Model 415C & 415 SGS
HPHT Pressurized Consistometer and
Cement Consistometer with Gel Strength Analyzer

Instruction Manual

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fann®
Fann Instrument Company

Model 415C & 415 SGS Instruction Manual

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1 Introduction

1.1 Model 415C

Model 415C pressurized consistometer is able to test cement slurries at temperatures up to 400ºF/204ºC and pressures to 15,000 psig / 103 MPa. The instrument is designed to perform thickening time tests in accordance with API specifications and recommended practices. If the instrument is also fitted with gel strength testing software it also is designed to perform static gel strength tests in accordance with API specifications. The consistometer slurry cup assembly uses a rotating paddle and a stationary cylindrical slurry cup assembly / pressure vessel. Pressure is applied to the vessel using mineral oil and an air driven hydraulic pump. A 1500-watt heater surrounding the slurry cup outside the pressure vessel supplies heat to the pressure chamber. A sidewall thermocouple is provided for determining the temperature of the cement slurry.

The slurry cup paddle is rotated through the use of an electric motor and a magnetic drive unit. The rotational speed of the slurry cup is set to the API prescribed speed of 150 rpm. Variable speed option is available for testing at RPM's from .0005 to 250.

The consistency of the cement slurry is measured through a servo motor which monitors the torque applied to the paddle in maintaining a constant rpm. The rotational force is proportional to the consistency of the cement slurry and is measured through the servo drive and customized software. The consistency is indicated and displayed on a plot generated by the data acquisition system (DAQ). The consistency values are recorded in Bearden Units of consistency (Bc).

Fann pressurized consistometers are equipped with a state-of-the-art temperature controller and data acquisition system that provides unparalleled ease of use for the operator. The parameters of interest may be displayed in either English or SI units. Temperature control and data acquisition are programmed through the use of a touch screen monitor. A separate PC and keyboard/mouse are not required but can be attached for added functionality. The plots may also be downloaded to a USB flash drive or network folder for transfer to a separate computer.

The equation for consistency as a function of torque (g-cm) is Bc = .05 x T - 3.91. So at a torque value of zero it's at least theoretically possible for the Bc be negative. In reality, the torque can never be zero. Even if there is air in the slurry cup there will be some drag on the paddle from friction, etc. When instruments only had voltmeters in the past, there was no way to ever make the Bc negative since the voltage was never negative. Now that computers have data scaling, they can be calibrated to indicate almost anything. The API consistency equation clearly states that consistency could start negative on ultra-thin slurries.

1.2 Model 415SGS

Model 415SGS combines thickening time and static gel strength testing into one compact, easy to use, simple to maintain unit. Model 415SGS represents the easiest to operate and most reliable static gel strength tester in the industry. This additional gel static gel strength determination software package is designed to perform static gel strength tests in accordance with API specifications.

The static gel strength of cement slurry is measured using a standard paddle and with the same configuration as a thickening time test. This makes transitioning from thickening time to static gel strength testing instantaneous, simulating real-world downhole conditions. The paddle is held in a virtually stationary position allowing for extremely precise direct measurement of static gel strength development in real time.

Model 415SGS represents the new standard for static gel strength measurement and is backed by over 20 years of proven research and results. The portable combination of API thickening time tester and static gel strength determination make his an economical and powerful tool for any laboratory.

Critical static gel strength (CSGS) is the specific static gel strength of a cement in which hydrostatic-pressure equilibrium is reached between the decayed hydrostatic pressure transmission of the cement column (and other fluids in the annulus) and the pore pressure of the formation. CSGS is measured in pascals or newtons per square meter (pounds force per 100 square feet).

Critical static gel strength period is the time interval required for the cement to progress from the CSGS to a static gel strength of 250 Pa (500 lbf/100 ft^2). Static gel strength (SGS) is the shear strength (stress) measurement derived from force required to initiate flow of a fluid. Also measured in pascals or newtons per square meter (pounds force per 100 square feet).

The apparatus contains a pressure chamber that can be heated and pressurized according to a simulated cement job schedule. The SGS is calculated from the torque required to rotate a paddle of known geometry at very low speed. The rotation speed of the paddle during the SGS measurement portion of the test is normally a continuous

0.0000092 r/s (0.2°/min). The initial stirring to simulate placement in the well is typically conducted at 2.5 r/s ± 0.25 r/s (150 r/min ± 15 r/min). The permissible range of rotational speed for the apparatus is 0.0000069 r/s to 0.0000231 r/s.

1.3 Document Conventions

The following icons are used as necessary in this instruction manual.

NOTE. Notes emphasize additional information that may be useful to the reader.

CAUTION. Describes a situation or practice that requires operator awareness or action in order to avoid undesirable consequences.

MANDATORY ACTION. Gives directions that, if not observed, could result in loss of data or in damage to equipment.

WARNING! Describes an unsafe condition or practice that if not corrected, could result in personal injury or threat to health.

ELECTRICITY WARNING! Alerts the operator that there is risk of electric shock.

HOT SURFACE! Alerts the operator that there is a hot surface and that there is risk of getting burned if the surface is touched.

EXPLOSION RISK! Alerts the operator that there is risk of explosion.

2 Safety

Safe laboratory practices and procedures should be observed while operating and maintaining the Model 422 & 422CC. Follow the instructions provided to avoid personal injuries or damage to the equipment.

Always wear appropriate personal protective equipment (PPE) when operating or maintaining the Consistometer.

2.1 Safe Pressurization

This Consistometer has pressurized air, water, and hydraulic lines that present a hazard if not depressurized before maintenance or disassembly.

The hydraulic diaphragm pump and the pressure relief valve require compressed air. Before working on any of these devices or connected air lines, shut off the compressed air supply to the machine, and carefully relieve air pressure from the machine.

2.2 Safe Heating

Before opening the pressure chamber, use the cooling system to lower the temperature to at least 120°F (49°C). The machine uses domestic water as coolant. Shut off the domestic water supply before servicing.

NEVER operate the heater on an empty chamber. The heater element will quickly overheat and fail. To prevent smoke and possible fire, always fill the chamber and pressurize before heating.

2.3 Safe Electrical Operation

Disconnect the power cable before attempting any electrical or mechanical maintenance. Be aware that after the power switch is turned off, the electrical terminals inside the panel will remain electrically energized.

Refer to the electrical schematic before performing any maintenance or troubleshooting.

Always disconnect the power cable before attempting any repair.

3 Specifications

Table 3-1 415C & 415SGS Specifications

Category	Specification
Electrical	
Input Voltage	230 VAC (+10%)
Current	10A
Input Frequency	50-60Hz
Mechanical	
Height	15 in. (38 cm)
Width (single)	26 in. (67 cm)
Depth	15 in. (38 cm)
Weight (single)	150 lb. (68 kg)
Environmental	
Operating Temperature	(32º to 105º F) 0-40º C
Operating Humidity	0-95% noncondensing
Heater	
Heater Power	1500W
Utilities – Water and Air	
Compressed Air	80 - 150 psig (5.4 – 10.2 bar); Must be water separated and filtered.
Cooling Water Pressure	100 psig (6.8 bar) maximum; Must be filtered and sediment free.
Utility Inlets	¼ inch MNPT (1): max 120psi, dry

4 Installation

Upon uncrating the instrument, verify that the instrument and any spare parts on the packing list have been received and are undamaged.

4.1 Air and Water Cooling Connections

Once the instrument has been moved to its desired location, air, water, and electrical connections can be made. The air inlet, coolant inlet and drain connections are each ¼ inch female NPT connections and are located at the rear of the instrument. ¼ inch compression tube fittings and 5/8" hose barb fittings and associated tubing are included for your convenience. You may select either depending on your preference.

Connect the coolant to the connector labeled Coolant Supply on the rear panel of the instrument. The water or coolant must be clean and free of debris, sediment, minerals, etc. that could cause major scaling, blockage, premature wear, or malfunction. Use of a heavy-duty water filter is required. Do not use a corrosive coolant mixture or any liquid that could damage copper, stainless steel, plastic or Teflon.

4.1.1 Connecting the Drain Line

Connect the drain line to the connector labeled Coolant Drain on the rear panel of the instrument. The drain system must be capable of handling hot water up to 212 ºF (100 ºC) or brief surges of up to 400 º F (204 º C) steam for short periods of time during initial cooling of the instrument. If two or more RP Consistometers are connected to a common drain line, it is recommended that the drain be 3/8 inch (10mm) inside diameter, minimum. It is also recommended that the drain system be all metal.

Connect the air supply to the connector labeled AIR on the rear panel of the instrument. The air is required to be dry and free from dirt and oil. The air should be supplied at a pressure of 80-150 psig (5.4 – 10.2 bar). The compressed air supply is required to be free from moisture and contamination of any kind. A heavy-duty filter is required to prevent premature wear, scaling, blockage or malfunction.

4.2 Electrical Connections and Control Box

Electrical connections are made using the receptacle on the rear of the instrument. A power cord is supplied with the instrument. Please observe the following precautions when making the wiring connections.

Wiring should be done by a qualified installer in accordance with local electrical codes.

The instrument should be securely connected to a separate earth ground. The ground wire must be larger in diameter than the supply conductors.

An 8BC or larger fire extinguisher to fight electrical and oil fires should be placed within 50 feet of the consistometer.

Some components such as touch screen LCD monitors may be removed from the instrument prior to shipment and shipped in a separate container to prevent damage. This device must be reinstalled before operating the instrument. The cables on the touch screen monitor must be plugged into the correct location on the supplied control box. These connections include a 15-pin SVGA cable, USB, and AC (120-240VAC) power. The touchscreen power should be powered by the instrument and not into a separate power source prevent electrical ground loops.

If a printer is included with the instrument, it may be connected to the rear of the control box. Connect the USB connector on the printer cable to an available USB port on the control box. The printer must also be connected to a suitable power source. A USB flash drive may also be connected to the instrument in lieu of a printer. Test data may be downloaded to the USB drive and then transferred to a PC for archival storage.

The control box must be properly wired to the instrument for operation.

Connect the 5-pin round power plug into the outlet labeled COMPUTER on the back of the instrument. In addition, a USB type-A to Type-B cord must be connected from the back of the control box to the back of the instrument, also labeled COMPUTER.

An uninterruptable power supply (UPS) is recommended for any areas experiencing poor power conditions. If you are installing a UPS, connect the output of the UPS to the outlet labeled UPS on your instrument. If not, you MUST CONNECT A POWER JUMPER (included). This jumper cable will connect the two outlets on the back of the machine labeled UPS. Make sure to fully seat the jumper cable.

4.3 Pressure Vessel Installation

The pressure vessel is shipped separately from the instrument; locate the pressure vessel assembly and the motor/drive assembly. The pressure vessel is installed into the heater block by carefully sliding it in from the top. A thermocouple is contained inside the instrument.

The thermocouple must be inserted into the bottom sidewall of the pressure vessel anytime the vessel is inserted into the instrument.

Installation of the thermocouple may be easiest if the thermocouple is pulled through the heater block and inserted before the pressure vessel is dropped into the instrument.

5 Hydraulic, Pneumatic, Cooling and Electronic Controls

5.1 Hydraulic Pressure Controls

This section consists of the pressure gauge and the pressure release valve. Components that make up this section are used to control the flow of oil used to pressurize the cylinder and to display the cylinder pressure. The pressure gauge is used to display the pressure inside the pressure vessel.

The pressure release valve is used to release pressure from the pressurized cylinder and discharges waste oil into a small plastic reservoir cup. The pressure release valve must also be fully opened to release pressure from the cylinder but should always be opened as slowly as possible the prevent cement spillage into oil lines. The part number for the pressure release valve is C-1302. This valve should remain closed while testing and should be opened following the test procedure to vent pressure from the slurry vessel.

Use caution when opening this valve when the slurry is still very hot (>150ºF).

Opening the valve will cause oil and possibly cement to vent from the pressure vessel into a supplied plastic container on the back of the instrument. If the test pressure is exceedingly high, then slowly open the valve to release pressure to a more suitable level taking caution not to remove all pressure especially at high temperatures.

5.2 Pneumatic Controls

The pneumatic section consists of the air pressure REGULATOR and the PUMP switch. The components in this section are used to power the air driven hydraulic pump that applies pressure to the sample.

The air pressure REGULATOR is used to control the air pressure to the air driven hydraulic pump. To adjust the pressure of the air supplied to the pump, pull the knob on the regulator out to unlock it. Turn the regulator knob clockwise to increase the pressure and counterclockwise to decrease the pressure. When the adjustment is finished, push the knob in to lock it in place if desired.

The REGULATOR pressure should not exceed 100psi and may not power the pump below 25psi.

The PUMP switch is used to turn the pump on and off. The user must take care not to over-pressure the vessel or apply pressure without properly bleeding air from the slurry.

5.3 Electronic Controls and Displays

The switch labeled POWER controls electrical power to the entire instrument. Nothing else is operable if this switch is not on including the touchscreen software.

The touch screen is used to control temperature and motor speed, display a plot of consistency and temperature as a function of elapsed time, and perform various operations.

A thermocouple is plugged into the THERMOCOUPLE connector located on the middle wall inside the instrument. This connector may be used for calibration or thermocouple replacement.

Always ensure the thermocouple is properly seated into the pressure vessel before beginning a test.

6 Using the Touchscreen Software

6.1 What is a touch screen and how does it work?

Touch screens were created to provide users with an easy to use interface. This allows the user to input and view data without a keyboard or mouse. The touch surface is able to detect contact and send position information back to the processor. Using the touch screen has the same result of using a mouse to point and click. One mouse click is accomplished by one touch of the screen. A double-click is achieved with two quick touches. With this standard method of input, no special software is required to utilize the screen.

6.2 Using the Touch Screen

A finger or stylus is most often used on the touch-screen. Experimentation will quickly show which objects will activate the screen and which will not. It is important to note the touch surface does NOT use pressure to detect input. A light touch is all that is needed. In addition sharp instruments (such as pencils, pens, screwdrivers, etc.) should not be used as they may damage the touch surface. A pen-like touch stylus has been included in your accessories to use if desired.

6.3 What can you do with the touch screen software?

The purpose of the touch screen is to provide the user with a single interface to the instrument. All instrument operations are accessed and controlled through the touch screen. This consistometer is a leap forward in design because it is the first time that mechanical control has been eliminated from the point of view of the operating technician. Filling and draining the pressure vessel with oil, heating and cooling, pressurizing and depressurizing, and rotational speed are all fully automated. Our unique testing and test data screens offer detailed control over test parameters and the way your plot looks including color designations and job properties. Alternately, test data can be exported raw and utilized however one wishes. Each instrument is complete and requires no additional software or hardware to function.

6.4 One Key Recovery for the Computer

Instruments manufactured after March 2014 have computer systems which have One Key Recovery factory restoration points. What this means is that if the computer has a severe virus attack, operating system crash, hard disk failure or corrupted programs and software then the user may take simple steps to restore the system to its original factory condition. Simply pressing F3 during the 10 second boot sequence brings up access to the recovery menu. Select option 1 for a factory restore. Original application programs and configurations will be restored. Alternately, a newer backup point can be created. For example if you have updated the CementLab software to a newer version, performed new calibrations, and have

installed any new programs then a new backup point would restore these. Option 2 creates a new backup.

6.5 Software Upgrades

From time to time, Fann makes software upgrades available that provide increased functionality or problem fixes. Generally, the only file that needs to be upgraded is CementLab.exe. It is located in the C:\Program Files\Fann folder. If it is necessary to install an updated CementLab.exe file, it may be copied from the USB memory stick. It may also be copied over a network if the instrument is connected to one. To copy the file from a memory stick, put the new file on the memory stick, rename the old CementLab.exe file to "Old.exe" and copy the new file into the proper folder using Windows Explorer, which is accessible from the start menu or My Computer icon. The memory stick will generally be the D: drive. Should the new CementLab.exe program not work properly, simply delete it and restore Old.exe to the original. However, we recommend you only upgrade your system with the expressed permission of a Fann engineer.

6.6 Using the USB Port and the Printer

The instrument is equipped with a Universal Serial Bus (USB) port on the front panel that allows the use of a USB memory stick for mobile storage. The memory stick is a flash disk that can be connected to the USB port on the instrument control box and used as an external hard drive. Simply insert the memory stick into the USB port and the memory stick will become the D: drive. Software upgrades may be installed using the memory stick and tests may be archived to the memory stick and transferred to a PC for permanent storage. A color inkjet printer is pre-installed at the factory and is shipped with a new instrument. The printer is a useful tool for providing immediate printed results directly from the instrument. A 115/230V power adapter and a USB data cable are provided to connect the printer. The printer power adapter must be connected to the back of the instrument to prevent instrument malfunction. See Installation section in section 4. The printers use 8.5x11" paper.

6.7 The Main Menu

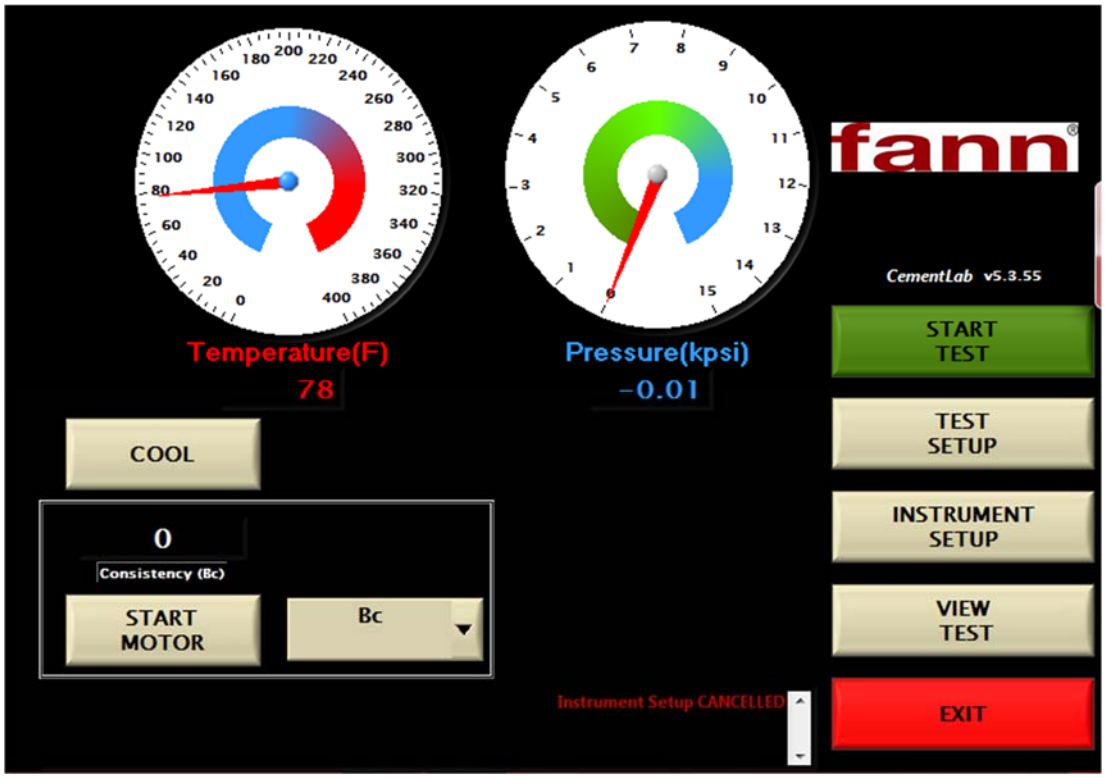

Figure 6-1 Software Screenshot

The main menu is the starting point for controlling the instrument. From here users may start new tests, setup test parameters, setup instrument parameters, or view an old test. Also located on the main menu is the reading for current temperature, consistency, and pressure. On the right side of the screen you will also notice the version software that is currently installed on your instrument.

The cooling button is located on the main screen and is operated by selecting it to turn it on. Select again to turn off. The cooling button is connected to a solenoid valve which is connected to the cooling input located on the back of the instrument. Typically, water is used at house pressure and temperature. However, you may also connect a circulating chiller. If cooling is turned on when start test is activated, the cooling will remain on and heating will not ensue. Turn cooling off if you wish to start a normal test.

The motor switch is located on the main screen and is operated by selecting it to turn it on. Select again to turn off. The motor speed is set to turn at 150 rpm.

6.8 Instrument Setup

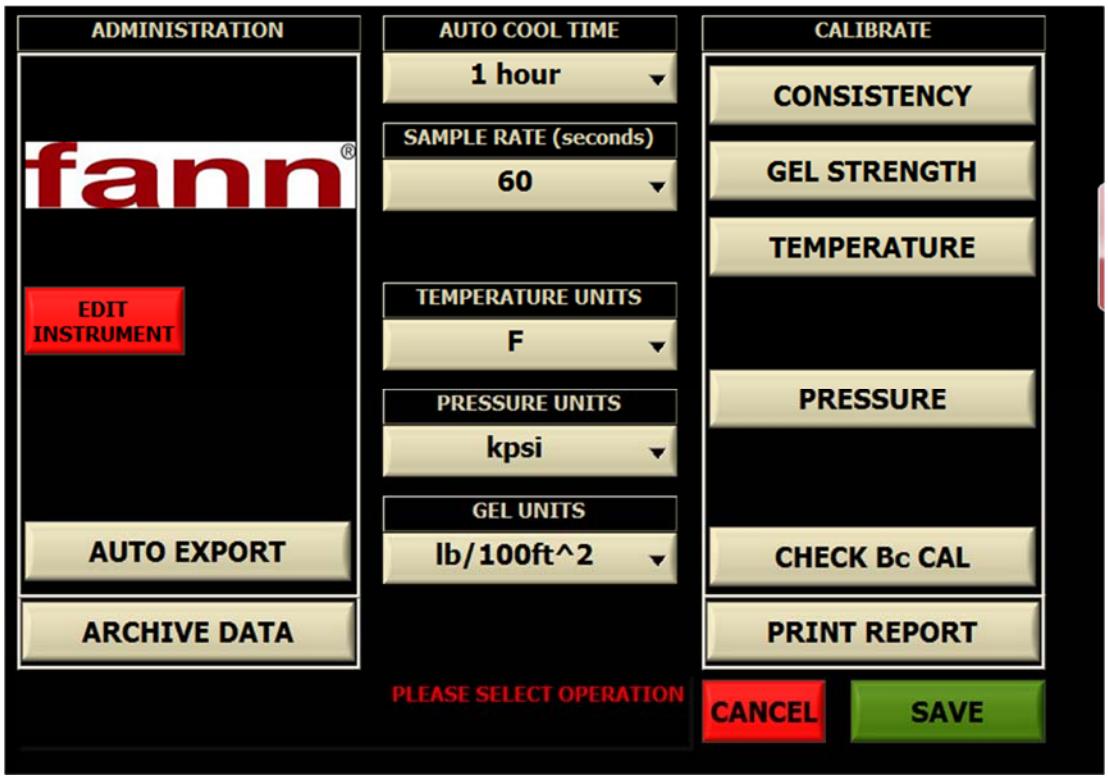

Figure 6-2 Software Screenshot

The instrument setup button takes the user to the instrument setup screen shown. From this screen the user may perform a variety of operations and change options.

6.8.1 Calibrating Temperature

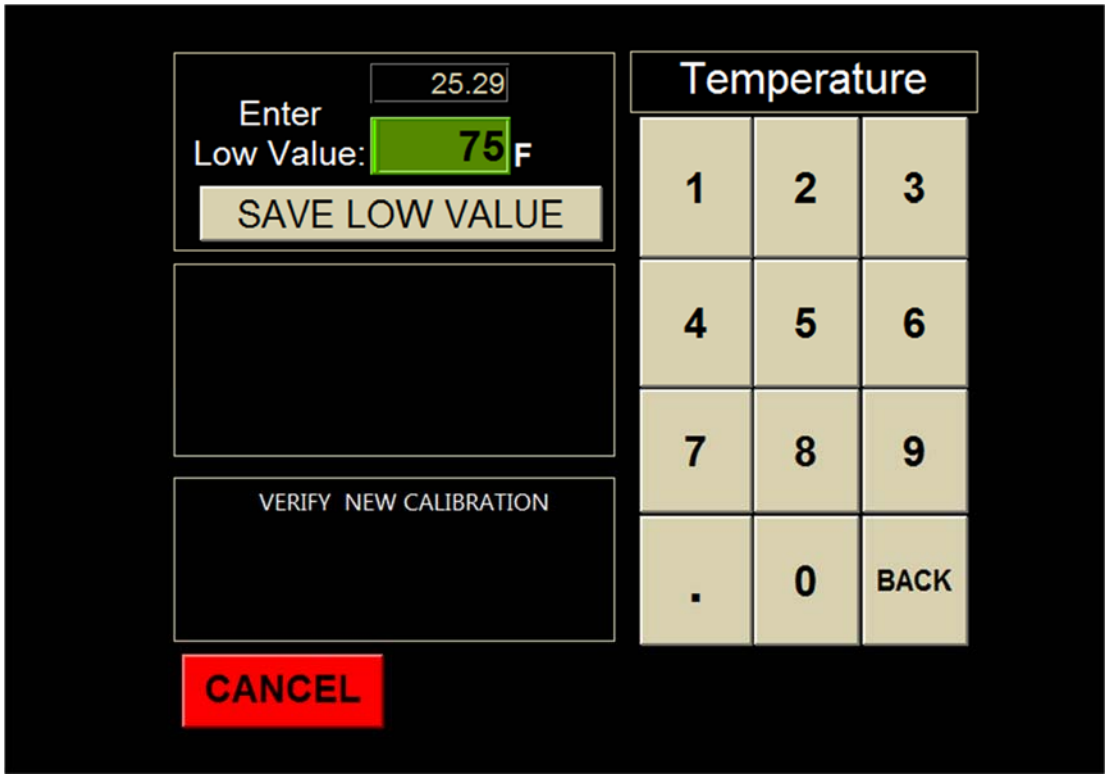

Figure 6-3 Software Screenshot

Temperature calibration must be performed by a qualified individual that has a certified temperature calibration device. When the screen in above appears, connect a J type temperature calibrator to the thermocouple connector input on the instrument. Enter a lower-limit temperature value on the calibrator. Touch the Enter Low Value parameter box shown above and then enter the correct temperature value for the low data point using the touchpad at the right. The raw value is the voltage signal read directly from the I/O hardware and it should change as the calibration signal changes. When the low data point has been entered, press the SAVE LOW VALUE button. The user can now enter the high data point on the calibrator and then again on the touchscreen as before. The raw value should be different for the low and high data points or there will be a computation error. After the high data point has been established, press the SAVE HIGH VALUE button. We recommend using a low value of room temperature and a high value of 400F or near maximum operating temperature. The user can now vary the calibration signal and see how the calibrated signal compares with that of the calibration device in the VERIFY NEW CALIBRATION box. If the signals compare favorably, press the SAVE button to save the calibration. The calibration values will be stored in a configuration file and take effect upon saving and exiting the Instrument Setup menu.

6.8.2 Calibrating Pressure

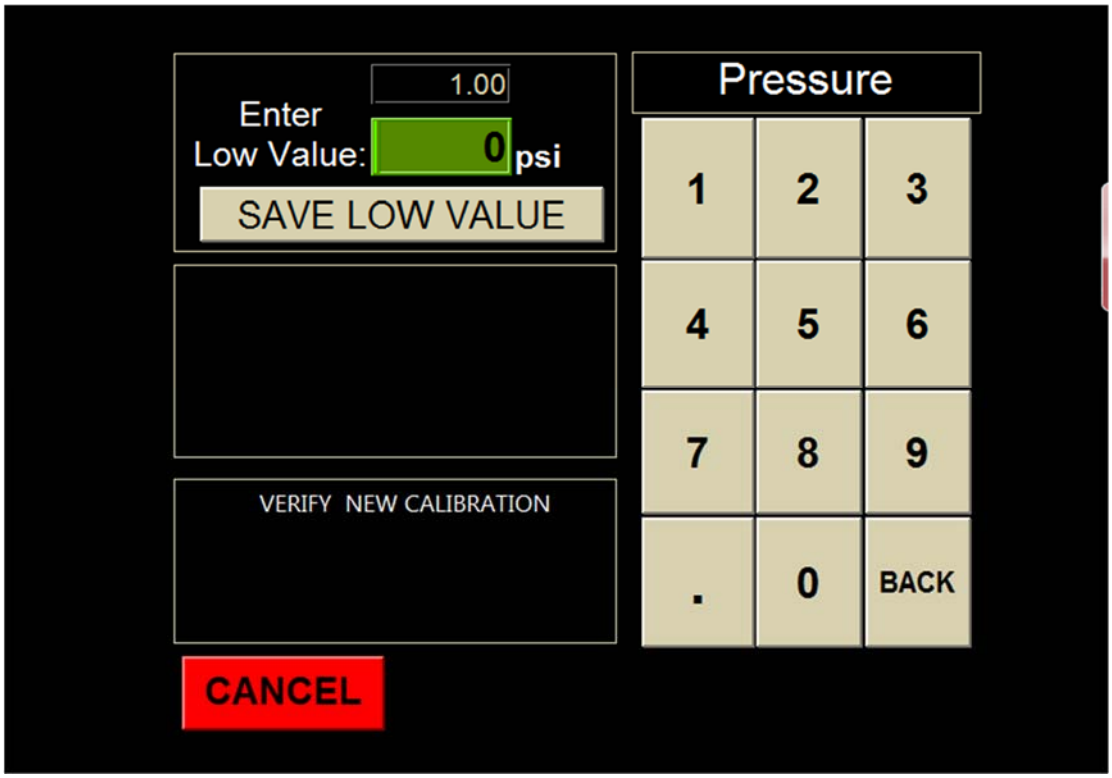

Figure 6-4 Software Screenshot

Pressure calibration must be performed by a qualified individual that has a certified pressure calibration device. When the screen above appears, connect the pressure calibrator to the top of the pressure vessel using a 9/16-18 high pressure nut. Enter a lower-limit pressure value on the calibrator. Touch the Enter Low Value parameter box shown in and then enter the correct pressure value for the low data point using the touchpad at the right. The raw value is the voltage signal read directly from the I/O hardware and it should change as the calibration signal changes. When the low data point has been entered, press the SAVE LOW VALUE button. The user can now enter the high data point on the calibrator and then again on the touchscreen as before. The raw value should be different for the low and high data points or there will be a computation error. After the high data point has been established, press the SAVE HIGH VALUE button. We recommend using a low value of house air pressure and a high value of 20,000psi or near maximum operating pressure. The user can now vary the calibration signal and see how the calibrated signal compares with that of the calibration device in the VERIFY NEW CALIBRATION box. If the signals compare favorably, press the SAVE button to save the calibration. The calibration values will be stored in a configuration file and take effect upon saving and exiting the Instrument Setup menu.

6.8.3 Calibrating Consistency

The consistency should be calibrated by using the consistency calibrator assembly. The assembly includes the calibrator base mounted to the top of the cabinet and calibrator arm.

1. Ensure that the inner magnet housing is oil-filled.
2. Assemble the unit dry, complete with paddle, and place in cast heater.
3. Mount calibration arm into calibration base.
4. On the screen, select Instrument Setup – Calibrate Bc.
5. Attach the wire to the outer magnet assembly.
6. Run wire over pulley.
7. Attach the 50g hook weight.
8. Add additional 50g (for total of 100g) to the hook weight.
9. Start the motor. On the touchscreen in the box labeled LOW DATA POINT input 9 on the touchpad. Select SAVE LOW VALUE. Turn motor off.

Do not allow cord to become jammed in motor.

10. Add an additional 500g (for a total of 600g) to the load.
11. Start the motor. On the touchscreen inside the box labeled HIGH DATA POINT input 72 on the touchpad. Select SAVE HIGH VALUE. Turn motor off.
12. Apply 350g (for a total of 400g) and start the motor. Ensure that the CALIBRATED VALUE is reading 47 ±5 Bc and press SAVE. Cancel and repeat if necessary.
13. To check linearity, use the table below for weight vs. torque and check various points. If readings do not match ±5 Bc, repeat the calibration.

14.

Table 6-1 Consistency as a function of Weight vs. Torque*

TORQUE (g/cm)	WEIGHT (g)	CONSISTENCY (Bc)
0	0	-4
128	50	2.5
258	100	9
378	150	15
509	200	21.5
759	300	34
1019	400	47
1279	500	60
1520	600	72
1780	700	85
2040	800	98
2080	820	100

* Based on the equation from API Specification 10A and Recommended Practice RP10B-2

$T = 78.2 + 20.02 \times Bc$

Where:
T = Torque, expressed in gram centimeters (g cm)
Bc = slurry consistency, expressed in Bearden units

6.8.4 Gel Strength Calibration Procedure

The gel strength meter, which indicates static gel strength development, should be calibrated by using the consistency mechanism calibrator. This device applies a known torque to the motor mechanism, allowing the Static Gel Strength equivalent to be resolved on the PC. Calibration of the gel strength is described in the example below. CementLab automatically adjusts motor for proper calibration.

1. Ensure that the inner magnet housing is oil-filled and any entrained air purged.
2. Assemble the unit dry, complete with paddle, and place in cast heater.
3. Mount pulley arm on instrument.
4. On the screen, select Instrument Setup – Calibrate GEL.
5. Attach the wire to the outer magnet assembly.

6. Run wire over pulley.

7. Attach the 50g hook weight. Add additional 50g (for total of 100g) to the hook weight.

8. Start the motor. Motor will make 1 turn at low speed to initialize.

9. Remove hook weight. 0g should now be on the string. Wait 10 minutes to allow for motor warm-up. Do not stop motor during GEL calibration.

10. On the touchscreen in the box labeled LOW DATA POINT input 0 on the touchpad. Wait a moment for stabilization and select SAVE LOW VALUE.

11. Carefully replace the hanger and 550g weights for total of 600g. Steady the load on string; make sure there is not excessive movement. Wait 10 minutes to allow the motor to warm up.

12. On the touchscreen inside the box labeled HIGH DATA POINT input 600 on the touchpad. Wait a moment for stabilization and select SAVE HIGH VALUE.

13. On the bottom of the screen, ensure that the CALIBRATED VALUE is reading 600g ±25 and press SAVE.

14. Remove the weight and the string, calibration is finished.

Hysteresis is introduced when the torque is suddenly changed by a large amount. Use care when removing/adding weight to system. If calibration result is unsatisfactory, repeat with care and allow motor to warm-up for a longer period. This warm-up time is necessary as the motor has not been running. During a test, the motor runs to simulate placement before the gel strength measurement is made. This is similar.

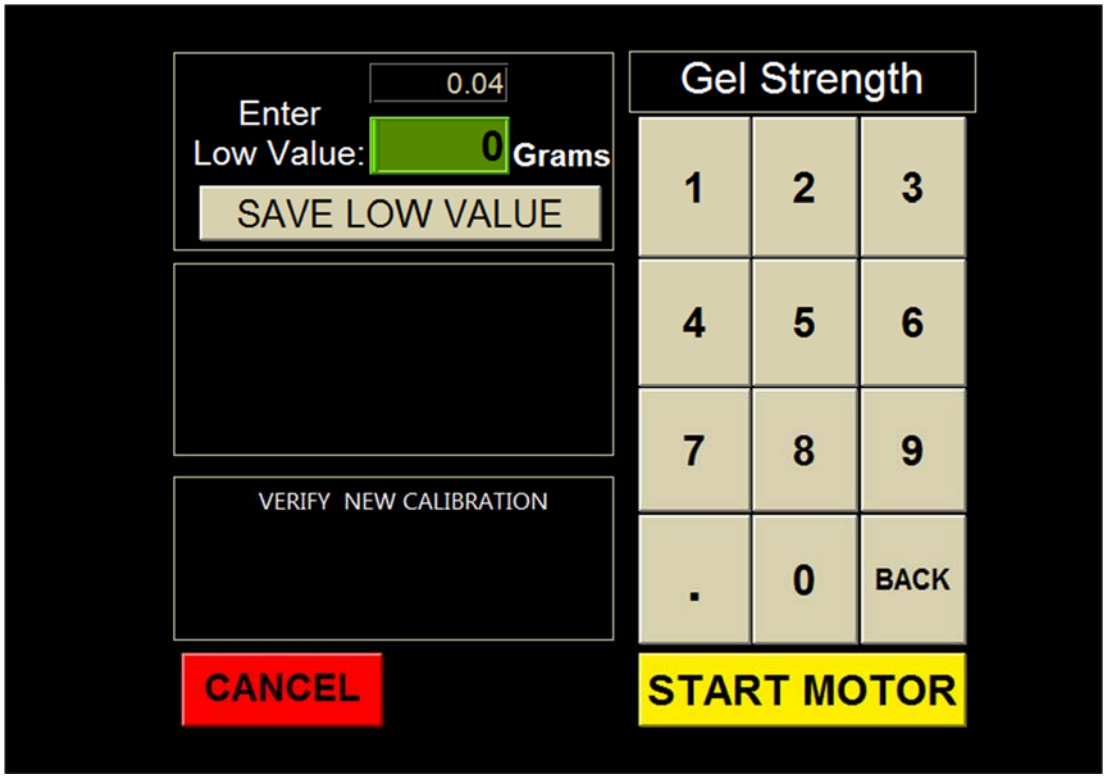

Figure 6-5 Software Screenshot

6.8.5 Print Report

A copy of the calibration time and date for temperature, pressure, and consistency may be exported to an attached printer or saved as a jpg file. An example is shown below.

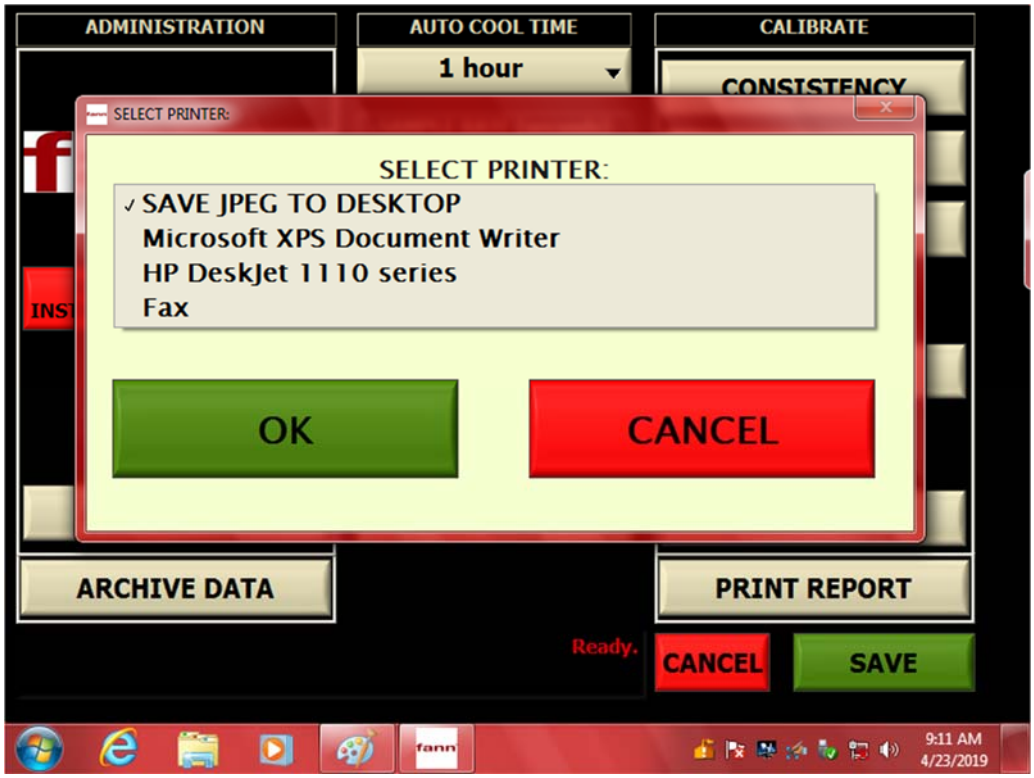

Figure 6-6 Software Screenshot

6.8.6 Auto Cool Time

After a test is completed and auto cooling has been selected in the test screen (see Start Test section), the cooling valve automatically opens and begins to cool the cylinder and oil reservoir. It is possible to select how long a period of cooling is active. Selections include between 1-24 hours and always on. If a test is started while cooling is still activated, the test will not heat even if it is programmed to heat. In other words, cooling must be deactivated if a test is to be started, even if it is still in automatic mode.

6.8.7 Sample Rate

This button allows the user to select a sampling rate for taking data. Rate is given in number of seconds between samples. To save data space and achieve acceptable test resolution, a sample rate of 30 or 60 seconds is recommended. For increased resolution lower the sample rate.

6.8.8 Temperature and Pressure Units

These buttons allow the user to select English or SI.

6.8.9 Archive Data

This button allows the user to transfer copies of all the test files stored in the consistometer to another location. The tests may be saved to the USB memory stick or to a local/network folder. Note that the program will ask for the storage location and the user may browse to any available drive or folder as shown. Selecting 'current folder' accomplishes the destination selection. Once the files are copied from the consistometer to another location, the files remain on the consistometer and will still be accessible from the instrument. To permanently delete these files, the user must go to their stored location and delete them manually. The default location for Fann test files is C:/Fann/Tests. This folder also stores the actual test parameters so any test deleted cannot be run again without reprogramming TEST SETUP.

6.8.10 Auto Export

This button allows users to store test files in a completely different folder automatically. If YES is selected, the user is prompted to select a destination folder to store test files. If NO is selected, test files are stored in their default Tests folder location. If yes is selected and tests are being stored in another location, no copies are kept anywhere else. If the user desires to change back to default, they must select NO as shown.

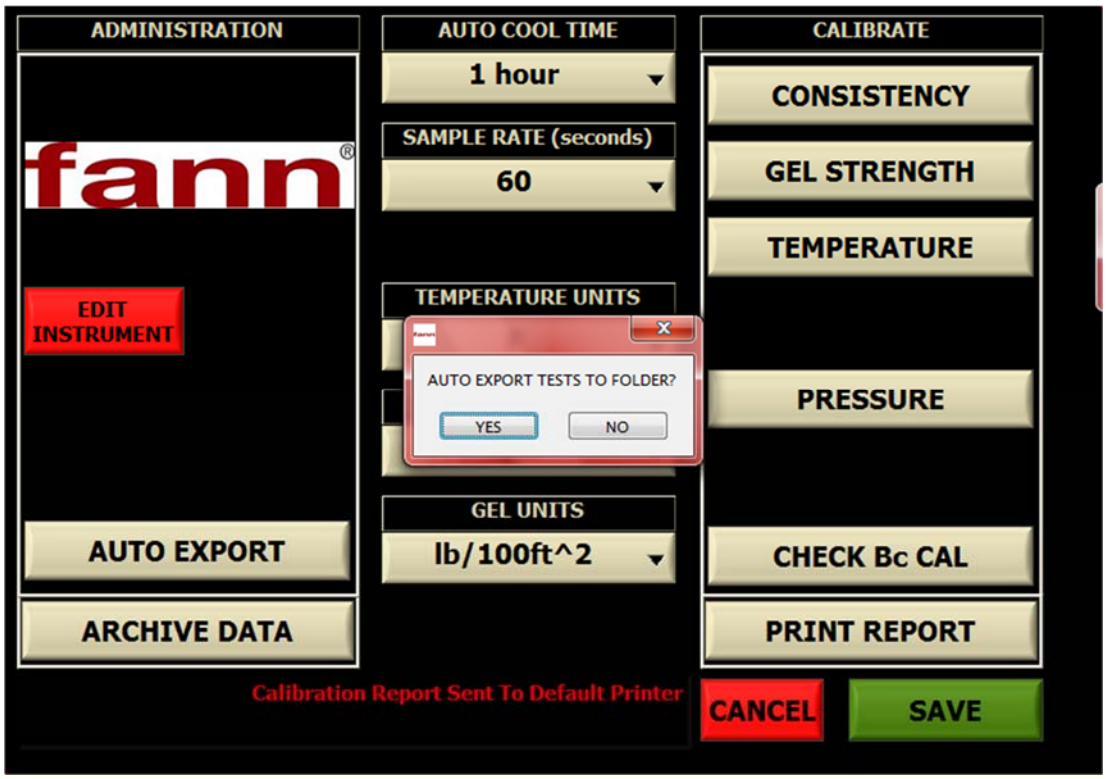

Figure 6-7 Software Screenshot

6.8.11 Edit Instrument

This button should only be used when instructed by Fann and is password protected. This application performs changes to the config.ini file.

6.9 Test Setup

From this menu the user can enter or reset a temperature and pressure ramp and soak schedule. The user can also configure the hesitation squeeze schedule, input sample properties, input time or consistency alarms, and input customer data.

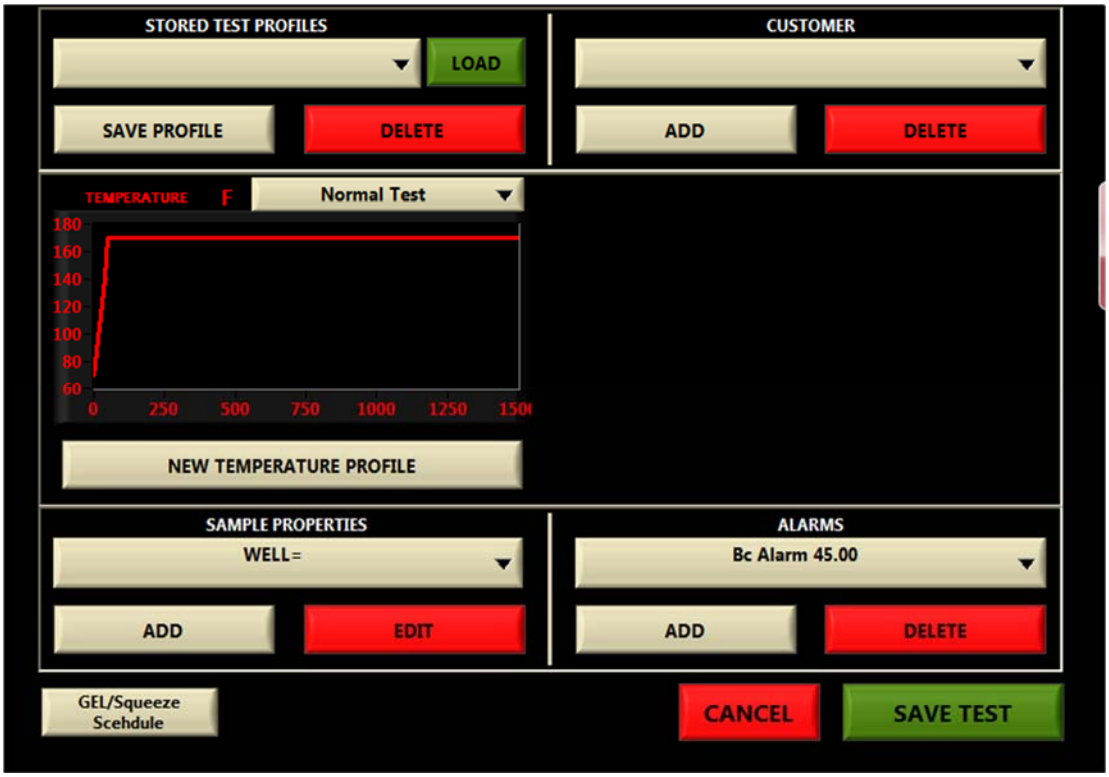

Figure 6-8 Software Screenshot

6.9.1 Temperature Control

Temperature is automatically controlled by programing a temperature ramp into the software. To create a new temperature profile either select that button or just above select the graph with the red temperature line. The program temperature screen is shown below. Enter desired set point values by touching the SET POINT parameter box and entering the values on the keypad. Time to set point is selected by touching the TIME parameter box and entering a time in minutes on the touch pad. The final segment should always be a SOAK segment where the temperature equals the final test temperature and the time equals SOAK. This guarantees the instrument will maintain final temperature for the remainder of a test. After a profile has been

entered, press the SAVE button. At this point a graph of the desired temperature ramp is displayed for confirmation. Press: ACCEPT to save ramp or CANCEL to exit without saving as shown.

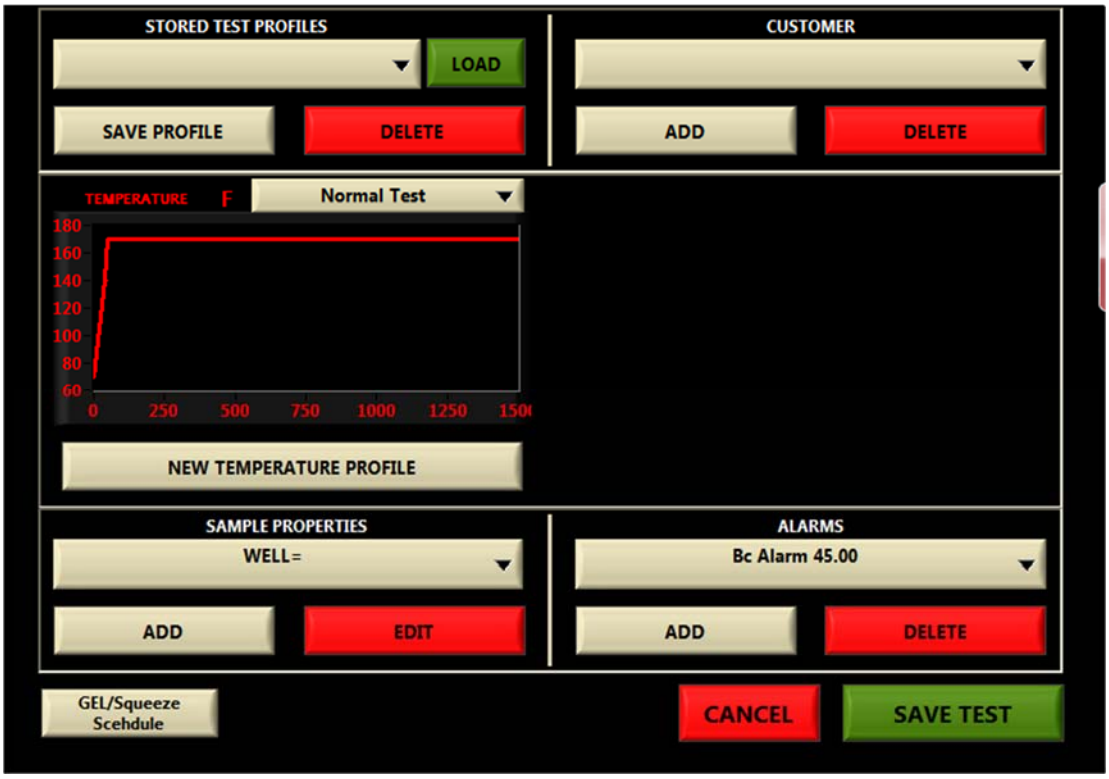

Figure 6-9 Software Screenshot

6.9.2 GEL/Hesitation Squeeze

On units equipped with the gel strength and hesitation squeeze options those are accessed using the button labeled GEL/Hesitation Squeeze. Pressing this button will bring up the screen shown.

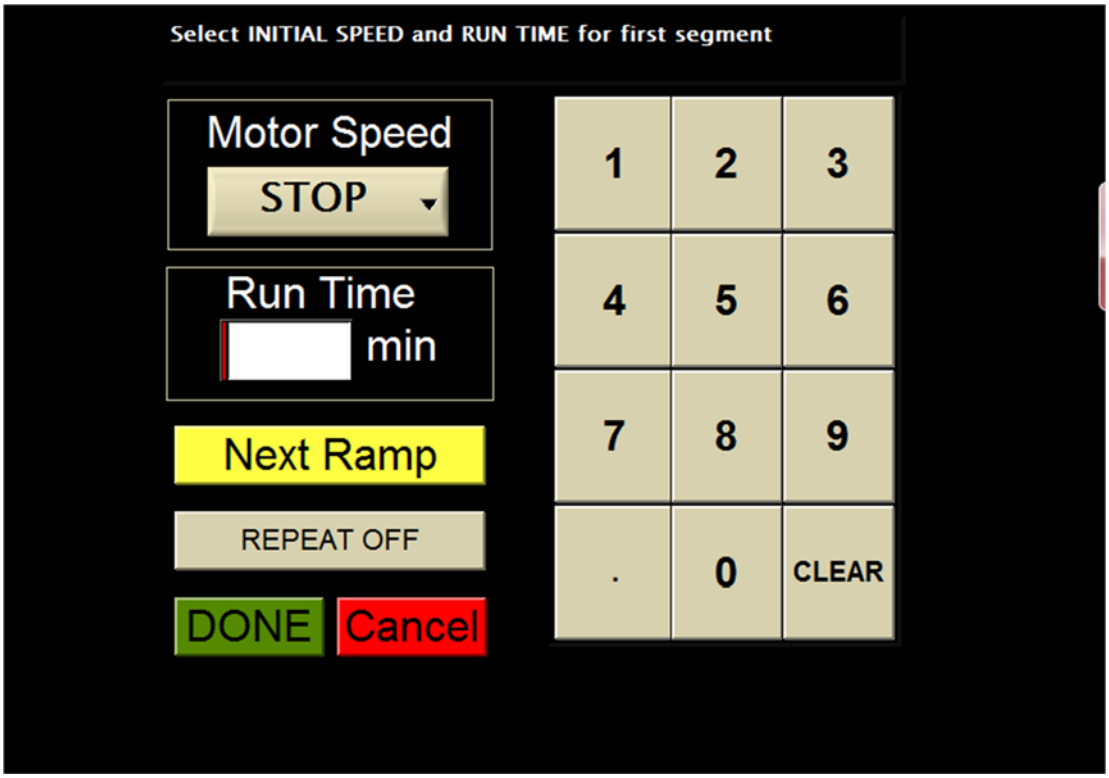

Figure 6-10 Software Screenshot

This programming screen allows a segmented schedule to be programmed using selected timing intervals and motor configurations.

Select Motor Speed = Bc to run the instrument in normal consistency mode at 150 rpm. Select Motor Speed = GEL to run the instrument in gel strength testing mode. Select Motor Speed = STOP for replicating a hesitation stoppage. Select the empty box under Run Time and enter the number of minutes using the touch pad on the right. The repeat button is used to repeat the segments that have been programmed for 999 minutes. At least two segments must be programmed to function correctly. A preview of the schedule will be shown for approval as shown. Here the first segment was started in Bc mode for 45 minutes, then STOP mode for 20 minutes and then GEL mode for the remainder of the time which is typically programmed as 999 minutes.

Typically an SGS test is programmed per API standard which is at the end of the slurry placement simulation (thickening time test, Bc mode). The rotational speed is instantaneously changed and the the circulation temperature and pressure are maintained. This instrument uses a paddle which does conform to the required API dimensions for determining thickening time. This means that during Bc mode the indicated consistency is the actual reading.

6.9.3 Sample Properties

Test printouts contain information cells which can be edited by the user. Sample properties such as well, district, cement, density, weight, water, etc. can be chosen as suitable information. An example of these sample properties is shown. Properties can be added and deleted here. The value for these properties will be selected after a test is complete. Select view test and select the test file to be chosen. Then select the PRINTING tab on the left hand side and sample properties can be seen and values edited accordingly.

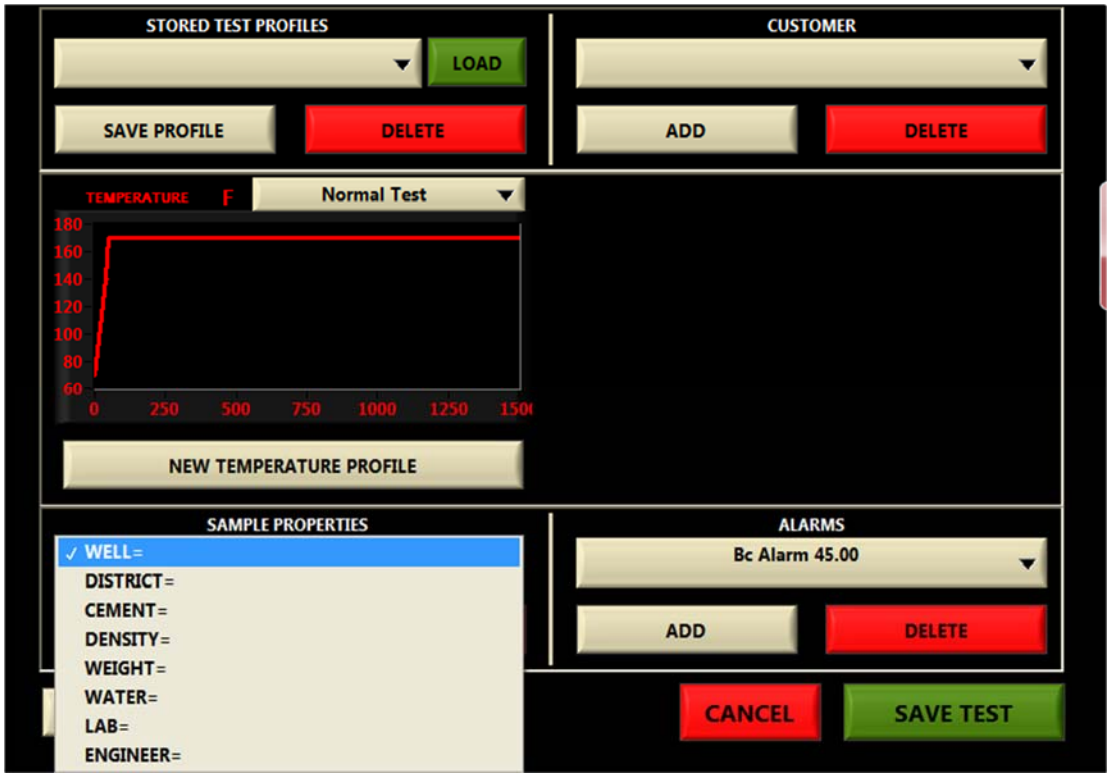

Figure 6-11 Software Screenshot

6.9.4 Alarms

Consistency and time alarms can be added to and deleted from a test setup. These alarms produce audible alerts and are displayed in the test printout. An example of programmed alarms is shown. Factory defaults may contain Bc alarms only. It is advisable to follow API and enter alarms for SGS determination and make it easier to report these values on the report. Enter alarms for 100, 200, 300, 400 and 500 lbf/100 ft^2.

Figure 6-12 Software Screenshot

6.9.5 Cool Test

The cool test drop down box allows the user to define whether or not you will be performing a below room temperature test. In other words, your testing temperature will need to be controlled downwards below ambient temperature. Effectively what happens is that the cooling solenoid is being opened and closed to allow more cooling fluid to flow through the heating jacket. This also stops any heater input. Below ambient tests necessitate that you connect a suitable cooling fluid properly chilled for the capacity required. Fann can provide you with a suitable chiller.

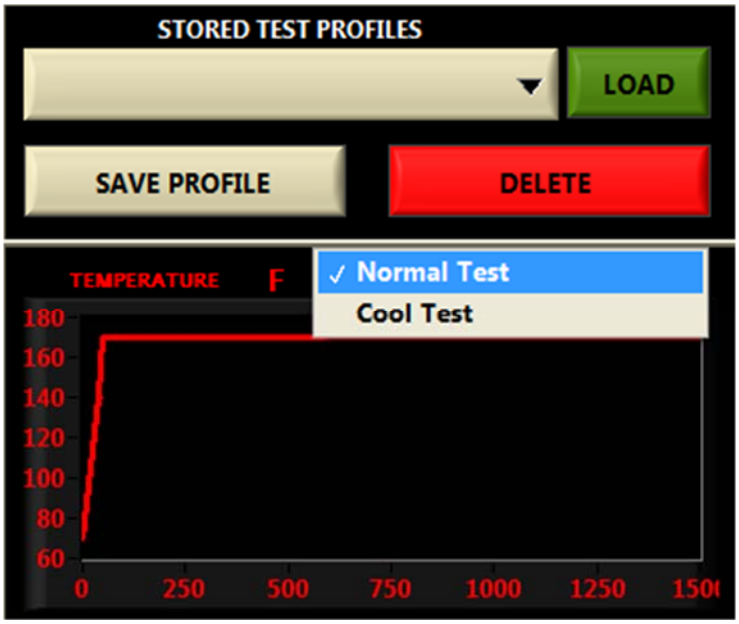

Figure 6-13 Software Screenshot

6.9.6 Customer Data

The customer button allows the user to input a customer name for the test being performed. It's no different than a sample property and can be added and deleted from the test setup.

6.9.7 Save Test

Once the user has finished selecting temperature and pressure ramp profiles the last step is to push SAVE TEST. A pop-up appears and requires the user to select a test name. This will be the test file name and will be stored in the tests folder located on the C drive. An example is shown. Choose a descriptive test name and select save. Once you have performed this action the software is ready and programmed for that specific test. The next action would be to start test. If a test setup is not performed prior to starting a test, the previous test file will continue to be written to. It is not automatic for the machine to know to start a new test file without user input.

6.10 Start Test

Once your instrument is properly configured and a test has been entered in the TEST SETUP section. You may begin testing by selecting the START TEST button from the main menu.

6.11 Live Testing Screen

Once a test has begun, a real-time display of current values will be presented. The user may view a live chart at any time by pressing the LIVE CHART tab button located at the top of the screen. Printing can be done at any time by selecting the ADVANCED CHART & PRINTING OPTIONS button (Please note that a printer must be connected to the instrument before trying to print.). This button will also enable the user to view detailed test information and streaming numerical data. The user can also create custom header and footer segments of the printed plot. Pressing the EXIT button returns the user to the RUN TIME MENU shown below.

6.11.1 Automatic Shutdown

The instrument is equipped with an automatic consistency or SGS shutdown and alarm. Use the up/down arrows to select the set point at which the alarm should occur. Pushing the Shutdown Type button allows one to select either type of alarm. If the Auto Shutdown feature is ON, the instrument will automatically stop the test when the indicated alarm value is reached. In addition to stopping the test, automatic shutdown will also turn the heater and motor off and the cooling water on. Note that the Auto Shutdown Alarm is in addition to the alarm values entered in test setup that are printed with each plot. In addition to the automatic consistency shutdown there is a timed shutdown. It is necessary to select the number of hours from the drop-down box that is required for a timed shutdown. SGS alarms greater than 600 lbf/100 ft^2 may allow the test to show the break of the SGS bond to the slurry cup causing the graph to fluctuate down to zero. The consistency alarm unit is Bc and the SGS unit is lbf/100 ft^2.

6.11.2 Stopping a Test

To stop the current test, the user must press the STOP TEST button on the RUN-TIME MENU screen. Once the test has been stopped, no further data will be logged and no further temperature or pressure control will be provided. The software will save the current test in a file on the instrument's local hard disk. The default location is C: /Fann/Tests. If auto-shutdown is enabled, the test will be stopped when the Consistency Alarm value has been reached. This action has the same effect as the user pressing the STOP TEST button; however it also turns the motor and heater off and the cooling water on. Note that there is a 5-10 second delay from the time a consistency alarm is triggered until automatic shutdown occurs. This is to prevent noise or spikes in the consistency signal from triggering automatic shutdown prematurely.

6.12 View Test

The view test button allows the user to access previously completed test data. The data may be viewed either graphically or in spread sheet format, customized,

scaled, printed, and exported. The print button will open a dialog box giving the user the option to select a printer or jpeg file option. The export button gives the user to option to output a txt file to a destination folder.

6.12.1 Graph Tab

The left y-axis displays Gel (if option is installed on the instrument), Consistency, Temperature, and Pressure. Each Curve is given a specific scale, color and units. The x-axis is given in minutes.

6.12.2 Scale Tab

The scale and plot customization tab allows the user to turn on or off the display of each curve by pressing the green “Visible?” button. The maximum and minimum scalar may also be edited using the Max and Min boxes. The color of the curve may also be edited using the Color box. These custom settings are shown.

6.12.3 Data Tab

The data tab displays the test file name and date recorded at the top of the screen. The data tab also displays all data for each sample point including time (HH:MM:SS), consistency (Bc), Gel ($lb/100ft^2$) (if option is equipped on the instrument), Temperature (units optional), and Pressure (units optional). Depending on the sample time selected the time stamp will be congruent. Data tab shown below:

6.12.4 Printing Tab

The printing tab allows the user to change specific test data that is outputted to the test print out. A company logo may be inserted into the print out header by selecting the logo box. Pixel size must be 192x96 before you insert the picture. Values for well, district, cement, density, water, etc. may be entered to further populate the test print out and further provide information to customers. Printing options are shown.

7 Operation

7.1 Running a Thickening Time Test

The steps listed below are for experienced users who are familiar with consistometer operation.

1. Close PRESSURE RELEASE valve.
2. Program test parameters using TEST SETUP.
3. Program Temperature ramp, always finish with SOAK.
4. Set/Modify alarm consistency values if needed.
5. Add/Modify additional test parameters as desired.
6. Select SAVE and enter test name.
7. Place the cleaned and fully prepared slurry cup (pressure vessel) into the instrument; insert the thermocouple into the bottom of the cup using the sidewall port.

Be certain the thermocouple is fully seated and reliably in place. Failure to verify this configuration may result in either a temperature run-away or a test error and a stop. Refer to the following section Thermocouple Retainer for those pressure vessels with threaded ports.

8. Mix the slurry and fill the slurry cup with paddle in place. Fill to approximately just above the paddle.
9. Install slurry cup plug being careful to not roll the Poly-pak™. Rotate the plug around until you feel the paddle shaft completely engage the paddle connecting rod The application of o-ring grease and/or anti-seize to the outside of the slurry cup plug and Poly-pak™ is necessary to improve installation and removal.
10. Secure the slurry cup cap onto the slurry cup.
11. Install and tighten oil lines. Loosen the small plug opposite the oil inlet to bleed air.

12. Close the pressure release valve.

13. Turn PUMP switch to ON and fill the pressure vessel with oil. Tighten the small plug when bubble free oil begins to run out the side.

14. Adjust AIR TO PUMP to adjust pump pressure as desired.

15. Loosen the small top plug located on top of the magnetic drive housing to bleed any air bubbles located in the magnetic drive system. (If the consistency reading is very high when you start the test it may be because there is entrapped air in the mag drive). Then close the plug shut.

16. Place the motor assembly onto the slurry cup plug and tighten the associated set-screws to prevent it from being dislodged or wobble.

17. Press START TEST

18. Activate AUTO SHUTDOWN and select desired shutdown value.

Be careful not to over-pressure the cylinder. As the heat increases during a test so does the pressure. Pressure is not released automatically and requires that the pressure be monitored and adjusted by a technician.

7.2 Stopping a Thickening Time Test

The steps listed below are for experienced users who are familiar with consistometer operation.

1. Press STOP TEST using the touch screen or allow AUTO SHUTDOWN to activate.

2. Activate the cooling button if not done so automatically.

3. Undo coupling tube set screws if installed and remove the motor and set it down away from any interference.

4. When the temperature has cooled below 212°F/100°C, release pressure on the cylinder and the instrument by opening the PRESSURE RELEASE valve.

5. Loosen the pressure lines at the bulkhead and head to remove the pressure release valve.

6. Remove the slurry cup lock ring and slurry cup plug (head). See following sections for more details in removing the slurry cup plug.

7. When the cylinder is cool enough, remove the slurry from the slurry cup.

Under certain heating/cooling conditions the slurry head and pressure vessel may be at very different temperatures. If the slurry head is hot to the touch and the pressure vessel is cool take extreme care in removing the slurry head as the two metals will be more prone to seizing. Slurry head and/or pressure vessel damage can be avoided by allowing the two temperatures to equalize somewhat before removal of slurry head.

7.3 Thermocouple Retainer

On some pressure vessels the bottom has a threaded thermocouple retainer which must be used correctly to help prevent the thermocouple probe from falling out. The assembly includes a threaded 10/32 set screw with a hole drilled through it and an o-ring as shown below. The o-ring is squeezed tight around the thermocouple probe by tightening the set screw. The thermocouple probe may be inserted or removed while the o-ring is still good. The o-ring may be required to be changed after a high temperature test or when after tightening the set screw further and the o-ring fails to grab onto the thermocouple probe.

Figure 7-1 Screw with hole and o-ring

7.4 Removing Slurry Cup Plug from Pressure Vessel

In the case where the head cannot be removed by hand alone please take caution and follow these steps:

Air pressure can be very dangerous and head can easily be ejected with force causing injury or component damage. Use safety gear not limited to eye, face, hand and foot protection.

1. Remove pressure vessel from the instrument and place in vise with slurry cup above table or flat surface.
2. Attach pressurized head removal nipple to the hand-driven air pump. The nipple is shown attached to the head and the hand-driven air pump.
3. Attach head removal nipple using the medium pressure nut to the head.
4. Loosen the slurry cup cap about 2 rotations making sure it does not come completely loose. This leaves a gap between the cap and the head to allow the head to dislodge from the cup.
5. Slowly apply increasing air pressure to move head. The head may eject with a “pop” or gently ease out of the slurry cup. The cap will stop the head from coming completely off the cup.
6. Undo the head removal nipple and remove the slurry cup cap.
7. Remove the head from the cup using caution.
8. If the head does not come loose it may be necessary to reinstall the slurry cup cap with an increased gap between the head and cap. Reattach the head removal nipple and hand-driven air pump and continue applying air pressure. Repeat steps 6-7.
9. If the head still does not come loose, it may be necessary to leave the slurry cup cap completely off and employ the use of a second individual with a pair of hands. This person must use caution and care while holding the slurry head and apply more air pressure via the removal nipple and air pump. The head may eject with a “popping” sound and with force. Take care to not let go of the head while ejecting from the cup. Damage to the head or technician may occur if proper protection and safe guards are not used.

Figure 7-2 Attachment from step 2

7.5 Slurry Removal

7.5.1 Cement Removal Plug Method

1. Wait until slurry is sufficiently hardened to allow removal in one piece.
2. Place slurry cup in a vise with slurry above waste container or table.
3. Remove the paddle retaining bolt from bottom plug.
4. Insert cement removal bolt. Long, brass bolt similar to the paddle retaining bolt.
5. Continue to screw in the cement removal plug until the slurry is easy to pull out by hand.

7.5.2 Air Pressure Removal Method

1. Wait until slurry is sufficiently hardened to remove in one piece. This will make cleanup much easier.
2. Place slurry cup in vise with slurry above waste container or table.
3. Remove Paddle Retaining Screw from bottom plug .
4. Insert slurry ejection bolt. Ejection bolt should have air fitting Schrader valve inserted into center hole.
5. Using hand driven air pump, apply pressure to the cement plug using caution to properly secure cement plug when it exits the slurry cup.

Use safety gear not limited to eye, face, hand and foot protection.

6. Cleanup slurry cup with soap and water. There is no need to remove bottom plug unless it is leaking and o-ring replacement is required.
7. Remove plug from paddle and reassemble slurry cup for another test.

8 Maintenance and Troubleshooting

Troubleshooting and regular maintenance procedures are described in this section. If more extensive maintenance or service of the instrument is required, please contact Fann Instrument Company.

Consistometers can be relatively reliable and trouble free - provided they are serviced and maintained properly. Instruments that are neglected and receive infrequent service or are subject to abuse are certain to cause trouble. Poly-paks™ and o-rings are important to reliable pressure sealing. If these components are free from debris and scratches/dents, reliable sealing will be easily achieved.

1. Inspect the pressure vessel's o-rings after each test and wipe free of cement particles and other debris. Do not use sharp objects, such as screwdrivers, when removing the o-rings as it will likely tear or scratch the o-ring.

2. It is recommended to apply an anti-seize compound to all threads occasionally. Fann has done this on all required surfaces initially and re-application should be on an "as-needed" basis.

3. The mineral oil in the reservoir should be drained and replaced when it becomes dirty. To thoroughly clean the reservoir, the entire unit may be taken out of the instrument and the bottom removed. Mineral oil may be conveniently added by pouring oil into the top of the reservoir. The mineral oil supplied with the instrument has an open cup flash point of approximately 188°C/370°F.

4. The magnetic drive should be flushed with clean solvent periodically and whenever cement flows into the upper plug or particles contaminate the drive. If cement enters the magnetic drive, it will cause the bearings to wear quickly. If the worn bearings are not replaced, it may cause the inner magnetic drive shaft to wear out prematurely. Worn bearings may also cause incorrect consistency measurement.

8.1 Slurry Cup Bottom Removal and Reinstallation

It is recommended that the slurry cup bottom not be removed frequently. It should be removed, serviced and reinstalled only when necessary such as when there is a leak through the slurry cup bottom.

1. Locate the wrench multi-tool and 3/8-24 bolts

2. Lock pressure vessel securely into bench mounted chain vice or suitable clamping mechanism. Example shown below.

3. Place "SLURRY" labeled section of tool over the slurry cup bottom notice the two holes in the wrench align with the two threaded holes on the plug.

4. Insert the 3/8-24 bolts through the holes and thread them into the bottom plug.

5. Use force to counter-clockwise unscrew plug.

6. Remove O-ring. Clean entire slurry cup bottom. Inspect for damage especially to threads. Replace if threads are damaged.

7. Apply high temperature, copper based anti-seize to the threads of both the slurry cup bottom and slurry cup.

8. Apply high temperature red grease to the new o-ring and reinstall it. If o-ring is too difficult to install, try heating the o-ring in warm water to soften it. Be careful not to burn yourself! A moderate amount of warming will soften the o-ring enough to make installation easier.

9. Use wrench to re-install the slurry cup plug. Confirm the use of anti-seize and red grease. Bottom of the slurry cup plug must be fully flush with the bottom of the pressure vessel to seal.

Figure 8-1 Pressure vessel locked securely into bench mounted chain vice

8.2 Paddle Shaft and Paddle

1. Check the point on the bottom of the paddle shaft. Replace it if it is worn to the point that the paddle rubs on the bottom of the slurry cup plug. Check to

see that the paddle shaft is not excessively worn where the shaft extends into the connecting rod. Replace if wear is excessive. Bent shafts need to be replaced.

2. Paddle should be free from damage. If any blades are bent or major wear exists replace the paddle by removing the roll pin and reinstalling with a new one.

8.3 Slurry Cup Plug Disassembly and Reassembly

8.3.1 Part A: Disassembly

1. Insert a paddle shaft and paddle assembly into the paddle connecting rod and unscrew the rod counter-clockwise from inner magnetic drive shaft.
2. Remove the nut and plug from the top of the outer mag drive housing.
3. Unscrew counter-clockwise the outer mag drive housing from the slurry cup plug. Take care to not spill any oil. Typically this can be done over a spill catch or sink.
4. Remove the ball bearing and upper bearing retainer.
5. Remove the inner mag drive assembly by rotating counter-clockwise and gently pulling up. The Poly-pak™ fits very tight around the shaft and will want to roll on itself unless an unscrewing action is used.
6. Remove ball bearing.
7. Insert retainer tool into seal retaining plug and unscrew counter-clockwise to remove seal retaining plug.
8. Remove Poly-pak™ and spring.
9. Inspect bearings and Poly-pak™s for wear and contamination. Replace if necessary. It is likely Poly-pak™ will need replacement after every very hot test or if wear is evident. Refer to drawing for proper orientation of Poly-pak™s.
10. 10. Clean all parts and further inspect for wear or damage.

8.3.2 Part B: Reassembly

1. Insert spring into the bottom of the slurry cup plug. Orient the plug so that the spring doesn’t fall out.

2. Orient and correctly place seal retaining plug and Poly-pak™ onto spring retaining tool then insert the two into the bottom of the slurry cup plug using a clockwise motion. Thread the retaining plug all the way down using gentle force. Do not over-tighten.

3. Insert the inner mag drive with bearing into the top of the slurry cup plug using a clockwise threading motion as the shaft of the inner mag drive moves through Poly-pak™ . This threading motion prevents the Poly-pak™ from rolling on itself and ripping.

4. Using the paddle assembly insert the paddle connecting rod by threading it clockwise onto the inner mag drive. Hold onto the inner mag drive to prevent spinning.

5. Gently anti-seize the outer threads of the slurry cup plug where the outer magnetic drive housing threads onto it.

6. Replace the nut and plug onto the outer mag drive.

7. Place upper bearing retainer and bearing correctly into the outer mag drive housing. Orient the mag drive housing so they do not fall out.

8. Fill the outer mag drive 1/3 full with mineral oil.

9. Without spilling the mineral oil, thread the outer mag drive onto the slurry cup plug. Once you have threaded the outer mag drive half way open the nut one or two turns to allow air bubbles to bleed out. Continue to thread the outer mag drive housing all the way down until the bottom touches the slurry cup plug. Be careful that Poly-pak™ does not roll on itself which will create an improper seal.

10. Repeat the previous steps if the inner mag drive housing does not thread all the way down. It is important that the air bubbles be purged.

Table 8-1 Troubleshooting Guide

Symptom	Cause	Remedy
System builds pressure but will not hold pressure	Leak	Check fittings for leaks and tighten fittings. **Check that all O-rings/Poly-pak™s are installed correctly and undamaged.** Rebuild slurry assembly
	PRESSURE RELEASE valve not closed tightly	Close valves tightly.
	PRESSURE RELEASE valve worn out.	Replace valve stem or entire valve. PRESSURE RELEASE valve is most likely to wear out.
System builds pressure and oil runs out between pressure vessel and top plug.	O-ring is worn.	Replace o-ring.
	O-ring sealing surfaces and/or seal shaft are worn, pitted, or scratched.	Lap o-ring sealing surfaces.
Pump strokes but little or no pressure gains.	Valve open, severe leak, blown rupture disc.	Locate problem and correct.
	Pressure vessel has trapped air.	Bleed all air from lines by manually pushing oil through tubing.
	Oil reservoir is empty	Fill reservoir with oil.
	Faulty pump check valve.	Clean and/or overhaul pump outlet check valve.
	No air supplied to air operated valve (if so equipped).	Check air lines leading to valve. Check valve solenoid valve. Restore air supply.
Pump builds and maintains pressure to a certain level then stops.	If no oil is coming from pump muffler, oil reservoir ran dry.	Add oil to reservoir.
	If oil is coming from pump muffler, the pump high-pressure seal is probably worn out.	Overhaul or replace pump.
Pressure cannot be released.	Stainless steel lines are plugged with cement.	Remove lines and inspect for blockage. Replace any that are plugged.
Slurry paddle will not turn.	Magnetic drive severely contaminated with cement.	Remove magnetic drive plug and inner magnet shaft and clean magnetic drive thoroughly.
	Faulty motor or controller.	Check connections on motor and instrument box. Ensure all connection between motor, cabinet, and control box are secure.

Symptom	Cause	Remedy
Erratic motor speed control.	Outer Mag-Drive Housing not tight on motor shaft	Disassemble and tighten mag-drive housing using HEXAGONAL wrench.
	Worn out magnetic drive outer rotator.	Check rotator for excessive run out or wobble with motor running. Replace if necessary.
	Pressure Differential in cylinder	Ensure inner magnetic drive housing and slurry head are properly assembles and paddle rotates freely.
Heater will not get hot.	Blown fuse.	Check fuses inside electrical box. Replace any that are blown.
	Loose heater wire.	Check heater terminals for loose wires and reconnect if necessary.
	Faulty heater.	Replace.
	Faulty solid state relay.	Replace.
Temperature display is erratic.	Faulty thermocouple.	Replace thermocouple.
	Loose connection in thermocouple wiring.	Check for loose wiring and correct if necessary.
Temperature displays unusually high /low number.	Open circuit in thermocouple.	Replace thermocouple.
	Open circuit in thermocouple circuitry	Check thermocouple circuitry for open circuits or loose connections.
Temperature is overshooting.	The instrument is optimized for higher temperature operation and may have difficulty at temperatures just above ambient.	Program a dual ramp instead of one single ramp. Also check the supplied voltage to the machine as higher or lower voltages may affect operation.
Temperature is lagging behind.	Supply voltage too low.	Check the line voltage to the instrument. If the voltage is too low, then this will affect heat rate.
	Cooling water solenoid leak.	Check the cooling water solenoid is not leaking water causing water to flow into the heater.
	Air gap.	Check that the pressure vessel is making solid contact between the inside of the heater and the outside of the pressure vessel. If there is no contact this will affect the heat rate. Check the slurry cup height adjustment ring is correctly installed. If upside down, this will cause an air gap.
Consistency reading is high when test is	Air trapped in mag drive.	Open the nut on the top of the mag drive housing and bleed air bubbles.

Symptom	Cause	Remedy
started.		Then close the nut. Add oil if necessary. Or disassemble the slurry cup plug and reassemble following maintenance guidelines.

9 Warranty and Returns

9.1 Warranty

Fann Instrument Company warrants only title to the equipment, products and materials supplied and that the same are free from defects in workmanship and materials for one year from date of delivery. THERE ARE NO WARRANTIES, EXPRESS OR IMPLIED OF MERCHANTABILITY, FITNESS OR OTHERWISE BEYOND THOSE STATED IN THE IMMEDIATELY PRECEDING SENTENCE. Fann's sole liability and Customer's exclusive remedy in any cause of action (whether in contract, tort, breach of warranty or otherwise) arising out of the sale, lease or use of any equipment, products or materials is expressly limited to the replacement of such on their return to Fann or, at Fann's option, to the allowance to Customer of credit for the cost of such items. In no event shall Fann be liable for special, incidental, indirect, consequential or punitive damages. Notwithstanding any specification or description in its catalogs, literature or brochures of materials used in the manufacture of its products, Fann reserves the right to substitute other materials without notice. Fann does not warrant in any way equipment, products, and material not manufactured by Fann, and such will be sold only with the warranties, if any, that are given by the manufacturer thereof. Fann will only pass through to Customer the warranty granted to it by the manufacturer of such items.

9.2 Returns

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

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

Our correspondence address:

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