Twickenham
Scientific Instruments

The Superconducting Magnet Controller (SMC)

Instruction manual, release 5.52 onwards

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Contents

In this manual, different typefaces have been used to highlight specific details. Following is a list of the special typefaces used.

Text in this typeface refers to the front panel button, e.g. Heater, or a connector on the back panel; the word on the unit is also written in slanted text.

Text in this typeface is describing a message on the display

`Text in this typeface is describing a message available via the computer interface.`

In the text, reference to the "SMC120-05" is used as an example, and should be taken as to include the unit actually supplied, unless otherwise stated.

Operating Precautions.

Superconducting magnet coils can have a substantial inductance and large energy storage capacity. To ensure safe operation, the leads from the power supply must be rigidly and permanently attached to the magnet. When the coil is energised the power supply must not be removed unless a suitable safety circuit has been fitted to the magnet. Any such safety circuit must be capable of absorbing the energy stored in the coil and prevent the occurrence of dangerous voltages at the magnet terminals or between magnet terminals and earth.

The voltage sense input, if used, must be securely and correctly connected to the magnet. This feature is available for units with the internal reversing switch BCSV or ECS options, but *not* those with just the BCS option. This feature must not be used if an external BCS option is installed. If the voltage sense input is reversed the power supply can never detect a voltage limit condition and will limit the maximum difference between output and magnet terminal voltage to 1.4 V. If this condition is maintained two fusible resistors in the power supply will burn out, making remote voltage sensing ineffective. Damage to these components is NOT covered by the warranty.

Serious damage to the power supply can only occur if a reverse current flow is forced through the unit. Under these conditions a very large voltage can be developed at the output terminals. If there is any possibility of such a condition arising, the power supply should be further protected with an external thyristor circuit available from Twickenham Scientific Instruments Ltd.

The unit must be connected to Earth

The unit must not be operated with any of the covers removed.

General Description.

The Twickenham range of Superconducting Magnet Controllers (SMC) provide a number of output current and drive voltage options. All models are based on the same fundamental design which has been specifically conceived for energising superconducting magnets. The frequency response of the double-stabilised analogue control loop, which operates in either voltage or current control modes, is tailored to ensure stability even when driving a purely inductive load. The switch mode power unit and the analogue output stage are both forced-air cooled.

The power supply incorporates a sophisticated microprocessor unit, with all operations controlled through the internal firmware. This provides great flexibility to respond to special requirements and for the evolution of high levels of 'intelligent' control. All operating functions are available either locally at the front panel or remotely via a standard digital interface.

Front panel control is via twelve push-button switches. Status indication is via an 80 character backlit alphanumeric liquid crystal display and eight LED indicators on the switches. Remote control is possible using the RS232 interface.

Adjustable parameters are held in a non-volatile memory. Configurations are therefore retained between runs but changes, to suit a different magnet system or a different mode of operation, are easily made by the user.

Two adjustable target current settings are available. Target currents can be set to 16-bit resolution (0.0015% of full output). The two set points are mutually limiting, such that the Upper point can never be set to less than the Lower point. These adjustable settings are in addition to the fixed zero target point and the arbitrary ramp pause facility. The display of current output can be switched between the direct Amps value or a calculated Tesla value (providing that a Tesla per Amp constant has been entered via the computer interface).

A digital ramp generator, under software control, drives high stability sweep control circuitry. Any one of 65 preset ramp rates may be selected. The ramp can be halted indefinitely with a temperature related drift no greater than 20 ppm/°C.

An adjustable voltage limit controls both the positive (ramping up) and negative (ramping down) voltages. Voltage limiting overrides the ramp generator if necessary. In the SMC120-05, and higher output supplies based on this unit, the voltage limit applies symmetrically about zero. In other models, the negative voltage limit is slightly less than the positive limit to reduce power dissipation on magnet de-energisation. The voltage limit can be set to a resolution of approximately 0.1 V.

The voltage limiting circuit can operate from an optional sense input. This enables voltage control directly from the magnet terminals to eliminate voltage drops in the connecting leads. When the sense input is connected, control from the power supply terminal voltage is automatically overridden. This feature is available for units using the BCSV or ECS reversing switch options, but *not* the BCS option.

Automatic quench protection shuts down the power supply immediately an increasing voltage with falling current is detected. A quench can be detected while not ramping and while ramping down, as well as when ramping up. A passive voltage limiting circuit across the output stage provides quench protection even when no power is applied to the unit, allowing the magnet to discharge through the power supply circuit with the terminal voltage clamped to a safe level.

The reference current shunt is manufactured from a very low temperature coefficient alloy ($< 5\,\text{ppm}/^\circ\text{C}$ over the range 15 – 40°C). For precision monitoring of the output current, the shunt voltage is available at the 'DVM' output on the rear panel. The output is unbuffered for the single unit models, buffered for the master-slave models. A calibration for the DVM output to 0.03% accuracy is marked on each individual power supply.

A secondary adjustable output for a persistent mode switch heater gives an output in the range 0 - 255 mA with 18 V compliance voltage and is protected against short term overload. The output current flowing when this output is switched is recorded by the firmware in non-volatile storage, and is used to generate a message on the display to remind the user that there may be a persistent mode current flowing in the superconducting magnet.

Preparing the unit for use

It is recommended that the packaging materials be retained as they serve as useful protection for possible future transportation of the unit.

A mains lead is supplied. The other end of this lead should be fitted to the available AC power line. Where appropriate, a lead with a moulded plug is supplied. If such a lead is not available, or suitable, the colour codes used in the lead are: Brown = Live, Blue = Neutral, Green/Yellow = Earth. Check that the input voltage rating matches the supply to which it is to be connected. The unit must be earthed.

A set of current leads may be supplied. For systems with M6 terminals, these will have 6 mm tags fitted at the end to be connected to the power supply, and a suitable size at the end to be connected to the cryostat.

The recommended torque when fitting the leads to the power supply is 3 – 5 lbft or 4 – 7 Nm. This ensures a good contact without overstressing the terminals. Always hold the cable tags when tightening to ensure that the terminals do not twist. Master – Slave systems should have their the current output terminals wired in parallel.

Other interconnecting cables between the Master unit and each and any Slave are also supplied, and should link the units as indicated by the labelling of the LEMO sockets. Similarly interconnecting cables between the unit and any external BCS / ECS unit should link the units as given in the separate manual for that unit.

The power supply is designed to drive inductors with low DC series resistance. To enable a short circuit test to be performed, the far ends of the current leads should be bolted together. If an attempt is made to run the supply with open circuit terminals, no damage will result.

Before switching on the power supply, ensure that there is a minimum of 150 mm clear space behind the unit to allow a free flow of air, and that the side ventilation holes are unobstructed. When mains power is applied, check that, after the self checking messages, the sign-on message is written to the display, that the *Zero* indicator (only) is on, and that the cooling fans are delivering a strong flow of air to the back of the unit.

Rear Panel Connections.

Mains Input

This is an IEC CEE22 socket for connection to mains supply. Supply requirements are shown on the rear panel:

200–250 Volt 50/60 Hz

Overall power line protection is provided by a circuit breaker integrated into the front panel power switch. This physically trips the switch to the off position if the input current exceeds 16 Amps. In addition, the main power unit, electronics power supply and the fan drive are protected by individual fuses.

Output +, Output –

For low current output modules, this is provided by a pair of M6 terminals to bolt the current leads to the flats of the terminals. For high current output modules, this is provided by a pair of M12 studs, to which the current lead is connected with the supplied nuts and washers. The recommended torque when fitting the leads to the terminal studs is 3 – 5 lbft or 4 – 7 Nm. This ensures a good contact without over stressing the terminal studs. Always hold the cable tags when tightening to ensure that the terminal blocks do not twist.

DVM +, DVM –

4 mm jack sockets for connection to external DVM. This provides direct reading of shunt voltage at 600 ohm source impedance (buffered for high output master – slave models). A calibration for this output is marked on the rear panel.

RS232 Interface

A standard 9 way D type connector is fitted for remote control via the RS232 interface. The interface is optically isolated from the power supply output.

Sense & Heater

A 5–way 240° DIN connector for optional connections to cryostat, the wiring of which is given by the table below. Note that units with the internal BCSV or ECS option have the Sense wires available at this socket, but there is no connection at this, or any other socket if the internal BCS option is fitted. Units with the external BCS option should not have the sense pins connected under any circumstance.

Pin	Function
1	Heater –
2	Sense –
3	Screen (see below)
4	Sense +
5	Heater +

Pin 1 is at the bottom left hand corner of the accessory plug. Pin 3 (screen) is common 0 V referenced to power supply internal 0 V. This is not isolated from the output and should not be used as a through connection.

XTrip – The External Trip Input

A 2–pin LEMO connector for an optional external trip switch or TTL drive. Pin 1 is the positive, or IN.

The external trip feature may be implemented and enabled by the user. The input can either be driven low by an open collector TTL gate capable of sinking 12 mA, or a switch connected between these two pins may be used to change the input state.

If the command `X1` is issued over the remote interface, the pins on this connector must be short-circuited or the IN pin driven low for the power supply to operate. If these pins are then open circuited (or if the IN pin is driven high) while the power supply is delivering current, the output will be immediately shut down (and the heater output will be switched on temporarily to ensure that a magnet in persistent mode is de-energised). The action is similar to that taken on detection of a 'quench', except that the display reads External Trip at... instead of Quench Trip at.... The external trip may be disabled by the command `X0` via the interface.

BCS / ECS – The Bipolar Current Switch Control

This connector is fitted on units requiring an external BCS or ECS option or where where no BCS / ECS option has been specified, and a retro–fitted connector and cable assembly to enable a future upgrade to add an external BCS / ECS would be difficult. Units with the internal BCS, BCSV or ECS options do not have this connector on the back panel.

A female DB9, or 10 pin LEMO for connection to an external BCS / ECS reversing switch unit. The wiring of the connector is given in the table below.

Pin	Function
1	FWD Output
2	REV Output
3	No connection
4	No connection
5	No connection
6	No connection
7	ID Input
8	STATUS Input
9	0 V Ground
10 (LEMO only)	No connection

The input on pin 7 reads high if no BCS / ECS is connected. When connected, a BCS / ECS pulls this line low.

The input on pin 8 reads high if no BCS / ECS is connected or if the BCS / ECS is short-circuiting the output (by being instructed by the control outputs, by being un-powered or by a fault condition). It reads low when the BCS / ECS is correctly set to either the forward or the reverse direction.

The BCS / ECS is set into the forward direction when the pin 1 output is high and the pin 2 output is low. It is set into the reverse direction when the pin 1 output is low and the pin 2 output is high. The BCS / ECS short circuits the output current if both outputs are low or if both outputs are high.

Local operation of the SMC

Front Panel Controls and Indicators

The front panel carries an illuminated main on/off switch (with integral circuit breaker), a 4 line by 20 character backlit liquid crystal display, and 12 engraved push-buttons (7 of which have LED status indicators). The push-buttons are arranged in a numeric keypad, and are therefore engraved with the numerals 0 - 9, decimal point and ENTER. Around the keys, the panel silkscreen shows the main function of these keys.

Reading from the top, and working clockwise, the main function of these keys are as follows:

Heater (L)	Switches the switch heater output on and off.
Up	Adjusts parameter values upwards.
Set	Selects parameters for adjustment.
Down	Adjusts parameter values downwards.
Remote/ENTER (LL)	Switches between remote and local control (see section 5).
Units (L)	Switches between Amps display and Tesla display.
Pause (L)	Suspends and releases ramp generation.
Zero (L)	Selects Zero Amps as the ramping target.
Lower (L)	Selects the Lower set point as the ramping target.
Upper (L)	Selects the Upper set point as the ramping target.

Buttons marked (L) have inbuilt red LEDs and are illuminated when active.

The button engraved 2 is used to select the secondary parameter(s), namely the output of the persistent mode heater switch power supply. The button engraved 5 has no other function.

The *Remote*/ENTER button also has a second, green, colour. The green LED lights up when the *Remote*/ENTER button is used to select the numeric keypad function. The red LED lights up when the unit is under remote control.

Power Up Conditions

When the unit is first switched on, a number of power-up checks are performed. While these are being done, the display shows

SMC - POWER UP TEST

If these are all successful, the second line will show the model number of the unit, and the third line will show the version number of the controller firmware.

SMC120-05 ROM Version 5.5x

Shortly afterwards, the top line of the display will show the terminal current on the left, and terminal voltage on the right.

Power-up defaults are *Zero* selected, *Pause* off, *Units* off and *Heater* off.

If a persistent mode condition was recorded when the SMC was last switched off then the SMC display will then show the message Heater switched off at x.x A on the lower two display lines. See ***The** Heater **Button*** for details.

If the standard External trip was enabled when the SMC was last switched off and the back panel input is in the disabling state (open or driven high) then the display will power-up showing the message External Trip Active on the lower display line. See ***The External Trip*** below and the comments concerning the `Xn` command in the next chapter for details.

Any other message on the display at power-up indicates that one of the initialisation checks failed (these messages are shown in Appendix 2). If a fault message appears, the unit will be inoperable. If the message is NOVRAM STORAGE FAULT Press “SET” & “UP”, see Appendix 3 for recovery information. Otherwise please contact Twickenham Scientific Instruments Ltd. for advice if any of the fault messages are seen.

Quiescent Status

When the SMC is switched on, the bottom two lines remain blank, so long as there is neither a persistent mode current in the magnet (according to the recorded settings within the SMC unit), or an active External Trip; these messages will remain on the display until any button is pressed. The *Zero* button is convenient to use as it is already active and will have no other effect.

```
0.00A            0.0V
     SMC120-05
L=80.00A    U=120.00A
 5.0V          4.92A/s
```

Typical Quiescent Status Display

The lower two display lines will then show the four most important parameter settings. The display now showing is the typical Quiescent status layout. On the third line down are then shown the Lower set point value and the Upper set point value. On the bottom line the the voltage limit value and the ramp rate value are shown. These parameter values will be as on the previous power-down.

Note that only the power-up version and interface message is cancelled as described above. The External Trip Active and Heater switched off at x.x A messages are not cancelled until the respective condition is cancelled.

The* Set*,* Up*, and* Down *Buttons

The four parameters shown in the normal quiescent status message may be changed by simple operation of the *Set* button, together with *Up* and *Down*. The first press of *Set* will enter the 'set mode' and bring the setting message for the last accessed parameter to the lower display line. Further presses of *Set* will cycle through the four primary parameters. When the message for the required parameter has been selected in this manner, the *Up* and *Down* buttons may be used to change the value.

A single short press of *Up* or *Down* will change the value by the standard step size. Holding the button in will, after a short delay, cause the value to auto-step. The changed value is not entered into the controller until the button is released. When the new value is entered, it comes into immediate effect to change any active or pending operation.

There are two methods available to prevent the entry of an incorrect value. Firstly, if both the *Up* and *Down* buttons are pressed simultaneously, stepping will halt. This provides a means of changing the stepping direction without entry of the intermediate value. Secondly, if *Set* is pressed simultaneously with either *Up* or *Down*, the parameter will return to its starting (last entered) value to cancel all previous stepping. These facilities are only of importance if settings are being changed while the power supply is in active operation.

The standard step sizes are 0.1 A for the *Lower* and *Upper* set points, and 0.1 V for the voltage limit. The ramp rate is stepped in a logarithmic fashion at 16 steps per decade.

For a finer setting of the *Lower* and *Upper* set points, or if a large change is required in these parameters, is it more suitable to use the numeric keypad to alter the values. The numeric keypad can also be used to set the voltage limit and the output of the persistent mode switch heater supply.

Set mode may be entered at any time during operation of the power supply. When *Set* is pressed, the setting messages replace any other messages on the lower display line. With no activity on the setting buttons (*Set*, *Up* or *Down*), the lower line will revert to the normal display after 10 seconds. Set mode will also be cancelled by operation of any of the non-setting buttons. Pressing of the currently active ramp selector button (*Zero*, *Lower* or *Upper*) will therefore force restoration of the normal display before the setting time-out with no other effect.

Setting the parameters with the Numeric keypad

If a finer setting of a parameter is required, or else a large change needs to be made, then the numeric keypad can be used. The parameter to be changed is called up on the lower two lines as described in the previous section. Instead of altering the parameter with the *Up* and *Down* buttons, the ENTER/*Remote* key is pressed. The green LED will light up, and while this LED is lit, all the buttons have the function that is engraved on the buttons, i.e. entering of a numeral. The bottom line of the display will also change, with the current numerical value of the parameter shown being replaced by 0.

```
0.00A              0.0V
      SMC120-05
 (L)ower Set point =
        20.  A
```

Typical Set Mode Display using Numeric key functions
(part way through this operation)

The value of the parameter is entered in the same way as a number is entered into a calculator with one exception. If the value entered is wrong, for whatever reason, then the way to clear the number to start again (the Clear Entry function of a calculator) is to ensure the decimal point is pressed for a **second** time. If the decimal point has not been pressed at all during this entry, it will need to be pressed twice; if the decimals were already being entered when the error was spotted, then the decimal point only needs to be pressed once more.

Note that it is the number as shown on the display that will be entered when leaving the numeric keypad function; if nothing has been entered when the numeric keypad was active, then that parameter will be set to zero, unless other factors as discussed put a lower limit on the value (for example the *Upper* set point value).

Once the value is entered, the ENTER/*Remote* key is pressed again. The green LED will go out, and all the buttons will return to their normal functional state. The display will return to the initial 'Set mode' display, with the new value showing, subject to any limits on the value entered. If the value entered is greater than that possible, it will be substituted for the maximum possible value when returning to the 'Set mode' display.

The** Zero**,** Lower **and** Upper **Buttons

A ramp from zero is initiated by pressing the *Lower* or *Upper* button. The *Zero*, *Lower* and *Upper* buttons are interlocked, with the currently selected target being shown by the appropriate LED indicator. While ramping to one of these target settings, the lower two display lines will show the target current and the ramp rate.

```
26.35A          2.8V
    SMC120-05
Ramping to 110.00A
    at 4.92 A/s
```

Typical Active Ramp Display

If the selected ramp rate causes the terminal (or sense) voltage to rise to the set voltage limit, the ..at x.x A/s message will change to the ..at +ve volt limit or at -ve volt limit message as appropriate.

Any changes to the set points, voltage limit or ramp rate will have an immediate effect on any active or pending ramp, and so may cause the Ramping.. message to be changed (when this is returned to the display after the setting operation). The message will also be changed if a different ramp target is selected before the ramp has completed. When the power supply is holding on a target (other than zero) and the value of that set point is changed, this will re-activate ramping and produce a new ramping message on the display (but, again, this will not be seen until set mode is terminated).

The completion (or halting) of a ramp will be indicated by the return of the quiescent status message to the display (this is normally the four parameter values).

The** Pause **Button

A ramp may be halted before the selected target has been reached by use of the *Pause* button. *Pause* alternately enables and disables the ramp generator, with the indicator being illuminated when ramping is disabled (i.e. *Pause* on). Any Ramping.. message will disappear from the display, as if the ramp had completed.

When *Pause* is on, the ramping target may be reselected and/or parameters adjusted with no effect until the *Pause* is released. When *Pause* is switched off, the Ramping.. message will reappear on the display (if appropriate).

The digitally implemented *Pause* function has excellent long-term stability, equivalent to that achieved when holding normally on a set target current. However, the *Pause* will not provide an instantaneous holding of the magnetic field value, or necessarily of the displayed output current on the front panel, for reasons such as magnetic induction, time constants within the SMC and the external circuit etc.

The* Heater *Button

If the magnet is fitted with a persistent mode switch, the heater should be switched on (*Heater* indicator illuminated) before starting to energise the magnet.

Note that the *Heater* button can only be operated, to either switch on or switch off, when no ramping is active. If an attempt is while the power supply is ramping, the heater does not turn on (or off), nor does the indicator change state; however a message appears on the display and stays there for 5 seconds, when it then returns to the message there before the *Heater* button was pressed.

```
87.35A              2.1V
      SMC120-05
  Ignored attempt to
 switch heater on/off
```

Typical display showing the warning message when the heater status is attempted to be changed while the SMC is ramping the current

Ramping is inactive when the selected target has been achieved, or if *Pause* is on.

In addition to ignoring any attempt to change the status of the heater while the power supply is ramping, there is a check to ensure the output current is the same as the SMC's stored persistent mode current value.

If the output current is held and matches the stored persistent mode current value, then pressing the *Heater* button will turn on the heater supply, and the indicator in the switch illuminates. The message Heater switched off at..., if it was on the display before, will disappear, to leave either other messages or the typical quiescent state display.

If the output current is held, but does not match the stored persistent mode current value (including a reset or zero value) then when the *Heater* button is pressed, the only action is that the following message appears on the display.

```
87.35A          1.1V
    SMC120-05
 O/P I not equal to
 persistent mode I
```

Typical display showing the warning message when an attempt to change the heater status when output current is not equal to the SMC's record of the persistent mode current.

This message appears on the display for 5 seconds, when it will then revert to the message that was there before the attempt to turn on the heater.

This double checking is to alert the user to a potential accidental de-persistance of the switch when the current leads are not at the same current as the magnet, which could cause a magnet trip, quench or even worse consequences.

If the attempt to turn on the heater is correct, that is the user is fully aware that they are turning on the heater when the output current is different to the stored persistent mode current, then the following procedure has to be followed to actually turn the heater on.

Firstly, an attempt to turn on the heater in the normal way is made; this produces the message on the display as shown above. *While this message is on the display*, the 2 button must be pressed and held in, and then the *Heater* button pressed. This will turn on the heater, and the indicator illuminated.

Operation of the persistent mode switch may be checked by following the above procedure at very low currents. Ramping the power supply to 2 or 3 Amps (use *Lower* or *Upper* together with *Pause*) with the heater off. An inductive voltage kick should be seen when the heater is then switched on, following the two-stage procedure in the previous paragraph. A similar method may be used to check the minimum current required to open the switch by progressively stepping up the switch heater current output from zero). This is *not* the optimum setting for the heater current output.

The normal quiescent (non-ramping) status message is, as described above, the four primary parameter values. If the heater is switched off with the power supply delivering current (which the power supply interprets as the switching of a magnet into persistent mode), the status message will change to a record of the current at which the heater was switched off.

```
0.00A              0.0V
     SMC120-05
 Heater switched off
    at 110.00 A
```

Typical 'Persistent Mode' Display

No checks are made to establish whether or not a magnet has actually been put into persistent mode. The message is provided purely as a reminder to the operator. It is valid as a persistent mode indicator only if this is a valid assumption for the system as a whole.

In the case where there are significant inductive voltages produced when energising at the operating ramp-rate, the lack of a (negative) inductive voltage when reducing the SMC output to zero is a indicator that the user can use to support the assumption that the magnet is in persistent mode.

The Heater switched off at... message will remain on the display (except while ramping or setting parameters) until the heater is next switched on or the persistent mode record is reset.

If the power supply is powered-down with the magnet in this state, the information is retained in non-volatile memory and the Heater switched off at... message will replace the version number message and the standard quiescent state message on the next power-up.

The *Units* ***Button***

If a field constant has been entered, pressing the *Units* button will convert the terminal current display and the *Lower* and *Upper* settings to read in Tesla instead of Amps. Note, however, that the ramp rate continues to read in Amps per second. The *Units* button toggles between Amps and Tesla, with the indicator being illuminated when *Units* is selected. If no constant has been entered, pressing the *Units* button will have no effect and the indicator will not illuminate.

```
   0.000T          0.0V
       SMC120-05
 L=6.350T    U=16.300T
  5.0V          4.92A/s
```

Typical Quiescent Status Display With *Units* Active

The Remote *Button*

The *Remote* button will not normally be used, as switching between remote and local control modes is performed automatically via interface signals (pressing this button when the interface is not being driven will have no effect). The red LED on this button indicates the current mode. If the LED is on, control is from the interface and none of the other buttons will be operative.

However, if remote control is selected without being locked, the *Remote* button may be pressed to seize local control temporarily. The red LED will turn off and the other buttons will be operable. As long as the remote device maintains the nominal remote enabled state, the *Remote* button may be pressed again to return control to the remote device. The remote device may issue a command to prevent this use of the *Remote* button (locking ALL buttons, instead of all buttons except *Remote*).

Do not confuse the red LED in the *Remote*/ENTER button, indicating remote control with or without full local lock-out of all other buttons, with the green LED within the same button, which is only accessible when in Set mode and local control, and indicates the numeric keypad function of all the buttons. Note that either the red, or the green LED, on, or neither of them on, are valid states.

Setting the Secondary parameters

In the course of normal operation, the heater output value and the magnet's Tesla per Amp parameter do not need to be altered. However, there are occasions, for example in setting up of the system, when they need to be set. In addition, the means of re-setting the SMC's recorded persistent mode current value is included here, as another parameter which does not need to be accessed during normal operation.

The setting of these parameters is very similar to the setting of the four principle parameters, *Lower*, *Upper*, Ramp rate and voltage limit.

The set mode for the secondary parameters is accessed by pressing the button engraved 2 (for secondary), and while holding that button in, pressing *Set*. The set up mode for one of the secondary parameters will then appear on the display. To move onto the next secondary parameter, the 2 button has still to be held in when the *Set* button is pressed.

The heater output is set in milliamperes. The SMC contains a constant current source which will output the set current, up to the maximum compliance voltage of 18 V at 255 mA. The heater output is set, and can be altered in 1 mA steps. The changing of the value is done in precisely the same way as the other parameters. Once the parameter is altered, the new value will immediately become active. After ten seconds, the bottom two lines of the display will also revert back to the previous mode. Alternatively, once the set mode for the output current is on the display, the ENTER/*Remote* key can be pressed to use the numeric keypad function.

```
0.000T          0.0V
    SMC120-05
     Heater =
      25 mA
```

Typical set up mode for heater output

The setting of a suitable heater current value is necessarily for the trouble free operation of the magnet system. Care should be taken to ensure that the power required to depersist the switch of the magnet (as given by the manufacturer) corresponds to the recommended value for energising and de-energising the magnet, and not just to the power needed to trip the magnet out of persistent mode at a small field. The staff of Twickenham will be pleased to offer advice if there is any problem.

The Tesla per Amp parameter, again, is set in a similar manner to the other parameters, but it is recommended to use the numeric keypad. There is an allowable band of values for this parameter, that is between 0.01 and 0.5, which should include the vast majority of solenoidal superconducting magnets. Should a value smaller than 0.01 be set, a value 0.0 will be returned (this will also disable the effect of the *Units* button. If a value higher than 0.5 is entered, the maximum value will be returned.

```
0.000T              0.0V
     SMC120-05
  Tesla per Amp =
   0.148500 T/A
```

Typical set up mode for the Tesla per Amp parameter

There are occasions when the SMC's persistent mode current record needs to be reset to zero in a safe way, that is not involving the *Heater* button in any way in case of accidental de-persisting of the magnet.

In this case, the message on the display appears as

```
0.000T              0.0V
     SMC120-05
  Persistent mode I
  "ENTER" to clear
```

Typical display when about to clear the persistent mode record.

The ENTER/*Remote* button has to be pressed within 5 seconds, otherwise the display will revert to that before the sequence started. Pressing the *Set* button, or the 2 and the *Set* buttons will bring up another menu, and will not change or reset the stored persistent mode current value.

Using the Voltage Sense Input

This section applies to units without a reversing switch and to those fitted with the internal BCSV or ECS options.

The power supply can operate in both constant ramp rate and constant voltage control modes. Switching between these modes is performed automatically by the controller. If the set ramp rate does not cause the sensed voltage to rise to the set voltage limit, the controller operates in constant ramp rate mode. If the sense voltage rises to the set voltage limit, the controller switches to constant voltage mode.

Switching of the sense voltage source is also performed automatically. If no connection is made to the voltage sense input, the voltage control circuitry operates from the voltage at the main terminals. If a voltage drive is applied to the voltage sense input, this is used as the control voltage. The terminal voltage will then be allowed to rise above the set voltage limit.

Typically, the sense input is driven from voltage taps connected directly across the magnet windings. Constant voltage control will, in these circumstances, produce a constant rate ramp.

Care should be taken in setting the voltage limit, when operating with the sense input, to allow a sufficient margin for the maximum resistive voltage difference between the sense input and the main terminals. If the main terminal voltage rises to the nominal maximum voltage of the power supply, while the sense input is below the set voltage limit, the controller will switch into a pseudo constant voltage mode (to avoid saturation of the output stage) which is less smooth and stable than the genuine constant voltage mode (the display message is the same as the genuine voltage limiting mode, however).

Reversed voltage sense leads will cause approximately $20\,\Omega$ to appear across the load. When operating with large inductance coils this will cause a significant and unexpected time constant to appear. Furthermore, the two $10\,\Omega$ protection resistors will be damaged if this condition is prolonged. For these reasons, great care should be taken to connect the voltage sense leads with the correct polarity.

For systems with the BCS (**not** the BCSV or ECS options) installed internally, the voltage sense inputs are not connected to the back panel socket.

The voltage sense input should never be used if there is a external BCS in the system.

Reporting of external events and problems during the normal operation of the SMC

Introduction

There are a number of events that could occur during the normal operation of the SMC unit, for example a quench of the superconducting magnet, or a signal supplied to the External Trip input if this function has been activated. The response of the SMC to these events is to protect itself, and to go into a 'shut-down' mode; specific action by the user must be performed before the SMC can be restored to normal operation again.

Quench Detection

Should the magnet go resistive ('quench') for any reason, the status message will change to a record of the event, including the current flowing in the output terminals at the time of the quench. The power supply instantaneously switches the demand current to zero when it detects an increasingly resistive load. The SMC considers that a quench has occurred when there is a rapidly increasing positive voltage across its output terminals while the output current is decreasing (even if it is trying to energise the magnet).

The *Zero* ramp target selector will be indicated after a quench, and the message will remain on the display until *Set* or one of the ramp target selector buttons is pressed. While it is on the display, the units may be switched by use of the *Units* button. The power supply must be reset by switching off and on again after the trip.

After a Quench Trip, the user can still interrogate the SMC using the computer interface to get details of the event, but it will not respond to commands such as ramping to a set point.

```
0.00A            0.0V
    SMC120-05
  Quench Trip at
     104.40A
```

Typical 'Quench' Event Display

Note that a quench which occurs in persistent mode will be detected, but the current shown in the message will be the power supply terminal current at the time of the quench detection, NOT the true persistent mode current.

The Overvoltage Trip

The Overvoltage Trip is somewhat similar to the Quench Trip, in that it is a condition brought on by non-intentional external events. The significant difference is that this trip is generated by a rapidly increasing negative voltage across the terminals of the SMC. The power supply must be reset by switching off and on again after the trip.

```
0.00A              0.0V
      SMC120-05
  Overvolt Trip at
       104.40A
```

Typical 'Overvoltage Trip' Event Display

The Overtemperature Trip

When de-energising a superconducting magnet, the stored energy is dissipated from the internal energy absorber as heat, which exhausts from the rear of the unit. If, for this or any other reason, the temperature of the energy absorber gets close to exceeding safe working limits, a built in heat switch opens, which will generate the Overtemperature Trip.

When this occurs, the SMC unit will short out the output terminals so as to continue to run down the magnet, and otherwise shut down. On the display, the Overtemperature Trip message will be seen.

This condition cannot be cancelled until the internal energy absorber has cooled down sufficiently.

It should be stressed that this is a rare event, only likely to happen in four circumstances:

1 If the SMC has been installed into a cabinet with insufficient ventilation and/or external cooling, under the circumstances described above, all the heat is held within the cabinet. This raises the local ambient temperature around the SMC unit to beyond is rated maximum (40°C), and hence the temperature of the energy absorber will rise accordingly and exceed its maximum. The cure for this is to ensure sufficient ventilation around the SMC unit.

2 The ventilation holes in the side panels and in the back panel have become covered or blocked. It is simple to ensure that all the ventilation holes are clear.

3 The cooling fan for the energy absorber has become ineffective or has failed. The air flow from the fan can be felt at the back of the SMC unit, with the air blowing through the obvious heat sink assembly. If no air flow can be detected, do not use the unit until further checks have been made.

4 With a high output voltage model of the SMC (for example the SMC80-20 and its multiples) when trying to de-energise a very large magnet faster than the recommended maximum rate when not situated in a free-airflow environment. The cure for this is to de-energise the magnet at a slower rate.

```
0.00A              0.0V
     SMC80-20
Overtemperature Trip
```

The Overtemperature Trip Display

The External Trip

There are circumstances when there is a need to perform a de-energisation of the magnet in response to environmental or external events. The SMC has an auxiliary input on the back panel which can be wired into external systems which, when activated, will trigger the External trip sequence of the power supply.

The Simple External Trip response is suitable for situations where the magnet must be de-energised as fast as possible, with no particular regard to factors such as helium consumption; in effect, it is a “panic button”. One example would be if the stray field of a magnet was affecting a heart pacemaker, and it was needed to de-energise the magnet immediately, even if that were to cause a quench.

The alternative External Trip response, Auto-rampdown, can be selected when a magnet system needs to be de-energised in a controlled manner. One such example would be in response to a signal from a Helium Depth Indicator, showing that the helium level was low, and that the magnet should be de-energised in a controlled manner to prevent a situation of the helium level falling below the level of the magnet, with possible awkward, or even damaging consequences.

There are two ways that the External Trip, and the response to the external trip signal can be selected; either by a power-on set-up menu, or via the remote interface.

The method of enabling and defining the response to the External Trip signal via the power-on set-up menu is described in Appendix 3 Reinitialisation of Non-volatile Storage (NOVRAM)).

Alternatively, these functions can be enabled via the remote interface using the `X1` command (Simple) or `X4` command (Auto-rampdown) - see section 5.

External Trip - Simple response.

When the Simple response to the External Trip mode is selected, the display will show the message External Trip Active.

The action taken by the power supply programmed for the Simple response on detection of an External trip is exactly the same as that taken on the detection of a quench, except that the heater is automatically switched on and the power supply is disabled for as long as the trip condition is active. Note that an External trip may cause a quench in a proportion of magnets.

The effect of an external trip is to de-energise the magnet at the fastest possible rate, whatever the existing conditions and parameter settings.

Because the heater is automatically switched on, and remains on until about 1 second after the terminal current falls to zero, an external trip will take a magnet out of persistent mode (subject to correct heater voltage setting and external wiring). The heater is automatically switched off after the magnet has been de-energised whatever the previous on/off state of the heater.

```
0.000A              0.0V
      SMC120-05
   External Trip at
      10.440 T
```

Typical 'External Trip' Event Display

Cancellation of the external trip event message is caused by the same button presses as cancel a quench event message. However, if the external trip condition continues to exist (if the Xn function remains enabled and the input line remains in the active condition), the ramp selectors are locked to *Zero*. Before the power supply can be used, the trip must be cancelled either by taking the input line to the enabling state (shorted to 0 V or driven low) or by disabling the external trip function `X0` via the remote interface (see section 5 for details).

If the trip condition continues to exist after the event message has been cancelled, or if a trip is triggered when there is no output current and no 'persistent mode' record, the message External Trip Active will be shown on the display, replacing the normal quiescent status message until the trip condition is cancelled. The external trip enabled/disabled state is held in the non-volatile memory. Therefore, it is possible for an external trip condition to exist at power-up. If this is the case, the External Trip Active message will replace both the version message and the normal quiescent message until the trip condition is cancelled.

```
0.00A               0.0V
      SMC120-05
    External Trip
       Active
```

Simple response External Trip Status Display

External Trip - Auto-rampdown response.

When the Auto-rampdown response to the External Trip mode is selected, there is no indication on the display until the trip is activated.

The action of the SMC unit when the Trip signal is sent is strictly defined, and cannot be cancelled once started (other than by turning off the SMC unit, which would be done at the user's own risk).

There are eleven steps that are taken once the trip signal is received. Some of these steps will be skipped if the particular conditions of the event make them redundant. The two most likely examples are discussed here.

If the coil is being energised at the time of the trip signal, the unit will respond by de-energising the magnet to zero, and, once everything is zero, turn off the switch heater.

If the coil is in persistent mode at the time, no matter what the operational status of the power supply at the time of the trip signal, the unit will initially energise the current leads to the current stored as the persistent mode current. Once there, the switch heater is turned on, the coil de-energised, and, once everything is zero, turn off the switch heater.

Remote operation of the SMC.

Concept

The remote interface concept is one of 'Speak only when asked' and brief mnemonics as commands. Commands and responses are restricted to printable ASCII characters. Where a response is sent from the instrument then strings are kept to defined lengths to simplify the control software. The serial port interface settings are 9600 baud, 8 data, no parity, and 2 stop bits.

The interface will interpret commands which are equivalent to operating the front panel buttons. In addition there are commands that will cause the instrument to send status reports over the interface. Strings returned after these commands are made up of the read back of a number of alpha commands followed by the numeral they are currently set to; this is to aid readability. The strings are terminated by <CR><LF> (0Dh, 0Ah).

There are a number of points to be aware of in the operation of the interface.

1. Leading zeros are optional on received data but are always included on responses.
2. If a command that requires a numeric argument is transmitted without an argument then it is assumed to be zero.
3. Commands which change any of the SMC internal parameters will take immediate effect. These are indicated in the tables following.
4. Concatenation of commands will be ignored; only the first will be acted upon.
5. The command should be terminated by <CR><LF> (0Dh, 0Ah).

Description of the Command set

Commands with arguments

Commands with arguments are mostly those that change an internal parameter, either one that would normally be used in an initial set–up of the SMC when connected to the computer, for example the Tesla per Amp calibration of the superconducting magnet, or one that is frequently used, for example the value of the *Lower* set point. A command consists of an alpha character followed by a number of numeral characters. The alpha characters define the command, and the numeral characters define the argument. There are two types of argument, which depend upon the structure of the command:

1 Simple commands, such as those that operate in the same way as the front panel controls, take a single numeral character argument. The single numeral value then represents which mode is being selected. For example, the command `T1` selects the Tesla units display.

2 Parameter commands, many of which are usually set on initial set-up only, take a multiple numeral character argument. The number thus formed is the same as that which would be entered in any of the set menus selected via the front panel controls. For example, the command `L10.000` sets the *Lower* set point to 10.000 in either Amps, or Tesla if this has been selected.

Commands without arguments

Commands without arguments are those which generate a response from the SMC. A single such command will generate a string which contains the current values of a number of parameters, prefixed by either the command code which is used to set that parameter, or an identification single alpha character code, for ease of identification.

For example, the command `C` is used to set the Tesla per Amp calibration factor of the superconducting magnet. The command `O` returns a string which includes, as the last parameter in the string, the entered Tesla per Amp calibration factor, prefixed by the alpha character `C`.

Each string that is returned from the SMC always have the same defined length, that is the same number of characters. Where some of the parameters can range over a number of orders of magnitude, the value of the parameter is reported back with appropriate zero padding before and/or after the numerals. The reason for this is two-fold. Firstly, it means that the fixed length strings are always returned by the SMC. Secondly, any particular parameter will always be in the same place within the string, and so any computer program will not require any complex parsing routines to extract the value of the parameter. Of course, the parameter is also prefixed by a single alpha character.

Returned characters with no command function

There are some alpha characters which appear in returned strings from the SMC, but do not appear in the command list. These alpha characters are used to identify the particular parameter which is being returned within the whole string.

Special considerations for command parameters

In the following, the character 'n' refers to a numeral character between 0 and 9, but may be restricted in range in some cases. The character 's' refers to the characters '+' or '–'. All of the commands are also listed in tables 5.4 to 5.6.

Simple Commands

The following commands take the single numeral 0 or 1 as an argument:

`Bn` Lock out of front panel;
`Pn` Pause ramp generator;
`Tn` Units used and displayed (Tesla or Amps).
`Dn` Direction; 0 = Forward, 1 = Reverse.

The command `Dn` (Direction) is only effective if one of the BCS, BCSV or ECS reversing switch options is installed, otherwise it has no effect. Without such a unit, it will always be reported back as `D0`. Although the Direction command is set and read back using the numerals 0 or 1, the effect of the command on the direction of current flow or magnetic field is shown by the '+' and '–' characters.

The `Rn` Ramp to target command takes the single numeral 0, 1 or 2 as an argument, for target = *Zero*, *Lower* and *Upper* respectively.

The `Hn` Persistent mode heater command takes the single numeral 0, 1, 2 or 9 as an arguement. However, only 0 and 1 are used in the read back values.

The action of the arguement 1 is ignored if the status conditions, as discussed in section 4, are not correct, namely if the unit is not holding a current, or if the stored value of the persistent mode current is different to the output current.

The action of the arguement 2 is to unconditionally turn on the heater. However, in the read back it returns the value 1.

The action of the arguement 9 can be seen in that the returned character string to the `J` or `N` command, where the value of the current in the returned string has been set to 000.000. It does not affect the read back value of H in the `J` or `K` commands, namely 0.

The `Xn` External trip command takes the single numeral 0, 1 or 4 as an argument; the action and the read back values are as Table 5.1.

Note that the External trip input can be used as a digital signal input without triggering the External trip; when set as `X0`, it will return `X3` when the signal is applied.

Argument	Command function	Status function
0	Off	Off
1	Simple Trip On	On but not active
2	No action	On and active
3	No action	Off but active
4	Auto-rampdown On	On but not active
5	No action	On and auto-rampdown active

Table 5.1. The actions of the arguments to the `X` (External trip) parameters for the SMC when issued as a command or when read as part of the status string.

Parameter setting commands

The following commands take a string of numerals as an argument, and sets the internal parameter to that value. If no string follows the command, then it is ignored. If the numeral after the command is beyond a limit, the parameter will be set to that limit unless indicated below.

`Ann.nnnnn` Ramp rate, set in Amps per second, and internally rounded to the nearest value of the 65 preset values.

`C0.nnnnnn` Calibrate the output to the Tesla per Amp value of the superconducting magnet. The value is assumed to lie between 0.01 and 0.5 T/A, and will be set to zero if a number outside this range is entered.

`Wnnn.` Sets the Heater current output to nnn mA. The maximum value is 255 mA.

`Ynn.n` Sets the maximum terminal voltage of the SMC. Depending on which model of SMC is selected, there is a specific maximum value which will be selected if a greater value is entered.

The following two commands take a string of numerals as an argument, and sets the internal parameter to that value. However, the format of the number entered and read back (the number of digits before and after the decimal point) also depends upon two other parameters:

1. If the SMC is set in Tesla mode, the SMC will interpret the numeral string following the command as being in Tesla, in the format nn.nnnn (two digits before and four after the decimal point), and ignore values that are greater than the maximum possible for the superconducting magnet and SMC unit combination. If the SMC is in Amps mode, then it will interpret the command string as being in Amps, in the format nnn.nnn

2. If the SMC unit is an SMC10, then each parameter, in Amps or Tesla, has one less numeral before, and one extra numeral after the decimal point.

   `Lnnn.nnn` Sets the Lower set point to nnn.nnn A or
   `Lnn.nnnn` Sets the Lower set point to nn.nnnn T (Units active)
   `Unnn.nnn` Sets the Upper set point to nnn.nnn A or
   `Unn.nnnn` Sets the Upper set point to nn.nnnn T (Units active)

Reporting characters with no command function

The following characters are used when reporting back parameters. These are connected with input and output information concerning the SMC unit.

`Enn` This gives and error code. The two numerals separately indicate type of possible fault, as given in the following table. The first digit refers to BCS / ECS reversing switch faults, and is zero if this option is not installed. The second code refers to internal faults in the SMC unit.

The meaning of the first digit is given in table 5.2 below, and the meaning of the second digit in table 5.3

First digit	Error description
0	No error or option not fitted.
1	Attempt to change direction when either I or V is not zero
2	BCS / ECS did not switch correctly
3	BCS / ECS not in a valid state

Table 5.2. The meanings of the first digit of the Error code parameter – BCS / ECS Reversing switch faults.

`Fsnn.nnnn` This gives the magnetic field value and direction(s) as derived from the current (I) value and the Tesla per Amp parameter. This parameter is replaced by `Isnnn.nnn` if there is no Tesla per Amp parameter entered or if the Units selection (Tesla) is off.

With the J command, the value given is the persistent mode current and direction in the magnet. With the N command, the value given is the equivalent magnetic field that would be generated by the output current of the SMC at the moment that the response to the command was issued.

`Isnnn.nnn` This gives the output current of the SMC in Amps at the moment the command `G` was issued. It is also used to indicate the current in

Second digit	Error description
0	No error.
1	Quench Trip
2	External Trip
3	External and Quench Trip
4	Brick Trip
5	Heatsink Overtemperature Trip
6	Slave trip
7	Heatsink Overvoltage Trip

Table 5.3. The meanings of the second digit of the Error code parameter – Quench and other power unit trip.

persistent mode in the magnet if no Units are selected, and the `J` or `N` commands are issued.

`Mn` This states whether the ramp generator has made target or not; 0 means not made target, that is the ramp generator is still ramping, and 1 means that the ramp generator has made target. Note that although the ramp generator has made target, various time constants, for instance the inductive lag of the magnet, within the entire system mean that it will take some time for the current in the superconducting magnet to be equal to the set point that has just be ramped to.

`Qsnnn.nnn` This gives the value of the output current of the SMC when a Quench or External Trip was detected. Under normal conditions, the parameter is zero. Again, when Tesla units are selected, the format of the parameter changes to `Qsnn.nnnn`

`Vnn.n` This is the terminal voltage of the SMC unit.

`Z0.00` This is currently a reserved parameter with no meaning, and always returns with the string 0.00

Read-back strings

The above should explain the meaning of each of the segments that are used to make up the six possible strings returned by the SMC upon request. There has been some deliberate duplication of the information within these strings, so that the reading of any particular string will not contain any ambiguity; for example, in reading back the *Lower* and *Upper* set points, the status of the Units `Tn` command is also given, so that it can be deduced whether the two set points are being returned in Units (Tesla) or current (Amps).

At the end of two of the strings, the `G` command and its relation, the `N` command, there is a single alpha character without an argument. Normally, this will be an `A`, which signifies that the unit will be performing any current ramping at the set Amps per second rate; however, if the character is a `V`, then the unit is ramping at constant voltage, possibly by user choice, indicating that the terminal voltage has reached and been clamped at the voltage limit (either as set or the maximum value).

Command List

Commands that generate no response from the SMC

Mnemonic	Action
`Ann.nnnnn`	Sets the Ramp rate in Amps per second.
`Bn`	Front panel lock-out: 0 = Off, 1 = On.
`C0.nnnnnn`	Sets the Tesla per Amp calibration factor; 0.5<nnn<0.01.
`Dn`	Sets the reversing switch direction: 0 = Forward, 1 = Reverse (†)
`Hn`	Persistent mode heater; 0 = Off, 1 = Conditional on, 2 = Unconditional on, 9 = resets persistent mode current record to zero.
`Lnnn.nnn` `Lnn.nnnn`	Sets the Lower Set point in Amps.) Depending on the status Sets the Lower Set point in Tesla.) of the Tesla parameter
`Pn`	Pause: 0 = Off, 1 = On.
`Rn`	Sets Ramp Target: 0 = Zero, 1 = Lower, 2 = Upper.
`Tn`	Sets the Units displayed: 0 = Off (Amps), 1 = On (Tesla).
`Unnn.nnn` `Unn.nnnn`	Sets the Upper Set point in Amps.) Depending on the status Sets the Upper Set point in Tesla.) of the Tesla parameter
`Wnnn.`	Sets the Heater current output to nnn mA.
`Xn`	Sets the External trip: 0 = Off, 1 = Simple trip On, 4 = Auto-rampdown On (see table 5.1)
`Ynn.n`	Sets the terminal voltage limit to nn.n V.

Table 5.4. The remote interface commands than do not generate a response from the SMC. † Only operates when reversing switch option fitted.

Commands that generate a response from the SMC.

Mnemonic	Response
`G`	Returns the output parameters as `Isnnn.nnnVsnn.nRx[A][V]`.
`J`	Returns the magnet status `Fsnn.nnnnHn` or `Isnnn.nnnHn`.
`K`	Returns the current status as `RnMnPnXnHnZ0.00EnnQsnnn.nnn`.
`N`	Returns the output parameters as `Fsnn.nnnnVsnn.nRx[A][V]`.
`O`	Returns operating parameters as `Ann.nnnnnDnTnBnWnnn.C0.nnnnnn`.
`S`	Returns the set point status as `TnUnnn.nnnLnnn.nnnYnn.n`.

Table 5.5. The Mnemonics that generate a response from the SMC.

Mnemonics read back from the SMC only.

Mnemonic	Description
`Enn`	Error code; See tables 5.2 and 5.3 for first and second digit
`Fsnn.nnnn`	Value of magnetic field derived from output current.
`Isnnn.nnn`	Output current value (`G`) or persistent mode current (`J` or `N`)
`Mn`	Whether ramp generator has made target, or ramping.
`Qsnn.nnnn` `Qsnnn.nnn`	Returns the value of field or output current at Quench or External Trip.
`Vnn.n`	Terminal voltage of SMC unit.
`Zn.nn`	Reserved function, always reads back 0.00.

Table 5.6. The read-back Mnemonics generated by the SMC.

Standard Product Warranty

All products manufactured by Twickenham Scientific Instruments Ltd. ('the company') are warranted to be free from defects in materials and workmanship for a period of one year after the date of dispatch. At no expense to the purchaser, the company will repair or replace (at our option) any parts which at the sole opinion of the company prove to be defective within the scope of this guarantee. Transportation costs of goods returned to the company for repairs will be prepaid by the purchaser. Goods must not be returned without prior consultation with the company to decide whether an on-site inspection and possible repair should be made. If the defect is determined to be as a result of misuse, improper repair, unauthorised user modification of abnormal operation conditions, then the repairs will be invoiced at cost.

This warranty does not apply to equipment not manufactured by Twickenham Scientific Instruments Ltd., for which the relevant manufacturer's warranty is passed on whenever possible.

General disclaimer

The seller, Twickenham Scientific Instruments Ltd., shall not, under any circumstances, be liable for any loss, damage or injury resulting from the misuse of this equipment.

Display Messages.

Normal Power-up

```
###.##A        ##.#V
     SMC###-##
  ROM Version #.##
```

Faults which lock out further operation:

```
HALT-SMC FATAL ERROR
POWER FAIL INT FAULT
```

Should the appropriate error occur, the follow messages will appear on the third line instead of the error given above:

ANALOGUE INT FAULT

CONTROLLER FAULT

CONT"LER & ANL FAULT

MULTIPLE ERROR

I2C INTERFACE FAULT

I2C & ANL INT FAULT

I2C & CONT"LER FAULT

GEN SUBSYSTEM FAULT

GEN AUX MEMORY FAULT

AUXILIARY RAM FAULT

AUX RAM & STOR FAULT

NOVRAM FAULT

NOVRAM & STORE FAULT

If two four digit numbers appear at the bottom right hand corner of the display, please note these down and include them in the report to Twickenham, as this gives an internal error code to help identify the nature of the fault.

This error is recoverable by following the instructions:

```
NOVRAM STORAGE FAULT
PRESS "SET" & "UP"
```

Normal upper two lines

```
###.##A        ##.#V
SMC###-##
```

Lower two lines - Normal Quiescent State

```
L=###.##A   U=###.##A
##.#V          @.@A/s
```

Lower two line - 'Persistent Mode Recorded' Quiescent State

```
Heater switched off
at @.## A
```

Lower Line - Quiescent State Following a Quench Trip

```
Quench trip at @.##A
```

Lower two lines - Active Ramp

Constant rate

```
Ramping to @.## A
at @.@ A/Sec
```

Constant Voltage:

```
Ramping to @.## A
at +ve Volt Limit
```

Reinitialisation of Non-volatile Storage (NOVRAM)

It may happen that the message NOVRAM STORAGE FAULT appears on the display at power up. This indicates that some corruption of the non-volatile RAM (NOVRAM) storage has occurred. In the longer term, this battery-backed RAM module may need replacement, especially if this error occurs regularly. However, the stored parameters may be restored to a valid default state by following the procedure below.

When the NOVRAM STORAGE ERROR message is on the display, or as power is switched on subsequently, press the *Set* and *Up* buttons simultaneously. If power has just been applied, the SMC - POWER ON TEST message appears first. Then following display:

```
SMC set up:
Model and Options
Press SET or switch
off to cancel
```

Pressing the *Set* key will change the display to:

```
Select desired item
using UP or DOWN &
press SET to save &
move on to next item
```

Pressing *Set* to move on:

```
Setting options:
Normal UPR/LWR funct

Select & press SET
```

Pressing *Set* again, unless an optional front panel operation of the unit is required (see application note) gives the following display.

```
If setting options
only, now switch off
else press SET to
configure SMC model.
```

To re-initialise the NOVRAM correctly, continue by pressing *Set*, and the display will show:

```
Model = SMC120-05
SET to save or use
UP/+ and DOWN/- to
select correct model
```

The SMC uses a single firmware version for all models, including the EMC range. The differences between models are stored along with user-configured parameters within the NOVRAM store. Therefore, be sure to select the correct model, including any `-nn` suffix. If the SMC model is a SMC120-05, press the *Set* button. Otherwise, press *Up* or *Down* until the correct model is shown on the upper line, then press *Set*. The display will change to:

```
Memory initialised,
now switch off, or press
SET to
configure XTRIP
```

Pressing *Set* to continue, the display will show:

```
XTRIP: OFF
SET to save or use
UP/+ and DOWN/- to
select setting
```

Pressing the *Up* or *Down* will cycle through the choices of External Trip function, namely OFF, ON (Standard), and AUTO RAMPDOWN. Selection of this is done by pressing *Set*.

Select the mode of XTRIP operation, and then press *Set* gives:

```
XTRIP: OFF
External trip mode
set, now switch off
```

At this point switching off the unit will complete the initialisation. The next switch-on should be clear of NOVRAM STORAGE FAULT. If it is not, the NOVRAM module has failed and you should contact the staff at Twickenham for advice.

Unfortunately, the reinitialisation of necessity resets all user-configured parameters to default values so these will need to be re-entered.

Note that if a NOVRAM STORAGE FAULT occurs, the only options are to switch off or press *Set* and *Up* to re-initialise memory. If you switch the unit off, the NOVRAM STORAGE FAULT will not be repeated at the next power up unless there is a serious problem with the stored data. The unit will attempt to operate with the data stored in the NOVRAM which could lead to erroneous operation.