MATELECT

PRODUCT GUIDE

2017

www.matelect.com

Thank you for consulting this product guide and for your interest in Matelect products. This guide outlines Matelect’s extensive range of potential drop equipment and testing solutions. At the rear you will also find some short applications notes which hopefully provide some background to the potential drop technique, its uses, and its variants. Historically PD has been used successfully to monitor the development of creep damage in metallic specimens, both during offline and online testing, and at room temperature as well as elevated temperatures. This guide provides some specific information on the application of PD in such contexts, however for more advice, please contact Matelect’s head office.

Inside this guide you will find information on all our off-the-shelf instruments and peripherals, covering both the AC and DCPD techniques as well as our induced signal monitors.

Matelect have been in the potential drop business since the beginning of the 1980's. The company was started by an electrical engineer and a materials scientist who together decided to turn the fruits of their university based research into a manufacturing business.

Matelect's first commercial product was the CGM-3 ACPD crack growth monitor. This was followed by the greatly improved version designated the CGM-5R. Today, after taking into account various user comments and suggestions we have the CGM-7 widely regarded as the premier ACPD instrument for research use.

Over the years we have augmented the AC instrument with a wide variety of peripherals, including multiplexing modules (which permit many signals to be processed by a single CGM instrument), hand held depth probes and sophisticated data acquisition software. Information on all these products is to be found in this Guide.

In 1993, we expanded into the then established, traditional DCPD market - with a definitely non-traditional microprocessor based pulsed DC system. This product, the DCM-1, proved to be very popular but as always we listened to what our customers wanted and have recently replaced this unit with a very much improved DCM-2, which we consider to be one of the best DCPD units on the market.

Whilst we remain a commercial organisation, Matelect has not lost sight of its research based roots - all of our employees are university graduates and we pride ourselves in our ability to provide end-users with detailed assistance and applications support. Matelect also undertakes bespoke design and manufacture - for those customers whose needs cannot be met from our standard product line.

Please note:
Prices within this document are correct at time of press. For current pricing customers are advised to contact Matelect Ltd for a quotation.

CONTENTS

CGM-7 ACPD CRACK GROWTH MONITOR

The CGM-7 is a modern microprocessor based instrument for measuring crack depth in metals undergoing materials testing. Building on the success of the CGM-5R this unit improves upon the CGM-5R specification by offering two channel operation, higher frequency and current outputs, full computer control and a variety of expansion options.
It utilises the alternating current potential drop method (ACPD) which is an established technique covered by the ASTM 647 standard. The technique involves passing an alternating current through the metal under test and measuring the resultant voltage drop that is created across the specimen. The presence of a growing defect will alter this voltage and by suitable calibration, a measure of the defect depth can be obtained.

CGM-7 FEATURES

- Continuously variable frequency output from 10Hz to 500kHz in 1Hz increments.*
- Advanced filtering capabilities with 3 user selectable ranges (and out).
- 10 pre-set gains built in. User selectable from 1000 to 30000.
- Two channels as standard on all models.

* Dependent on model option

- High output currents up to 5 amps. Continuously variable in 1mA increments.[1]
- User selectable offsets. Continuously variable from –4v to +4v.
- Resistive and inductive components simultaneously displayed.
- Pre-amplifiers provided as standard for each channel for superior SNR.

Applications

- Slow crack growth
- Crack sizing
- Dynamic crack growth studies
- Crack closure studies
- Crack initiation
- Fatigue crack initiation
- Condition monitoring
- Stress corrosion testing

SM-HF MODULAR SCANNER SYSTEM

The SM-HF scanner system provides a modular way of monitoring multiple specimens or areas of Interest and is designed for use in conjunction with the CGM-7 or ACM-1A series of ACPD crack growth monitors manufactured by Matelect or indeed as a standalone scanner system.
The SM-HF system is modular and can be specified (or expanded) to cover a total of 256 specimen channels. Each module is based on a 4 channel switching unit. Two types of unit exist; the SM1-HF is used for switching the ACPD 0 degree and 90 degree signals, whilst the SM2-HF is used to switch the AC excitation current. Both modules are under the control of an SC1 scan controller module built into both the CGM-7 and ACM-1A, and supplied as standard.

SM-HF FEATURES

- The SM1-HF is capable of switching signals running at up to 500kHz.
- The SM2-HF is capable of switching currents running at up to 500Khz and 5Amps, a perfect partner for the CGM-7.
- The SM-HF system can handle up to 256 channels, all controllable from PDsoft.

Applications

- For use with ACM-1A and CGM-7 ACPD units.
- Monitoring of multiple specimens using one CGM-7 unit.
- Monitoring multiple areas of interest on one specimen.

MAT-3 PROBE

Matprobes are designed to be used with the CGM series of crack growth monitors, allowing the user to obtain crack depth data in the field without the need to provide permanent contact to a specimen. Spring loaded pins are utilised to form some or all of the contacts necessary for operation. The probes are designed to be used as handheld devices although it is possible to incorporate them into other apparatus to maintain fixed geometries (e.g. for use on a production line).
The MAT-3 handheld probe is an advanced crack depth measurement probe which is made up of an outer aluminium tube body and two PTFE inserts containing, a high precision pre-amplifier circuit as well as a detachable probe head that contains all the necessary contacts to pass both the current and pick up the resultant ACPD voltage signals.

MAT-3 PROBE FEATURES

- Spring loaded pins.
- Built in precision pre-amplifier circuit.
- Detachable probe heads for user specific measurements.

Applications

- In field crack depth measurement with CGM units.

ACPR-2 (FILTERED)

The ACPR-2 (FL) is a filtered pre-amplifier, specifically developed for use with the CGM-7 and CGM-5R. When using an induction furnace for high temperature experiments the induction coils can affect the signals of the ACPD test, therefore a filter is required to cut-out the high frequency interference.

As standard these units have a 10kHz cut-off frequency, other cut-off frequencies may be available on request.

ACPR-2 (FL) FEATURES

- High grade analogue circuitry used to reject induced signals from the environment whilst allowing the measured signal through.
- 10kHz cut-off frequency as standard, other frequency cut-offs available on request.

Applications

- For use with CGM-7 and CGM-5R ACPD units.
- Filters signals from within induction ovens that would otherwise be affected by the induction coils.

CGM-7 & ACCESSORIES SPECIFICATIONS

CGM-7 Model range	
Option1	2A Max current output and 300Hz to 100kHz frequency range.
Option2	2A Max current output and 300Hz to 240kHz frequency range.
Option3	5A Max current output and 300Hz to 100kHz frequency range.
Option4	5A Max current output and 300Hz to 240kHz frequency range.
Option5	5A Max current output and 300Hz to 500kHz frequency range.
Option6	2A Max current output and 10Hz to 100kHz frequency range.

Specifications	
Current O/P	High stability (better than 0.2%) continuously variable current supply. Continuously variable up to 5 Amperes* RMS maximum in 1mA increments.
Frequency O/P	Continuously variable from 10Hz to 500kHz*, in 1Hz increments to a stability better than 0.01% and a distortion of less than 0.1%.
Amplification	Independent gain setting of each channel, 1000, 1500, 2000, 3000, 5000, 7500, 10000, 15000, 20000 and 30000.
Offset	Continuous offset adjustment of both resistive and inductive components. Variable from –4v to +4v in 1mV increments.
Filter	Filter with sharp cut-offs at 0.1Hz, 80Hz, and 1KHz, as well as an OUT position.
Display	Large 240*128 back-lit LCD displaying the following; Current set/read, Frequency set, gain set, bias set, filter set, resistive and inductive components of each channel.
Outputs	Separate analogue O/P of resistive and inductive components of each channel (BNC) Digital O/P of all set and displayed values. (Via RS-232 or USB)
Connectors	Current O/P 2-way Lemo Pre-Amp Input 8-way Lemo (one per channel) 9-pin D-type for RS232 USB-Type B 25-way D-type for SM1-HF and SM2-HF units.
EMC and Safety	Conforms to all relevant European directives.
Power supply	110-120V or 220-240v (Switch selectable) AC Mains, 50 or 60Hz. Mains input via earthed and fused IEC connector.
Line Fuses	Two 20mm anti surge 1Ampere fuse.
Mechanical	Frame made of aluminium extrusions and die-cast pieces, covers made of zinc-plated steel. All finished in a RAL epoxy powder coat. Optional 19” rack mountable handles.
Dimensions / Weight	450mm wide x 340mm deep x 145mm high. Net weight 12Kg. (approx)
Operating Temperature	0˚- 35˚C main unit. LCD 10˚- 30˚C. 30 minutes warm up time is recommended.

*Total frequency and current range is dependent on model purchased.

ACPR-2 Pre-Amplifier specifications (Two included with each CGM-7)	
Pre-set gain	500
Mechanical	Extruded aluminium silver anodised case. With optional mounting brackets available on request.
Dimensions Weight	63mm wide x 84mm deep x 33mm high. Net weight 120g. (approx)
Operating Temperature	0˚-35˚C.

Available accessories and options on all models	
SM1-HF	4 dual channel signal switching unit. (500KHz compliant)
SM2-HF	4 channel current switching unit. (5A compliant)
PDSOFT	16 channel data logging software, with formula entry for real time ‘mm’ output.
19" rack mounting	Rack mounting kit, please state when ordering.
Mounting brackets	Mounting brackets are available for the pre-amplifiers and scanner modules.*

*Please specify this option when ordering.

PRICING	
CGM-7 (option 1)	**P.O.A**
CGM-7 (option 2)	**P.O.A**
CGM-7 (option 3)	**P.O.A**
CGM-7 (option 4)	**P.O.A**
CGM-7 (option 5)	**P.O.A**
CGM-7 (option 6)	**P.O.A**
CGM-7 ACPR-3	**P.O.A**
CGM-7 ACPR-2 (FL)	**P.O.A**
CGM-7 SM1-HF	**P.O.A**
CGM-7 SM2-HF	**P.O.A**
CGM-7 CABL1-HF	**P.O.A**
CGM-7 CABL2-HF	**P.O.A**
MAT-3 Handheld Probe	**P.O.A**
PDSOFT (BASIC VERSION)	**P.O.A**
CGM-7 CALIBRATION SERVICE	**P.O.A**

DCM-2 DCPD CRACK GROWTH MONITOR

The DCM-2 is a modern microprocessor based instrument for measuring crack depth in metals undergoing materials testing. Building on the success of the DCM-1 this unit takes on board customer comments and suggestions, as shown in its impressive features list.
It utilises the pulsed current potential drop method (DCPD) which is an established technique also covered by the ASTM 647 standard. The technique involves passing a constant current through the metal under test and measuring the resultant voltage drop that is created across the specimen. The presence of a growing defect will alter this voltage and by suitable calibration, a measure of the defect depth can be obtained. DCPD is generally regarded as easier to set-up than ACPD, but care is required to attain comparable crack depth resolutions due to the extra opportunity for experimental noise.

DCM-2 FEATURES

- Capable of reversing DCPD*.
- Sophisticated filtering options. The unit has advanced sampling and filtering options.
- High Current O/P, up to 50A. Variable in steps of 10mA.
- Built in scan controller*, for direct control of high current scanners.

***Dependent of model option**

- Pulsed DCPD as standard.
- Advanced triggering*, including peak, trough, and mid-point of load cycle waveform input.
- Variable DC offsets for the removal of standing voltages.
- Two channels as standard, reference and specimen.

Applications

- Slow crack growth
- Crack sizing
- Dynamic crack growth studies
- Crack closure studies
- Crack initiation
- Fatigue crack initiation
- Condition monitoring
- Stress corrosion testing

SM-HC MODULAR SCANNER SYSTEM

The scanner system provides a modular way of monitoring multiple specimens or areas of interest and is designed for use in conjunction with the DCM-1 or DCM-2 series of crack growth monitors manufactured by Matelect or indeed as a standalone scanner system.
The SM-HC system is modular and can be specified (or expanded) to cover a total of 256 specimen channels. Each module is based on a 4 channel switching unit. Two types of unit exist; the SM1-HC is used for switching the DCPD X and Y signals, whilst the SM2-HC is used to switch the DC excitation current. Both modules are under the control of a single Scan Controller unit, the SC1 or in the case of the DCM-2 a SC1 scan controller module built into the unit.

SM-HC FEATURES

- The SM1-HC switches both reference and active signals at the same time.
- The SM2-HC is capable of switching currents at up to 50 Amps, a perfect partner for the DCM-2.
- The SM-HC system can handle up to 256 channels, all controllable from PDsoft.

Applications

- For use with DCM-1 and DCM-2 DCPD units.
- Monitoring of multiple specimens using one DCPD unit.
- Monitoring multiple areas of interest on one specimen.

DCM-2 & ACCESSORIES SPECIFICATIONS

DCM-2 Model range	
Option1	10A maximum current output.
Option2	10A maximum current output, with Advanced triggering
Option3	10A maximum current output, with Advanced triggering, and 20 volt output supply
Option4	50A maximum current output.
Option5	50A maximum current output, with Advanced triggering
Option6	50A maximum current output, with Advanced triggering and reversing output current

Other Configurations are available please call for a quote

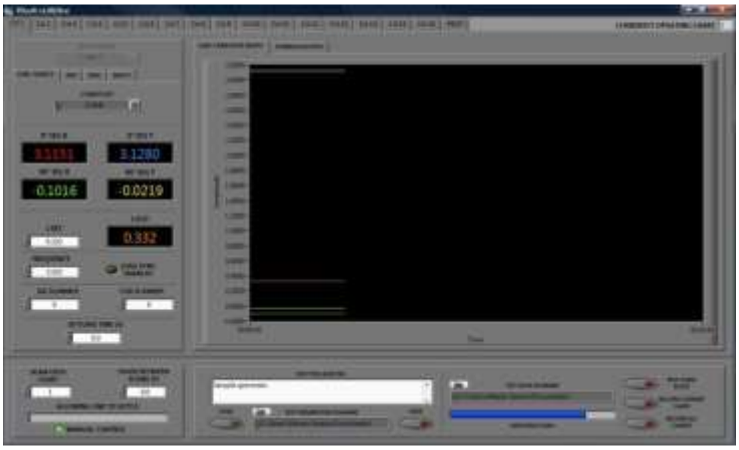
Specifications	
Current O/P	High stability (better than 0.01%) continuously variable current supply. Continuously variable in 10mA increments.
Input ranges	+/-4500µV with a resolution of 0.1µV. +/-450µV with a resolution of 0.01µV. +/-45µV with a resolution of 1nV.
Offset	+/- 4.5mV with respect to input signal. Adjustable in 1µV steps.
Filters	User definable filtering with 3 pre-defined settings.
External sync	Input voltage range, Max +/-20V Min +/-150mV Frequency range, Max 1kHz Min 0.1Hz Unit will trigger on peak, trough or mid-point of load cycle waveform input.
Display	Large 240*128 back-lit LCD displaying all user definable settings. As well as the X, Y and X/Y signals.
Outputs	Separate analogue O/P's of X, Y and X/Y signals. (BNC) Digital O/P of all set and displayed values. (Via RS-232)
Connectors	Current O/P 2-way and 3-way Lemo (2B size) Signal I/P X and Y 2-way Lemo (0B size) Analogue signal out X, Y & X/Y: BNC Ext sync BNC RS232 9-pin male D-type USB-Type B
EMC and Safety	Conforms to all relevant European directives.
Power supply	110-120V or 220-240v (Switch selectable) AC Mains, 50 or 60Hz. Mains input via earthed and fused IEC connector.
Line Fuses	Two 20mm anti surge 3Ampere fuse.
Mechanical	Frame made of aluminium extrusions and die-cast pieces, covers made of zinc-plated steel. All finished in a RAL epoxy powder coat. Optional 19" rack mountable handles.
Dimensions / Weight	450mm wide x 340mm deep x 145mm high. Net weight 12Kg.
Operating Temperature	0˚- 35˚C main unit. LCD 10˚- 30˚C. A 30 minutes warm up time is recommended.

*Total current output is dependent on model purchased.

Available accessories and options on all models	
INTERNAL PRE-AMP	Internal Preamplifier providing 2 extra concurrent inputs.
EXTERNAL PRE-AMP	External Preamplifier. (Availability TBA)
INTERNAL SC1-HC	Scanner control with 25-way male D-type for SM system, 2x BNC to give analogue position of current and signal channels.
EXTERNAL SM1-HC	4 dual channel signal switching unit.
EXTERNAL SM2-HC	4 channel current switching unit. (50amp compliant)
19" rack mounting	Rack mounting kit, please state when ordering.

PRICING	
DCM-2 (option 1)	**P.O.A**
DCM-2 (option 2)	**P.O.A**
DCM-2 (option 3)	**P.O.A**
DCM-2 (option 4)	**P.O.A**
DCM-2 (option 5)	**P.O.A**
DCM-2 (option 6)	**P.O.A**
DCM-2 SC1-HC	**P.O.A**
DCM-2 SM1-HC	**P.O.A**
DCM-2 SM2-HC	**P.O.A**
DCM-2 SM2-HCR (Reversing version of above)	**P.O.A**
DCM-2 CABL1-HC	**P.O.A**
DCM-2 CABL2-HC	**P.O.A**
PDSOFT (BASIC VERSION)	**P.O.A**
DCM2 CALIBRATION SERVICE	**P.O.A**

PDsoft & LABVIEW DRIVERS



PDsoft is a new fully integrated software package that has been developed to provide a single environment in which to talk to all of our current and previous PD products, and control them where applicable.
PDsoft has many advanced features, not only has it the usual scanner controls but it also has the ability to perform load synchronisation for ACPD equipment. It has a formula entry system, this allows the software to give an 'mm' output in real time.
Why not download and try the evaluation version from our website, if you like it just get in touch and we can send out a license file to activate it fully.

PDsoft FEATURES

- Control and read up to 16 different instruments, or select any channel of our scanner systems from the same package sequentially.
- Adjust and store the settings of your instrument. (Where the instrument allows)
- All readings displayed on a graph in real time in a CSV file.
- Enter your own user formulas using the readings of your PD instrument as variables, and get real time 'mm' outputs, displayed in a graph and stored in CSV format.
- Synchronise your ACPD readings with the load cycle of your machine. (Extra hardware required)

LABVIEW DRIVERS

The following LABVIEW drivers are available free of charge for download from our website.

- ACM-1A (inc SM-HF SCANNERS)
- CGM-5R (INC SM SCANNERS)
- CGM-7 (inc SM-HF SCANNERS)
- ISM-6A
- DCM-1 (inc SM-HC SCANNERS)
- DCM-2 (inc SM-HC SCANNERS)
- ICF-6R

ISM-6A INDUCED SIGNAL MONITOR

Used mainly in the EBIC mode (electron beam induced current), the ISM-6A is employed in conjunction with a scanning electron microscope to image electrically active defects in semiconductor materials and devices. Long regarded as the industry leader, the ISM series offers quantitative as well as qualitative facilities, the former enabling device parameters and materials data to be obtained. The ISM-6A builds on the original ISM-5 unit which is found in many research labs worldwide.

ISM-6A FEATURES

- Induced Current and/or Voltage options. Through use of dedicated current or voltage preamplifier units.
- Possible internal bias source range –100V to +100V (Model dependant). Allows biasing of a sample to a resolution of up to 0.1mV.
- Large back-off current range from –20mA to +20mA. Digitally displayed with resolutions ranging from 1uA to 0.1pA
- Wide bandwidth. 3kHz bandwidth at 0.1pA resolution and 230kHz at 100nA resolution.
- Complete microprocessor control, with interface to PC via Labview drivers.
- Intuitive interface with adjustable backlight control for use in reduced ambient conditions.

Applications

- Characterization and observation of junction areas
- Failure analysis (FA) of semiconductor devices
- Locating areas of ESD (Electrostatic Discharge) damage
- Quality control and assurance (QA) o semiconductors
- Detecting subsurface damage or defects
- Can also be used for OBIC, EBIV, SOMSEM and CL (transmitted or emitted) studies

ISM-6A SPECIFICATIONS

INDUCED CURRENT AMPLIFIER (ICA-1)

Range	F.S.D.	Resolution	Accuracy	Bandwidth	Noise (r.m.s.)
1	2 nA	0.1 pA	1 pA	3 kHZ	2.5 pA
2	20 nA	1 pA	10 pA	6 kHZ	2 pA
3	200 nA	10 pA	100 pA	24 kHZ	2 pA
4	2 uA	100 pA	1 nA	70 kHZ	1 pA
5	20 uA	1 nA	10 nA	100 kHZ	1 pA
6	200 uA	10 nA	100 nA	150 kHZ	1 pA
7	2 mA	100 nA	1 uA	230 kHZ	1 pA

INDUCED VOLTAGE AMPLIFIER (IVA-1)

Range	F.S.D.	Resolution	Accuracy	Bandwidth
1	2 mV	100 nV	1 uV	The bandwidth performance for the IVA-1 depends on sample impedance.
2	20 mV	1 uV	10 uV	
3	200 mV	10 uV	100 uV	
4	2 V	100 uV	1 mV	

BEAM CURRENT MONITOR IN ICA-1 AND IVA-1

Range	F.S.D.	Resolution	Accuracy	Bandwidth	
1	2 nA	0.1 pA	1 pA	200 Hz	
2	20 nA	1 pA	10 pA	6 kHz	
3	200 nA	10 pA	100 pA	24 kHz	
4	2 uA	100 pA	1 nA	70 kHz	
5	20 uA	1 nA	10 nA	100 kHz	
6	200 uA	10 nA	100 nA	150 kHz	
7	2 mA	100 nA	1 uA	230 kHz	

BACK-OFF CURRENT

Range	Resolution	Range	Resolution
0-2 nA	0.1 pA	0-20 uA	1 nA
2-20 nA	1 pA	20-200 uA	10 nA
20-00 nA	10 pA	0.2-1 mA	100 nA
0-200 uA	10 pA	0-2 mA	100 nA
0.2-2 uA	100 pA	2-20 mA	1 uA

BIAS VOLTAGE		SHORT-CIRCUIT TRIGGER LEVELS	
Range	**Resolution**	**Range**	**Resolution**
0-2V*	0.1mV*	0.1, 0.5, 1 and 10mA	5%
2-20V*	1mV*		
20-100V*	10mV*		
0-40V	10mV		
*Cost options Contact Matelect for further information			

OTHER SPECIFICATIONS

DIMENSIONS	Head amp: 110mm x 160mm x 30mm (W*D*H)
	Main unit: 450mm x 280mm x 130mm (W*D*H)

PRICING

ISM-6A	**P.O.A**

SR-80 CAPACITANCE DISCHARGE WELDER

The model SR-80 thermocouple welder has been specifically chosen by Matelect for the welding of potential drop current and signal cables to the specimen under test. Using capacitance discharge as the energy for the weld, wires of up to 1.6mm diameter can easily be welded with minimum user experience.

Three selectable power ranges are provided allowing for fine adjustment of the weld power. This is particularly useful when welding very fine wires. Wires of dissimilar and similar metals can be welded.

SR-80 FEATURES

- Three adjustable power ranges: 20, 40 and 80J.
- Argon gas flow-meter incorporated.
- Charge indication and 'wait' lamp with interlock.
- Weld delay in Argon mode to allow gas shield to form.
- Ideal for all transducer / sensor production.
- Hands free foot switch included.

SR-80 SPECIFICATIONS

GENERAL SPECIFICATIONS	
ENERGY OUTPUT	0 to 80 Joules via selectable outputs
WELD CAPACITY	Up to 2 wires 1.6mm diameter
POWER SUPPLY	220/240v AC or 100/120v AC
POWER CONSUMPTION	Max 360VA, quiescent 5VA
ARGON CONSUMPTION	300 l/hr @ 5psi
DIMENSIONS & WEIGHT	310 x 230 x 120mm, 5Kg

INCLUDED ACCESSORIES	
Mains lead	Spare carbon electrodes
Plier electrodes for arc welding	Viewing filler glass attachment
Argon hose with end fittings	Hands free footswitch

OPTIONAL ACCESSORIES	
Tweezer electrodes for very fine wires	Pen and plate mini resistance welding kit

PRICING	
SR-80	**P.O.A**

STORK THERMOCOUPLE ATTACHMENT

The Stork Thermocouple Attachment Unit (TAU) has been specifically chosen by Matelect for the welding of potential drop current and signal cables to the specimen under test. Using capacitance discharge as the energy for the weld, up to 24 gauge (awg) wires can easily be welded with minimum user experience.

Three selectable power ranges are provided allowing for fine adjustment of the weld power. This is particularly useful when welding very fine wires. Wires of dissimilar and similar metals can be welded.

STORK TAU FEATURES

- Three power settings available in both automatic and manual mode.
- Stainless steel case.
- Battery or mains operated.
- Single handed operation in automatic mode.
- Automatic switch off after 3 minutes to save battery power.
- Simple to operate.

STORK TAU SPECIFICATIONS

GENERAL SPECIFICATIONS	
WELD CAPACITY	0.5, 1 & 2mm selectable
POWER SUPPLY	220-240v AC or 100-125v AC, please advise when ordering
POWER CONSUMPTION	5.0 VA
BATTERY CAPACITY	2.7 Ah
BATTERY VOLTAGE	12V
No. OF DISCHARGES	Approximately 1000 on setting 2 at a rate of 200 discharges per day with fully charged battery.
DIMENSIONS & WEIGHT	210 x 215 x 90mm, 4.25Kg

INCLUDED ACCESSORIES	
Pliers	Magnet
Recharging cable	Integral stainless steel case

PRICING	
STORK TAU	**P.O.A**

ACM-1A ACPD CRACK GROWTH MONITOR

Designed as a ‘Black Box’ ACPD crack growth monitor to reduce costs and simplify end user installation, the ACM-1 is ideally suited to semi-permanent installations for long term crack growth monitoring, for example in power utility installations and structural applications.
The ACM-1 utilises the alternating current potential drop method (ACPD) which is an established technique covered by the ASTM 647 standard. The technique involves passing an alternating current through the metal under test and measuring the resultant voltage drop that is created across the specimen. The presence of a growing defect will alter this voltage and by suitable calibration, a measure of the defect depth can be obtained.

ACM-1A FEATURES

- 300 Hz output frequency, normally fixed. Variable frequency models available.
- Built in scan controller, measure multiple locations from one unit.
- Built in high precision pre-amplifier circuitry.
- Small compact size! Measures only 160mm * 160mm * 60mm.
- 2 Amps output, normally fixed. Variable current models available.
- Two channels as standard, measure active and reference signals.
- Wi-Fi and Ethernet communication modules available.
- Fixed gain setting at 20,000

Applications

- Slow crack growth
- Crack sizing
- Stress corrosion testing
- Crack initiation
- Fatigue crack initiation
- Condition monitoring

ACM-1A SPECIFICATIONS

Main Specifications	
Current O/P	2Amps High stability fixed current supply. At our discretion it may be possible to increase the current output to as much as 5 Amperes, and make it adjustable, call for further information.
Frequency O/P	Fixed frequency output set at 300Hz At our discretion it may be possible to make the frequency adjustable between 300Hz and 30kHz, call for further information.
Amplification	Fixed gain setting of each channel set to 20,000.
Offset	No offset feature provided
Filter	No filters provided At our discretion it may be possible to add filters, call for further information.
Display	No display provided, all display of variables via PC display
Outputs	No analogue O/P's Digital O/P of all set and displayed values. (Via RS-232) The unit outputs the following parameters via RS-232, Ethernet or wifi; Current o/p Frequency o/p Signal X (0 degree **or** 90 degree component **ONLY**, as chosen by user before dispatch) Signal Y (0 degree **or** 90 degree component **ONLY**, as chosen by user before dispatch)
Connectors	6-pin Lemo for both current output and signal in * 2 9-pin D-type for RS232 25-pin D-type for scanner control
EMC and Safety	Conforms to all relevant European directives.
Power supply	To be advised
Line Fuses	To be advised
Mechanical	To be advised
Dimensions / Weight	160mm * 160mm * 60mm **(approx)**
Operating Temperature	0˚-35˚C.

Other specifications	
Built in Pre-amps	Two built in pre-amplifiers will be provided, for signal X and Y
Software	The basic price of the unit includes simple software to control and read the unit and also store the values to a text file. (This does NOT include control or reading of any scanners)

Available accessories and options on all models	
SM1-HF	4 dual channel signal switching unit. (500KHz compliant)
SM2-HF	4 channel current switching unit. (5A compliant)
PDSOFT	16 channel data logging software, with formula entry for real time 'mm' output.
Mounting brackets	A range of mounting brackets are available for directly mounting to any flat surface.*

*Please specify this option when ordering.

PRICING	
ACM-1A Main Unit	**P.O.A**
ACM-1A Adjustable frequency option	**P.O.A**
ACM-1A Adjustable Current option	**P.O.A**
ACM-1A Software for scanners	**P.O.A**
ACM-1A Wi-Fi module	**P.O.A**
MAT-3 Handheld Probe	**P.O.A**
ACM-1A Cable converter for use of standard CGM-7 leads	**P.O.A**
ACM-1A 0.1Hz output filter.	**P.O.A**
PDSOFT (BASIC VERSION)	**P.O.A**

CGM-5R ACPD CRACK GROWTH MONITOR

Designed for the accurate measurement of crack growth in metals, the CGM-5R Crack Growth Monitor operates by establishing an alternating current of constant amplitude and frequency in the specimen surface, or across some region where a crack is expected to develop this is an established technique covered by the ASTM 647 standard. Very high sensitivity and accuracy is possible because the frequency of operation may be chosen to suit the electrical properties of the particular metal or alloy under investigation. This induces a pronounced skin-effect enhancement of the A.C.P.D. signal level.

CGM-5R FEATURES

- High stability and ultra high resolution.
- Switchable output filters, very low freq, 80Hz and out position.
- Automatic phase setting, maintains the correct phase as conditions change. Also fixed and manual phase operation.
- Variable supply current, 0 to 2 amps continuously adjustable
- Multi frequency operation, frequencies of 300Hz to 100kHz can be selected in steps.
- Full range of options, the unit may be enhanced by multiplexing units, probes and data acquisition software.

Applications

- Slow crack growth
- Crack sizing
- Dynamic crack growth studies
- Crack closure studies
- Crack initiation
- Fatigue crack initiation
- Condition monitoring
- Stress corrosion testing

SM MODULAR SCANNER SYSTEM

To increase the versatility of the CGM-5R crack growth monitor, Matelect developed a compact, modular signal multiplexing system designed to allow multi-point monitoring of specimens undergoing crack growth Measurements.
In its most basic form the system is capable of measuring up to 8 signal points sequentially and the most sophisticated version a maximum of 256 points. A basic system comprises an SC-1 controller and either an SM-1 and/or an SM-2 multiplexing unit as shown in the picture.
The SC-1 can control up to a maximum of 100 current and signal channels which enables the system to be simply expanded by the addition of SM-1 or SM-2 units as required.

SM FEATURES

- The SM1 is capable of switching signals running at up to 100kHz.
- The SM2 is capable of switching currents running at up to 100Khz and 2Amps, a perfect partner for the CGM-5.
- The SM system can handle up to 256 channels, all controllable from PDsoft, 100 from the front panel.

Applications

- For use with CGM-5R units.
- Monitoring of multiple specimens using one CGM-5R unit.
- Monitoring multiple areas of interest on one specimen.

SM-3 THERMAL COMPENSATION UNIT

Matelect manufactures the SM-3 for switching between two channels of ACPD data and performing the division of the recorded values automatically. This frees the user from having to attend the experiment and allows temperature normalisation to be performed during long term tests (where it is more likely to prove important to do so).
The SM-3 unit switches between the two ACPD channels a preset time (of variable duration). The switched signal is routed via a standard CGM-5R for processing and then routed back to the SM-3 so that a highly accurate analogue division can be performed. The resultant normalised signal can then be recorded by a chart recorder or a PC via Labview drivers for the SM-3.

SM-3 FEATURES

- Can be used as a standalone unit to perform thermal compensation of ACPD measurements.
- Switching between channel A and B is carried out continuously, at rates of 3.2, 8 and 16 seconds, user selectable.
- Both analogue and digital outputs are provided. The unit is primarily designed to work with the CGM-5R.

Applications

- Thermal compensation for use with CGM-5R units

CGM-5 & ACCESSORIES SPECIFICATIONS

CGM-5R Model range	
CGM-5R	2A Max current and up to 100kHz max frequency.

Specifications	
Current O/P	The current amplitude may be set, using a 10-turn helipot, to any value up to 2 Amps r.m.s. and it will be stable to better than 0.1 %. The CGM5R can deliver a maximum of 3 volt-amps to the load.
Frequency O/P	The frequency can be set to one of six preset values: 300Hz, 1kHz, 3kHz, 10kHz, 30kHz or 100kHz.
Amplification	A high quality input transformer is used in the CGM-5R to ensure excellent common mode rejection and perfect balance. This transformer is followed by a very low noise amplifier with a maximum gain of 90db. A front panel control allows the gain to be reduced to 50db in steps of 10db.
Offset	Continuous offset adjustment via front panel pot.
Filter	Filter with sharp cut-offs at 0.1Hz, 80Hz as well as an out position.
Display	Phase sensitive detection, followed by selectable filters, is used to process the final output, which can be displayed on the 41/2 - digit auto ranging LCD display on the front panel of the CGM-5R.
Outputs	A socket on the rear panel provides digital outputs of the current and A.C.P.D. signal levels for a computer or a digital data-logger. Software is available to read the digital output port. A separate socket provides both analogue outputs for XY recorder users, and a front panel 10-turn pot allows a variable offset for convenient positioning of the display.
CONTROL INPUTS/OUTPUTS	A further rear panel socket on the CGM-5R makes it possible to sample some of the internal waveforms within the instrument. The socket also gives access to a control relay in the CGM-5R which may be used to stop the test or sound an alarm when a crack is detected or has grown to some preset length.
EMC and Safety	Conforms to all relevant European directives.
Power supply	Standard CGM-5R units are powered from AC supplies of 100-130, and 220-240 volts, 50/60Hz, user selectable from the rear panel.
Line Fuses	Two 20mm anti surge 1Ampere fuse.
Dimensions / Weight	350mm x 130mm x 262mm deep. 10kg.
Operating Temperature	0˚- 35˚C main unit. LCD 10˚- 30˚C. 30 minutes warm up time is recommended.

Available accessories and options on all models	
ACPR-2 SEPARATE PRE-AMPLIFIER	Useful when CGM-5R has to be some distance away from the test. It also improves the noise performance marginally.
ACPR-2 (FL) Input filter	Required when specimen under test is heated by high frequency induction heating.
SC-1, SM-1, SM-2 MULTIPLEXING SYSTEMS	Modular signal and current multiplexers are available so that multiple specimens or crack sites can be monitored. Computer control and sophisticated software allow unattended scanning and data logging. Low cost manual scanners are also available.
MAT-3 PROBES	Standard hand held products for crack sizing in the field are available. Custom units, designed and built to agreed specification, can also be supplied.
SM-3	For use with a reference specimen to eliminate the effects of temperature in situations where extremely high stability and accuracy are required.
PDSOFT	16 channel data logging software, with formula entry for real time 'mm' output.

PRICING	
CGM-5R	**P.O.A**
CGM-5R ACPR-3	**P.O.A**
CGM-5R ACPR-3 (FL)	**P.O.A**
CGM-5R SC-1	**P.O.A**
CGM-5R SM-1	**P.O.A**
CGM-5R SM-2	**P.O.A**
CGM-5R CABL1	**P.O.A**
CGM-5R CABL2	**P.O.A**
MAT-3 Handheld Probe	**P.O.A**
CGM-5R SM3	**P.O.A**
PDSOFT (BASIC VERSION)	**P.O.A**
CGM-5R CALIBRATION SERVICE	**P.O.A**

APPLICATION NOTES

Use ofthe Potential Drop method to detect and measure creep damage

A Short Applications Note

BACKGROUND

Potential drop is a technique that relies upon the changes in resistance (for DCPD) or impedance (for ACPD) of the specimen under test (SUT), when defects are present. Such defects generally comprise surface breaking cracks, but internal defects (such as porosity or creep induced cavitation) can also generate measurable differences. The change in property is measured by passing a current into the SUT and then measuring the resultant voltage drop across the zone of interest, under a conventional four point connection regime.

Current flow in DCPD is through the bulk of a specimen, whilst in ACPD it mainly flows in a zone (known as the skin depth) close to the specimen surface. In theory, this therefore makes ACPD much more sensitive to surface breaking defects, whilst DCPD, although still used mainly in this role, is theoretically capable of “seeing” defects that are subsurface.

Modern ACPD systems permit the AC frequency to be altered over a wide spectrum. This in turns allows a variation in skin depth and, at low excitation frequency, the current can penetrate deep into the specimen (depending on the material) and can also therefore respond to sub-surface defects. As a result Matelect have supplied both AC and DCPD apparatus to end-users who are intent on performing creep studies.

The discussion over which variant of the PD technique is more appropriate than another for creep testing (also see our publications on AC vs DCPD) often comes down to the prior experience of the end-user. For those who are new to PD, it is likely that DCPD will provide the fastest return on the investment of time when it comes to creep work, offering “out-of-the-box” sensitivity to sub-surface damage, and a simpler set up.

PRACTICAL CONSIDERATIONS

The are no special precautions with regard to connections when using PD for creep experiments, other than those that might applied for any hightemperature testing scenarios. Thus care should be taken to select a connection method that will not be unduly affected by oxidation.

The choice of connection material is also influenced by resistivity considerations – using connections with too high a resistance can affect either the maximum current passable (thus relevant to the current input wires and cables) or the noise on the signal (here the voltage connections are relevant). There are also input impedance considerations on the signal feeds. Relevant to the high temperature environment is that fact that resistivity changes usually rises with temperature, hence what might appear “OK” at room temperature, may quickly prove problematic at elevated levels. Some thought and care also needs to be taken over insulation – the choice of high temperature insulation is quite limited, and becomes more so as the temperature is raised. A good general purpose high temperature insulation is one made from silica braid (e.g. Dalfratext) which should be quite happy at 1000 DegC. Other glass based insulation materials are available for lower temperature ranges, and some polymers (such as polyimide) are capable of operation in the 250-300 DegC range.

Additionally some thought should be given to how the connection cables/wires are carried through into a high temperature environment (again with an eye to keeping resistances low) and how said connection are supported. Sag of wires (themselves subjected to creep) can certainly affect the geometry of the connection/specimen combination, and if we recall how ACPD readings are often highly dependent upon this relative geometry, we can see how a signal change could occur, seemingly suggesting a material change, when no creep damage is being generated.

ADVANCED CONSIDERATIONS

An internal Matelect study of creep damage on steel pipes used in the power generation industry revealed that both AC and DCPD responded well to creep damage. Rather curiously the results obtained using ACPD were more consistent than those obtained using DCPD (on comparable samples) indicating that the enhanced depth penetration of DCPD may not always be a significant factor. It should be said that in this study, cumulative creep damage was measured at room temperature, on pipe samples prepared after prolonged high temperature exposure.

Linkage to creep damage obtained via destructive tests (for example optical and electron microscopy) was seen, but DCPD was not as sensitive to the variations observed. One suggestion for this was that ACPD was more sensitive to changes on a microstructural level, than DCPD, rather than simply responding to "bulk" defects such as cavitation. Another possibility was that the expected subsurface damage was not as pronounced and that defects closer to the surface were also present and more significant (percentage-wise). Furthermore, given ACPD's sensitivity to surface path length, one cannot discount that ACPD could actually register a surface effect (e.g. roughness caused by spalling) rather than any bulk effect such as cavitation. Clearly end-users need to be aware of such possibilities, and construct experiments to test for any possible hypothesis.

Although, as stated earlier, the current in DCPD, flows through the bulk of the specimen there is good literature evidence to suggest that different penetration depths can be achieved by moving the current injection points close to, or away from, the area under investigation. When the injection point is very close to this, the penetration is minimised. A rough rule of thumb is that the separation of the injection points should be at least twice the thickness of the specimen, for the bulk flow regime to be established. This offers an interesting way of using DCPD under more "focussed" conditions, making it more sensitive to damage in a particular area or closer to the surface of a specimen.

Calibration of PD in creep testing scenarios is far more complex than in "regular" crack growth work. This occurs for many reasons – for example because creep damage may not generate "traditional" cracks, or because creep damage is spread over a large area, and is unlikely to be a single defect, and because creep damage is often delocalized and therefore difficult to monitor using a conventional 4 connection set-up. In most cases, "calibration" takes the form of post-validation of damage by other methods (as cited above) and the development of a damage-PD relationship that can be applied to the next batch of tests.

Matelect is happy to discuss specific testing issues and offer applications advice, for the life of its products. Creep testing continues to be a major area of application for the potential drop technique as it offers the convenience of an electronic measurement of creep phenomenon in an unattended manner. The stability of Matelect instrumentation means that it is ideally suited to the sorts of long terms tests that are prevalent in creep testing.Further information and advice can be obtained from Matelect's head office.

Use of the Potential Drop Technique to Monitor Stress Corrosion Cracking

A short Applications Note

Potential drop methods are ideally suited to the measurement of crack initiation and propagation in the presence of stress corrosion effects. Testing a material in a corrosive environment is vital if valid predictions are to be made of the behaviour in real life or in-service conditions. The presence of even a small amount of an extraneous foreign substance can have a marked effect on the tensile or fatigue properties of a material.

With regard to metallic materials, common corrosive media range from reactive chemicals such as strong acids and strong alkalis to, apparently, benign substances such as sea water. Even fresh water under conditions of high temperature and pressure can become highly corrosive.

Stress corrosion cracking is the term given to defect propagation that occurs in the presence of both a stress and a corrosive medium. It is also possible for cracks to be initiated in materials due to the joint effect of stress and corrosion. More importantly, such defects can propagate at rates which are significantly greater than those in a benign environment. This can lead to the failure of components well before the expiry of their design life, often with catastrophic consequences.

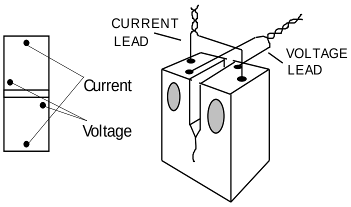
Emulating stress corrosion cracking in the laboratory often leads to difficulties in monitoring the initiation and growth of defects. This is because corrosive media are usually gaseous or liquid and, therefore, some means of containment around a test piece is required. Most techniques used to monitor defect propagation need to either contact the specimen or observe it whilst a test is in progress. Thus sealed mechanical, optical, or electrical feedthroughs are required.

Additionally, if sensors such as strain gauges are utilised, both they and their method of fixture have to be able to withstand corrosive attack and retain their integrity of operation throughout the test.

Potential drop methods offer a straightforward solution to the monitoring of stress corrosion cracking. Two methods exist, AC potential drop and DC potential drop.

As their respective names suggest, either an alternating or direct current is passed through the specimen under test and the resultant potential developed between two points on the specimen is monitored. If a constant current is used then the initiation or propagation of a defect, sited between the two voltage measurement points, will lead to an increase in the measured voltage. In essence, both techniques, detect a change in the specimen resistance (or the impedance in the case of ACPD) and this can be interpreted as either the initiation or propagation of a defect such as a crack.

The simplest implementation of the potential drop method requires four electrical connections, appropriately placed as shown below and linked to suitable current generation and measurement apparatus.



Naturally there are further considerations and subtleties to both the DCPD and ACPD techniques and a knowledge of these is required before any meaningful data can be obtained. However, there is no doubt that both techniques are capable of detecting and measuring crack propagation and they are routinely used throughout the materials world for this purpose.

ACPD offers some advantages over DCPD, not least of which is the greater degree of sensitivity to the presence of a defect. Additionally ACPD requires a constant current supply that is an order of magnitude below that of DCPD, thus permitting a commensurate reduction in the thickness of the supply leads. ACPD equipment tends, however, to be more sophisticated and therefore more costly and the technique is not as conceptually simple to understand as DCPD.

When performing stress corrosion studies using the PD method it is important not to compromise the integrity of the contacts by the action of the corrosive media. Thus, resistant materials such as nickel, silver or platinum are used as appropriate. Electrical contact can be made either mechanically, for example, by clamping or by using a screwed connection, or alternatively by a bonding method such as spot welding. The latter is better for corrosive environments assuming the bonded metals are electrochemically compatible.

A further electrochemical consideration is the fact that traditional DCPD methods can often cause enhanced corrosion both at the point of electrical contact and, more seriously, at the crack site. This is because the DC current causes a potential drop which can drive a corrosive chemical reaction, similar in this respect to electrochemical etching. Unfortunately, this is a prime example of an experimental result being affected by the method employed to observe it.

Such detrimental effects can be countered by using a pulsed direct current technique. Here the excitation current is passed through the specimen for a short period of time and then turned off. This is repeated at regular intervals. Measurements of the DCPD are taken during the "on" period. A schematic of a pulsed DC system is shown below.

The fact that the current is pulsed means that, on average, a reduction in the electrochemical effects is observed. By adjustment of the "on" with respect to the "off" periods, users can largely eliminate these effects.

A better method would be to reverse the DC current at regular intervals. Reversing DCPD was developed for this very purpose. The technique is not common and the equipment tends to be expensive. More importantly, the pulse widths utilised still give rise to electrochemical effects within each "cycle".

Conceptually, the step from reversing DCPD to ACPD is small and the distinction between the two is, at first, difficult to see. However, a difference does indeed exist. This subtlety is responsible for two further enhancements in the use of PD methods for stress corrosion studies. The reversing frequency of a DC system is very much less than that of an AC instrument. In the latter case, frequencies of 10-100 kHz are usually employed, with research work being conducted at even higher values. Unlike DCPD, at these frequencies, the excitation current flows non uniformly through the specimen with more current flowing in the surface regions than through the bulk. This phenomenon is known as the skin effect and its occurrence leads to several significant advantages of ACPD over DCPD.

Since most defects originate and propagate from the specimen surface, it is sensible to confine the excitation current to these regions, thereby maximising sensitivity to the initiation or propagation of the said defects. This is also the reason why the ACPD technique utilises lower specimen currents - less current is required to obtain a similar defect sensitivity.

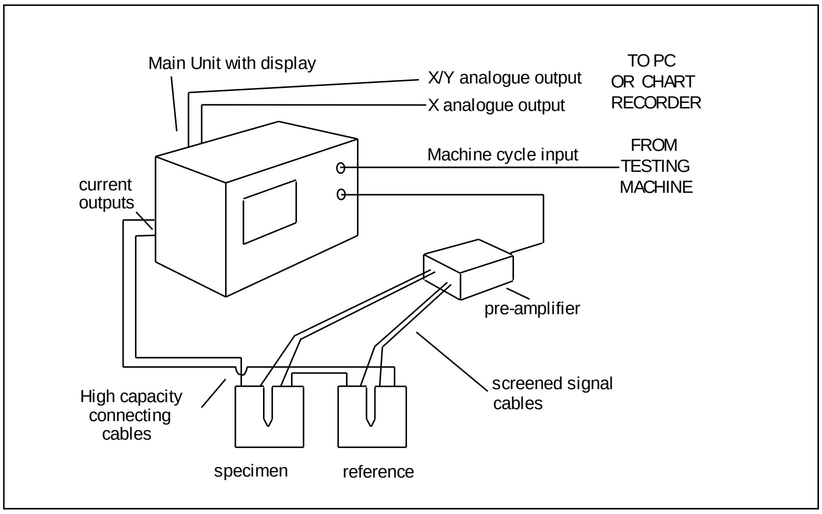
Additionally, using alternating currents naturally gives rise to an alternating voltage. Sophisticated electronics can then be employed to lock-in to the frequency of the AC voltage and measure its magnitude. This effectively eliminates other frequencies that usually manifest themselves as noise on the signal of interest.

A reduction in noise further improves the resolution of the potential drop technique. Thanks to its increased sensitivity, ACPD is often used to detect defect initiation in addition to the monitoring of defect propagation.

In conclusion, potential drop techniques offer a highly effective method of obtaining information on stress corrosion cracking. Their main advantages lie in their simplicity of operation, ease of integration and sensitivity to the phenomenon under investigation.

Both DC and AC potential drop techniques can be used to monitor initiation and propagation of defects in electrically conducting materials. ACPD offers the highest sensitivity with the minimum detrimental electrochemical interaction, whilst DCPD equipment tends to be cheaper and still maintains a popular following.

***T**his applications note has been prepared by Matelect Limited who manufacture a range of standard AC and DC potential drop instruments and peripherals.. Please contact Matelect at the address given below for applications information or details of available equipment.*



Schematic of a typical DCPD test configuration

Induced Pick-Up and the Resistive Mode Operation in ACPD

A Short Applications Note

ACPD signals are by their very AC nature representable 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 CGM-5R (in AUTO mode).

The vectors are shown in the diagram below. 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.

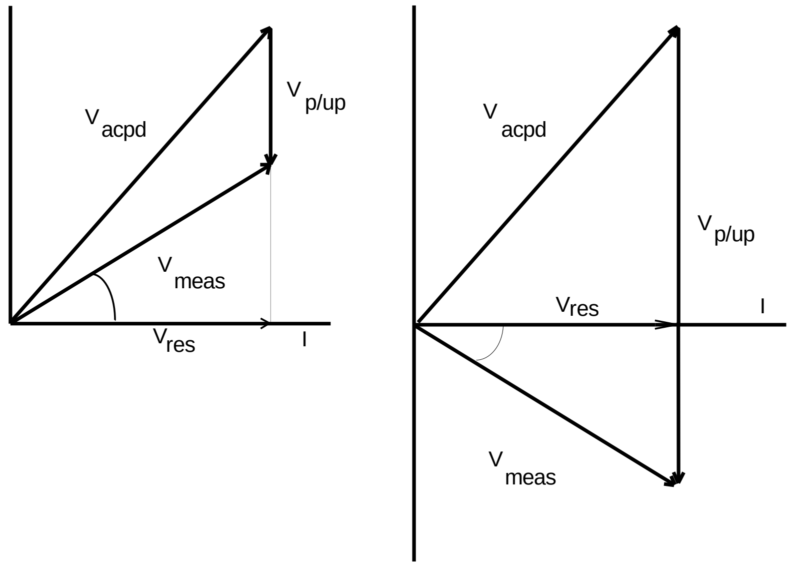


Fig. 1. The relative vectorial positions of signals in ACPD studies.

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 resistive 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.

The CGM-5R can be operated in resistive mode, this being a refinement over the original CGM-5 design. In this mode the displayed ACPD value is actually that which is in-phase with the applied current and is therefore purely resistive.

In resistive mode the readings are much less susceptible to lead movement. This is most marked at the lower operating frequencies (0.3 to 10kHz). At 30kHz and above, the advantage conferred by the resistive mode reduces but it nevertheless remains worthwhile. This deterioration indicates that the simple theory given above may not describe the entire situation.

Users should not be surprised if a considerable reduction in signal amplitude is noticed between AUTO and resistive modes. This indicates that much of the original processed signal is due to induced pick-up.

It is also possible to adjust a standard CGM-5 to operate under a resistive mode. This involves use of an oscilloscope and further advice can be obtained from Matelect.

The Use of the Potential Drop Method for Crack Growth Studies in Ceramics

A Short Applications Note

Measuring crack growth in metals by the potential drop method has been employed for many years in research and the procedure is now widely accepted as a routine materials testing tool. The ASTM organisation has recently published a standard that covers the application of the technique to metals testing. No mention is, however, made of the use of potential drop in the measurement of crack growth in ceramics. This important area is the subject of this note.

Ceramics, although at first unlikely candidates for stable crack pro-pagation, can exhibit crack growth under fatigue conditions. The most difficult aspect of fatigue crack growth in ceramics is the initiation stage. This can take as long as several days in certain ceramic systems. It is during the initiation stage that most premature specimen failures occur.

Once a crack has been initiated, measurement of the growth rate is usually performed by optical methods, whereby a travelling microscope is used to follow the progress of the crack and measurements are made against a calibrated scale. The brittle nature of ceramics places a serious limitation on the degree of crack opening displacement that is observed in a specimen under test. This does little to assist the optical measurement of crack length which relies upon crack opening to generate a noticeable optical contrast.

The optical method also suffers from the need for an operator to collect data at regular intervals. This can lead to logistical problems as well as missed data. Electrical methods such as those reliant upon strain gauges offer unattended and continuous monitoring of defect propagation and are therefore to be preferred. The potential drop technique falls into this category but suffers from the requirement that the specimen be electrically conducting.

Although some ceramics exhibit conduction at elevated temperatures, most testing is performed at room temperature. More significantly, the structure and mechanical properties of ceramics can be dramatically altered by changing their thermal history. Thus intrinsic conduction is not the answer.

A simple but effective method of electrically measuring crack growth is to bond or evaporate a pattern of metal strips onto the side of the ceramic specimen. Changes in the electrical resistance of the pattern occur as the crack grows and progressively severs the strips in succession. This arrangement is shown schematically below in Fig 1.

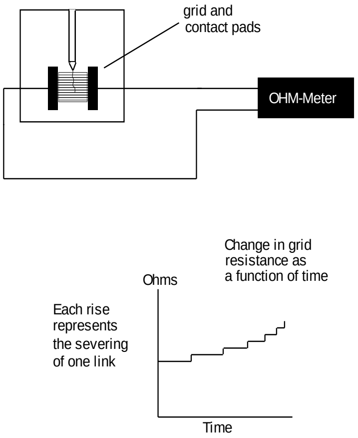


Fig 1. Use of a bonded metal grid to monitor crack propagation.

By monitoring the resistance of the metal pattern using a suitable Ohmmeter, the progress of the crack can be followed. The one major deficiency of this method is the poor resolution achievable. The ultimate resolution is determined by the number of links in the grid. It is therefore difficult to obtain resolutions below fractions of a millimetre.

By depositing a metallic layer rather than a grid, the resolution limitation is removed, and the emphasis shifts to the resolution of the measuring instrument used to record the resistance data. The resistance of a continuous metallic layer will be dependent upon the metal's resistivity and the thickness of the layer. However, it is likely that a milli-ohmmeter will have to be employed in order to measure the resistance.

Once the user has graduated to using a metallic layer, many advantages in terms of resolution and noise reduction can be gained by employing a dedicated potential drop instrument rather than an Ohmmeter to monitor crack length. DC potential drop (DCPD) can be simply thought of as a means of measuring specimen resistance. A direct current is passed through the specimen and the corresponding voltage drop across a particular area on the specimen is measured. The direct current flows through the bulk of the specimen.

The AC potential drop method (ACPD) employs a high frequency alternating current and therefore measures specimen impedance. A phenomenon known as the skin effect confines the alternating current to the surface regions of the specimen. The skin depth characterises the current distribution and is the order of a few millimetres for ferritic materials at commonly employed AC frequencies.

ACPD is generally accepted as being more sensitive to crack growth than the DCPD technique. This is in part due to the skin effect which acts to both maximise the signals from surface breaking defects and also imparts a linear signal response with respect to the crack depth.

Detection and amplification of the small voltages generated by the passage of the supply current also benefits from AC techniques such as phase sensitive detection. This dramatically reduces noise and thereby increases the sensitivity to changes in crack length.

The DC technique suffers from the effect of thermoelectric EMFs which are generated at the point where the specimen and leads are connected. These can be of the same order of magnitude as the voltages generated at the crack site. Whilst nominally of constant magnitude, any slight temperature variation or gradient between contact points can easily mask the potential drop changes that are being sought.

DCPD instruments have improved markedly in order to counter the sensitivity criticism. Techniques such as dual channel operation, whereby a reference channel is simultaneously used to normalise the active channel, remove the effect of thermal variations in the DCPD itself. Such variations are caused by changes in the specimen's resistivity with temperature.

More significantly, the advent of the interrupted DCPD technique, whereby the excitation current is supplied in regular pulses, has lead to the elimination of thermoelectric EMF problems. Measurements of the DCPD are made during and after a current pulse. Subtraction of these values removes any thermoelectric EMFs and yields the true DCPD.

A metallic layer deposited on the surface of a ceramic can be regarded as a very thin metal specimen for the purpose of PD measurements. In this respect ACPD loses the benefit of the skin effect since the skin depth is invariably greater than the layer thickness. Hence, both AC and DC potential drop methods offer similar performance in terms of resolution for such thin layers.

The choice of which method to use then largely depends upon personal preference, although the AC technique is far better at following rapid crack propagation and registering transient responses. For mechanical tests lasting hours or days, both techniques are suitable.

A schematic of a typical test set-up is shown in Fig 2.

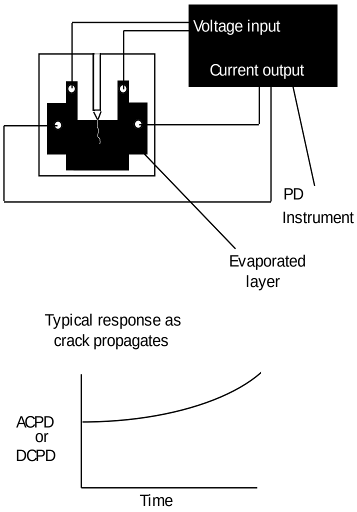


Fig.2 Using the potential drop technique to monitor crack propagation

For an accurate result, the metallic layer must be in intimate contact with the ceramic surface. This is most readily achieved by evaporating the metal onto the specimen. Gold coating instruments are widely used in most electron microscope laboratories and these offer a quick route to layer deposition. The area of interest should be masked and the coating conditions should be optimised to give a uniform, adherent gold layer of approximately a micron in thickness. If other evaporation sources are available, then the use of a higher resistivity material such as a nickel-chromium alloy may give better results.

Connection of the current supply and voltage pick-up leads can be prob-lematic. It is difficult to contact to such a thin coating without damaging it, but users should experiment with sprung contacts (with area rather than point contact) and conductive paints or pastes.

The use of solders can also be considered as a means of achieving contact but good results are only likely if a solder paste is first applied and heated gently. Too high a temperature can cause the evaporated layer to diffuse into the ceramic surface and disappear almost completely!

Ultra-sonic ball bonding is another possibility but the equipment for this is usually only found it semiconductor processing laboratories. Some of these methods are schematically illustrated below in Fig 3.

Any contacts are likely to be delicate and fragile. Consequently, precautions should be taken to anchor wires and leads to prevent undue strain from being transmitted to the contact points during a fatigue test.

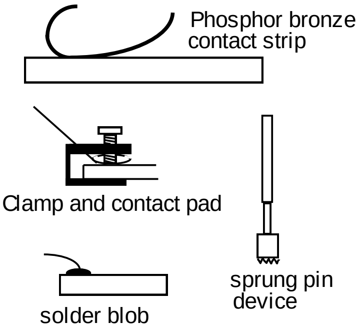


Fig 3. Suggested methods of achieving specimen contact.

The one major disadvantage of detecting and following crack growth in ceramics by using a conductive surface layer is the fact that what occurs on the surface is nearly always different from what is happening inside a specimen. In other words the crack profile can significantly alter the user's app-reciation of the results. If possible, steps should be taken to ascertain the significance of this fact before a firm conclusion is reached on the basis of surface growth. This caution applies to both optical and potential drop methods.

By careful work, the use of the potential drop method in conjunction with a metallic layer is capable of monitoring crack propagation in ceramics to sensitivities below 10 microns. This together with the obvious advantage of continuous, unattended measurement, offers the ceramicist new opportunities for crack initiation and propagation studies.

The Potential Drop Technique and Its Use In Fatigue Testing

A Short Applications Note

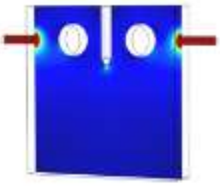
The potential drop technique has been in use to measure and characterise the propagation of defects in metallic specimens for many years. It is one of the few methods that directly measures the depth of a defect or flaw providing this penetrates the surface of the material under test.

BACKGROUND

The potential drop technique relies upon the passage of a constant current through a specimen and the subsequent measurement of the voltage generated across an area (usually the crack site) on the specimen.

Two forms of the technique exist; AC potential drop (ACPD) in which small (ca. 1 amp) alternating currents are passed through the specimen and DC potential drop (DCPD) in which large (ca. 30 amp) direct currents are used.

The techniques essentially measure resistance (DCPD) or impedance (ACPD). The change in these quantities generated by a propagating defect usually results in an increase in the potential drop being measured.



Typical DCPD current path in CT specimen

Typical ACPD current path in CT specimen

Both techniques have their protagonists and associated advantages.

ACPD provides a linear increase in voltage with crack depth and hence permits simpler calibrations. It is also theoretically more sensitive than the DC technique since most of the current in the specimen is confined to the surface regions via a pheno-menon known as the skin effect.

These properties have lead to ACPD being used to measure crack depth in the field in addition to its laboratory role. DCPD is usually confined to the materials testing and research applications and is the more traditional, and hence accepted, of the potential drop methods.

The major disadvantages of the DCPD method have been the generation of thermoelectric EMFs at the contact points and the poor noise performance. These effects have been largely overcome by the use of modern electronics and by pulsing the applied currents.
Pulsed or interrupted DCPD units eliminate thermoelectric EMFs by taking two PD measure-ments, one during a current pulse and one after (i.e. at zero current). By subtracting one from the other, the thermo-electric EMFs are removed.

ACPD has always suffered from the effect of pick-up (voltages induced in the signal lead by the current supply lead).

The pick-up signal is superimposed upon the true ACPD and can dramatically alter measured signal magnitudes.

Pick up is not a problem in itself except for the fact that altering the position of the leads during a test will change the measured PD value.

Although the influence of the AC pick-up phenomenon can be reduced by careful test set-up, it is also possible to electronically remove the offending signal.

FATIGUE TESTING

Both potential drop variants have extensively been used for fatigue testing by industry and academia alike. They are now accepted as methods for the measurement of crack size by the ASTM organisation (ref. 1).

In general, ACPD is suitable for both high and low frequency fatigue studies whereas pulsed DCPD is only suitable for low frequency work.

Modern pulsed DC systems permit the synchronisation of the current pulse to the machine cycle waveform so that measurements can be taken at, for example, peak tension. Such operation is ideal for the study of crack closure effects in metals.

The rapid response of AC systems makes them ideal for high cycle studies. ACPD has even been used to obtain data during impact testing.

Both techniques suffer from the effect of crack shorting, whereby rough, fresh crack surfaces can exhibit alternative current paths that disappear once the crack is opened after the application of a stress.

This phenomenon is often put to good use to characterise crack closure effects but it can be problematic when static measurement of crack depth in the field is performed since it causes an effective underestimation of the crack depth.

Sometimes regarded as a complicating factor, is the observed dependence of both the DC and AC potential drop on elastic and plastic strain.

The strain effect has been used in ACPD to detect the onset of crack initiation (ref. 2) and has now been used to measure stress within a specimen (ref. 3). In fatigue studies, the change in PD with stress leads to a cyclic variation in the PD signal that mimics the load waveform.

In general, for low frequency fatigue testing it is very important to use equipment that offers high stability and low noise operation.

ACPD systems based on a single channel instrument need to incorporate a high stability current source if sensible long term measure-ments are to be made.

It is possible to use poorer quality sources by using a second measuring channel to act as a reference. The active channel is then normalised using the passive channel.

Increasing the number of signal channels by employing signal multiplexing makes it also possible to obtain information on how a crack profile alters during a fatigue test. For this purpose the ACPD technique is far better than DCPD as the low currents employed in the former permit the current lines to be multiplexed as well. This ultimately leads to greater sensitivity and selectivity - essential if profiling is to be performed correctly.

Multiplexing is, however, confined to low frequency cycling studies where the time delay between readings on any one channel (caused by the necessity of scanning through other channels) is not likely to prove a problem.

For profiling during high frequency fatigue studies, specialist real time multi-channel equipment is required.

Matelect have been established suppliers of potential drop instrumentation for over 10 years with sales extending world-wide.

Matelect supplies both standard single channel ACPD and dual channel pulsed DCPD systems together with multiplexing equipment. Multi-channel, real time (non-multiplexing) ACPD units are also fabricated to customer requirements.

For further information on our products or if you just require advice on any aspect of potential drop technology, please contact our offices at the address below.

References:

1. ASTM E647 Guidlines for electrical potential difference determination of crack size
2. Okumura et al. Application of the AC potential drop technique to the Determination of R curves. Eng. Frac. Mech. 1981(14) 617
3. M Saka et al. Measurement of Stress--intensity factor by means of AC Potential Drop Technique. Experimental Mechanics vol 31 1991(3) 209

AC or DC

A Short Applications Note

AC or DC Potential Drop? A primer for decision makers

This primer has been written primarily to assist end-users, who having determined that the potential drop method offers them the performance and flexibility of an electrical method for crack growth studies, remain unsure as to which of the two available variants (ACPD or DCPD) they should invest in and utilize.

Introduction

Potential drop techniques rely upon the basic principle that a conductive specimen that carries an electric current will exhibit a voltage drop across its surface. If the resistance of the specimen is known, the voltage drop can be calculated for any particular value of the current. Specimen resistance can be altered by the presence of a defect such as a crack. Thus, by maintaining a constant current through the specimen, it is possible to detect the initiation and propagation of a defect by monitoring the value of the potential drop. When considering ACPD, it is the change in specimen impedance, rather than resistance, that is effective being measured. In potential drop studies, it is not usually important to know the absolute value of the resistance or voltage since it is the relative change in potential that is used to monitor crack growth.

The two main variants of the PD technique that exist, alternating current potential drop (ACPD) and direct current potential drop (DCPD), have been in use for many decades. DCPD was historically the first embodiment of the PD method, given its relative simplicity in both equipment design and use. ACPD followed in the early 1980's and offered some important advantages, including better sensitivity to crack measurement.

DCPD technology did not stand still however, and with the advent of pulsed and reversing DCPD (which began to bridge the gap between the DC and AC regimes) the differences in sensitivity performance dramatically reduced. In the mid 1990's microprocessor control and advances in digital electronics arguably removed the performance gap (in terms of sensitivity) but there are still important differences between the two variants which can influence the end-user choice.

The salient qualities of each technique are summarised in table 1, and most of these will be discussed below in some detail to give the end-user a better understanding of the relevant issues.

DCPD	ACPD
Direct currents typically to 50 Amperes **Signals of nanovolts** Sensitive preamplification required **Usually a two channel system**	**Specimen currents typically 1 Ampere RMS.** **Frequencies of tens of kHz** **Signals of nano or microvolts**
Simpler than ACPD **Traditional method** **No inductive pick-up problems** **Ease of reproducibility**	**Developed as an alternative to DCPD** **Theoretically more sensitive - skin effect** **Lower noise - phase sensitive detection** **No thermoelectric EMFs** **Electrochemically non intrusive** **No specimen heating** **Linear response - depth vs. volts** **Smaller/portable equipment**
Non linear calibrations **High specimen currents can cause heating*** **Errors due to thermoelectric EMFs*** **Heavy equipment/cables/contacts.**	**Errors due to induced pick-up*** **Lead movement alters results***

* Many of these issues have been resolved by new equipment or application regimes.

With appropriate care and attention, resolutions in the sub 10 micron region have been obtained by some (using either technique). The methods for achieving such sensitivities differ depending on which variant is employed, and the precise experimental set-up. ACPD was historically the first to achieve resolutions in this region, but recent DCPD instruments are also capable of reaching down to these levels.

The electronic circuitry used to deliver such performance differs between the variants. As a consequence, this can influence the performance of a particular variant in other ways. This is explained further below.

All PD techniques require at least four connections to be made to the specimen. Two are used to carry the current to and from the specimen whilst the remaining pair transmit the signal to the measuring apparatus. Normally the current source is designed to be constant across the range of likely load (i.e. specimen) impedances. This complicates the instrumentation, but does permit the measurement of absolute voltages using a single set of connections. If the current was not constant, then a separate reference channel would have to be employed, to "normalise" out any variations - and a two channel instrument would therefore be required. Many PD instruments do offer two channel operation as standard, however, but this is usually for the purpose of normalising out other variables such as temperature.

Modern PD instrumentation such as the Matelect CGM-7 ACPD monitor or the Matelect DCM-2 DCPD monitor, contain both the constant current source and the signal measurement circuitry in one integrated unit. Before the advent of such instrumentation users had no alternative but to build up the monitoring system from separate modules. These were invariably sourced from different manufacturers. The sum of the parts was often more costly, performed less well and was difficult to set-up. Some users still choose this route, particularly where DCPD is concerned, as they may already have some relevant instrumentation to hand (e.g. a constant current power supply). Doing the same for ACPD is rather more of a complex task. Incompatibility between the configurations of different users can often made data comparison dubious because of the unknown effect of instrumental differences.

Specific issues: Current magnitude, nature and some consequences.

When a direct current flows through a specimen, it is normally regarded as spreading out throughout the bulk of the material as soon as it enters through the input connection. In order to generate a "good" potential drop signal from this current (good in respect of being measurable by the instrumentation and detectable over any noise) large currents are usually required (remember the specimen is essentially a short circuit with very little resistance).

DCPD instruments typically source currents in the range of 10-50 amps but 100 amp supplies have been used in the past and would be required for large specimens, where the current density (and hence the measured PD) would otherwise be low.

In ACPD, advantage is made of the fact that the current chooses to flow in a tight "layer" adjacent to the surface of the specimen between the input wires. This is a consequence of the well known "skin effect" phenomenon. Given that the current is concentrated near the specimen surface, lower currents are required to obtain PD signals of similar magnitude to those obtainable by DCPD methods.

This in turn allows ACPD equipment to consume less power and be smaller than a corresponding DCPD apparatus. Thus ACPD lends itself to battery power and portability, and most PD units that are employed outside of a lab environment for field-based NDE purposes, utilize ACPD. Additionally using a continuous direct current in a resistive specimen will often generate a measurable temperature rise - this in turn can alter the resistivity of the specimen and hence affect the measured DCPD. It is true that such specimen "self-heating" effects can be compensated for by using a dummy specimen as a reference (placed in a series circuit with the active specimen), but some commentators would still prefer that the temperature of the specimen remains relative constant.

With the advent of pulsed DCPD technology, both the size of the DC kit and the self heating effect can be dramatically reduced, and most modern DCPD systems utilize pulsed direct currents. In pulsed DCPD, the current is pulsed on and held for a short period of time before being turned off. During the "on" period, the signal is also recorded. Pulsed DCPD also offers a ready route to the removal of thermoelectric emfs (see below). This is done by also taking voltage readings when the excitation current is in the "off" state - and subtracting the two sets of readings from each other.

Reversing DCPD, where the current is periodically reversed, also provides a route for the removal of thermoelectric emfs, and is often the preferred method for crack monitoring during stress corrosion studies. This is because there is (divided) opinion that the single polarity driving potentials present during conventional DCPD could affect the electrochemical (especially at the crack tip) and hence alter the rate at which stress corrosion cracking occurs. This would be a case of the measurement system affecting the parameter being measured. The ultimate DC variant is of course, pulsed reversing DCPD, where both the electrochemical and specimen heating issues are tackled together.

It should be noted that in ACPD, the skin effect is frequency dependent and hence if a user has control over the frequency of the AC excitation, then this gives an extra degree of freedom and sometimes extra information/data obtainable from the PD signal.

Signal level, sensitivity and linearity

In DCPD, the bulk nature of the current flow means that the voltage drop that it creates is that due to the resistance of the whole specimen. If a crack propagates through the specimen, the voltage changes in line with the reduction in cross sectional area of the material available for conduction. In ACPD, the current largely flows within the defined "skin depth" and if the electrical connections are positioned appropriately, the current flows up to and along the faces of a crack, so that the potential drop measured is actually dependent upon the depth of the defect, not the remaining uncracked portion.

The result of these differences on the current path and hence measured voltage dependency, is that the change in PD with crack depth is different for the two variants. In DCPD, the response is non linear. As the remaining ligament tends to zero length, the resistance tends to infinity and the measured voltage thus also tends to infinity (although the instrument will "top-out" at its compliance limit). For ACPD, the path length dependency of the PD, means that the response is largely linear with crack length (although there may be some initial non linearity due when the crack length is well below the skin depth).

This difference in response essentially makes DCPD less sensitive the shorter the crack is, whereas ACPD becomes less sensitive as the crack length increases. Using high frequencies essentially accentuates this difference, and this is often the reasons that ACPD is the preferred method for studies involving short cracks or the investigation of crack initiation.

Additionally, it should be noted that a linear response, at least in theory, makes calibration of the potential drop signal against crack length easier. In practice, this is an oversimplification, given the additional problems associated with "pick-up" inherent in ACPD work - this is discussed further below. Furthermore, although DCPD is non-linear, the simplicity of the current flow under DC conditions means that its is far easier to numerically model the current flow, and thus the resultant PD signal, should end-users wish to develop a theoretical basis for their calibration. Indeed there exists several analytical models in the literature for DCPD calibration, that give adequate approximations of the PD vs. crack length response. Achieving the same for ACPD has been attempted, both numerically and analytically, but modelling AC response is more complex and highly dependent upon specimen geometry and contact positions.

Practical Issues: Connection, and ease of use.

There are many differences between the two PD variants that have a direct implication upon practical and experimental issues and the test set-up. A good example of this relates to the type of wire used to connect the PD equipment to the specimen and the method of connection used at the specimen. In DCPD, the large currents involved mean that thick cables are required to deliver the current to the specimen. This applies even in the case of pulsed DCPD.

The use of thin cables will cause cables to warm and dissipate power (very noticeable when the current is continuous) but also will severely limit the ability of the instrument to pass the maximum rated current through to the specimen. This is because all real/practical current sources have a voltage compliance limit, (the potential drop across the output terminals of the current supply, which is used to drive the current through the wires, connections and specimen) and thin cables simply mean that this limit is reached well before the maximum rated current has been achieved.

Using thick cables has obvious implications upon the size and robustness of the connection points on the specimen and on the flexibility of the cables. Often large bolted connections are employed and flexibility is achieved through the use of cables containing several hundred strands of copper wire. The voltage connections are not subject to such problems and are normally of the type and gauge used for ACPD. Given the currents are often an order of magnitude less in ACPD work, current connections similar in gauge to the voltage connections can be easily employed.

Another relevant practical issue is that of specimen isolation. It is normally necessary during DCPD studies to electrically isolate a specimen from whatever grips or testing machine it happens to be fitted into. This is because the grips and the machine can create a path for the excitation current to Earth, rather than through the specimen, or if the DCPD equipment is of the "fully-floating" type, an alternative current path (in parallel with the specimen) can be created through the testing machine - in other words, the testing machine acts to "short-out" the specimen.

It is highly likely that the route through the testing machine poses far more of a resistance to the current than that through the specimen, so the main effect of a lack of isolation will be a reduction in the measured PD of perhaps 10% maximum. The real issue however is the fact that the parallel path may be intermittent (for example, during fatigue loading, the path may alter its resistance as more load is placed on the specimen/grips) and may change in magnitude during testing. This has obvious implications for the signal to noise ratio achievable for the over DCPD measurement.

Isolation is fairly straightforward to achieve experimentally, although the complication of insulating the specimen from the grips, does add to the cost and set-up time of a test. Additionally when undertaking stress corrosion studies in an aqueous environment, or high temperature creep/fatigue studies, reliable electrical isolation becomes difficult to engineer. For ACPD studies, however, it is often unnecessary to isolate the specimen or grips. This is largely because of the enhanced resistance to current flow that a pressure based contact makes. In other words ACPD is much more sensitive to surface resistance and therefore the current flow is likely to be more readily interrupted by a contact that is formed when two metals mechanically touch, rather than one where they intimately touch (as would be the case if a welded contact is employed). Additionally the influence of current focussing (see above) will also help to force the current through the specimen rather than around the testing machine.

With regard to ease of use, it is probably fair to say that DCPD is the preferred variant for end-users who are "new" to the technique and who wish to be up and running, obtaining reliable data, with the minimum of fuss, training and attention to detail. One of the principal reasons for this is the issue of "pick-up" which is inherent in any AC based method.

Pick-up, in essence, is an additional signal that vectorally adds to the true ACPD signal from the area under test. It occurs because the PD signal wires act as a very effective aerial arrangement which in turn receives a signal via induction from the current input wires - which are acting as relatively efficient transmitters.

The effect of pick-up is to alter the signal magnitude being measured. This is because the ACPD instrumentation is sensitive to the vectorial summation of the two signal sources, not just to the "true" signal from a crack site. In itself, pick-up poses no real threat to the ACPD measurement, assuming it is remains constant during the duration of a test. It will change, however, any time the configuration of the leads (i.e. the spatial relationship between the transmitter and receiver) changes - and hence the measured ACPD signal will alter commensurately. Thus it is important that during an ACPD test, little or no lead movement occurs. This is simple to ensure in practice, but the sight of a signal that changes simply because the wires to the specimen are moved, often dissuades end-users from trying ACPD.

A more significant issue associated with pick-up is the fact that it can make comparison of the ACPD readings with calibration data impossible. This renders a calibration useless of course. This problem arises from the fact that a variation in wire/connection configuration between the calibration run and the actual experimental test, will vary the pick-up and hence the ACPD, rendering absolute comparisons of voltage readings flawed. Once again, careful attention to the experimental technique (e.g. maintaining lead positions between tests by using a jig arrangement) can eliminate such problems. Additionally, there are well known methods for reducing the magnitude of the induced pick-up (e.g. shielding of leads and twisting of wires to reduce the efficiency of the antennas created by the leads), which can largely eliminate it as a consideration.

Speed of response

One area where ACPD remains king over DCPD is in speed of response. ACPD instrumentation has a far higher bandwidth than DCPD and can thus follow rapid crack growth. It is possible, for example, to generate a meaningful signal from an impact test. additionally, the way that ACPD instrumentation rejects noise in and experimental set-up (by "locking into" a particular frequency and hence rejecting all others) means that the fast response is achieved with low noise (and hence good resolution).

In contrast, DCPD instrumentation achieves the resolutions required by experimenters by using signal averaging techniques, where sometimes hundreds of reading are taken over a time period that could be as long as seconds, to reject the noise via brute-force numerical averaging. This is achieved nowadays by using microprocessors to handle the maths, but was once achieved through capacitor-resistor filtering.

Additionally, when pulsed DCPD is considered, the need to take readings during both the current-on and current-off periods further lengthens the time require to obtain a single data point. There is simply no solution to this issue. Of course, for some tests and with some types of apparatus it may be possible to operate in a continuous current mode, and, with the advent of fast analogue to digital electronics, to acquire readings quickly, but this still does not deal with the issue of noise. Speed will therefore always come at the expense of noise rejection, and hence ultimate resolution.

Current focussing

ACPD provides end-users with a unique ability to control the path of the excitation current using a technique known as current focussing. Matelect can provide more information about the methodology associated with this technique but put simply it can be thought of in a similar way to the skin effect. The skin effect forces the excitation current to flow in a tight region near the surface – in other words it focuses it in the Z direction. The current focussing method further controls the current in the XY plane. The basic result is dramatically increased current densities in the areas of interest – and hence larger PD signals. This simply cannot be achieved using DCPD. In defence of DCPD however, it is true that whilst current focussing increases sensitivity to cracking, it also increases the sensitivity of the technique to where the measurements are being made. Try to measure the ACPD where no current is flowing and no signal is, of course, registered.

Extra information

It is sometimes seen as ironic that the very factors that make ACPD problematic can also provide end-users with positive benefits over the DCPD variant. For example, the induction effect which is responsible for the generation of the troublesome pick-up signal is also linked to the beneficial phenomenon of current focussing in a specimen. Similarly, it is found that ACPD is much more sensitive to stress levels in ferritic materials (due to changes in magnetic permeability under conditions of elastic and plastic strain) than DCPD. Indeed it has been used to measure internal stress in structures and load bearing members, and even residual stress levels in shot peened components. This added sensitivity however can sometimes complicate basic fatigue tests where the stress state is periodically varying – and hence give the impression of generating “noise”.

It is important to note therefore, that one person’s disadvantage is often another’s advantage and what may appear to favour the adoption of DCPD instrumentation may exclude end-users from obtaining extra information about the material under test. Another good example of this is the depth information that ACPD can generate via the alteration of the frequency of the excitation current (hence varying the skin depth). Such methods have been used in the past to extract parameters such as case hardening depth from components such as shafts and gears.

Scanning and multichannel operation

This used to be a clear advantage that ACPD had over DCPD – the former (because of the low currents and non-pulsed nature) was always easier to multiplex up. Thus it was fairly simple to expand an ACPD system to cover multiple channels (sites) on one specimen or even multiple systems. DCPD was never multiplexed and if multiple channel capability was required, this necessitated multiple (and simultaneous) signal acquisition circuitry. Matelect changed this a decade ago with the introduction of high current switching units which were intelligently linked to the pulse cycle in our DCPD crack growth monitors. It, of course, may remain an issue should DCPD instrumentation from other manufacturers be employed.

Conclusion

In summary, the choice of AC over DC (or vice versa) often comes down to personal preference. It is fair to say however that ACPD offers a speed of response to crack growth, which DCPD can never match, and hence the possibility of following rapid propagation events - even impact testing, if care and attention in taken. DCPD is notionally, at least, easier to understand and set-up, and is ideally suited to first-time users of the PD technique or those who are involved in routine specimen testing. The added degree of freedom that ACPD offers (the frequency domain) does lend strength to this variant when unusual tests, or applications where new properties are being measured, are being considered.

In the end analysis, the resolutions of both techniques are broadly similar thanks to developments in the instrumentation, but ACPD adds that extra degree of freedom which may be viewed as either an advantage or a disadvantage, depending on one's application, experience or viewpoint. Matelect are conscious of this dilemma and are happy to advise end-users and potential customers alike of the pros and cons of each variant, assuming sufficient information can be provided about the end-use application.

FORTHCOMING PRODUCTS

64-WAY PROBE

Used in conjunction with any of the Matelect PD products, this small device has 64 pins laid out in a 8 x 8 grid, two pins can be simultaneously selected allowing for a potential drop measurement to be made.
Coupled with the provided software, a scan of the specimen under test can quickly be made and presented in a 3D display, allowing for quick defect detection within a flat area.
Different sized grid arrays are available allowing for finer resolution or larger areas to be scanned.
For further information please contact our head office.

PD TOMOGRAPHER

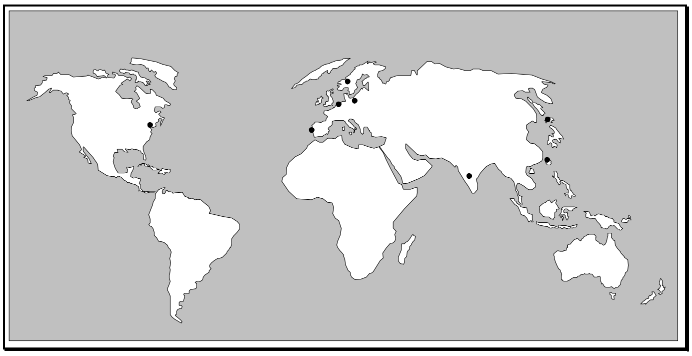
For larger area scanning, Matelect have designed a sophisticated X-Y PD scanning system, which can be used in conjunction with either AC or DC instrumentation to map the PD activity on a specimen's surface. Similar in concept to the 64-way probe above, software controls all available functions and is used to generate a false colour 'image' of the surface voltages. This enables multiple crack defect sites to be 'imaged' rather than simply providing an integrated PD signal.

PURCHASING

Please contact Matelect for a formal quote should any of our products interest you. We are also able to provide demonstration units for short term loans for evaluation, longer term loans can be arranged on a rental or leasing basis, again please contact Matelect head office for further information on this.
Payments can be made via a letter of credit if required, there is a fee of P.O.A for this service.

LOCAL AGENTS

Matelect has built up a network of local agents that handle customers in various parts of the globe. Some of the countries covered by agents are shown below.



In most locations, customers are free to deal either through their local agent or directly with Matelect. If you have obtained this guide through your local agent, then it is best to trade via that agent. Further details are available from our head office. Our agents can usually assist with minor technical issues and repairs but are primarily local points of contact between the end user and Matelect UK.

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