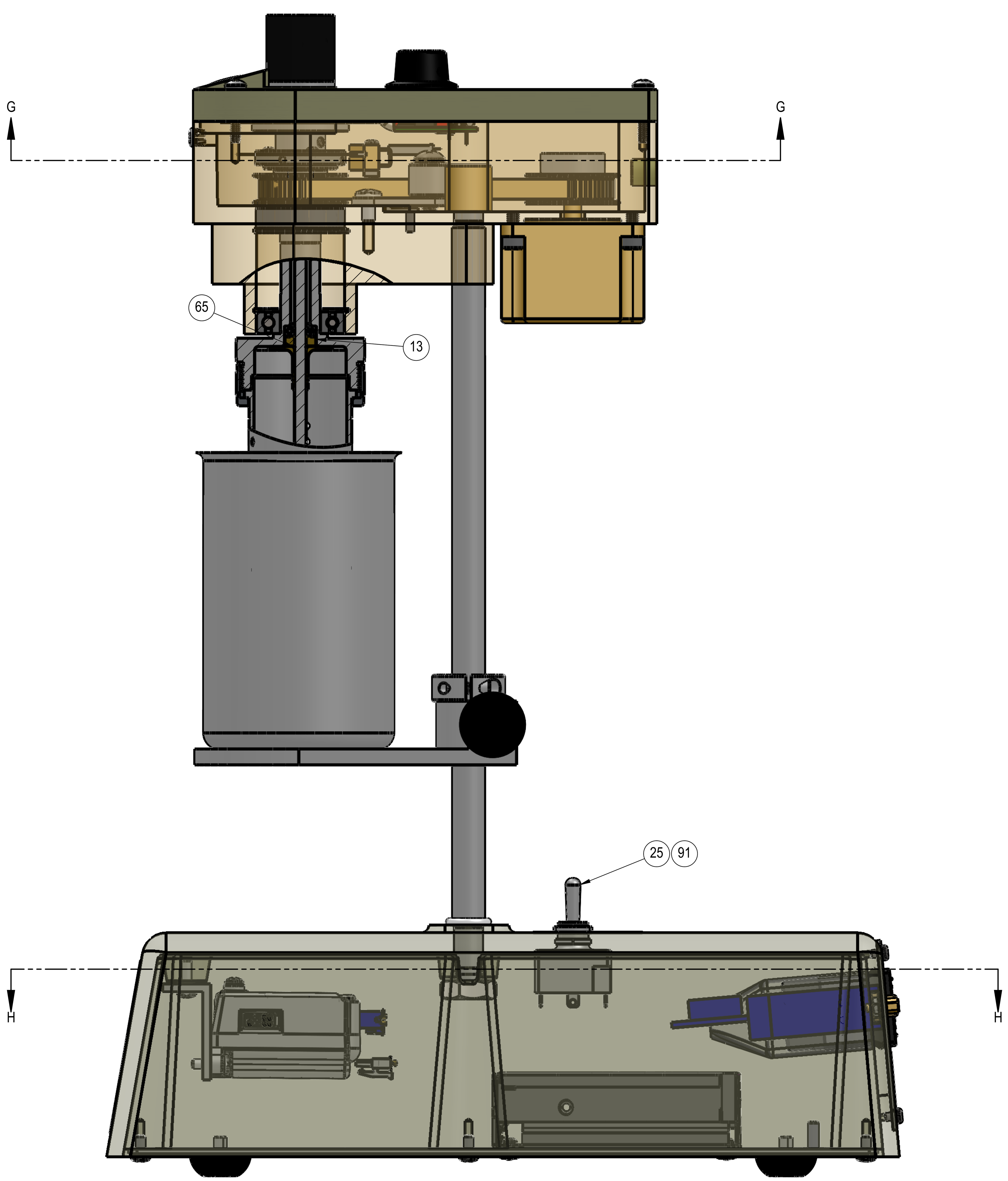
TITLE BLOCK REV 3

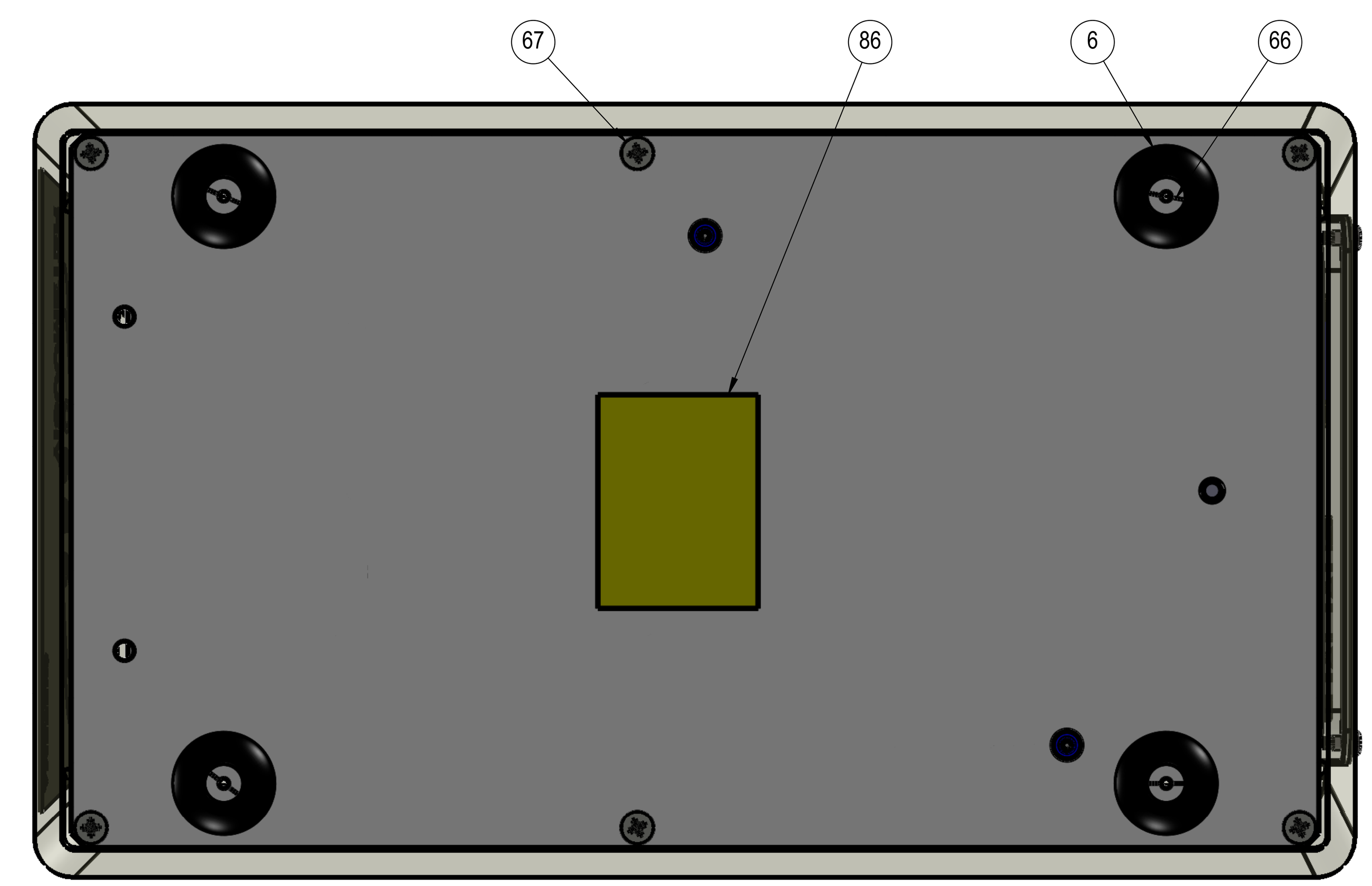


SECTION G-G



SECTION H-H





BOTTOM VIEW

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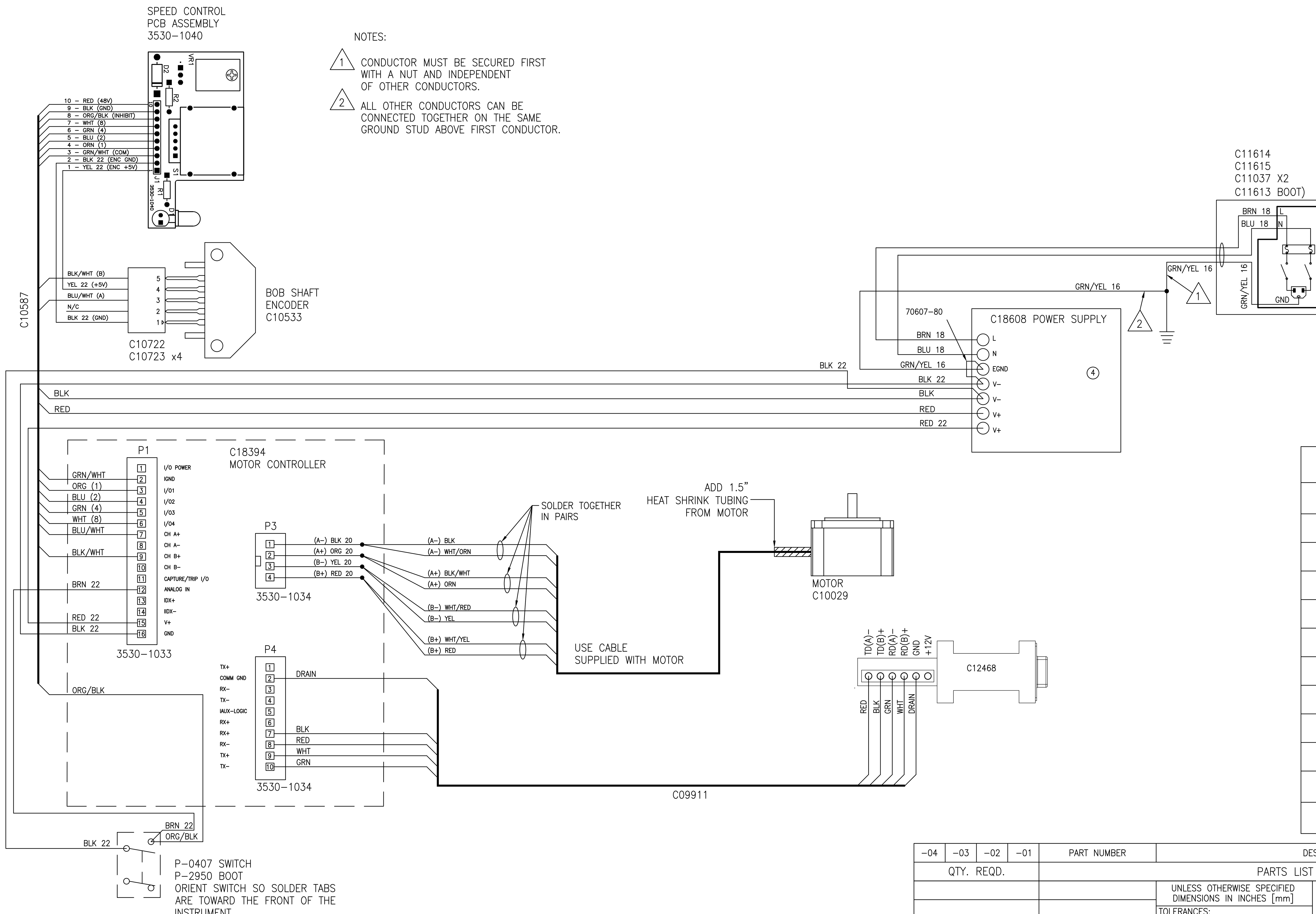
TITLE BLOCK REV 3

REVISIONS					
ZONE	REV	DESCRIPTION OF REVISION	DATE	APPROVALS	
A7	AA	ECN T9504; REPLACE C15683 W/ C15684	09SEP22	JS	TAS
	AB	ECN T9644; REPL WIRE DUE TO INSUL THICKNESS	20JUL23	JS	GC
	AC	ECN T9712; CHANGE TO UL1007 WIRE	20OCT23	JS	DR
	AD	ECN T9982; FIXED GROUND WIRE GAGE SIZE	18SEP24	DR	JS

NOTES:

1. CONDUCTOR MUST BE SECURED FIRST WITH A NUT AND INDEPENDENT OF OTHER CONDUCTORS.
2. ALL OTHER CONDUCTORS CAN BE CONNECTED TOGETHER ON THE SAME GROUND STUD ABOVE FIRST CONDUCTOR.



WIRE TABLE	
ITEM	P/N
BLK 22	C07409
RED 22	C07408
ORG 22	C07403
BLK 20	94-251
ORG 20	94-255
YEL 20	94-253
RED 20	94-279
BRN 18	94-249
BLU 18	94-248
YEL/GRN 16	C17844

-04	-03	-02	-01	PART NUMBER	DESCRIPTION	MATERIAL SPEC.	ITEM
QTY. REQD.					PARTS LIST		

NEXT ASSY	USED ON
APPLICATION	
BREAK SHARP EDGES, DEBURR	

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES [mm]
TOLERANCES:
1 PLACE ±0.030 [.76]
2 PLACE ±0.010 [.25]
3 PLACE ±0.005 [.127]
ANGLES ±1/2°
SURF. FINISH 63

APPROVALS		DATE
DRAWN:	TRB	2/18/03
CHECKED:	TRB	2/18/03
ENGR.:	TRB	2/18/03

CHANDLER ENGINEERING

TITLE
SCHEMATIC
MODEL 3530 – MFORCE

SIZE	S.O. NO.	DWG NO.	REV.
C		3530-1030	AD
SCALE: 1 = 1	TITLE BLOCK REV: 1.0	SHEET: 1 of 1	

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Please Send Us Your Comments on This Manual

Model Number ____________________ Serial Number ____________________

Printing Date of this manual (from the Title Page) __________

Please circle a response for each of the following statements. Use:

(1)= Strongly agree (2) =Agree (3) =Neutral, no opinion (4) =Disagree (5) =Strongly disagree

a) The manual is well organized.	1	2	3	4	5
b) I can find the information I want.	1	2	3	4	5
c) The information in the manual is accurate.	1	2	3	4	5
d) I can easily understand the instructions.	1	2	3	4	5
e) The manual contains enough examples.	1	2	3	4	5
f) The examples are appropriate and helpful.	1	2	3	4	5
g) The manual layout is attractive and useful.	1	2	3	4	5
h) The figures are clear and helpful.	1	2	3	4	5

i) The sections I refer to most often are ______________________________

____

Other comments ____

____

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Serial Number ____________________

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