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USER MANUAL FOR ELECTROSTATIC FIELDMETER JCI 111

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Contents:

1. INTRODUCTION
2. PRINCIPLES OF INSTRUMENT OPERATION.
3. SPECIFICATION FEATURES.
4. OPTION FEATURES
5. POWER SUPPLY AND BATTERY CHARGING ARRANGEMENTS.
 - 5.1 Mains and battery operation
 - 5.2 Conformance to IEC 348
6. SIGNAL OUTPUT CONNECTIONS.
7. USE OF INSTRUMENT.
 - 7.1 Earthing.
 - 7.2 Zero reading.
 - 7.3 Instrument support and mounting.
 - 7.4 Unsuitability for use in flammable atmospheres
 - 7.5 Operational checking
 - 7.6 Response to alternating electric fields.
 - 7.7 Settable alarm facility - Option A
 - 7.8 RS423 communications interface - Option C.
 - 7.9 Fast response - Option F
 - 7.10 Manual/auto range selection - Option M.
 - 7.11 Timer circuit - Option T
8. INTERPRETATION OF OBSERVATIONS
 - 8.1 Introduction
 - 8.2 Basic aspects
 - 8.3 Measurement of electric field
 - 8.4 Measurement of potential
 - 8.5 Measurement of charge
 - 8.6 Measurement of surface charge density.
 - 8.7 Measurement of static charge dissipation
9. FIELDMETER SET UP AND CALIBRATION
 - 9.1 Principal instruments and facilities required
 - 9.2 Basic electrical checks
 - 9.3 Preparation for general set up and calibration
 - 9.4 Set up of DVM section
 - 9.5 Set up of angular alignment of chopping vane
 - 9.6 Adjustment of phase sensitive detector
 - 9.7 Set up sensitivity
 - 9.8 Calibration
 - 9.9 Fast response and long life instruments
 - 9.10 Signal noise and variation of zero setting.

USER MANUAL FOR JCI 111

A versatile, high performance instrument for the measurement and monitoring of electric fields from static charges and surface potentials.

1. INTRODUCTION

The **JCI 111** is a 'field mill' type electrostatic fieldmeter providing auto-ranging sensitivities of 2, 20, 200 and 2000 kV m⁻¹ FSD. Measurements are displayed on a 3½ digit LCD with polarity and low battery indication. Surface potentials can be measured to a volt at a separation distance of 90mm (3 1/2") and potentials of 50 volts can be observed a metre away. This performance in a compact and lightweight unit provides the capability needed for the easy and reliable investigation of static problems in a wide variety of industries - and is specially relevant for studying the low levels of static which present risks in the semiconductor and microelectronics industries.

The instrument can be operated from internal batteries or from the mains supply. It includes integral battery charging facilities. An analogue signal output of electric field reading and range is provided for chart recording and long term monitoring applications.

The bayonet pin mounting arrangement around the sensing aperture provides easy attachment for a Faraday Pail (JCI 151) for measuring charge on small objects, a Zero Check Chamber (JCI 152) or Voltmeter Adaptors (JCI 156, 158) for zero current drain measurement of discrete voltages. Options, such as computer linkage, are available to broaden the range of application of the basic instrument and to match various special modes of operation.

2. PRINCIPLES OF INSTRUMENT OPERATION

The basic principle of 'field mill' operation is that when the instrument sensing surface is exposed to an electric field a charge is induced in proportion to its' area and the strength of the field. With a defined capacitance between the sensing surface and earth this charge appears as a voltage which is presented to a high input impedance amplifier to generate a signal directly related to the electric field. Because the sensing surface and the input connections always have some finite leakage resistance, if left to itself the charge on the sensing surface will leak away. However, by chopping the electric field with a rotating earthed vane in a time-scale which is shorter than the RC leakage time constant of the sensing surface and the amplifier input circuit, an a.c. signal is generated whose peak to peak amplitude accurately relates to the strength of the source electric field. This a.c. signal is then amplified and rectified to produce an output directly proportional to the strength of the observed electric field. The polarity of the source electric field is obtained using a secondary chopping vane to generate a signal that drives a phase sensitive detector for rectification of the a.c. signal. Phase sensitive detection also provides good immunity to low frequency noise and to alternating fields that are not harmonically related to the chopping frequency. With this 'field mill' approach the input time constant of the instrument is infinite and the noise low. This means that 'field mill' instruments such as the JCI 111 have a stable zero and offer high usable sensitivity. The instrument can hence be used for both short term investigatory studies and for long term continuous measurement and monitoring of electrostatic conditions.

3. SPECIFICATION FEATURES.

- Sensitivity ranges: - 2, 20, 200, 2000 kV m⁻¹ full scale, auto-ranging
- Accuracy and linearity: - within $\pm 1\%$ of range full scale on display and on direct analogue buffered signal output.
- Zero offset stable long term within $\pm 50\text{V m}^{-1}$
- Noise below $\pm 10\text{V m}^{-1}$
- Controls: - 3 position slide switch for operation by batteries or integral mains power supply
- slide switch for 10mA battery recharging.
- screwdriver zero set adjustment.
- Display: - 3½ digit liquid crystal display of electric field as kV m⁻¹, with display of polarity and indication of battery low condition.
- Signal outputs: - signal outputs via 4 pin connector pin 1: earth;
pin 2: electric field analogue signal (+2.0 V FSD);
pin 3: sensitivity range (1/4, 1/2, 3/4 or 1 volt);
pin 4: with Option A, 5 volt signal indicating alarm state; with Option T, electric field signal with superimposed pulses indicating operating range (every 10 min) and full scale calibration (each hour) with timing by quartz crystal.
- Facilities: - bayonet pin socket arrangement around sensing aperture for easy mounting of additional units.
- A 1/4" Whit thread tripod mounting bush.
- two holes in the back panel for safety strap support
- Operation: - integral nickel cadmium rechargeable batteries, 100 mAh, providing about 4 hours continuous operation (about 2 hours with Option F).
- integral mains power supply - 240V/3A 50Hz supply (115 V/3A 60Hz alternative).
- Battery charging: - 10mA integral battery charger with led indicator.
1mA trickle charge while connected to mains supply
- Earth Bonding: - 'Durable Dot' earth bonding connector on back plate.
- Packaging: - in injection moulded case with foam inserts with User Manual, mains lead and signal lead.
- Calibration: - the instrument is set up in manufacture on the basis of measurements whose accuracy is traceable to NPL standards. Formal Calibration and Calibration Certificate available as extra.
- Dimensions and weight: - 65 mm square by 240 mm long, 900 grams.

4. OPTION FEATURES.

Option A: The Alarm option gives visual and acoustic warning during the time when the electric field observed is above a user settable alarm threshold level. The threshold level may be set anywhere within the dynamic range of the instrument - from say 100 V m up to 2 MV m. This alarm facility is particularly useful where it is necessary to monitor and/or control electrostatic conditions in manufacturing processes or in work environments. The alarm gives immediate local warning of unacceptable conditions so that these may be directly correlated with particular operational activities and appropriate remedial actions taken. A signal output of the alarm state is provided via the 4 pin connector.

The alarm level is set with a 4 position slide switch and a potentiometer in the bottom surface of the fieldmeter. A key button is provided for temporary alarm buzzer muting.

Option C: Integral RS 423 communications interface for linking electric field measurements to microcomputer via a serial data port (RS 232). Useful for data logging, correlation of observations to other plant operating conditions and for process control. A 25 way D type connector is mounted in the bottom plate. Operation at 9600 baud gives up to 400 12 bit resolution readings per sec. Software for operation on IBM PC and compatible microcomputers.

Option F: Fast response for following rapid electric field changes.

Response time below 3 ms on the analogue output signal which enables 50 and 60 Hz signals to be monitored. Useful in high speed process control applications. This Option includes the proprietary Ibrushless fieldmeter design arrangement (Option L) and the Manual/Auto range selection (Option M)

Option L: proprietary Ibrushless arrangement for long term continuous measurements of electric fields

Option M: Additional 3 position slide switch in back panel providing manual selection of sensitivity as alternative to normal auto-ranging. Useful where static conditions may exhibit sudden short term excursions as it enables the short term upset of observations immediately after range changing to be avoided. Automatic range change/range hold/range scan. If the instrument is switched off in the 'hold' state then operation will restart with the same sensitivity setting when switched on again.

Option T: Quartz crystal timer circuit providing superimposed time reference pulses on second electric field output signal to indicate sensitivity range, zero setting and full scale calibration. Useful for long term monitoring as all relevant information on a single chart record.

5. POWER SUPPLY AND BATTERY CHARGING ARRANGEMENTS.

5.1 Mains and battery operation

The JCI 111 may be operated from:

internal rechargeable battery (switch to 'BATT' - B on back plate.)

internal mains regulated power supply (switch to 'MAINS' - M on back plate).

The JCI 111 may be operated from its internal rechargeable batteries with capacity for up to about 4 hours of continuous use. The batteries can be recharged using the internal mains charger. Whenever the instrument is energised from the mains the batteries are trickle charged at about 1 mA. For more rapid charging the slide switch at the bottom of the back plate may be moved to the rightmost position (marked C) to initiate charging at a regulated 10 mA. Full recharging of the batteries at this current is achieved in 14 hours and this time should not be appreciably exceeded or the batteries may be damaged. The batteries should not be charged again until the instrument has been operated on its batteries for at least a few hours. With Option T battery recharging time is automatically limited to 14 hours. Charging at 10 mA is indicated by the light emitting diode on the back plate. The instrument may be used on 'mains' during battery charging.

The rechargeable batteries are nickel-cadmium cells. If these need to be replaced at any time the cells should be disposed of according to any relevant national regulations.

The JCI 111 can be set in manufacture for 240V/50Hz or 115V/60Hz operation.

The mains supply plug should be fused at 1A or 3A. A 250 mA quick blow fuse is wired into the 'line' connection on the power supply printed circuit card. The integrity of this fuse may be checked by measuring the resistance between the line and neutral connections at the mains input connector.

5.2 Conformance to IEC 348 Class 1.

This instrument has been designed and tested in accordance with IEC Publication 348:1978 'Safety Requirements for Electronic Measuring Apparatus' and has been supplied in a safe condition. The present instruction manual contains some information on warnings which have to be followed by the user to ensure safe operation and to retain the apparatus in safe condition.

This instrument has been designed for indoor use. It may occasionally be subjected to temperatures between +5°C and -10°C without degradation of its safety.

Before switching on the instrument make sure its voltage setting corresponds to the voltage of the power supply

The mains plug shall only be inserted into a socket outlet provided with a protective earth contact. The protective action must not be negated by the use of an extension cord without a protective conductor. Any interruption of the protective conductor inside or outside the instrument or disconnection of the protective earth connection is likely to make the instrument dangerous. Intentional disconnection is prohibited.

When the instrument is connected to a mains supply internal connections may be live and the opening of covers or removal of parts is likely to expose live parts. The instrument shall be disconnected from all voltage sources before it is opened for any adjustment, replacement, maintenance or repair.

Any adjustment, maintenance and repair of the opened instrument under voltage shall be avoided as far as possible and, if inevitable, shall be carried out only by a skilled person who is aware of the hazard involved.

Make sure that only fuses of the required 250V and 250mA ratings are used for internal fuse replacement. The use of makeshift fuses and the short circuiting of fuse connections is prohibited.

Whenever it is likely that the protection has been impaired the instrument shall be made inoperative and be secure against any unintended operation. The protection is likely to be impaired if the mains connection sockets are cracked, if the mains cable is damaged or if the mains cable has been pulled from its connectors.

6. OUTPUT CONNECTIONS.

The JCI 111 fieldmeter provides a buffered output of the analogue signal presented to the internal digital voltmeter and displayed on the LCD. This analogue signal may be displayed on an ultraviolet or paper chart recorder. This signal is output via pin 2 (red lead) of the 4 pin connector in the back plate as a bipolar analogue signal (+2.0 V FSD) with pin 1 as signal earth (black lead). The output impedance is 1 k ohm. Pin 3 (blue lead) provides continuous indication of the sensitivity range of operation as a buffered signal of about 1/4, 1/2, 3/4 or 1 volt. Pin 4 is only connected with Options A and T - the alarm circuit and timer circuits.

7. USE OF INSTRUMENT.

7.1 Earthing

The fieldmeter needs to be earthed (or held at a defined potential) if the readings are to be interpreted and used with confidence. The instrument is best earth bonded by connecting the 'Durable Dot' ESP earth bonding point on the back plate of the instrument to a suitable earth point. Alternatively, the instrument may be earthed via the mains power supply connection or via mechanical mounting of the front plate.

7.2 Zero reading

In normal operating conditions the reading in the absence of any applied electric field will remain below +50 V m. Checking the zero reading needs to be done with some care because the high sensitivity of the instrument makes it susceptible to even very low levels of charge or voltage on surfaces close to the sensing aperture. Thus different apparent zero readings will be observed if the instrument is rested directly against different metal surfaces. This is because of the different electrochemical potentials of the surfaces of different materials. Contamination or corrosion on such surfaces may generate additional effects. The best way to check the zero reading of the fieldmeter is to mount it to 'look' into a closed clean metal chamber where the nearest surface is at least 50 mm away from the sensing aperture with this chamber connected to the fieldmeter earthing point. A Zero Check Chamber JCI 152 is a convenient unit for easy checking and setting of zero.

The zero reading exhibited by the fieldmeter may be affected if contamination is present on surfaces in and around the sensing aperture. Care should be taken not to handle the rotating chopper or the sensing surfaces. So long as the zero reading of the instrument is stable and adequately small it is satisfactory just to subtract the zero reading from the observations made. If however the zero reading gets too large or is unstable (for example becomes very susceptible to breathing into the sensing aperture) then it may be desirable to carefully wash the sensing aperture region (for example using isopropyl alcohol) and/or to readjust the zero setting.

7.3 Instrument support and mounting

The side extrusions of the JCI 111 are designed for comfortable hand support so the instrument can be used easily for handheld investigatory studies. Two 3 mm holes are provided on either side of the base flange of the back plate of the instrument so a safety wrist or neck strap may be connected.

The back plate of the instrument has a 1/4" Whit threaded insert in the base flange so the instrument may be mounted from a standard photographic tripod for extended duration studies.

The fieldmeter may be mounted from the bayonet pins socket arrangement around the sensing aperture. The bayonet pins are mounted into M3 tapped holes on a 62.62 mm pcd around a 47 mm diameter aperture. For flush mounting of the sensing aperture the plate thickness needs to be 3.0 mm.

7.4 Unsuitability for use in flammable atmospheres.

Although the JCI 111 electrostatic fieldmeter is of low power consumption it is not BASEEFA certified as suitable for use in flammable atmospheres.

7.5 Operational checking

The JCI 111 fieldmeter has proved reliable and stable in extended operation. It is however recommended that if the instrument is being used in critical applications that the zero reading and the calibration be checked occasionally. As noted above the zero reading is susceptible to contamination and while experience is gained in the use of the instrument in particular applications it is recommended that the zero setting should be checked at least once a week. Calibration should not need checking more often than every 6 to 12 months. Instrument sensitivity may be checked quite simply at any time with the instrument bonded to earth and held 90 mm away from a large plate (say 1/2 m square) at a defined voltage. The reading on the LCD should correspond to the plate voltage divided by 50 - i.e. a reading of 1.000 should be obtained with a plate voltage of 50 volts at 90 mm separation.

7.6 Response to alternating electric fields

The chopping frequency during operation of the standard JCI 111 is about 180 Hz - but may fall to around 150 Hz by the time the batteries have nearly run down. With this chopping frequency there is no significant interference to either the analogue output signal or the LCD reading until the signal frequency reaches the chopping frequency or an odd harmonic to produce beat signals. Fieldmeter operation is insensitive to basic mains frequency signals.

The response of the analogue signal output on the standard JCI 111 to alternating signals is down to a half at 5 Hz and is very small by 20 Hz.

7.7 Settable alarm-facility - Option A

The alarm threshold is set with the controls accessed through the bottom cover of the fieldmeter. A 4 position slide switch allows selection of the sensitivity range - range I is the most sensitive (2 kV m^{-1}) and range 4 the least sensitive (2000 kV m^{-1}). The potentiometer provides setting within the selected range - clockwise rotation for a higher level. The threshold setting applies for both polarities ~ and the setting is reasonably polarity symmetrical. The alarm level may be set using a piece of charged plastic to generate the desired level of field as indicated by the display and then adjusting the potentiometer accordingly. If the fieldmeter sensitivity range is set 2 or more steps higher than the alarm set range then the alarm sounds.

When the observed electric field increases above the set threshold the light emitting diode and the piezoelectric buzzer in the bottom surface are activated and pulse on and off at about 1 Hz. These warnings remain activated while the electric field remains above the set threshold level. A key button is provided to allow muting of the acoustic warning until the next time the electric field rises above the set threshold. While in the alarm state a steady output signal of about 5 V is provided on pin 4 of the 4 pin output connector on the back panel. Use of the muting button does not affect operation of the led warning or the alarm output signal. If the alarm warning is not required to be active the slide switch may be set to range 4 and the potentiometer turned fully clockwise.

7.8 Operation with RS423 communications interface - Option C

7.8.1 Introduction

The RS423 interface of Option C enables observations of electric field to be transferred directly into an IBM PC or compatible microcomputer for data storage, alarm threshold comparison, process control and/or data analysis. This requires operation from the mains supply.

7.8.2 Allocation of pins on 25 way 'D' type connector.

Allocation of pins on 25 way 'D' type socket connector on back cover and on 9 way D type connector of serial data port of IBM PC or compatible microcomputer:

25 way D	type	9 way D type
1	frame ground	5 (cable screen)
2	Transmit data TD	3
3	Receive data RD	2
4	RTS	7
5	CTS	8
6, 8, 20	linked together	1,6
7	signal ground	1
20		4

7.8.3 Cable

The cable should be a 'straight through' (DCE/DTE) multicore cable with no crossovers - and preferably screened.

With the external RS423 communications unit it is necessary to link pins 1 (earth), 2 (signal) and 3 (sensitivity) between the 4 pin connector on the unit and the 4 pin connector on the JCI 111 fieldmeter.

7.8.4 Data communication arrangements

Transmission of an RTS signal from the computer initiates 12 bit analogue to digital conversion of the fieldmeter signal. The results of this conversion are communicated back directly to the computer as two bytes of information. The first byte contains the least significant 8 bits (the LO byte). This is followed immediately by the second byte which contains the remaining 4 bits of the 12 bit conversion with bits 5 and 6 as a 2 bit number giving the sensitivity range of the fieldmeter.

The analogue to digital conversion factor of 5.0 volts as 4096 is arranged to provide bipolar capability of ± 2.5 volts with zero at 2048. The sensitivity is hence 1.2207 mV (1.2207 v m⁻¹) per bit.

The 12 bit data conversion and two byte communication proceeds on receipt of a single RTS signal with no additional signalling from the computer and no preceding transmission of a CTS signal from the interface. This is done to provide the highest data transfer and acceptance rate. The data structure uses 1 stop bit and no parity on each byte.

7.8.5 Data rate

The baud rate is set by links on the communications interface circuit card at 9600 baud. The software can accept and handle data at this rate with direct writing to memory can achieve 400 fieldmeter readings a second. This gives about 2.5 ms between readings. In the program JCI111 the rate of reading is limited by arrangements for screen display.

7.8.6 Microcomputer

IBM PC or compatible microcomputer with CGA or better graphics capability. Operation of the software does not depend on whether a fast or slow processor clock is used - but operation will be a bit quicker with a higher clock rate.

7.8.7 Program structure and operation

The software for the transfer, storage and analysis of data from the JCI 111 has been written in assembler and Pascal for standard IBM PC and PC compatible microcomputers.

After connecting the JCI 111 fieldmeter to the computer via the serial data port and with the fieldmeter operating from the mains supply start program operation by typing JCI111. The initial menu allows selection of COM1 or COM2. If COM1 yields a data communications failure then COM2 should be tried.

In operation the screen display shows a continuously scanning table of fieldmeter readings in kV m⁻¹ and these same readings are appended to a file LOGFILE on the same disc drive as the program. The date and time are written at the beginning and end of each period of data filing. A file SETUP provides simple opportunity to set the numbers of observations which are averaged for each reading displayed and recorded and the frequency of taking readings. (The program will fail unless files SETUP and LOGFILE exist).

Program operation may be halted at any time by pressing Ctrl C.

The program JCI111 in Turbo Pascal uses the following procedures to obtain readings from the fieldmeter:

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CRT DECAINIT DECAHHD GRAPH CLKINT HEAD SERIALTP
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Opportunity is provided for 1 bit logic data input via pin 4 of the 4 pin Bulgin connector. This will activate bit 6 of the HI byte and this will require some appropriate adjustment of the software.

The Turbo Pascal source code JCIII.PAS is supplied so that the software may be adjusted to user requirements.

Option C may be used for simple charge decay observations by the JCI 111 to be recorded and analysed by the software developed for the JCI 155 Charge Decay Test Unit - eg DECAY15. Because the DECAY software does not recognise range changing information from the JCI 111 it is important to use the manual range selection switch (Option M) to fix the sensitivity range during the period of the charge decay observation. Alternatively the data recorded in LOGFILE may be 'imported' directly as numbers into a spreadsheet program such as Lotus 123 for numerical processing.

7.8.8 Runtime errors

Although the software has been well tested it is possible that Runtime Errors may occur. If this does happen the system should be 'reinitialised' by pressing at the same time CTRL, ALT and INS or 'rebooted' with CTRL, ALT and DEL.

7.8.9 Software copyright

The general copyright of the above software for operation with the JCI 111 is owned by John Chubb Instrumentation.

7.9 Fast response ~ Option F.

The fast response with Option F is achieved using a higher chopping frequency provided by a chopper with 20 instead of 3 blades, use of a higher speed motor and with enhancements to the signal processing circuit. An electronically commutated motor is used to provide long operational life. Construction of the fieldmeter is also changed in that the rotating chopper is no longer earthed but any potential developed on the chopper is compensated by a secondary fieldmeter system (16). This arrangement avoids wear of brushes earthing the rotating chopper and reduces drag but may allow a slightly larger zero drift on warm-up than with standard JCI 111 instruments.

The response time to step function changes of electric field is about 3 MS on the analogue signal output. Observations via the liquid crystal display are the same as with the basic JCI 111 instruments.

With the electronically commutated motor about 1 hour of operation on batteries can be expected before battery recharging is needed.

Option M is included so that automatic range changing can be avoided when studying sudden large signal excursions.

7.10 Manual/auto range selection - Option M.

The additional slide switch in the back panel allows selection of operation between normal auto-range changing in the rightmost position (A) and manual range selection. In the middle position the current range setting is held (H) and in the leftmost position the range setting is incremented, or scanned (S), at about 1 range per second. Any desired range may be selected by moving the switch to leftmost position and then moving the switch back to the middle position when the desired range is accessed.

If the fieldmeter is switched off while in the hold (H) state the same sensitivity range will be set when it is switched on the next time. The range indicating signal at pin 3 of the 4 pin connector operates as normal with option M.

When manual range selection is used in conjunction with the alarm circuit (option A) the alarm will be activated continuously if an operating range is selected two decades or more higher than the range set for the alarm threshold level. This advises the user to reconsider the relation between the alarm setting and the operating range.

7.11 Timer circuit - Option T.

When the timer circuit is fitted a signal is provided on pin 4 (yellow lead) as the electric field signal with timed pulses superimposed indicating the operating range, signal zero, signal polarity and full scale calibration. Every 10 minutes the output is switched for a short interval between signal zero and a level of 1/4, 1/2, 3/4 or I volt depending on the operating range of sensitivity. A similar switching occurs after any range change. Each hour the output is switched from full scale negative to full scale positive to identify the hour point. As pulse timing is controlled by a quartz crystal an accurate time reference is provided for signal correlation in long duration recording. A multi-turn screwdriver adjustment potentiometer is provided in the back plate to enable the chart recorder trace with the time and range information to be scaled to convenient values.

8. INTERPRETATION OF OBSERVATIONS.

8.1 Introduction.

Insulating and semi-insulating materials acquire electrostatic charge when rubbed against other insulating materials or against metals. The degree of charging varies with the materials involved and is usually higher for higher speeds and higher pressures of rubbing. Such 'tribocharging' can present risks of ignition of flammable gases, shock risk to personnel, attraction of dust and debris, cling of thin films, damage to semiconductor devices and upset operation of microelectronic systems. The problems caused by 'static' and they may be controlled are discussed in published papers and a number of Standards documents (eg references 1-12). The quantities of charge, amounts of energy and levels of voltage relevant are in general lowest in relation to damage to semiconductor devices. So it is usually in this area that there are the most critical demands on the capability of instrumentation and measurement methods.

"Electrostatics" relates to phenomena associated with the presence, rather than motion, of electrical charge. Charge is the key parameter. However, it is usually more convenient to measure features associated with the influence of charge - for example the voltages or electric field created. This involves less disturbance to the system being measured.

Electrostatics seems "difficult" for many people - so it is sensible to retain a healthy skepticism when making electrostatic measurements and wise to cross check even simple and basic observations with alternative approaches.

8.2 Electric Field Measurement

Fieldmeter measurements relate to the electric field in the vicinity of the sensing aperture and the response to this electric field is established by calibration with the fieldmeter sensing aperture mounted flush with the earth plate of a large parallel plate calibration rig. The size of the plates needs to be large in comparison to the spacing to ensure a uniform electric field in the region of the plates where the fieldmeter aperture is located. Fieldmeter calibration was described at the International Electrostatics Conference in Oxford April 1987 (13).

For some measurements the fieldmeter may be mounted flush with a conducting boundary. In this case the fieldmeter is used in the same way as when it was calibrated and the readings obtained may be interpreted directly in terms of the local electric field at the boundary. However, in many instances the fieldmeter is used by itself - in particular for handheld studies. In such use, as the fieldmeter is brought towards a charged conducting or insulator surface there is a convergence of electric field lines towards the sensing aperture region of fieldmeter because of its relatively small cross section. This is illustrated in Figure 1. The local electric field at the sensing aperture is increased over that which would apply in a plane parallel field geometry. The factor by which readings need to be multiplied to give a value corresponding to a plane parallel field situation varies with gap is shown in Figure 2.

With sensitive fieldmeters care needs to be exercised with zeroing (as noted in section 7.2 above) to avoid problems with surface trapped charges and contact potential effects. The best approach is to mount the fieldmeter to 'look' into a clean closed metal chamber in which the nearest surfaces are at least 50 mm away from the sensing aperture of the instrument (eg JCI 152 Zero Check Chamber).

When fieldmeters are used for hand held investigatory studies care needs to be taken to ensure that the instrument is properly earth bonded (as noted in section 7.1 above). Metal bodied instruments may have a good connection to the operator's hand - but no assumptions should be made about the effective conductivity of footwear or flooring.

8.3 Measurement of potential

The electrostatic potential of a surface may be obtained by observing the electric field generated at a nearby earthed fieldmeter. However care is needed with small structures to avoid the proximity of the fieldmeter affecting the capacitance of the body as this will depress the potential to be measured. Care may also be needed in interpretation of readings where the size of the body or area of charge is not too large in comparison to the size and spacing from the sensing aperture.

The electrostatic potential of a person may be measured using an earthed fieldmeter to observe the field at a convenient distance from the person's hand. A hand is preferable to clothing to avoid the risk of susceptibility to any localised surface charges on clothing material. Alternatively, the person may measure his own potential by holding the fieldmeter a known distance from an earthed surface. In either case the potential is obtained as the reading multiplied by the distance and by the appropriate correction factor from Figure 2. With the JCI 111 fieldmeter at a separation distance of 90 mm the potential of a surface in volts is obtained as the LCD reading multiplied by 50 (the distance of 90 mm X 0.56 - the 'correction factor' for this distance). Thus a reading of 1.000 at 90 mm corresponds to 50 volts - and measurements may readily be made to a resolution better than a volt.

The potential of isolated metal structures may be measured using the 'electrostatic voltmeter' approach - using for example the JCI 156 or JCI 159 Voltmeter Adaptors with the JCI 111 fieldmeter. The Adaptor provides a shielded enclosure within which a smooth boundary electrode is mounted in a mechanically stable arrangement in relation to the fieldmeter sensing aperture. The design is arranged so that there is a simple relationship between the voltage on the electrode and the reading of the fieldmeter. While the capacitance of the electrode and connection is low some charge sharing will occur and this may affect the potential observed.

8.4 Measurement of charge

The standard method for measuring net electrostatic charge on an item is to use a Faraday Pail. The arrangement is illustrated in Figure 3.

With this approach the net quantity of charge introduced into the volume of the conducting pail appears as induced charge of the same sign and magnitude on the outside of the pail, providing all the charge introduced couples to the inside of the pail. It is not necessary that the charge introduced is conducted to the inside walls of the pail - so the pail is equally effective for charged insulating materials as for conductors.

The charge induced on the outside of the pail may be measured by a suitably sensitive charge integrating circuit or with the pail insulated from earth using a fieldmeter to measure the voltage to which the pail is raised in relation to its capacitance. This is the approach adopted with the JCI 151 Faraday Pail adaptor used in conjunction with the JCI 111 fieldmeter.

8.5 Measurement of surface charge densities

Where a charged web of insulating material is fairly remote from any nearby earthed surfaces there is an electric field E normal to the surface and related to the algebraic sum of the charge densities Q_1 and Q_2 on the two surfaces of the web as:

$$E = (Q_1 + Q_2) / (2\epsilon_0)$$

where ϵ_0 is the permittivity of free space $8.854 \times 10^{-12} \text{ F m}^{-1}$. If an earthed fieldmeter is mounted reasonably close to a section of the web and if this is much closer than any other earthed surfaces, then all the charge on the web will couple to the fieldmeter. If the fieldmeter is mounted within a plane surface several times larger than the spacing to the web, then the field between the web and the fieldmeter will be essentially uniform and relate to the surface charge densities as:

$$E = (Q_1 + Q_2) / (\epsilon_0)$$

Charge densities residing on individual sides of an insulating web may be monitored using a sensitive fieldmeter to measure the electric field from the web as the web passes over an earthed roller. The charge on the surface contacting the roller will be so closely coupled to the roller surface that it will produce little external field - but the charge on the outside surface will not be so closely coupled and will produce an electric field able to be measured by a nearby electrostatic fieldmeter. For a web of thickness t (m) and of permittivity k and the fieldmeter sensing plane at a distance d (m) the charge density on the web Q_1 will relate to the observed electric field E as:

$$E = Q_1 t / (k \epsilon_0 d)$$

A charge density of say $1 \times 10^{-6} \text{ C m}^{-2}$ on a web of 100 micron thickness and permittivity $k=2$ lying on an earthed surface will give a field of 564 V m at an earthed sensing surface 10 mm away - a modest field strength but quite sufficient for proper measurement.

8.6 Measurement of static charge dissipation.

Traditionally the ability of materials and surfaces to dissipate static charge has been assessed by measurement of resistivity - bulk and surface. This is not a satisfactory guide to the timescale for charge dissipation because with many practical materials the mechanisms of charge migration are not uniform over the surface or volume of the material and vary with the residual electric field. The appropriate way to study charge dissipation is to deposit a localised patch of charge on the surface to be tested and then to use a fieldmeter for non-contact measurement of how quickly the potential of the charged patch decreases as the deposited charge migrates away. This approach is used in the JCI 155 Charge Decay Test Unit (14, 15). Charge decay measurement is described in a document being discussed by the International Electrotechnical Commission committee SC15D considering Standards in Electrostatics (17).

The JCI 111 fieldmeter can be used very simply for qualitative assessment of the charge decay characteristics of materials when the decay time is at least a few seconds. An area of the material or installed surface is rubbed with a tissue or piece of teflon or polythene sheet. The JCI 111 is laid onto the surface with the sensing aperture close to the area rubbed. The initial fieldmeter reading and the rate of decrease will show very directly the degree of charging and the rate of charge decay.

9. SENSITIVITY SET UP

The JCI 111 fieldmeter is carefully set up during manufacture. No adjustments should be attempted unless suitable instruments and facilities are available to check the set up and sensitivity of the instrument. The following notes describe procedures to set up the JCI 111 and set its sensitivity. The procedure to check calibration is described in Section 9.8.

The primary basis of setting sensitivity and measuring calibration is to establish a uniform electric field between two large plane metal surfaces and to mount the fieldmeter sensing aperture flush with one of these surfaces. For the electric field to be uniform and well defined in the region around the mounting location of the sensing aperture:

- a) the surfaces need to be large in comparison to the spacing between them so that the field in the central region is not affected by fringing field effects or any external sources of charge so that the value of the electric field may be accurately related to the separation gap and the voltage difference.
- b) the gap between the surfaces needs to be suitably large in comparison to the size of the sensing aperture so that perturbation of the electric field in the vicinity of the recess of the sensing aperture is localised and does not reach across the gap to the other surface.

Consideration of the above requirements has been published (13). It is found necessary for calibration of JCI 111 type fieldmeters to better than 1% that the separation distance between the plates should be more than 1.5 times the sensing aperture diameter with the surfaces having a radial extent at least 15 times the sensing aperture diameter. This has been checked in

computer modelling calculations and, in practice, by looking at constancy of calibration as the separation gap is increased.

The physical arrangement of components, test points and adjustment potentiometers for the main processing board and for the power supply and timer board are shown in Figures 4 and 5. Figure 6 identifies the use of the 17 leads of the flexible board to board connection.

9.1. Principal instruments and facilities required

- uniform electric field calibration unit. This may consist of a pair of rigid, flat and parallel metal plates, for example at least 500 mm x 500 mm spaced a defined and stable distance apart, for example 50.0 mm, with a 47 mm diameter hole in the middle of the top plate where the metal thickness over a diameter of 95 mm is 3.0 mm so that the front of the fieldmeter lies just flush with the underside of the plate. The lower plate needs to be insulated and protected to that voltages up to 30 kV may be safely applied for establishing the higher value of calibrating electric fields.
- regulated voltage sources of +2 V, +0-1 kV and +0-30 kV.
- voltmeters capable of measuring 2V, 100V, 1kV and 30kV to an accuracy better than +1%.
- oscilloscope with a sensing probe having an input impedance of 10 Mohms.

9.2 Basic electrical checks.

- remove back plate by the two M3 screws and slide out the top and bottom covers.
- energise fieldmeter circuits from own internal battery (if adequately charged) or from the internal mains power supply (taking care to avoid touching or shorting exposed mains energised connections).
- check at the board to board connection points on the lower, power supply, board (see Figure 5) that the rail voltages of the internal regulated supply are +7.5 and -7.5 volts (within ± 0.5 V) and are free from noise and ripple. (Take care not to short rail to rail as this may destroy to opto-sensor).
- check that the led indicating 'charging at 10 mA' illuminates when the charging switch is moved to initiate charging.
- check the trickle charging voltages and currents, these should be about 19 V and 2.4 mA to ground (the charging current to a fully charged battery will be about 1.2 mA).
- check the '10 mA' charging current to be correctly set by measuring the current to earth of inter-board connection points 6 and 11 (see Figures 4 and 5) while the batteries are being charged. The currents should be about 12 mA, the sum of the trickle and controlled charging currents.

9.3 Preparation for general set-up and calibration adjustment.

- remove back plate of fieldmeter, slide out top and bottom covers. If it is desired to clean or check the state of wear of the chopper earthing brushes or to adjust the phase sensitive detector

then it will also be necessary to remove the right hand side plate and fold out the power supply and timer circuit card. Do not remove both side extrusions at the same time - always have one extrusion in place to provide support for the main processor board from the front plate.

- if the fieldmeter is energised from its rechargeable batteries then care must be taken to avoid shorting out the supply rails during probing and
- the fieldmeter should not be energised from the mains during general set up and calibration because of the shock risk from exposed connections on both the fieldmeter and the power supply printed circuit cards.

9.4 Set-up of DVM section.

- with the end of R21 nearest to C13 grounded check that the LCD reading is 0.000. If not there is a fault in the DVM circuitry.

- inject positive and negative voltages -1.90 to +1.90 to the end of R21 nearest C13 and adjust RV9 so LCD reading corresponds exactly to injected voltage for both polarities and check at lower voltages over range.

9.5 Set-up angular alignment of chopping vane. - connect oscilloscope probe to R16.

- either apply a positive potential to the plate of the calibrator facing the fieldmeter or bring a positively charged body (a sheet of methyl methacrylate, 'Perspex', charges up positively when rubbed with a paper tissue) up in front of the Voltmeter sensing aperture. The signal at R16 should consist of negative half-cycle sinusoidal waves.

- if the chopping of the waveform observed at R16 occurs part way through the half-cycles or if the waveform is composed of positive half-cycle waves then the fieldmeter should be switched off and the right hand side extrusion of the instrument temporarily removed to gain access for resetting the relative angle between the front and the secondary chopping vanes. The grub screw clamping the front chopping vane should be loosened slightly and the relative angular positions of the front and rear rotor vanes re-adjusted until the signal at R16 corresponds to the desired pattern of exact half-cycle waveforms of negative polarity.

- carefully re-tighten the screw clamping the front chopping vane, check the waveform at TP3 and then replace the side extrusion.

9.6 Adjustment of the phase sensitive rectifier

- shield the sensing aperture of the fieldmeter (but do not have the shielding surface too close to the sensing aperture) or, if using the calibrator, mount the fieldmeter on the calibrator and apply zero voltage.

- temporarily earth TP3 and adjust RV1 so that the LCD reading is zero.

- mount the fieldmeter mounted on the calibrator and apply a voltage of at least 50 volts across the plates.

- switch on the fieldmeter and connect an oscilloscope probe to R16 and examine the waveform. Successive half cycles of the waveform should be of equal amplitude. If this is not

so, adjust RV12 to achieve this. If the signal observed is noisy it will be helpful to apply rather higher voltages than 50 volts across the calibrator.

- check that the equality of amplitude of successive half cycles applies for the other polarity of voltage on the calibrator plate.

9.7 Sensitivity setting.

- during sensitivity setting it is desirable to have to provide shielding of the sensitive preamplifier circuits. A dummy cover may be used pierced with holes matched to the locations of the various potentiometers (as shown in

Figure 4) to provide access for adjustment.

- if the fieldmeter is very out of adjustment then set RV8 to about the midtravel position, otherwise proceed by just adjusting potentiometers RV3 to RV6.

- set the voltage across the calibrator to the value to be used for calibrating the top range. For a calibrator plate gap of 50 mm 15 or 30 kV will be convenient - with the voltage chosen as a convenient multiple of the actual gap in mm. Adjust RV6 to give correct reading on LCD.

- reduce the voltage carefully to a value corresponding to a reading of 110 kV m I on the top range - without allowing the range to change down. (With a 50 mm gap this will be 5.50 kV). Adjust RVI to achieve an LCD reading of 110. Take the calibration voltage back to the maximum calibration figure and reset RV6. Iterate between these two levels until the readings match at both points.

- short out the calibrator plates and adjust RV10 to give an LCD reading of zero.

- set the voltage across the calibrator to provide calibration fields preferably towards the top value for each sensitivity range. The voltages listed below are based on use of a 50.0 mm gap. Adjust the potentiometers as listed to obtain the desired readings on the LCD. Because the setting of RV3 has some effect on the setting of RV4 it is appropriate to set up RV3 on the most sensitive range before setting RV4. As the sensitivity ranges overlap check that the fieldmeter is operating on the appropriate range before adjusting the potentiometers.

Reading		Range	Calibration voltage	Adjust Potentiometer
600.0	kV m-1	4	30.0 kV	RV6
(110.0	kV m-1	4	5.50 kV	RVI)
110.0	kV m-1	3	5.50 kV	RV5
1.900	kV m-1	1	95.0 V	RV3
19.00	kV m 1	2	950 V	RV4

- after setting the appropriate potentiometer on each range reduce the voltage across the calibrator to the point at which the range changes automatically to the next most sensitive range and check that this change occurs at LCD readings of 100 and 10.0.

- reverse the polarity of the voltage across the calibrator and check that the polarity and LCD readings are correct. If not, check and readjust the angle of the chopper vane and/or the balance of the phase sensitive detector as described in section 9.6 above.

- reposition the top and bottom covers and replace the back plate.

- run the fieldmeter for several hours or overnight in a zero field situation or on the calibrator with the plates shorted out and record the observations on a chart recorder. Check that the noise level of the output signal is suitably low and that the zero setting remains stable.

9.8 Calibration

Formal calibration of the sensitivity of the JCI 111 requires use of voltage and distance measuring instruments which have been calibrated with accuracy traceable to National Standards. The procedure and information to be recorded for formal calibration has been described in a draft document prepared for the UK Working Party of International Technical Commission Technical Committee SC15D (18,19).

9.9 Fast response and long life versions of JCI 111

For the fast response and long life version of the JCI 111 (options F and L)

The input amplifiers for the two fieldmeter sections are mounted on an annular circuit board around the electronically commutated motor. The only adjustment available on this circuit board is that for 'charge balance' of the rotor. The charge balance should be checked and set before checking or adjusting the

sensitivity of the instrument. The rotor should be earthed using a clean metal rod to connect the rotor to the side of the sensing aperture. The fieldmeter should then be switched on and the zero reading noted with the fieldmeter looking into a clean metal 'zero check chamber'. Switch off the fieldmeter, add some charge to the rotor by touching it with a low voltage supply (for example 9V relative to the instrument earth), switch on the fieldmeter and note the reading when the instrument is again looking into the zero check chamber. The readings without and with charge should be close. If they are not then the multi-turn potentiometer on the annular circuit board should be carefully adjusted to achieve this. The charge balance setting should not be affected by the zero setting adjustment.

9.10 Signal noise and variation of zero setting.

The output signal with the instrument in a zero electric field situation should be within about ± 10 V m. Higher noise levels are likely to be due to dirt in the area of contact of the gold wire brushes used to earth the chopping vane behind the motor. The problem will probably be solved by carefully cleaning the brushes and the local area of the motor shaft - for example with the end of a matchstick dipped in isopropyl alcohol. Access for cleaning is obtained by removing the back plate and one side extrusion.

As noted in section 7.2 the zero setting of the instrument on the most sensitive range can easily be affected by contamination on surfaces in and around the sensing region. If the zero setting

is unstable or is rather susceptible to breathing into the sensing aperture then it is desirable to carefully clean surfaces around the sensing region using, for example, isopropyl alcohol or clean water.

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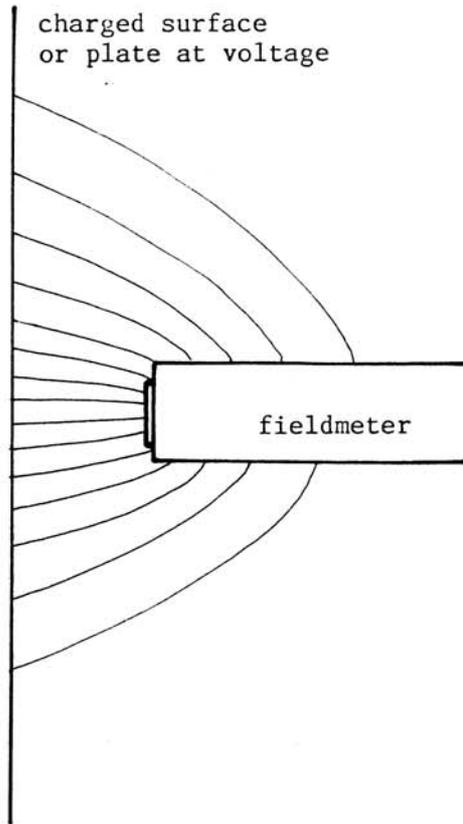


Figure 1: Concentration of field lines to fieldmeter sensing region.

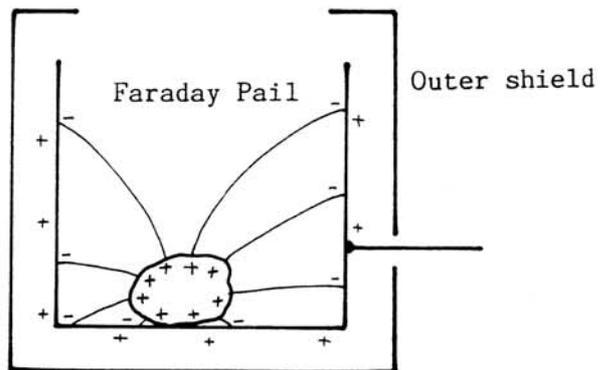


Figure 3: Faraday Pail system for measurement of charge.

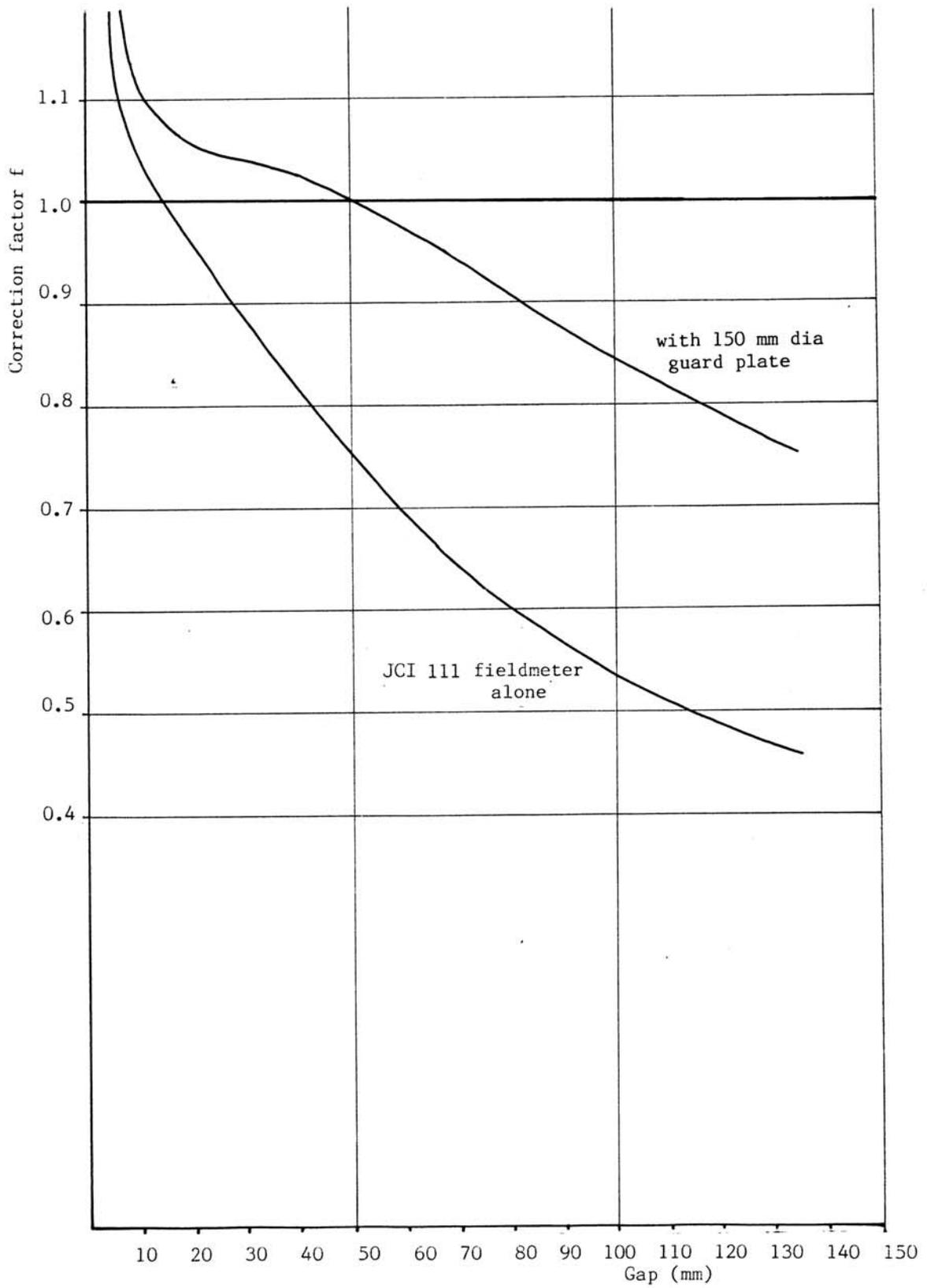


Figure 2: Variation of correction factor with spacing from a plane surface of 65 mm square section fieldmeter with 32 mm diameter sensing aperture.

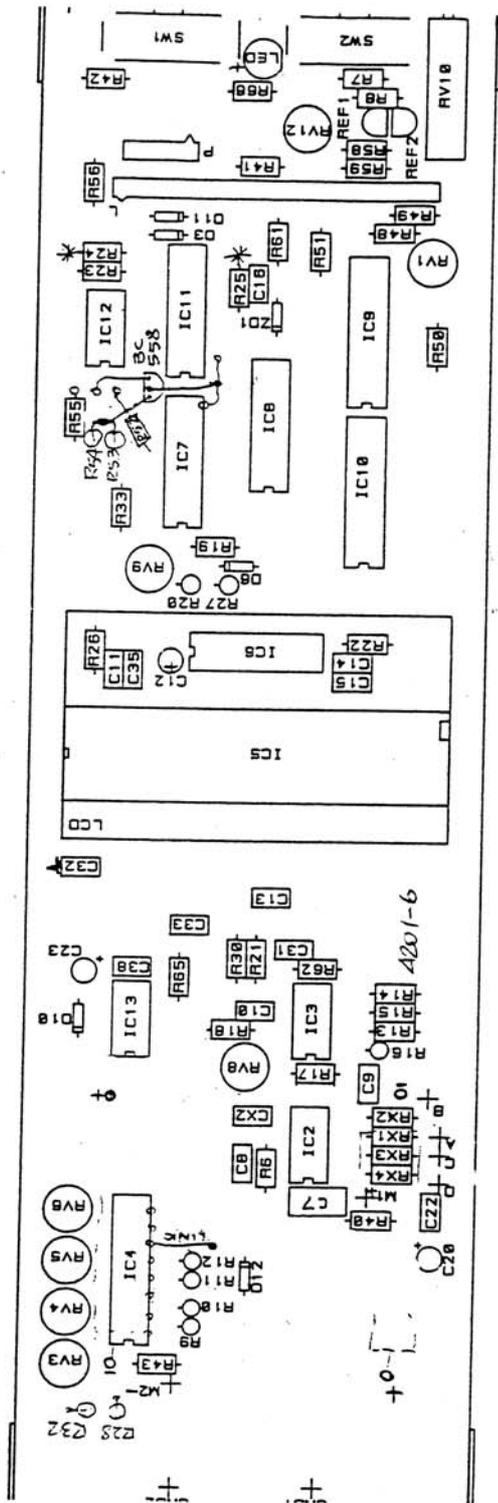


Figure 4: Component layout for main processing board.

ISS	MOD. NO.	DATE	ISS	MOD. NO.	DATE	DRN.	DATE	USED ON	PER SET	MATERIAL	UNLESS OTHERWISE STATED ALL DIMENSIONS IN MM/INS
								111F			TOLERANCE:-
		11 MAY 1992				CHKD.				FINISH	LINEAR + -
						APPVD.					HOLES + - 0
						SCALE					ANGULAR + -
<p>THE CONTENTS OF AND INFORMATION IN THIS DRAWING MUST NOT BE COPIED OR DISCLOSED WITHOUT THE WRITTEN CONSENT OF:</p> <p>John Chubb Instrumentation</p>											DRG. N°
											JCI 4224
TITLE COMPONENT LAYOUT											
111F SIG. PROC. PCB											

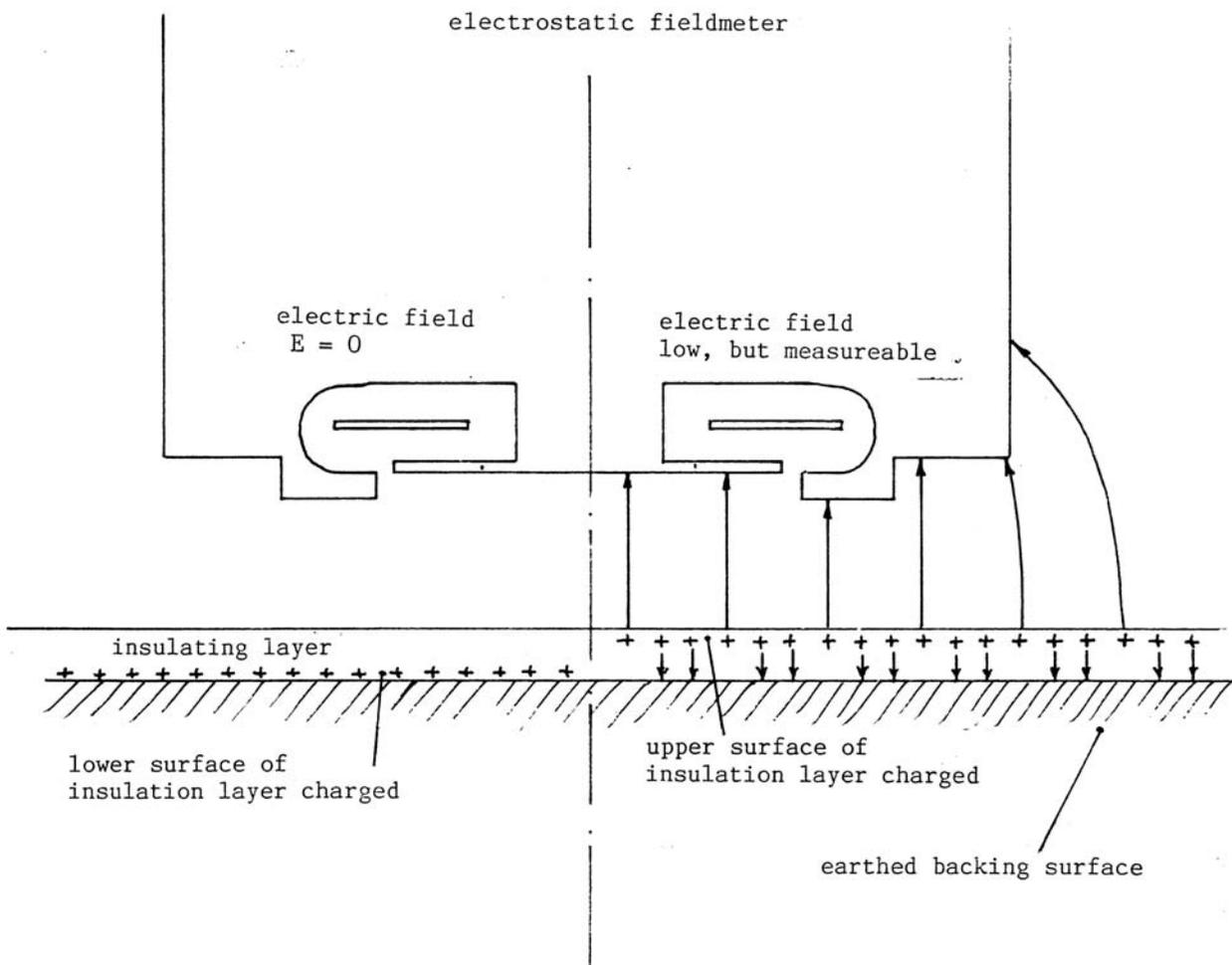


Figure 6: Arrangement of fieldmeter for measuring charge on individual sides of an insulating film

- 1 - ve supply rail from fieldmeter circuit
- 2 + ve supply rail from fieldmeter circuit
- 3 0V logic
- 4 analogue signal from fieldmeter circuit
- 5 + ve trickle charging, about 1 mA
- 6 + ve 10 mA charging
- 7 + ve line from mains power supply
- 8 0V, earth line
- 9 - ve line from mains power supply
- 10 'neutral' of mains power supply
- 11 - ve 10 mA charging
- 12 - ve trickle charging, about 1 mA
- 13 'line' of mains power input
- 14 analogue signal output
- 15 logic signal for range indication (bit 1)
- 16 logic signal for range indication (bit 2)
- 17 logic signal of range change enable

The above sequence is as viewed from the component side of the power supply printed circuit card with the connection link to the left of the board - line 1 is then at the top and line 17 at the bottom, as labelled on the board.

Figure 6: Connections via flexible board to board link.