MATELECT ACPD
DATA ACQUISITION SOFTWARE

Version 1.0 for ICF-6R systems

INSTRUCTION MANUAL

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MATELECT ACPD CRACK GROWTH MONITOR

TYPE ICF-6R

Thank you for your interest in our product, we hope that it will serve your needs and prove a reliable tool.

This product has been designed to the highest standard in both electronic and mechanical design, with careful attention to stability, reliability and electrical safety.

Matelect's CGM-5 has established itself as the world's best selling laboratory ACPD equipment by far. The ICF-6R is the latest instrument in this family and incorporates several new features. Matelect produce a range of peripherals to support the ICF-6R and have also built up many years of experience in the ACPD technique. Please contact us should you ever require further information or assistance.

This manual applies to the ICF-6R. Manuals for earlier versions can be obtained from Matelect at the address given below.

IMPORTANT

Please read these instructions carefully before you use the instrument. Please pay particular attention to the section that follows on mains operation. For your reference please also read our terms and conditions of sale printed at the rear of this manual.

Use only a slightly dampened cloth and mild detergent to clean the ICF-6R. Never use a solvent cleaner or any fluid.

Please note that there are no user serviceable parts within the ICF-6R. Never attempt to open the instrument case as this will void any warranty. Please contact Matelect should you ever experience any difficulties.

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2. MAINS OPERATION

This section applies to all mains operated instruments
PLEASE READ BEFORE OPERATION

Before use, please make sure that the instrument's supply rating is correct for the location it will be used in. The ICF-6R can be operated on both 110 and 220V supplies by appropriate selection on the input voltage switch (see page 15). Before shipment, your instrument will have been set for the commonly used voltage in your locality.

The instrument must be connected to the mains supply using an IEC mains lead terminated with the appropriate local mains plug. The unit is supplied with a suitable lead for this purpose.

The instrument is housed in a metal case for strength and electromagnetic screening purposes. Therefore, PLEASE ENSURE that the instrument is earthed to the mains earth via the IEC connector.

In addition to the fuse that may be present in the mains plug (e.g. UK versions), the ICF-6R is fitted with two equipment fuses for protection. These fuses are located in the IEC input socket on the rear panel of the ICF-6R. Both fuses need to be functional if the equipment is to be operated.

The instrument fuses are rated at 1 ampere and are of the 20mm "anti-surge" type. Never replace these with fuses of a different type or rating as the instrument can be seriously damaged.

Ensure that the ICF-6R does not come into contact with fluids or corrosive gases and that it is operated within the temperature range of 0-40 ºC

60 Hz mains supplies

In order to avoid harmonic frequencies affecting the operation of the ICF-6R when using mains inputs of 60Hz, the 300Hz current setting is actually set at 270Hz. This does not affect the operation of the unit or the interpretation of results.

3. CONTENTS

4. OVERVIEW

The Matelect ICF-6R has been designed for the accurate and sensitive determination of crack growth in conductive materials using the alternating current potential drop (ACPD) technique. The instrument is based on the original CGM-5R and the ICF-5R developed and sold by Matelect but with the ability to supply resistive and inductive signal components simultaneously.

The ACPD technique is well established as a method for crack growth measurement. Originally a laboratory technique, it is now used in several other areas of research and industry. The technique involves the supply and passage of an alternating current (AC) through the test specimen and the simultaneous measurement of the resultant potential drop (PD) across an area of the specimen. If the correct area is chosen, the voltage drop will be proportional to the defect depth within the specimen. As the defect propagates, the PD measured will increase.

ACPD initially appears to differ little from its direct current equivalent, DCPD. There are however a number of important phenomena which significantly alter the interpretation of the results and the mode of use of the technique. The most important of these is known as the skin effect.

Skin effect is the term used to describe the effective confinement of an alternating current to the surface of a conductor. The skin depth is defined as a depth measured from the specimen surface within which the majority of the current supplied actually flows. The skin effect becomes more pronounced as the frequency of the AC current is increased (thus reducing the skin depth). The strength of the skin effect depends upon the material being tested, being weaker for non-magnetic materials such as titanium and aluminium. The phenomenon is used to great advantage in the ACPD technique as it confers linearity to the voltage-crack depth relationship. Such linearity minimises the calibration required for accurate crack depth measurement and is therefore to be welcomed.

The skin effect also ensures that relatively low specimen currents can be employed to obtain reasonable signal levels. Currents of an ampere or below generate signals comparable to those obtained in DCPD testing at current levels well in excess of 50A. This high signal to current ratio effectively increases the resolution of the AC technique. Additionally the use of alternating currents permits electronic lock-in methods to be employed, which further increase depth resolution by greatly minimising signal noise.

ACPD can be used to detect crack initiation in laboratory specimens, for example, during a fatigue test. Once a crack has been initiated its progress can then be followed using the same technique. If an appropriate calibration is available, a measure of the crack depth can also be obtained. In this way it is possible to measure such materials parameters as fracture toughness and fatigue life.

ACPD can also be used in the field to monitor the initiation and growth of cracks in industrial plant. In such circumstances it is usual to use one CGM unit to monitor several crack sites. Matelect produces a range of signal and current multiplexers for this purpose.

It is usual for the current supply and voltage measurement contacts to be fixed onto the specimen (e.g. by spot welding) to ensure a good electrical contact. However, ACPD can be used to size cracks in the field by the use of hand held probes which incorporate spring loaded contact pins. Matelect manufacture a number of different probe types and can also undertake the design and manufacture of specific probes systems for a particular testing need.

One of the traditional difficulties with the ACPD technique has been the existence of inductive pick-up (PU). This is simply an additional voltage that is superimposed upon the ACPD from the defect, due to the interaction between the voltage measurement leads and the current supply leads. Unfortunately PU changes with an alteration of the relative position of the leads, thereby altering the overall measured potential drop. This limitation is effectively overcome by preventing lead movement during a test. It is possible, however, to electronically reduce the pick up effect.

The ICF-6R can source an infinitely variable alternating current of up to 2 amperes RMS. Seven different frequencies are available to maintain effective use with materials of widely differing magnetic properties. The system incorporates a very stable current source and a lock-in amplifier/phase sensitive detection system for the measurement of the resultant ACPD with excellent rejection of extraneous noise. The ICF-6R also allows the resultant ACPD to be calculated by providing the resistive and inductive signals components when in I/R mode.

Adjustable signal offsets, analogue and RS232 signal outputs, variable amplifier gain and a 3 position filter are additional features of the system. The unit can be used in a number of signal lock-in modes, among which the I/R mode provides effective immunity to induced pick-up voltages.

This manual applies to the ICF-6R ACPD monitor. Users who experience any difficulty in operation of the equipment are advised to contact Matelect at the address given at the beginning of this manual.

5. FRONT PANEL DESCRIPTION

The front panel of the ICF-6R is shown below in Fig 1. The controls are described fully in this section. For further technical information please refer to the sections entitled General Usage Advice and Specifications.

Fig 1. The front panel of the ICF-6R

1. Power Indicator

The red front panel indicator illuminates when power is applied to the unit.

2. Signal GAIN

This rotary knob allows the user to select an appropriate gain setting from the following values;

50dB	equivalent to a multiplication factor of	316
60dB	"	1000
70dB	"	3162
80dB	"	10000
90dB	"	31620

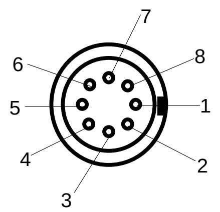
It is always advisable to use the minimum gain possible commensurate with obtaining a adequate signal level. Many factors such as the frequency and magnitude of the applied current, together with geometric considerations with respect to the specimen, can affect the signal level. These factors should be considered before increasing the gain setting.

3. Signal INPUT socket

This is an 8 way LEMO type socket and is polarised to prevent incorrect insertion of the signal plug. Insert the signal plug into this socket only when the red dots on both the plug and socket are aligned. If correct alignment of the plug and socket has been achieved, the insertion force is minimal. Users *must not* force the plug into the socket, nor rotate the plug once inserted. The plug can be removed by grasping the knurled outer collar and squarely pulling the plug from the socket. Minimal force is required.

The input signal is transformer decoupled to the main amplifier within the ICF-6R. This gives a high common mode rejection ratio and reduces signal noise. The input signal should always be fed via low impedance cables and contacts.

The input socket is wired as follows:

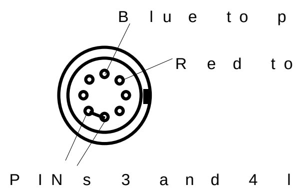


pin 1.	-12 V to optional preamplifier
pin 2.	Ground to optional preamplifier
pin 3.	shorted to pin 4 inside plug when pre-amplifier not being used.
pin 4.	Signal high for optional preamplifier
pin 5.	Signal ground for optional preamplifier
pin 6.	+12 V to optional preamplifier
pin 7.	Standard input high
pin 8.	Standard input low

Fig 2. Connections to the ICF-6R signal input socket

Two contacts (pin 7 and 8) serve to carry the input signal whilst the other contacts are used to power and communicate with the optional pre-amplifier unit (available from Matelect). This unit is only required when long signal cables lengths are being employed (e.g. 10 metres or more) or when the signal is to be routed through a noisy environment such as an industrial plant location.

For the standard case of a ICF-6R without preamplifier, the input cable must be wired as shown below in Fig 3. Any deviation from this may cause serious damage to the unit. Always use the cables supplied with the ICF-6R to prevent such damage.



Drawing indicates solder bucket view
Connector is LEMO FGG2B308CNAD62Z
Cable is twisted pair and screen (7/0.2mm)

Fig 3. Pin connections on a standard LEMO type input plug

Users should contact Matelect for further information on cabling or if longer cable lengths are required.

4. FREQUENCY Selector

This rotary switch is used to select the frequency of the alternating current supplied to the specimen. It has 6 positions corresponding to frequencies of 0.3, 1, 3, 10, 30 and 100kHz. The choice of frequency will depend on the material under investigation. The frequency determines the skin depth with higher values corresponding to smaller skin depths. The smaller the skin depth, the larger the corresponding ACPD (for a particular value of applied specimen current). The magnetic properties of the material will also influence the skin depth and hence the choice of frequency. Ferritic materials such as the steels exhibit small skin depths at relatively low frequencies (e.g. 0.3-1kHz) whereas non magnetic materials such as aluminium require 30 or 100kHz in order to obtain sensible ACPD readings.

Raising the frequency in order to increase the ACPD is not always recommended since the magnitude of the inductive pick up (PU) also increases with frequency. Users should thus consider raising the current through the specimen and then the gain as alternatives. Because of its effect on the skin depth, frequency is one of the fundamental variables in ACPD work. Careful choice of the frequency is required in order to obtain the optimum results from the technique.

5. FILTER Switch

Although the signals displayed on the panel meters are only refreshed at 1.5 times per second, the actual ACPD levels are available as analogue signals at the rear of the ICF-6R. These signals can be filtered to remove some of their components by use of the front panel filter switch. The switch has 3 positions as follows.

***OUT** position:* No filtering is applied to the ACPD signal. The analogue output will consist of the unsmoothed ACPD value. Details of the nature and shape of this waveform are given in the description of the **RECORDER** output in the next section. The LCD panel meters will indicate changes at their maximum response. The **OUT** position should be selected when the user wishes to record ACPD during dynamic or fast materials testing.

***MAX** position:* Maximum filtering is applied to the processed analogue output signal. The filter removes all frequencies above 0.67Hz. This effectively smoothes the **RECORDER** output and removes all traces of the original AC waveform. It also acts to remove any medium to high frequency noise that has otherwise not been removed by the phase sensitive detection circuitry. The response of the LCD panel meters will be slowed by use of this filter. The **MAX** position should ideally be used during slow strain rate experiments or long term continuous testing of specimens and structures.

***MIN** position:* In this position a low pass filter with a cut-off at 80Hz is selected. This acts to remove noise and the AC frequency whilst still permitting the recording of lower frequency phenomenon such as the changes in ACPD during a fatigue testing machine cycle.

6. Mode LED indicator

The operation of this indicator is summarised in Table 1. The indicator is used to visually determine whether the ICF-6R has reached lock in when in either **MANual** or **AUTO** mode. Three modes are available and these are selected by use of the adjacent mode switch (7).

In **I/R** mode the LED is always off. In the **AUTO** mode, the LED is normally unlit to indicate that the phase sensitive detector has locked onto the ACPD signal. When a specimen is first connected to the instrument the LED will flash RED whilst lock-in is being achieved. This process normally takes a few seconds but in certain circumstances (e.g. at low signal levels) up to 10 seconds may be required. Once lock-in has been achieved, the LED will extinguish and normally remain so during a test.

If the LED flashes during a test this indicates that a large phase change in the measured ACPD signal has occurred. This could be due to poor electrical contact to the specimen or to a rapid alteration in crack length.

In **MANual** mode, the LED flashes red until the value is close to the maximum signal. In this mode, the **PHASE** potentiometer (control 8) is used to adjust the phase of the signal to which the instrument is sensitive. This facility is sometimes of use to those who are studying the fundamentals of ACPD theory. In the **MAN**ual mode the LED will remain extinguished only when the selected phase is that which would have been chosen by the instrument in **AUTO** mode. At all other positions of the **PHASE** adjust potentiometer, the LED will flash red.

7. Mode Selector Switch

This is a three position toggle switch that allows the user to select the mode of operation of the ICF-6R.

In the up (**MAN**) position the ICF-6R is in **MAN**ual mode. In this mode control (8) is used to adjust the phase of the ACPD signal to which the ICF-6R is sensitive to.

In the centre (**I/R**) position, the instrument is in the **I**nductive/**R**esistive mode which effectively reduces the influence of induced pick-up (PU) on the ACPD measurements. This mode gives the resistive component and inductive component of the received signal on components (12) and (16) respectively.

In the down (**AUTO**) position, the ICF-6R automatically locks into the phase of the measured ACPD signal without user input. This signal will consist of the magnitude of the vectorial summation of both the true ACPD, as developed across a defect, and the pick-up (PU) signal.

8. PHASE adjustment control

This is a ten turn potentiometer that is used in conjunction with LED (6) which enables the user to adjust the phase that the ICF-6R is sensitive to when operated in **MAN**ual mode. The position of the potentiometer is lockable to prevent accidental movement.

9. Current Display

The current display gives the value of the current being supplied to the specimen as set by the user.

The display determines the active operating range of the ICF-6R since too high an ambient temperature will cause the display to darken and too low a temperature will result in a slow response to changes in the displayed characters. In both cases the display will return to normal when the ambient temperature is within an operating range of 10 to 35 degrees Celsius.

The value displayed on the LCD panel meter is refreshed every 660 milliseconds which corresponds to a refresh rate of 1.5 Hz. If no ACPD leads are connected to the ICF-6R, the LCD display may indicate random numbers.

10. Current LED indicator

A summary of the operation of this and the two other LED indicators is given in Table 1 at the end of this chapter. The LED flashes green when the compliance limit is exceeded indicating that the overall AC resistance (impedance) of the specimen, current contacts and current leads exceeds the maximum load level that can be supported at the desired current setting. The most likely cause of exceeding the compliance limit is the use of long current supply leads, for example during long term monitoring of large structures. In such cases users should attempt to reduce the load on the current source. This is most readily accomplished by reducing the resistance of the leads by minimising their length and/or increasing the cross sectional area of the conductors. The capacitance of the cables strongly affects the impedance value, especially at the higher AC frequencies. It is therefore recommended that low capacitance cable types (e.g. coaxial cables) are employed for long cable runs.

If at any time this indicator flashes red, the user is warned that the processed ACPD signal is being clipped. Clipping describes the effect of reaching a threshold signal level beyond which any increase in gain or current will have no effect on the signal level. This limiting condition is due to the electronic constraints within the ICF-6R. Users should never operate at or close to the clipping level (which corresponds to approximately 3.8 volts as displayed on the front panel signal meters).

If clipping is indicated by the LED, the signal gain and/or current supply should be reduced. Alternatively a lower frequency can be selected if appropriate.

11. SET CURRENT adjustment

This ten turn potentiometer permits the user to select the magnitude of the alternating current supplied to the test specimen. The current is continuously variable from zero to 2 Amperes (RMS).

When adjusting this potentiometer, the current flowing through the specimen should be monitored on the front panel LCD meter (9). Please note that a specimen must be connected (or the ends of the current supply lead shorted) in order for current to flow and thus be displayed and adjusted.

If, whilst adjusting the potentiometer, LED (10) flashes RED, users should check the integrity of their connections and/or the resistance of their cables (see section on LED (10) earlier).

The value of the current determines the resultant ACPD signal and should therefore be adjusted in combination with the **FREQUENCY** and **GAIN** controls in order to obtain a satisfactory signal level. For most materials a level of 0.5 Amperes, at the frequency appropriate for the material, will prove adequate. Currents below 250mA are not usually employed.

The position of the potentiometer and hence the value of the current can be locked using the lever mounted on its underside. Slide this down to lock and up to unlock. Do not apply excessive force to the lever.

The LCD meter displays the current set to a resolution of 1 mA. Although the current source is extremely stable (better than 0.1%) it is important to note that the potentiometer position will correspond to currents that will differ slightly between frequency settings. Thus, if the frequency is altered, users should readjust the position of the current potentiometer in order to maintain the same current supply conditions.

12. Voltage Display

This voltage display gives the value of the processed ACPD when in **MANual** and **AUTO** modes and the resistive component of the ACPD when in **I/R** mode. The meter autoranges at 1.9990V and then reverts to 3 decimal place accuracy. Users should always try to stay within the maximum 4 decimal point range in order to attain the maximum possible measurement resolution. This can be achieved by reducing the value of the applied current or signal gain.

The display determines the active operating range of the ICF-6R since too high an ambient temperature will cause the display to darken and too low a temperature will result in a slow response to changes in the displayed characters. In both cases the display will return to normal when the ambient temperature is within an operating range of 10 to 35 degrees Celsius.

The value displayed on the LCD panel meter is refreshed every 660 milliseconds which corresponds to a refresh rate of 1.5 Hz. If no ACPD signal input lead is connected to the ICF-6R, the LCD display may indicate random numbers.

13. OFFSET LED indicator

The operation of this indicator is summarised in Table 1. The indicator illuminates green if an offset has been selected. This occurs when switch (14) is in the up or down position. The indicator should remain unlit when switch (14) is in the centre position.

14. Variable OFFSET switch

This toggle switch has three positions and enables the user to offset (using control 15) the processed ACPD voltage when in **MANual** or **AUTO** mode and the resistive component of the signal when in **I/R** mode. An offset is normally employed to zero (remove) the initial ACPD present when a specimen is connected to the ICF-6R. Any change in the ACPD will then be easily visualised.

By using the offset it is possible to ensure that the ACPD is displayed to the maximum 4½ digit resolution since voltages over 1.9990 V are displayed to 3 decimal places. The offset can also be used to reduce the initial signal level, thereby permitting the user to increase the signal gain. This allows smaller variations in the ACPD to be detected.

Users should note that the offset is applied to the processed ACPD voltage and therefore it cannot be used to remove signal clipping should this occur.

15. OFFSET control

This ten turn potentiometer should be used in conjunction with control (14) to vary the offset applied to the processed **MANual**, **AUTO** or **R**esistive component ACPD signal. The applied offset is continuously variable throughout the range selected by control (14). The position of the potentiometer can be locked to prevent accidental movement during a test. A digital scale within the potentiometer body can be used as an aid to accessing the level of offset applied.

16. Inductive Signal Display

This display gives the value of the inductive component of the ACPD signal when operating in **I/R** mode. The meter uses a non-backlit liquid crystal display of 4½ digit resolution. The meter autoranges at 1.9990V and then reverts to 3 decimal place accuracy. Users should always try to stay within the maximum 4 decimal point range in order to attain the maximum possible measurement resolution. This can be achieved by reducing the value of the applied current or signal gain.

The display determines the active operating range of the ICF-6R since too high an ambient temperature will cause the display to darken and too low a temperature will result in a slow response to changes in the displayed characters. In both cases the display will return to normal when the ambient temperature is within an operating range of 10 to 35 degrees Celsius.

The value displayed on the LCD panel meter is refreshed every 660 milliseconds which corresponds to a refresh rate of 1.5 Hz. If no ACPD signal input lead is connected to the ICF-6R, the LCD display may indicate random numbers.

17. OFFSET LED indicator

The operation of this indicator is summarised in Table 1. This indicator is only functional when operating in **I/R** mode. When in **I/R** mode the indicator illuminates green if an offset has been selected. This occurs when switch (18) is in the up or down position. The indicator should remain unlit when switch (18) is in the centre position.

18. Variable OFFSET switch.

This toggle switch has three positions and enables the user to offset (using control 19) the processed INDUCTIVE component of the ACPD voltage when in **I/R** mode. The switch has no use when operating in other modes. An offset is normally employed to zero (remove) the initial ACPD present when a specimen is connected to the ICF-6R. Any change in the ACPD will then be easily visualised.

By using the offset it is possible to ensure that the ACPD is displayed to the maximum 4½ digit resolution since voltages over 1.9990 V are displayed to 3 decimal places. The offset can also be used to reduce the initial signal level, thereby permitting the user to increase the signal gain. This allows smaller variations in the ACPD to be detected.

Users should note that the offset is applied to the processed ACPD voltage and therefore it cannot be used to remove signal clipping should this occur.

19. OFFSET control

This ten turn potentiometer should be used in conjunction with control (18) to vary the offset applied to the processed **I**nductive component ACPD signal. The applied offset is continuously variable throughout the range selected by control (18). The position of the potentiometer can be locked to prevent accidental movement during a test. A digital scale within the potentiometer body can be used as an aid to accessing the level of offset applied.

Summary of LED indicator functions

The operation of each LED indicator is described in the main text, however, a summary to assist users in interpreting the various combinations observable, is given below.

	PHASE LED	**OFFSET LEDs**	**CURRENT LED**
LED OFF	Phase correctly adjusted in AUTO or MAN mode	Offset not selected	All current leads OK
LED FLASHING RED	Phase incorrectly adjusted in MAN or AUTO mode	N/A	Signal clipping is occurring
LED FLASHING GREEN	N/A	N/A	Compliance limit reached or poor or broken contacts
LED GREEN	N/A	Offset selected	N/A

Table 1. LED functions

Please note that if no ACPD signal lead is connected to the ICF-6R, the amplification circuitry may become unstable and a random flashing of the phase LED can occur.

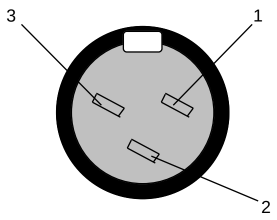
7. REAR PANEL DESCRIPTION

The rear panel of the ICF-6R is shown below in Fig 4. The controls are described fully in this section. For further technical information please refer to the sections entitled General Usage Advice and Specifications. Located on this panel are the analogue, RS232 and current outputs, together with the mains input socket and a large heatsink.

Fig 4. Rear Panel of the ICF-6R

1. Auxiliary output socket

This socket is used to power peripheral instrumentation that can be connected to the ICF-6R, for example, the SM signal multiplexing system. The socket is wired as follows.



Pin 1. positive 12 V unregulated 100mA max.
Pin 2. circuit common
Pin 3. negative 12 V unregulated 100mA max.

Fig 5 Auxiliary output socket

The auxiliary supply is nominally ±12.5V DC unregulated. Under maximum load this will drop to ±10V. The outputs are current limited to prevent damage to the ICF-6R should a short circuit occur.

2. COMmon terminal

The circuit common line is available at this terminal. Connection to this is made by depressing the sprung button and inserting a suitable length of equipment wire, then releasing the button. The circuit common of the ICF-6R is electrically isolated from the case Earth. If it is desired to connect common to Earth, a wire link can be used between the **COM**mon terminal and the **EARTH** terminal (item (3) below).

Isolation of the common is useful if external peripherals such as chart recorders are connected to the ICF-6R. If their signal common is connected to Earth, an earth loop could occur, should the ICF-6R's common also be connected to Earth. Such loops are sources of signal instability and should therefore be avoided.

3. EARTH terminal

Connection to the case (chassis) is available at this terminal (see item (2) above).

4. Voltage selector switch

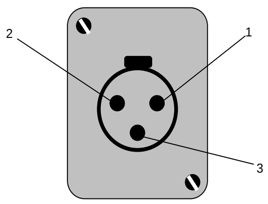
PLEASE READ THE SECTION ON MAINS OPERATION at the beginning of this manual before attempting to alter the position of this switch.

The switch permits the ICF-6R to be used with either 100-120V or 220-240V mains supplies. The ICF-6R is factory adjusted to the correct mains input voltage before shipment but users may wish to alter this depending on the location of the instrument. A wide blade screwdriver should be inserted into the slot within the switch and rotated to the appropriate input voltage (as marked on the switch).

CARE! Disconnect the unit from the mains supply before altering the position of the switch. Operation of the ICF-6R with this switch incorrectly positioned will cause serious permanent damage to the unit.

5. CURRENT output socket

The alternating current delivered to the specimen is sourced from this 3 pin socket. An appropriate mating lead is supplied with each ICF-6R. The socket is of the latching type. The mating plug is inserted by first aligning the depression on the plug with the locking lever, then firmly pushing the plug home. To remove, depress the locking lever and pull the plug away from the socket. The socket is wired as follows:



Pin 1. Current high output
Pin 2. Current low output
Pin 3. Chassis earth (Com. on pre '94 units)

Fig 6 The current output socket

6&7. RECORDER outputs

These are standard BNC connectors used to output the processed ACPD signal to a chart recorder or other suitable recording device such as a computer based acquisition system. This permits unattended and continuous recording of data from the ICF-6R. Output (6) gives a valid voltage for all modes of operation and provides the resistive signal component when in **I/R** mode. Output (7) only operates when in **I/R** mode and provides the inductive signal component output.

Suitable cables to mate with these socket are supplied with each ICF-6R. The cable is terminated at the opposite end with two 4mm banana type plugs for use with standard chart recorders.

The analogue output from these sockets match those on the LCD front panel meters. The value on the panel meters are refreshed at a maximum rate of 1.5 times a second whereas changes in the analogue **RECORDER** outputs are dependent only on the bandwidth of the instrument and the setting of the front panel **FILTER** switch. In addition to its dependency upon the position of the front panel **FILTER** switch, the nature of the analogue output will also depend upon the lock-in mode of the ICF-6R.

8&9. RS232 INTERFACE sockets

These are 9 way D connectors with male (pin) contacts. They provides a serial digital output of the ACPD voltage (as indicated on the front panel meter). One link provides AUTO, MANual and Resistive signals and the other, the Inductive signals dependent on the mode. Only three connections are required for serial data transmission. These are of the standard RS232 format. Matelect can supply a suitable serial cable, terminated in either a nine or 25 way connector (at the PC end). Standard graphical software is also available for data logging, display and storage.

10. Mains input socket

PLEASE READ THE SECTION ON MAINS OPERATION before attempting connection to this socket.

The socket is of the standard IEC mains input type with integral line filter, mains switch and mains fuse. A suitable lead, terminated with a local mains plug, will have been supplied with the ICF-6R. If this is missing, only use an approved mains IEC connector as a replacement.

The instrument is fitted with two 1 Ampere anti-surge 20mm fuses. If any of these fail, then the equipment should be disconnected from the mains supply, and the fuses replaced with ones of the same rating and type. DO NOT use a fuse of a higher rating as permanent damage may result to the ICF-6R. The fuses are accessible via a sliding carrier tray. This can be levered out using the blade of a slotted screwdriver placed in the recess within the carrier.

If the local mains plug also incorporates a fuse (e.g. UK versions) then this should be of a similar rating to the fuses within the IEC socket.

Always ensure that the mains input lead has an Earth connection and that this is in good order. This is necessary both for safety purposes and in order to obtain sensible results.

7. CONNECTIONS TO THE SPECIMEN

Specimen connection in ACPD work is not a trivial subject and will therefore only be dealt with briefly in this operating manual. It is also assumed that the user is reasonably familiar with the ACPD technique. For further information please contact Matelect who will be pleased to offer applications advice and more detailed assistance.

Four electrical connections are required to be made to the specimen, two current and two voltage. As far as is practical, the leads, as supplied with the instrument, should be employed for connection purposes. It is important to obtain a good electrical contact between lead and specimen and it is usual to use spot welded, soldered or screwed connections in this respect.

For a typical compact tension specimen (CT) the connections should be made as shown in Fig 7 below.

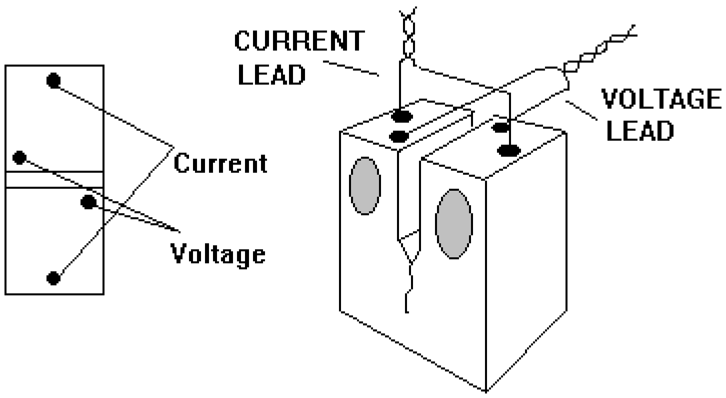


Fig 7. General ACPD connection locations

This is a general arrangement that can be adapted to other configurations such as three point bend and wide plate specimens. Long term monitoring of large components may involve a more complex arrangement of contacts, especially if multiple sensing points are required and if temperature variations are likely to occur during a test. Further information is available from Matelect.

The current leads should be positioned such that the current path encloses the crack. In this manner, the propagation of a defect will cause a perturbation in the current flow that will lead to a change in the measured ACPD.

The voltage sensing leads should be positioned symmetrically about the crack site and between the current connections. By locating the voltage connections as shown in the above diagram, the average depth across the advancing crack front is registered.

It is highly advantageous to make the connections to the specimens as rigid as possible. This minimises possible lead movement during a test and hence reduces any errors due to changes in the pick-up (PU) signal. This unwanted signal is derived from the interaction of the voltage leads with the magnetic field generated by the passage of the alternating current through the supply leads and specimen.

Rigid connections can be made using thick gauge copper wires. The relevant cables can then be attached to these conductors as close to the specimen as the testing configuration allows. Use adhesive tape to secure the cables themselves to prevent any possible lead movement during a test. If the ICF-6R is operated in **I**nductive/**R**esistive mode some lead movement can be tolerated without causing gross errors by relying on the resistive components, as the pick up will primarily be inductive.

To reduce the actual magnitude of the pick-up voltage it is important to tightly twist the leads (as shown above). It is important to note that the magnitude of the PU can be reduced by minimising the area enclosed by both the current and voltage leads. This is illustrated in the following diagram. If large loops are unavoidable, it is best to position them perpendicular to each other.

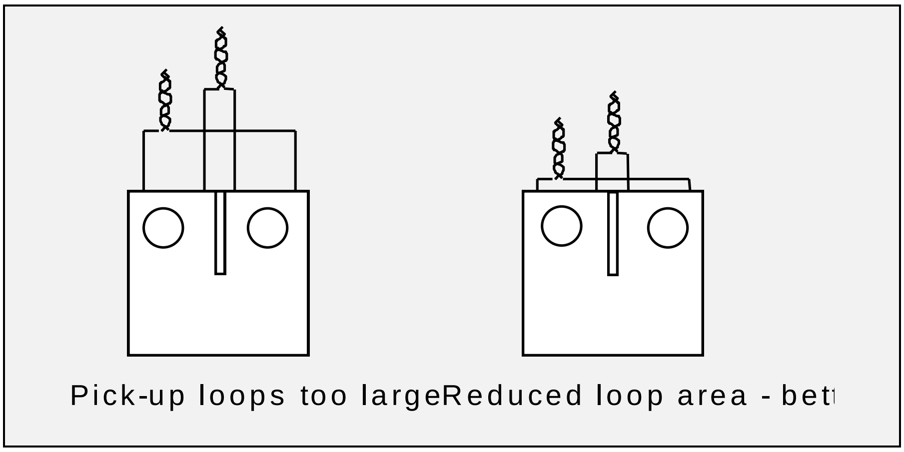


Fig 8. Loop area considerations

It is not usually necessary to isolate the specimen from the testing machine since the specimen presents a far lower impedance to the flow of current than does the alternative path via the grips and body of the machine. Care must be taken, however, if a clip gauge is used in conjunction with ACPD measurements. The gauge can easily short out the signal from the specimen, so it is important to provide some form of electrical isolation in such cases.

A phenomenon known as current focusing can occur in ACPD experimentation. This effect causes the specimen current to closely follow a path defined by one of the current leads. It is especially prevalent when the current lead is close to the specimen's surface. Current focusing is used to great effect to increase ACPD sensitivity but it can lead to errors in interpretation of results. Further details of this advanced technique can be obtained from Matelect.

Excessive cable length can seriously degrade the performance of the ACPD system. If it is found necessary to extend the factory supplied cables or substitute different cables types then users must always try to minimise cable impedance. If the impedance is excessive, the voltage compliance limit will be reached and the maximum specimen current available will drop from its 2 ampere maximum.

These considerations are especially important for high frequency operation (30/100 kHz). The impedance will be a function of resistance, capacitance and inductance. It will be necessary to minimise all these variables if it is desired to utilise the instrument over the full range of current.

Long signal cables can also lead to problems, especially with regard to induced pick-up and external sources of noise. An optional signal pre-amplifier is available from Matelect to counter this problem. All signal and power supply lines for the pre-amplifier are already present in the factory fitted front panel LEMO connector.

8. SETTING UP A TEST

This section is intended as a brief "getting started" procedure. No attempt has been made to cover detailed aspects of ACPD testing as further advice is readily available from Matelect and published literature.

It is assumed that users have first read, and become familiar with, the preceding sections of this manual before commencing a test. The settings suggested below are generalisations. Once experienced in the operation of the ICF-6R, users will be able to select and optimise their own settings as appropriate to the particular specimen configuration employed.

1. Connect the specimen using the method most suitable to the specimen and testing regime (see preceding section) and switch on the ICF-6R. If possible allow the instrument to warm up for a least 20 minutes. This is especially important if sensitive work is to be carried out and if the unit has been moved between areas differing in ambient temperature.

2. If employing a testing machine, it is sometimes a good idea to select the appropriate current, gain and frequency levels with the specimen away from the rig. Once this is done, the specimen can be positioned as appropriate and the settings reassessed.

3. Select the frequency of the alternating current. This choice will be influenced by the type of materials being tested. As an example choose 300 Hz for a mild steel. In general the higher frequencies are more suitable for observing surface phenomena such as crack initiation. For dynamic testing such as high cycle fatigue or impact testing, higher frequencies can assist in capturing the crack growth.

4. Choose a suitable current value. Begin at about 0.5 Amperes, and raise if required.

5. Choose the mode of operation - initially it is best to experiment in **AUTO** mode. **I/R** mode is used in situations were lead movement can be a problem and were substantial amounts of induced pick up are present, or where advanced studies using induced current focusing techniques are being employed. **MAN**ual mode is not normally employed unless users are engaged in fundamental ACPD studies.

6. Wait for the ICF-6R to lock-in and note the value of the amplified ACPD signal on the front panel meter. Check that all fixed and variable offsets are switched out. Adjust the gain control until a signal of about 0.5 volts is observed. The current can also be adjusted in order to obtain this approximate signal level.

7. Use the variable offset control to zero the ACPD output if desired. This is not absolutely necessary but can aid the setting up of recording devices such as chart recorders. Note that if a scanning system is being used, the offset should not be employed as the value that has to be offset will invariably vary between signal channels.

8. Use the filter facility if engaged in long term testing or low cycle fatigue work.

9. Connect a suitable recording device (chart recorder, PC based acquisition card) to the **RECORDER** output, or use the **RS232** serial data facility. The choice of device will depend on the data acquisition rate and the type of signal that is being recorded. For long term monitoring, the RS232 link is ideal, whereas for fatigue studies, a chart recorder would be appropriate. For rapid crack growth (e.g. during impact studies) a transient recorder should be employed.

10. Begin the test, but assume that it will be necessary to modify the settings in light of your results!

9. GENERAL USAGE ADVICE

This section covers a number of topics mentioned earlier in the manual in greater detail together with other points of relevance. Users should note that further information is available from Matelect and from the published literature. It is assumed that the user has read and become familiar with the preceding chapters.

SIGNAL NOISE, GAIN, DRIFT AND RESOLUTION

In common with all measurement techniques, the minimisation of noise is important in ACPD work. The advanced design of the ICF-6R endows it with excellent noise immunity, but this can only be appreciated if sensible precautions have been taken to complement this feature. In particular, the gain of the amplification circuitry should be minimised. Always use the lowest gain setting possible by raising the supply current in preference to increasing the gain. A signal level of about 0.5 volts is a good starting point as it allows for a substantial increase in the ACPD before reaching the 2 volt autoranging point (which would otherwise lower the resolution by one decimal point).

Increasing the frequency will also raise the signal level, but this option can also lead to a greater susceptibility to pick-up and hence lead movement. Indeed it is possible that much of the increase in signal level that occurs with a rise in frequency is due to a larger induced pick-up component. The **I**nductive/**R**esistive mode may then be preferable in order to remove much of the pick-up (see below).

The use of the filter facility can improve the noise performance somewhat and it should always be employed during long term testing or low cycle fatigue work.

In general, the measured noise on the analogue output signal with the filter applied is less than 200μV (at 70dB gain). When referred to the input (i.e. the gain is used to calculate the noise at the specimen), this figure amounts to less than 100nV. The long term drift of the ICF-6R has been estimated at ±500μV in a 1V output, over a period of 200 hours (or 0.05%).

For a typical mild steel specimen, a change of approximately 1 volt can be expected for every 10mm change in crack depth (current = 2 amperes @ 3kHz, gain = 70dB). This, when combined with the drift figures, gives a crack growth sensitivity of 2×10^{-8} mm s^{-1} over the long term. Over a few hours, however, the drift is lower and even this performance is improved.

THERMAL EFFECTS

The ACPD potential drop technique is sensitive to temperature variations. Temperature affects both the magnetic permeability and the resistivity of materials. Since these are factors determining the skin depth at any particular frequency, it is expected that the measured ACPD will also be a function of temperature. In general ACPD rises with temperature.

During normal room temperature testing it is unlikely that any errors will occur due to temperature changes. However if the ACPD is being measured during anisothermal testing (e.g. thermal fatigue studies) a correction will need to be applied. This is usually accomplished by using a referencing technique and computing a ratio which is independent of temperature. Users wishing to perform such tests should contact Matelect for further applications information (see Optional Equipment Section).

CALIBRATION

It is important to note that the value of the processed ACPD at any one time is of little use in the determination of crack depth except perhaps in carefully calibrated systems where the connection configuration is maintained rigidly between specimens. It is the change in the ACPD signal that is significant. It is therefore usual to perform calibration before testing commences so that a sensitivity to crack depth changes can be defined.

Calibration can be carried out simply by using an artificially introduced defect (e.g. a saw cut) and measuring the resultant changes in the ACPD. The calibration curve should be linear (unlike DCPD studies) and therefore only a small number of readings need be taken. A calibration can also be obtained using the specimen itself if, (for example), optical measurements are related to the ACPD values.

INDUCED PICK-UP AND RESISTIVE MODE

ACPD signals are by their very AC nature represented as vector quantities. Theory predicts that pure ACPD, as generated by passage of an AC current through a metal, will exhibit a phase difference of 45 degrees with respect to the actual current delivered to the specimen.

Unfortunately, the true ACPD is masked by the superposition of a second vector quantity. This vector represents the potential induced in the measurement leads by the current flowing in the supply leads. Theory predicts that this "pick up" vector lies at 90 degrees to the specimen current vector.

The resultant of the two vectors, is the actual ACPD as measured by an automatic phase lock loop detecting circuit within a standard ICF-6R (in **AUTO** mode).

The vectors are shown in the diagram overleaf. Two different pick-up vectors are indicated, for a particular true ACPD vector. It can be seen that these will give widely different ACPD readings. Since the magnitude of the pick-up vector will vary depending on the relative position of the supply and measurement leads, significant errors can occur in ACPD measurements.

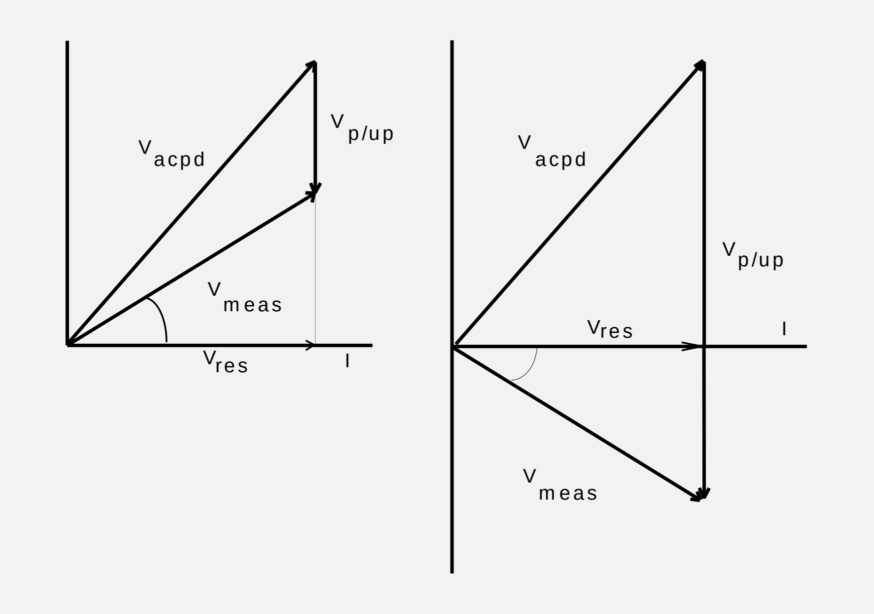


Fig 9. The relative vectorial positions of signals in ACPD studies

The resistive or real portion of the ACPD signal lies along the specimen current vector, (i.e. they share the same phase). The magnitude of the **R**esistive vector does not change with a change in the magnitude of the pick-up. Monitoring the resistive ACPD will therefore theoretically confer an immunity to errors caused by variation in lead position.

In **I/R** mode the displayed ACPD values are actually that which is in-phase with the applied current (i.e. purely resistive) and that which is 90º lagging the current (i.e. purely inductive). The resistive readings are much less susceptible to lead movement. This is most marked at the lower operating frequencies (0.3 to 10kHz).

10. SPECIFICATIONS

GENERAL

The ICF-6R is a multi-frequency single channel alternating current potential drop system. It is housed in a portable enclosure and employs the phase sensitive detection technique to process potential drop signals generated by passage of an internally sourced, high stability alternating current.

ELECTRICAL SPECIFICATIONS

Current: High stability (better than 0.05%) infinitely variable current supply adjustable between Zero and 2 Amperes RMS max. via a ten turn potentiometer. Load regulation is better than 0.05%. The actual applied current can be monitored on the front panel display meter.

Frequency The frequency of the alternating current can be selected from one of 6 preset values of 0.3, 1, 3, 10, 30 and 100kHz, accurate to ±0.1% The stability of the frequency is better than 0.02% and the distortion is less than 0.1%.

Amplification The signal gain is adjustable in 10dB steps form 50 to 90dB, accurate to 0.1dB. The unit can be operated in three mode:

AUTO Automatic lock-in to ACPD signal
MANual Manual adjustment of phase sensitivity
I/R Gives components of signal.

Lock-in time in **AUTO** mode is less than 10 seconds depending on phase of signal w.r.t. current supply, but typically 3 seconds. Warm up time of amplifier is less than 5 minutes. 20 minutes recommended for gross temperature changes.

OUTPUTS

1. Processed ACPD, Inductive PD and Current displayed on 4½ digit LCD meter, non backlit, wide viewing angle.
2. Analogue outputs of displayed voltage (± 5V) with facility for continuous independent offset adjustment.
3. Serial digital (RS232) output for computerised data acquisition. 9600 Baud. Mark (logic 1) -6.8V (through 3kΩ load). Space (logic 0) +6.8 V (through 3kΩ load). Short circuit current 21mA, slew rate 100V/µSec. Power consumption 95mW (through 3kΩ load), 77mW no load.

ADDITIONAL FEATURES

3 position filter control, with 3dB points at 80 and 0.67Hz.

AUXilary power output for peripheral devices (e.g. scanner system)
Optional input pre-amplifier for long cable runs.
Separate **COM**mon and **EARTH** terminals.
Independent offsets for inductive and resistive signal components.
Simultaneous display of current, resistive and inductive values.

POWER

220-240 and 110-120 AC mains, 50 or 60 Hz line frequency.
Input voltage range must be pre-selected by user.
Input via earthed and fused IEC connector.

LINE FUSES

Two 20mm anti-surge 1 ampere fuses protect both Live and Neutral lines. Fuses located within IEC connector

DIMENSIONS

Without handle,
360 x 310 x 210 mm (W x D x H)

MECHANICAL

Cast aluminium frame with pressed aluminium alloy panels finished in standard RAL epoxy powder coat colours.
Adjustable tilt handle (3 positions).
Optional padded aluminium carry case available.

OPERATING TEMPERATURE RANGE

0-40 Degrees Celsius for electronics.
10-35 Degrees Celsius for LCD display.

MASS 12kg
SEALING To IP20
STANDARD Constructed in accordance with CEI/IEC 1010-1 1990

11. PERIPHERAL EQUIPMENT

HARDWARE PERIPHERALS:

The ICF-6R can be expanded into a complete system for ACPD studies by addition of a number of hardware based peripherals.

MULTIPLEXING SYSTEMS: When it is desired to detect and record ACPD in multiple specimens or at multiple sites on a single specimen, it is necessary to multiplex (scan) between signal sources. To maintain sensitivity it may also be necessary to switch the current supply to the various locations. Variations in ACPD with temperature can also be compensated for by multiplexing reference and signal channels and subsequently performing a division of the two quantities to normalise for temperature fluctuations.

Automatic scanning systems: SM. series (SM1, SM2 and SC1 units)

Standard systems are assembled from combinations of 8 way signal switching and 8 way current switching modules, together with one overall controller module which permits control of the scanning parameters either under manual, internal (auto) or external (PC) supervision. Most applications require between 8 and 16 channel capability although the SM series of scanners is expandable up to 99 channels. High quality screened construction and locking LEMO connectors are used for all signal inputs and outputs.

Users who wish to monitor in excess of 32 channels are advised to contact Matelect to discuss the possibility of custom systems.

Automatic scanning systems for temperature compensation only (D2M-1 units)

A simple automatic method employing a two channel scanner can be used to compensate for temperature variations in the ACPD via a division normalisation technique. This is especially useful for single specimens undergoing anisothermal testing (e.g. thermal fatigue tests).

The D2M-1 unit can interface to both a PC (with appropriate software) and provide an analogue output of the normalised ACPD signal.

Manual Multiplexing units (M2M-1 and M6M-1)

These provide cost effective signal and current switching via high quality low noise manual switches mounted in metal enclosures. Terminals are provided for connection of the signal and current cables.

CRACK DEPTH MEASUREMENT PROBES

These optional items are used in conjunction with the ICF-6R to measure crack depth without the need to make permanent connection to a specimen. Spring loaded probes are used to form the electrical contact to the specimen. Two types of probe are available.

Matprobe 1 2 pin traditional ACPD depth probe with separate current lead complete with magnetic/toothed grip contacts.

Matprobe 2 Advanced 4 pin probe incorporating both current and voltage contacts in one unit. Probe is designed to enhance depth resolution and position sensitivity whilst minimising sensitivity to lead movement and specimen edge effects.

SOFTWARE OPTIONS:

A number of different software packages can be supplied by Matelect for data acquisition from the CGM series monitors.

For end users who require bespoke software, Matelect provide a cost effective custom software facility. Existing programs can be modified or fresh code written to solve a particular applications problem.

Please contact Matelect for further details on all hardware and software options.

12. WARRANTY AND SERVICE INFORMATION

The following text is an extract from our standard conditions of sale. It covers the terms of warranty and liability only. Please refer to the full text, supplied upon delivery of the goods or contact Matelect Limited.

Extract 6. WARRANTY

Items sold by the company are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the company agrees to correct, whether by repair or, at it's election, by replacement, any defect of materials or workmanship which develops within twelve months after delivery of the instrument to it's original purchaser by the company or by any authorised representative provided that investigation and factory inspection by the company discloses that such defect developed under normal and proper use (unless covered by a separate agreement or guarantee written by the company).

The exceptions and conditions mentioned above are the following.

a). The company makes no warranty concerning components and accessories not manufactured by it. however, in the event of the failure of such components or accessory, the company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

b). The company shall be released from all obligations under it's warranty in the event of repairs or modifications being made by persons other than it's own or authorised service personnel unless such repairs by others are made with the written consent of the company or unless such repairs are minor or merely the installation of a new Matelect component.

c). The warranty is only valid providing that the terms of payment in clause 4 are strictly adhered to.

d). No product may be returned except with the company's permission in writing. After receiving factory authorisation, goods requiring repair or replacement should be sent prepaid to the factory in the original container properly packed accompanied by a Return Goods Authorisation, purchase order or letter stating as completely as possible the defects and the condition under which it occurred.

Extract 8. CONDITIONS PARAMOUNT

The company expressly disclaims any liability of whatsoever nature and in any circumstances whatsoever, to it's customers, dealers or agents, except as stated in the forgoing terms and conditions.

Extract 9. These terms and conditions of sale may be amended or altered at any time the company feel it necessary to do so.

REPAIR AND RECALIBRATION:

Matelect Limited can repair and/or recalibrate instruments manufactured by it, after the warranty period has expired. If this service is required then please contact Matelect and we will be pleased to provide a quotation for the work necessary.