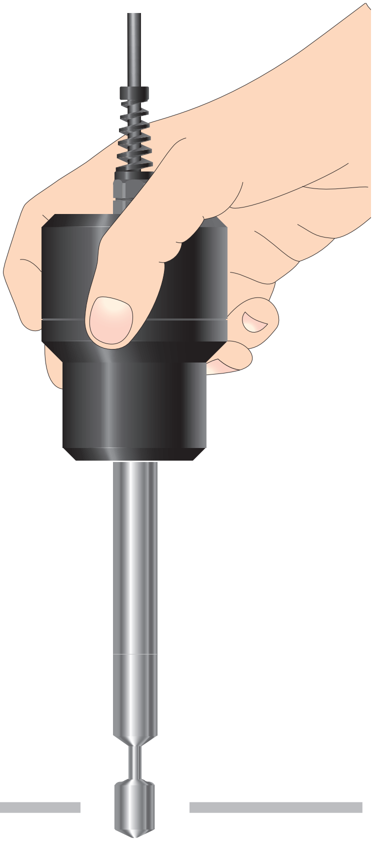
Hydramotion
innovators in fluid measurement

Viscolite 700HP

small sample volume
Model VL700-T15

solid state
insertion
viscosity meter



User Manual

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The Viscolite 700 and all its associated technologies are protected by UK and International Patent Applications.

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Ref: U01-04-008 R0 02/04

Guarantee

Hydramotion Ltd will repair a Viscolite 700 free of charge within 24 months of the date of purchase if satisfied that the fault is the result of defective materials and/or workmanship and if the instrument is returned to Hydramotion Ltd carriage prepaid and undamaged in transit.

This Guarantee shall ***not*** *apply to any fault resulting from (i) negligence or lack of proper care by the owner or user, (ii) a failure to follow the recommendations set out in this User Manual, or (iii) normal wear and tear on the instrument.*

Hydramotion Ltd shall in no case be liable for any loss of output, revenue or any other losses or costs, consequential or otherwise, howsoever incurred.

1 Introduction

The Viscolite 700HP is a handheld or bench-mounted instrument for the instant measurement of viscosity of fluids by insertion.

The actual sensor has a solid construction with no moving parts. It is connected to a bench-top microprocessor (HP550) unit by a flexible cable, and the whole instrument is powered by a transformer/adaptor unit. This combination of toughness, light weight, and no wearing parts makes the instrument ideal for the spot measurement of viscosity in either a harsh factory environment or laboratory.

The Viscolite can be used with any volume of fluid. Unlike conventional rotating cylinder viscometers there is no specific quantity of fluid, or size of vessel, required to ensure accuracy. Hence the same instrument can be used for testing liquids in vessels of virtually any size, from a large tank down to a small beaker.

1.1 How It Works

The sensor element consists of a shaft with an end mass, or bob, which is made to vibrate (also called resonate) at its natural frequency. When vibrating, the moving parts of the sensor shear through the fluid. As this shearing takes place, energy is lost to the drag forces on the sensor caused by the viscosity of the fluid. The loss of energy in each cycle of vibration is measured by the sensor electronics and the microprocessor in the Display Unit. From this energy loss, the actual viscosity of the fluid is determined.

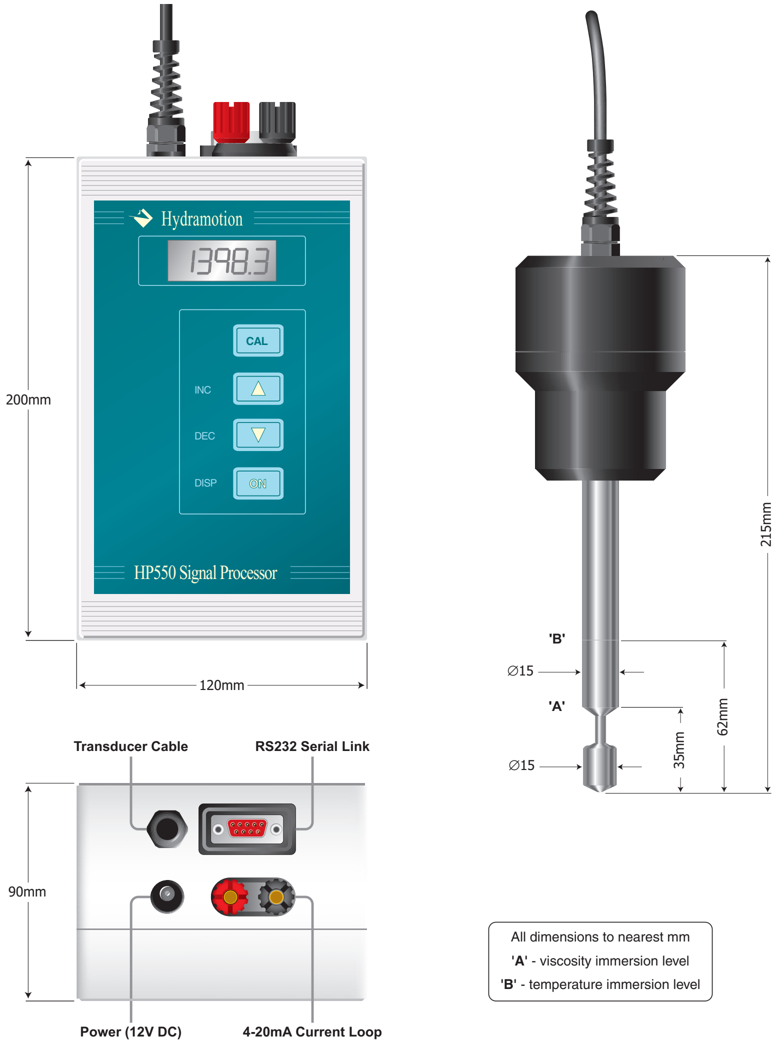
The Viscolite is therefore in a class of instruments sometimes called ‘resonant’ or ‘vibrational’ viscometers.The response of these devices is not purely with viscosity but with the product of viscosity and density, i.e. viscosity x density. In practice, viscosity changes on a far greater scale than density, and the fluid density can be accommodated by simply entering its nominal value in the Display Unit.

1.2 Specifications and Options

Included with the instrument is its **Certificate of Calibration/Conformity** which should be used to verify the particular model/specification. The standard Viscolite 700 has the following specification:

Viscosity Range		Calibrated 0 to 5,000cP (useful measurements can usually be made up to 10,000cP on s21 models)
Temperature Range		–40 to +150 deg C
Materials		Wetted parts: 316L stainless steel Non-wetted parts: acetal
Power		12V 800mA transformer/adaptor (supplied)
Options:	/T	Integral platinum resistance thermometer (PRT)
(/code)	/P	Polished sensor surface 0.4 micron AA

Always ensure the Viscolite 700 is used with fluids compatible with the sensor materials and within the specified range of operation.



All dimensions to nearest mm
'A' - viscosity immersion level
'B' - temperature immersion level

Signal Processor

Hand Held Sensor

Fig 1a Viscolite VL700HP Portable Viscometer

1.3 Unpacking and Handling

The Viscolite 700 will be delivered in purpose-made packing. It is advisable to retain the packing for the safe storage or further transport of the equipment.

Each viscometer carries a Certificate of Conformity and Calibration which gives important information for that particular instrument, such as serial number, material specification etc (see Section 1.2). The conformity information should be checked to verify that the instrument is compatible with the process fluid and the Certificate retained in a secure place.

Carefully remove the items from the packaging. The Viscolite is a robust instrument capable of enduring vigorous day to day use, but it is important that the sensor is perfectly straight as any distortion of the shaft will significantly affect performance. To help resist the effects of occasional knocks or accidents the probe is fitted with a shock absorber; as a result, small movements of the metallic sensing part relative to the plastic enclosure are quite normal and no cause for concern.

Inspect the probe and readout unit and immediately report any apparent shipping damage to Hydramotion or its representatives, and the carrier.

1.4 Power and Electrical Wiring

The transformer unit supplied with the instrument should be connected to the HP550 processor using the DC power connector at the top of the HP550 Signal Processor.

The supplied serial cable may be used to connect the HP550 signal processor to a host PC in order to provide remote viscosity readout. The unit has been designed to operate over a male-to-female ‘straight-through’ 9-pin serial link.

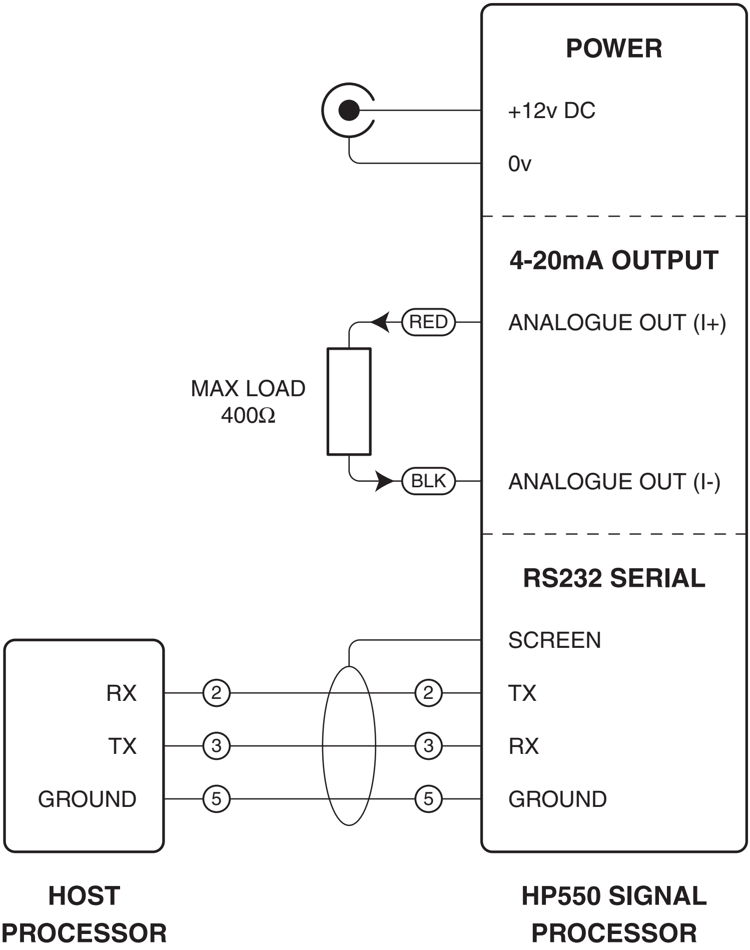


Fig 1b Viscolite VL700HP Viscometer Wiring

Connections for the 4-20mA analogue output are made through the screw terminals at the top of the signal processor enclosure. The maximum permissable load resistance is 400Ω.

2 Using Viscolite 700

This section forms a simple guide to the basic operation of the Viscolite 700 to allow its immediate use for viscosity measurement. The more advanced features and user settings are covered in Section 3, ‘Detailed HP550 Operation’.

The HP550 has a 5-digit display and 4 keys. The display shows all the main measurements of live viscosity, corrected viscosity and temperature.

Each time a key is pressed a bleeper sounds. At this stage we are only concerned with the ON key and the ▽ and △ keys. The CAL key can be ignored for now.

The ▽ and △ keys are used to cycle from one measured value display to the other. The ON key is not used for power-on in transformer powered units, but is used to access various displays.

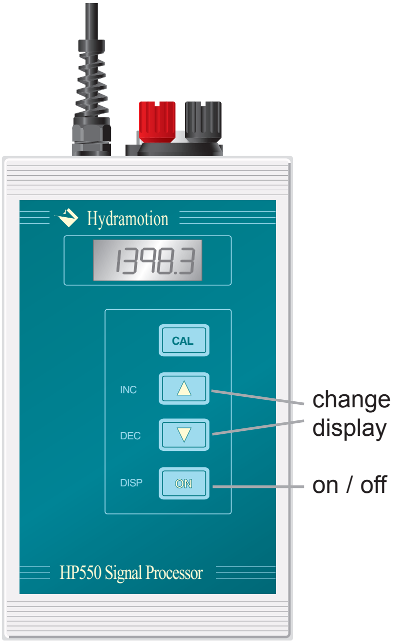


Fig 2 Basic key operations

2.1 Turning On the Viscolite

Plug the transformer into the mains and turn on. When power is first applied, the microprocessor in the Display Unit goes through its start-up routine. The display runs through all its digits and settles on the display of viscosity, with the letters 'VL' shown briefly, in units of centipoise (cP ≡ mPa·s). This is called Normal Mode.

Each time the ▽ and △ keys are pressed the display briefly shows a symbol for a particular measurement, followed by its value. Displays are as follows:

VL	Live viscosity reading
VC	Viscosity corrected to reference temperature
t	Fluid temperature

The live viscosity value, VL, is the actual instantaneous viscosity of the fluid at its current temperature. The corrected viscosity value is calculated from the fluid temperature and keypad entered correction constants (see Section 3).

Following power-up the Display Unit will display the dynamic viscosity of the fluid surrounding the sensor. It is that simple.

2.2 Measuring Viscosity

If the sensor is in air, *and perfectly clean*, the instrument should read zero. Measurement of viscosity is straightforward. Simply insert the sensor into the fluid to be measured, *to the depth shown in Fig. 3* and the reading of viscosity in centipoise will appear on the VL display.

Note: For greatest accuracy enter the nominal fluid density in the d-n display in the LCAL menu described in Section 3.4.2. This is factory set to 1.000 g/cc.

If the instrument is to be used on a bench-top it may be convenient to support the probe — for example, using a retort stand and clamp. **Always clamp the probe at its plastic enclosure and not on any metallic part.**

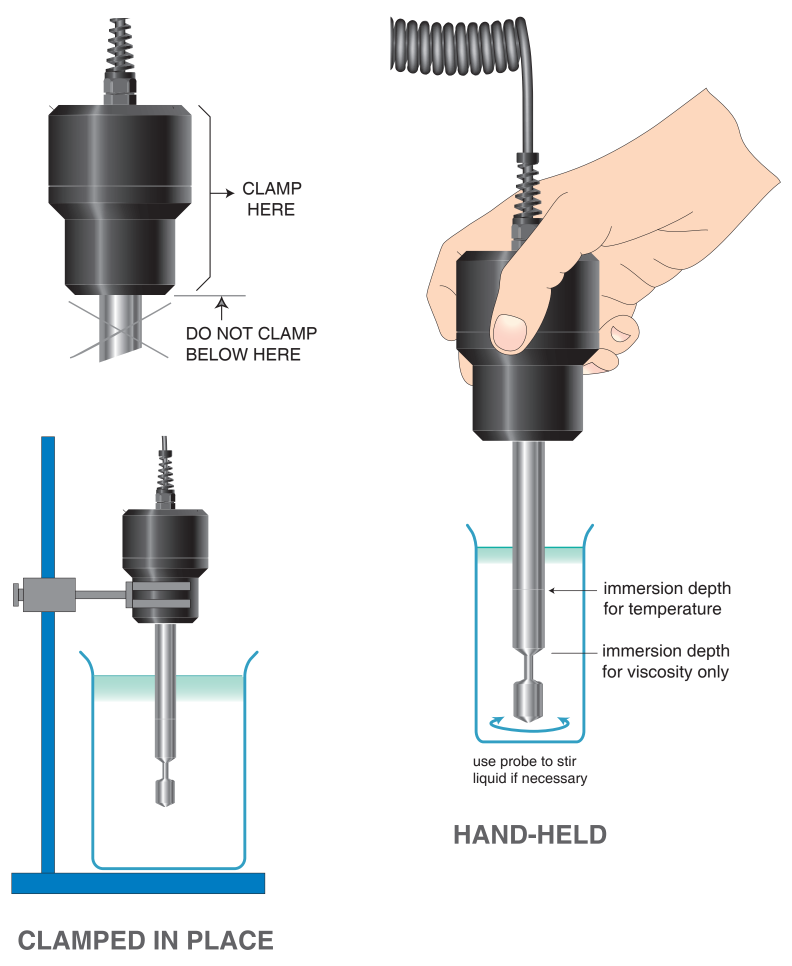


Fig 3 Taking viscosity readings using the Viscolite 700

Ensure there are no local variations in viscosity (sometimes due to temperature differences within the fluid). Within reason, you can use the probe to stir the liquid.

Fluids containing large amounts of solids may exhibit unusual shear behaviour and show some instability in the reading. In this case a better measurement can be made by reading the viscosity when the probe is being moved in a stirring action. The best results will be obtained on fluids which show a near newtonian behaviour.

2.3 Temperature Effects

The viscosity of all fluids is strongly dependent on temperature. In most cases a very small change in fluid temperature can cause a significant and visible change in the reading of live viscosity, so the effect cannot be ignored.

If there is a difference between the temperature of the sensor and that of the fluid then this may show with the initial VL readings in one or two ways:

i) When the instrument is first introduced into a liquid which is at a significantly different temperature to the sensor, there may be a period of temperature equalisation needed. This will be seen as a gradually changing, sometimes dithering, reading. Once the temperature of the sensor and the fluid are the same, then the viscosity value should be steady. Stirring will reduce the time for the temperatures to be equalised.

ii) A cool sensor in a warm fluid can cause local cooling of the fluid resulting in a change of viscosity surrounding the sensor. Conversely a warm sensor in a cool fluid will cause a similar change. Again, stirring the fluid should quickly remove any local effects.

2.4 Temperature-Corrected Viscosity - VC

Because of the effect of temperature on viscosity, in some situations it is preferable to refer the viscosity of the fluid to a specific temperature; this is called Corrected Viscosity and is shown on the display as VC.

Corrected Viscosity is useful for detecting genuine changes in fluid viscosity rather than thermal effects since it is independent of temperature variations. The value of VC is derived from VL , the fluid temperature and two fluid correction factors which are specific to the particular fluid. The value of VL is obviously automatically measured by the Viscolite; temperature can be either keypad entered or, if the integral temperature sensor option is fitted, be measured and displayed automatically by the Viscolite. The calculation of VC and entry of the appropriate correction factors needs some thought and is described in detail in Section 3.6.

2.5 Temperature Measurement Option

It is important to note that **if the Viscolite has the integral temperature option the probe should be immersed to the depth shown in Fig. 3**, in order for the temperature to be accurately determined.

In the event of large temperature differences, it may be necessary to wait a few seconds for the probe to reach fluid temperature when first introduced into the fluid.

2.6 Non-Newtonian Fluids

The Viscolite 700 operates at very high shear rates which helps achieve its high repeatability.

For shear rate dependent, non-newtonian fluids, the viscosity reading will be that for high shear rates. If, like most non-newtonian fluids, the fluid is shear-thinning then the Viscolite will show a lower reading than that observed on a low-shear viscometer, and vice versa for a shear thickening fluid.

Instability in the measured value may be observed in fluids with a suspended solid content or notable yield stress. This is due to the uncertain rheological behaviour of solids, or solid-like environments, under shear and the situation is usually significantly improved if the probe is used in a gentle stirring action.

For newtonian fluids, the viscosity is independent of shear rate and the reading can be accepted without any consideration of shear conditions.

3 Detailed HP550 Operation

The digital Display Unit interfaces directly to the sensor, providing all the measurement and control functions needed to derive fluid viscosity. This Section describes all the functionality and displays of the Display Unit.

- enables access to data and settings
- entry and accept function for keypad entered data

- movement through menu tree
- increment numbers in data entry mode

- movement through menu tree
- decrement numbers in data entry mode

- exit from sub-menus in menu tree

Fig 4 Detailed key operations

The Display Unit has 4 keys and a 5-digit display. Through this display and keypad all measured and calculated variables, and a number of setup, maintenance and diagnostic facilities are accessed. Each time a key is pressed a bleeper sounds; the bleeper is also used to signal various events in the operation of the unit.

There are two Operational Modes:

1	**NORMAL MODE**	This is the usual user mode for the instrument. Automatically entered on start-up
2	**SET-UP MODE**	Used for setting up parameters for the normal operation of the instrument such as temperature correction and scaling factor and viewing some diagnostic information

3.1 Operation in Normal Mode

All the main display parameters of VL , VC and t needed for day-to-day operation are shown in Normal Mode. This is covered in detail in Section 2.

3.2 Operation in Set-Up Mode

Setup Mode gives access to all the measured and calculated variables used to derive the final viscosity readings, and a number of keypad-entered parameters which can be adjusted to suit the needs of the particular application or fluid.

The mode is entered by pressing the CAL and ▽ keys *together* for about a second. The abbreviation VISC will be displayed. This is the Main Menu which leads to a selection of other menus. The Setup Mode menu tree, with keypad commands to access displays is shown in Fig. 5.

3.3.1 Moving through display menus

Following entry into Setup Mode, the various sub menus are accessed by pressing CAL. Exit from a menu is by pressing ON.

From the Setup Menu Chart the main part of the menu tree is headed by the VISC display. The VISC menu holds all the information for configuring the instrument to provide a reading of Line Viscosity.

For Temperature Measurement and Correction there are additional menus associated with these functions which are accessed by pressing the ▽ or △ keys - these options are covered later in this Section.

Pressing CAL on the VISC display will give access to the various sub-menus shown in Fig. 5. Each sub-menu is accessed by pressing the ▽ or △ keys. To view the contents of a sub-menu simply press CAL when displaying the menu title. Each item in the menu can then be viewed by pressing the ▽ or △ keys.

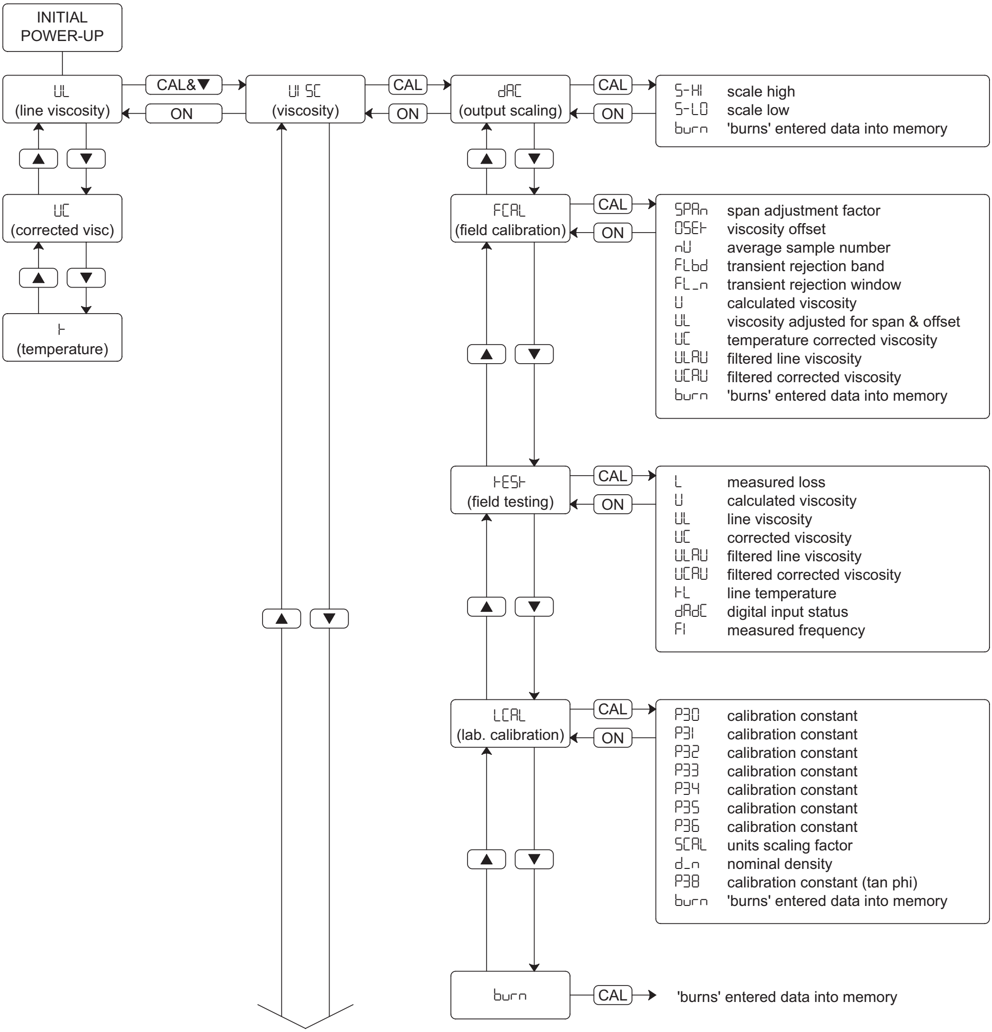
To exit a menu and return to a higher level in the tree, press the ON key. Repeated pressing of ON will return the instrument back to Normal Mode.

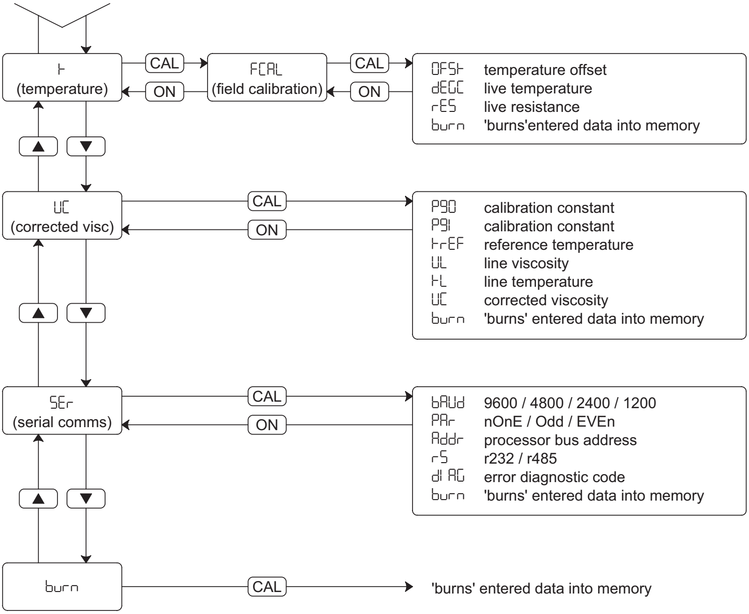
3.3.2 Entering Data

In general, to change a parameter press CAL for around a second, the display will flash and then use the ▽ or △ keys to decrement or increment the displayed value. Press CAL again to exit this entry mode.

Pressing the ON key will abort any entry in Setup Mode and return to the state prior to pressing CAL. Pressing ON will also return the display back to Normal Mode.

Set-Up Mode Menu Tree





Entering constants in E-Format

Temperature Correction and some Calibration Constants are entered using a special E-Format.
The numbers are held in three parts:

X . XXX EXX
Integer INT Fraction FRAC Exponent EXP

With display showing the constant's P number e.g. P91, pressing CAL for three seconds displays **E** shortly followed by a number, which is value of the exponent of the calibration constant in the format shown above. Pressing ▽ or △ at this point displays **Int** shortly followed by a number which is the integer value of the calibration constant. Similarly, pressing ▽ a further time brings up **Frac**, the fraction value of the constant. To change the value of any of these numbers, press CAL and the number will begin to flash. The ▽ or △ keys can then be used to change the value in the display. Pressing CAL returns from this change mode. Any entered values will be lost on power down unless the user goes to the **burn** display and presses CAL for three seconds which then programs the values into non-volatile memory.

Fig 5 Set-Up Mode Menu Tree

3.3.3 Burning Data

Within the display menus the user will see ‘burn’ displays. Pressing CAL for three seconds on the burn display will write the entries into non-volatile memory which will then be retained on power loss. If values are not entered using the burn display, they will be lost upon power fail and the previously 'burnt' values used on restart.

In summary:

Press CAL + ▽ to enter Setup Mode
Press ON to exit Setup Mode

Press CAL to drop a level in the menu tree
Press ON to go up a level in the menu tree

Press CAL to *enter* 'number entry mode'
Press CAL to *exit* 'number entry mode'

3.4 Determination of Viscosity

The Viscolite determines viscosity by measuring the amount of energy lost through vibrational oscillation of the sensing element. This technique, combined with a high performance transducer architecture, provides a response that displays extremely high repeatability, even under austere process conditions.

The actual signal generated by the transducer is an indication of energy loss and is therefore referred to as the ‘Loss Factor’, L. The following sections describe how the Loss Factor is converted into a usable reading of viscosity.

3.4.1 Viscosity Conversion

The loss factor is converted to a ‘raw’ reading of Dynamic Live Viscosity, V, using a multi-term polynomial equation. The coefficients of each term of the equation are the calibration constants P30, P31, P32 etc. The actual polynomial expression can vary between transducer models and is given on the Calibration Certificate for the particular transducer. Generally,

$$\text{Raw Line Viscosity} = (1/\text{density}) \,.\, (P30 + P31.L + P32.\,L^2 + \ldots \text{ etc})$$

3.4.2 Units Conversion and Fluid Density

To accommodate the many units of viscosity, a factor called SCAL is employed which is a multiplier for easy conversion from one unit to another by the user. As standard, instruments are factory-calibrated in mPa·s (≡ cP) unless otherwise specified. In addition, there is an adjustment to be made for the fluid density by means of a keypad entry for the Nominal Density, d-n in the LCAL menu. Taking account of the units conversion and fluid density, the calculation of line viscosity becomes:

$$\text{Viscosity} = V = \frac{SCAL}{d\text{-}n} \,.\, (P30 + P31.L + P32.\,L^2 + \ldots)$$

3.4.3 Calibration Adjustment

The equation for V is developed further to accommodate simple adjustments to factory calibration. Two further factors are introduced: a *gain* factor SPAn, and an offset figure OSEt. Calibration adjustment is discussed in detail in Section 4. The full equation for Instantaneous Line Viscosity, VL, is given as:

$$\text{Line Viscosity} = VL = V.\,SPAn + OSEt$$

3.4.4 Filtering

Finally, to allow real-time filtering of the viscosity signal to reject excessive noise VL can be processed by an 'Averaging Filter'. The filtered value of VL, is called VLAV. Filtering is described in more detail later in Section 3.5.

Filtered Line Viscosity = VLAV = Filter (VL)

All intermediate values of viscosity - V, VL and VLAV - are displayed in the Field Calibration FCAL submenu in Setup Mode. There are equivalent displays for Instantaneous Corrected Viscosity, VC, and filtered Corrected Viscosity VCAV.

The main display in Normal Mode therefore shows **VL, Live Viscosity,** which is actually the same as **VLAV**. **Corrected Viscosity** is actually **VCAV**.

3.5 Averaging Filter

The Viscolite has a very high natural rejection of exterior noise and vibration, so the averaging filter is usually unnecessary. Therefore, **in most practical applications the averaging filter should not be used**. Any setting above the value of nV=1 will slow the response of the instrument and lead to a longer settling time for a spot reading.

Filtering should only be considered if the user wishes to make a very high sensitivity measurement over a long time period or any situation where there is some noticeable jitter in the reading. Averaging is achieved using the nv display in the FCAL sub-menu in Set-Up Mode. The figure displayed in the nv display is the number of readings contained in the average calculation. If set to "1" there will be no filtering. The greater the number the heavier the filter damping, *but also the longer the response time of the system*. This is illustrated in Fig 6.

The system takes a viscosity reading around every 2 seconds, so the time response of the instrument becomes nV × 2 seconds.

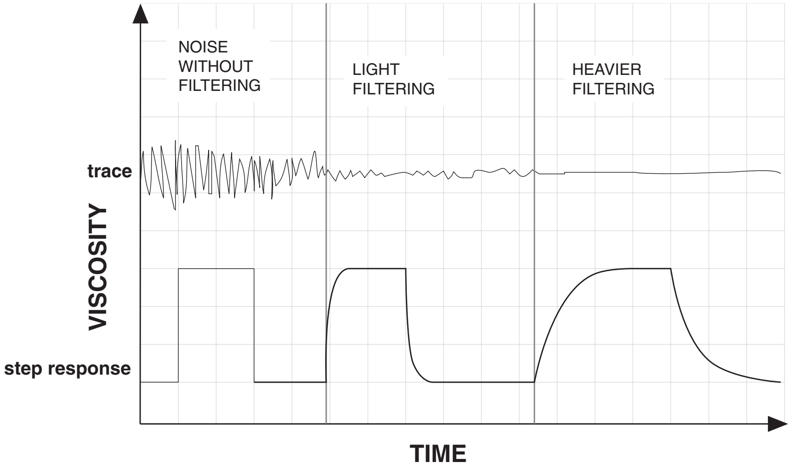


Fig 6 Effect of Averaging Filter

3.6 Corrected Viscosity, VC

The Display Unit microprocessor has an integral algorithm for the correction of viscosity from line conditions to some other reference temperature value. The correction algorithm is based on the commonly accepted Arrhenius relationship:

$$\text{viscosity} = A\,e^{B/t}$$

where A & B = fluid constants

t = absolute temperature

This equation is rewritten to provide temperature correction of a given viscosity to a reference condition, as follows:

$$\mathbf{VC} = \mathbf{VL} \,.\, e^{\mathbf{P91}.[1/(\mathbf{trEF} + 273) - 1/(\mathbf{tL} + 273)]} - \mathbf{P90}$$

where VC = Viscosity corrected from line temperature, tL, to reference temperature, trEF
VL = Live Viscosity
trEF = Reference temperature, °C (keypad entered)
tL = Fluid temperature, °C
P90 = Keypad-entered constant for fluid
P91 = Keypad-entered constant for fluid

All parameters are accessed through the VC sub-menu. The constants P90 and P91are very much fluid dependent, and are usually determined by experimental means. P90 is simply an offset and is usually zero. The main parameter required for temperature correction is P91 - the Viscosity Temperature Correction Factor.

Both the P90 and P91 constants are held in “E-format” in the display unit and are entered using the procedure described in Fig. 5. As with all other permanent settings, always ensure the ‘burn’ display is used to ensure the values of the constants are not lost following a power-down.

Fluid temperature, t, and Corrected Viscosity, VC, are visible on the main display in Normal Mode.

IMPORTANT: Sensor must be immersed to the correct depth (shown in Fig. 3) to ensure accurate fluid temperature reading for automatic calculation of Corrected Viscosity VC.

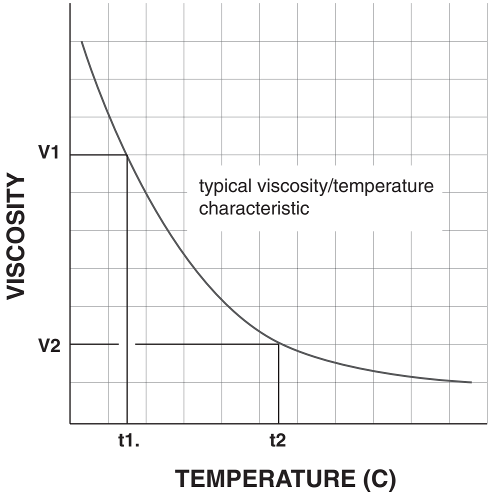
3.6.1 Calculation of P91

It is possible to determine the temperature correction factor from charts such as those found in the Engineering Sciences Data References where the viscosity of the fluid at different temperatures is shown. Using values of temperature and viscosity from a chart, P91 can be calculated as follows:

$$P91 = \frac{\log_e V1 - \log_e V2}{1/(t1 + 273) - 1/(t2 + 273)}$$

where V1 = Viscosity at t1 (deg C)
V2 = Viscosity at t2 (deg C)

To achieve a realistic correction factor, always try and make sure that temperature values are chosen around the temperature of the line and the reference temperature (see Fig. 7).



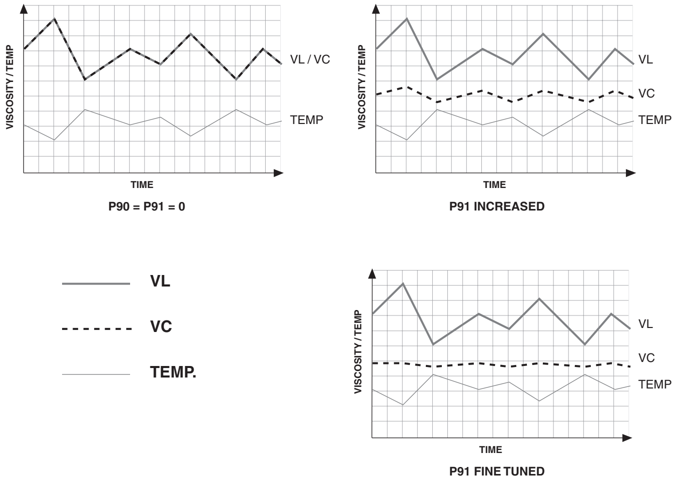
For best results, ensure t1 and t2 are close to the fluid temperature and reference temperature

Fig 7 Calculation of P91

3.6.2 Manual Derivation of P91

Alternatively, P91 can be derived by trial and error. If the *corrected* viscosity of the process is known to be stable over a measurement period, and there is variation in the fluid temperature causing changes in live viscosity VL, then such a situation can be exploited to derive P91. In the VC sub-menu Line temperature, t, Corrected Viscosity, VC, and P91 are all easily visible. The objective is to enter a value of P91 which causes the VC reading to stabilise out at a constant value, even though t and VL are changing.

The procedure is to start with a value of P91 of about 5000. Check the result to see if VC is becoming constant? Try increasing P91. Is VC getting better (less variable) or worse (more variable)? If VC is getting better, slightly increase P91 again, to (e.g.) 5500. If worse, decrease P91 to around 4500. And so on, until the value for VC in changing temperature conditions stabilises at a nearly constant value (see Fig. 8). *Note*: it is important to recognise that this technique only works if the corrected viscosity is truly constant and is not legitimately changing.



P90 = P91 = 0

P91 INCREASED

P91 FINE TUNED

Fig 8 Manual Derivation of P91

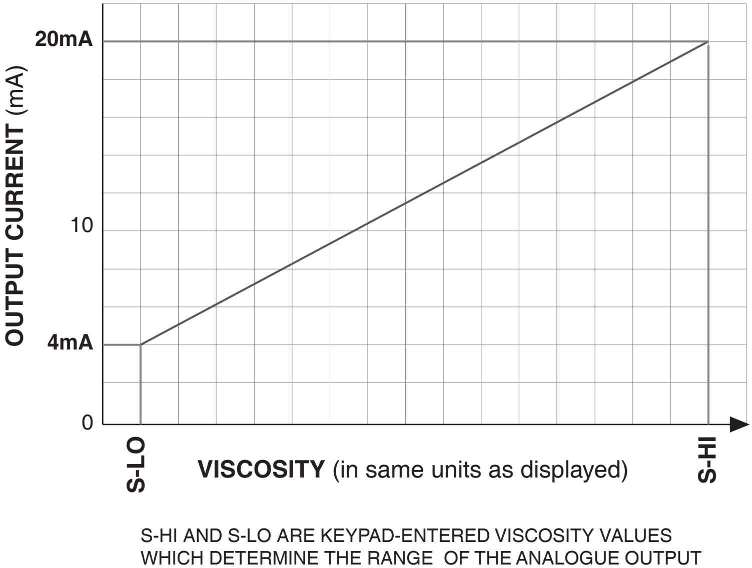
3.7 Analogue Output Scaling

The 4-20mA analogue output representing viscosity is configured in the dAC sub-menu in Setup Mode (‘dac’ means ‘digital to analogue converter’).

There are two points which require setting, S-HI (scale high) and S-LO (scale low). The viscosity value representing 20mA (highest point on the scale) should be entered in the S-HI display and the viscosity value representing 4mA (lowest point on the scale) should be entered in the S-LO display. **The viscosity figures entered will be in the same units as the viscosity displayed on the main display.**

See Fig. 9.

Remember to press CAL on the ‘burn’ display if the settings are to be permanently retained.



S-HI AND S-LO ARE KEYPAD-ENTERED VISCOSITY VALUES WHICH DETERMINE THE RANGE OF THE ANALOGUE OUTPUT

Fig 9 Analogue Output Scaling

3.8 RS232 Serial Data Link

The Serial Data Link Option runs Modbus Protocol on RS232 hardware standard.

The full Modbus protocol description can be found in the Appendix. Electrical configurations for the serial port are shown in Section 2.

The displays for configuration of the Serial Data Link can be found in the **SEr** sub-menu in Setup Mode. These are as follows:

bAud	Baud Rate - 1200, 2400, 4800,or 9600
pAr	NONE, EVEN or ODD parity
Addr	Slave address in range 1 to 127
diAG	4-digit diagnostic indicating the status of the slave port

The full Data Address Map showing the transmitted parameters is given in the Appendix.

4 Calibration and Maintenance

This section assumes the reader is familiar with the operation of the Viscolite as described in Section 3.

4.1 Basic Calibration Checking

Following power-up the Viscolite will display the dynamic viscosity of the fluid surrounding the sensor. Unless it has been damaged, any unexpected results are unlikely to stem from the sensor, but will probably be due to the properties of the fluid (non-newtonian behaviour).

Remember also to consider the nominal density of the fluid in the LCAL menu. This is factory-set to 1.000g/cc but if the fluid density is different then it will affect the absolute accuracy of the measurement.

If there is no process fluid and the **sensor is perfectly clean**, the instrument should read zero. A check for a zero reading is an excellent verification of calibration. If there is an opportunity to test with a fluid of stable and known viscosity, such as water (1cP @ 20deg. C), then a further calibration check of the instrument can be made by comparing the reading on the display with the expected value.

Note: When the instrument is first introduced into a liquid which is at a different temperature to the transducer there may be a period of temperature equalisation needed. This will be seen as a gradually changing - sometimes dithering - reading depending on temperature difference. Care should be taken not to make any judgements on instrument calibration based on observations during this period.

4.2 Testing Newtonian Fluids

The Viscolite 700 has been rigorously calibrated to traceable standards using silicone test fluids. Silicone oils are Newtonian, that is, they do not exhibit a noticeable change in viscosity with shear rate. With its high repeatability, the Viscolite can be expected to maintain its absolute accuracy when measuring other Newtonian fluids.

As a result, the process readings for Newtonian fluids should compare well with any other viscometer that has been *well-maintained and calibrated*. Care should be taken to ensure that, in any comparison, the conditions at the reference viscometer should exactly match those experienced by the Viscolite 700 in the fluid — in particular, temperature, which can have a dramatic effect on viscosity.

It is common for the Viscolite reading to be matched to some other reference viscometer which may produce a measurement in an obscure or arbitrary viscosity unit. This should not be considered as recalibration but ‘rescaling’, and is covered in Section 4.4.

4.3 Testing Non-Newtonian Fluids

The Viscolite 700 operates at very high shear rates. For shear rate dependent, non-newtonian fluids, the viscosity reading will be that for high shear rates.

Generally, most non-newtonian fluids are shear thinning and the very high shear rate of the Viscolite will usually mean a lower reading than the relatively low-shear rotational-type laboratory instruments.

However, *repeatability* is maintained, even in very non-newtonian fluids, and the Viscolite will accurately track any changes in viscosity in the fluid. If required, the reading can be scaled so the displayed value matches the viscosity from a reference viscometer operating at another shear rate. This is covered in more detail in Section 4.4, following.

4.4 Instrument Calibration and Recalibration

All instruments are factory-calibrated using a range of reference fluids. The standard reference fluids are certified silicone oils, although in some cases alternative fluids can be used by special request.

The result of the factory calibration phase is a series of P-constants which are located in the LCAL menu in Setup Mode. The P-Constants define the characteristic response of the resonant system to fluid damping and can be found on the Calibration Certificate; the calibration curve they define is only likely to change if there has been a modification to the physical structure of the transducer. The main sources of such change would be physical damage, wear or corrosion, or possibly operation outside of specification. If the instrument is used correctly and there is no reason to suspect wear or damage, a discrepancy between the Viscolite and a reference may be caused by one or both of the following:

i) The calibration status of the reference viscometer is uncertain
ii) The fluid is non-newtonian and the difference in apparent viscosity readings is a result of different shear rates between the two instruments

Table 1 identifies the various circumstances where an adjustment to the factory calibration settings may be contemplated.

Table 1

Scaling and Calibration Adjustment of Viscolite Viscometers

1	Minor Null Adjustment	A non-zero value of viscosity in air can be nulled by entering appropriate offset value in **OSEt** display in **FCAL** menu
2	Minor Calibration Adjustment	Use **SPAn** in **FCAL** menu to alter gradient of calibration curve
3	Scale Viscosity Reading to other Units	Enter Conversion Factor into **SCAL** in **LCAL** menu
4	Scale Viscosity Reading to match the reading from a reference instrument. Usually with non-newtonian fluids	Use **SPAn** in **FCAL** menu to alter gradient of calibration curve The value to be entered in **SPAN** will be the ratio of readings from the Viscolite and the reference instrument.
5	Full transducer recalibration	Return to factory

Minor calibration adjustments are simply handled using the Span and Offset facility built into the instrument and can be easily performed by the user; full recalibration is beyond the scope of most users since it requires a special thermally-controlled environment, traceable standards and equipment, and sophisticated calibration programs.

4.4.1 Minor Null Adjustment

With the sensor free from any fluid and completely clean and dry, the reading in air should be zero. If there is a non-zero viscosity reading it should be small (less than one unit). This is easily nulled using the OSEt display in the FCAL menu.

4.4.2 Minor Calibration Adjustment

Any adjustments to factory Calibration are easiest achieved using the SPAn entry in the FCAL menu rather than attempting to recalculate new P-constants. Simply adjust the value of SPAn to make the Viscolite display reading of VL match the expected result. Also in the FCAL menu, the value of viscosity before the SPAn factor is applied, V, can be observed, as well as the value after SPAn, VL.

4.4.3 Scale Viscosity to Other Units

Conversion to other units of viscosity is achieved using the SCAL display in the LCAL menu. The conversion factor to change from one unit to the other is simply entered in SCAL.

For example: Convert cP to P set SCAL = 0.01 (1 cP = 0.01 P)

4.4.4 Scale Reading to Match Reference Viscometer

As with many adjustments to factory settings, rescaling the viscosity reading for a non-newtonian, or to match another instrument, is easiest using the SPAn entry in the FCAL menu rather than attempting to recalculate new P-constants. Simply adjust the value of SPAn to make the display on the Viscolite match the result from the reference instrument.

To calculate the appropriate value of SPAn use the following equation:

$$\text{SPAn} = \frac{\text{Reading of reference viscometer}}{\text{Reading of Viscolite}}$$

The value of viscosity before the SPAn factor is applied is shown in the FCAL menu as V and the value after SPAn is VL.

4.4.5 Full Recalibration

A full recalibration should only be necessary in the following situations:

i) Following repair after damage to the transducer
ii) Corrosion or erosion of the sensor
iii) Operation outside specification of sensor e.g. extreme heat
iv) Special request calibration for special non-newtonian fluid
v) Routine calibration to comply with Quality Assurance Procedures

Air and water checks are useful but to test for a fundamental shift from factory calibration, the Viscolite can be tested by immersing the sensor in a fluid of known viscosity. To perform this test accurately is more difficult than it may seem. There are many effects, mainly associated with temperature, which can lead to potentially erroneous results so patience and care are essential.

Set up the instrument as shown in Fig.10. Follow all recommendations: do not rush the test — temperature equalisation is very important, and takes a particularly long time with highly viscous fluids. Use only *certified* standard calibrated silicone oils.

Small variations in calibration can be adjusted using SPAn as described in

Section 4.4.2 or 4.4.4. If a full multi-point recalibration is required contact Hydramotion or its representatives regarding full Calibration Service.

IMPORTANT NOTES

1. Ensure transducer is stably supported whilst testing
2. Sensor should be immersed to depth shown in Fig. 9
3. Allow time for sensor and fluid to reach same temperature
4. Ensure all calibration fluid sample is at the same temperature by stirring
5. Calibration fluid must be at the same temperature as that shown on its Certificate
6. Caution should be taken with highly viscous fluids; temperature equalisation is very slow and large errors can result if sufficient time is not allowed

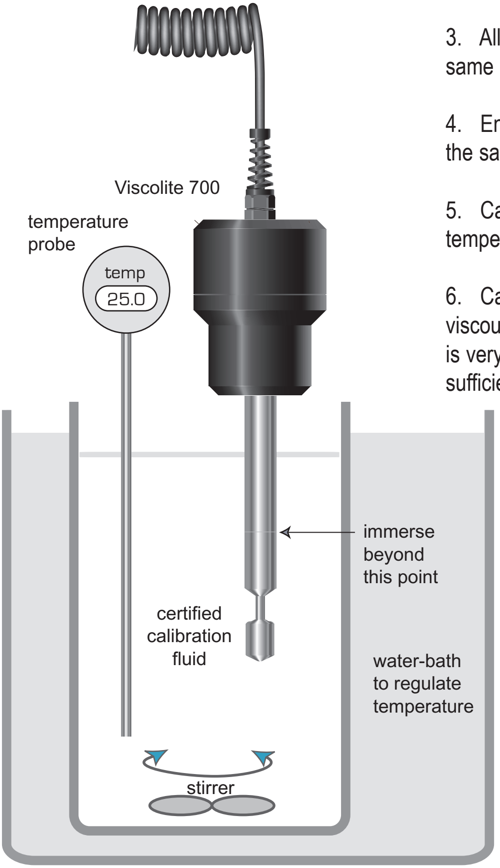


Fig 10 Checking Viscolite reading against traceable reference fluid

4.4.5.1 Return for Calibration Service

The instrument packaging should be retained for the purpose of return shipping for calibration, service or repair. Ensure the Viscolite is securely packaged to minimise the risk of damage in transit.

Accompanying documentation should clearly state the reason for return with any supporting information, quoting instrument Serial Number. Any commercial considerations (costs, export/import documentation, formal order etc) should be clarified prior to shipment.

Following formal calibration the instrument will be issued with a new Calibration Certificate showing the revised Calibration Constants.

4.5 Viscolite Maintenance

Maintenance requirements are minimal, as the instrument contains no seals, bearings or moving parts.

The transducer can withstand vigorous cleaning so long as the sensor shaft is not distorted in any way. Check for signs of wear or abrasions which might indicate an impact received during service.

The following checks will ensure correct instrument operation:

1. Always operated within instrument specification
2 Periodically check for damage
3. Remove batteries when not in use for prolonged periods
4. Whenever possible, keep transducer in its case or protective packaging and avoid leave resting on the sensor shaft
5. Never use sensor for levering or any other non-measurement activity.

Appendix

Modbus Protocol for Serial Data Link

Introduction

The HP550 supports a single RS422/485 or RS232 serial port, allowing process data to be read and parameters to be read and modified.

The protocol used is a subset of the modbus ASCII standard whereby the HP550 acts as a slave to a host master computer. Up to 20 slaves (identified by unique addresses) may be connected on the same RS422 serial line. The host computer is responsible for initiating all communications and, to allow the HP550 sufficient processor time to perform its measurements and calculations, should not poll more frequently than once per second.

HP550 serial settings

Access to the HP550 settings is via the “SEr” menu item within the Setup menu. The serial menu offers -

1. baud - 1200,2400,4800 or 9600 - factory setting: 1200
2. par - NONE, EVEN or ODD parity - factory setting: EVEN
3. addr - slave address in range 1 to 247.
4. diag - 4 digit diagnostic indicating the status of the slave port.
   1st digit - telemetry task stage.
   2nd digit - result of decoding host query.
   3rd digit - parity error status.
   4th digit - framing error status.
5. burn - to write the settings to e2 memory
6. esc - to ascend to the technician menu.

The settings must match those of the host computer.

For instructions on entering Setup Mode and making changes, see Section 3.

NOTE: Four null characters precede the colon at the start of each HP550 transmission to allow time for synchronisation with the transmission.

Character format

For no parity -
1 start, 7 data and 2 stop bits
For even and odd parity -
1 start, 7 data, and 1 stop bit

With the exception of the start and end frame, all characters are in the ASCII hexadecimal printable character range 0 to 9 and A to F.

Query - response overview

The host computer issues a query message in the following general format:

Beginning of frame - a colon character.
Slave address - range 1 to 247.
Function code - identifies type of query (or command).
Start address - data address within the modbus map.
Count - no. of data items to be read.
LRC - result of error check algorithm.
End of frame - carriage return followed by line feed.

The HP550 receives and validates the message and responds with:

Beginning of frame - a colon character.
Slave address - range 1 to 247.
Function code - identifies type of query or command.
Byte Count - no. characters in the data content.
Data content - function code dependent.
LRC - result of error check algorithm.
End of frame - carriage return followed by line feed.

Function code 04 - Read input registers

Obtains value of one or more holding registers. The HP550 regards calibration constants etc as sets of holding registers. As the Modbus protocol only supports 16-bit format registers, the constants are individually scaled (e.g 0 - 1,000).

example query

:	start of frame
01	slave address
04	function code
0000	start address
0002	data count (4 registers)
F9	LRC
0D0A	CR-LF (end of frame)

example response

:	start of frame
01	slave address
04	function code
04	data count
00D8	cyclic counter value
0C3D	VL (scaled 0 to 1000)
D6	LRC
0D0A	CR-LF (end of frame)

00FF	cyclic counter
7FFF	VL half-scale

Data Address Map

Holding registers are mapped as follows:

Format Dependent Address	Parameter	
0000		**cyclic counter**
0001	**VL**	**line viscosity**
0002	**VC**	**corrected rigidity**
0003	**t**	**temperature**
0004		**alarm low limit**
0005		**alarm high limit**

Representation of status data

For the reading of coils and status data, 4 points are packed into one character. The hexadecimal equivalent of the first character contains the first 4 addressed coils. The low order bit of this value represents the first coil and the rest follow.

LRC algorithm

The error check is an 8-bit binary number represented and transmitted as 2 ASCII hexadecimal characters. The error check is produced by converting the character pairs in the message (excluding start of frame and the LRC CONTENT) to binary, adding the binary values together without wraparound carry and twos complementing the result.