User Manual

JCI 131 / JCI 131F Adverse Conditions Electrostatic Fieldmeter

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WARNING

This equipment is not suitable for use where hazardous flammable atmospheres are or may be present (hazardous areas as defined in IEC 60079-10-1 and IEC 60079-10-2) inside or outside the equipment. Furthermore, even in the absence of designated hazardous areas, this equipment should not be used in close proximity to flammable substances without first conducting a risk assessment which is the responsibility of the end user company.

SAFETY WARNING

The operator of this equipment must ensure that, especially in remote operations, appropriate warning signs are posted in conjunction with suitable protective measures (e.g. fencing) to ensure as far as is reasonably practicable that unauthorised and untrained personnel cannot come into contact with JCI 131 Fieldmeters, for the following reasons:

- **Allowing fingers to enter the sensing aperture when the chopper is running could cause severe injury.**
- **In use the Operational Health Shield (where fitted) is energised with a potentially lethal power supply, which could cause injury.**

CE Conformance

Declaration of CE conformance

Chilworth Technology Ltd, Beta House, Southampton Science Park, Southampton. SO16 7NS, UK declares, as designer and manufacturer of the JCI 140 Static Monitor, that the design and construction of these instruments conform to the requirements of the EC Directive on Electromagnetic Compatibility (EMC) 89/336/EEC to Standards EN 50081-1:1992 and EN 50082-1: 1992. These instruments also conform to the requirements of the Electrical Equipment (Safety) Regulations 1994 (S.I. 1994/3260).

Dr Stephen Rowe, for and on behalf of Chilworth Technology Ltd.

RoHS and WEEE Directives

JCI Chilworth electrostatic measuring instruments are not required to conform to the RoHS Directive because they come within Category 9 exemption.

To comply with the requirements of the EC WEEE (Waste Electrical & Electronic Equipment) Directive all JCI Chilworth instruments, at the end of their useful life, should be returned to Chilworth Technology Ltd for disposal or recycling in an environmentally appropriate way. Chilworth Technology Ltd is a member of the Producer Compliance Scheme ECONO-WEEE Ltd registration number WEE/KB1414VU.

PRODUCT WARRANTY

All test instrumentation supplied by Chilworth Technology Ltd., is manufactured to the highest specification, and as such Chilworth Technology Ltd., warrants the product against defects in materials and workmanship for a period of twelve (12) months from the date of receipt at the Customer premises, on a return to base policy.

It is a necessary requirement of the warranty conditions that the instructions given in the user manual are read, understood and adhered to before putting the instrumentation into first use. If any doubt exists, please consult the manufacturer for further assistance. In such cases where the product is returned to Chilworth Technology Ltd., we will inspect the product on receipt to diagnose the fault, and will issue the Customer with an inspection and condition report.

If the product proves defective during the warranty period, Chilworth Technology Ltd., at its option, will repair the product at our facilities in Southampton, UK.

Provided the product has been used in accordance with the manufacturers guidelines and that the fault is due to a manufacturing defect or component failure and is not due to expected wear and tear caused by the operating environment in which it is used, this warranty covers all parts and labour, but specifically excludes any consumable parts supplied with the product and any shipping costs to Chilworth Technology Ltd.

Chilworth Technology Ltd. shall not be obliged under this warranty:

a) to repair damage resulting from attempts by personnel other than Chilworth Technology Ltd. representatives to install, repair or service the product unless directed by a Chilworth Technology Ltd. representative,
b) to repair damage, malfunction, or degradation of performance resulting from improper use or connection to incompatible equipment or memory,
c) to repair damage, malfunction, or degradation of performance caused by the use of non Chilworth Technology Ltd. supplies or consumables or the use of Chilworth Technology Ltd. supplies not specified for use with the product,
d) to repair an item that has been modified or integrated with other products when the effect of such modification or integration increases the time or difficulty of servicing the product or degrades performance or reliability,
e) to perform user maintenance or cleaning or to repair damage, malfunction, or degradation of performance resulting from failure to perform user maintenance and cleaning as prescribed in published instruction/user manual,
f) to repair damage, malfunction, or degradation of performance resulting from use of the product in an environment not meeting the operating specifications set forth in the instruction/user manual,
g) to repair damage, malfunction, or degradation of performance resulting from failure to properly prepare and transport the product as prescribed in published product materials
h) to replace items that have been refilled, are used up, abused, misused, or tampered with in any way;
i) to support software not supplied by Chilworth Technology Ltd.;
j) to provide software or firmware updates or upgrades.

In the maintenance of the product, Chilworth Technology Ltd. may use new or equivalent to new parts, assemblies or products for equal or improved quality. All defective parts, assemblies, and products become the property of Chilworth Technology Ltd.

Any additional service identified and provided by Chilworth Technology Ltd. at the Customer’s request shall be invoiced to Customer at Chilworth Technology Ltd.’s current rates for parts, labour and travel.

User Manual

JCI 131 / JCI 131F
Adverse Conditions Electrostatic Fieldmeter

for precise, high resolution, continuous measurement of electric fields in adverse environmental conditions

1. INTRODUCTION

The JCI 131 Electrostatic Fieldmeter is a compact and robust instrument for continuous long term measurement of electric fields in adverse environmental conditions. It is particularly suitable for continuous monitoring of atmospheric electric field conditions - for example those associated with varying weather conditions, thunderstorm and volcano activity, and outdoor power supply cables.

The design of the JCI 131 is based on the proprietary approach that has been developed for 'field mill' type fieldmeters that do not require earthing of the rotating chopper [1, 2].

The output signal is proportional to the electric field. Full-scale signal outputs for the various ranges are ±2.0 V for electric field values at the sensing aperture of ±2, ±20, ±200 or ±2000 $kV.m^{-1}$. Measurements are to high precision with low noise and a stable zero (see Specification at the end of this manual for full details). The sensitivity is calibrated according to the principles of British Standard BS 7506: Part 2: 1996 [3, 4]. When the fieldmeter is used as a potential probe (see Section 12), well away from nearby structures, the full-scale readings of the 4 ranges of sensitivity are equivalent to local space potentials of ±0.2, ±2, ±20 and ±200 kV full scale. This means that when the fieldmeter is used, for example, for atmospheric electric field measurements mounted 2 m above ground level at the top of a vertically mounting pole (for example a JCI 137) and connected to earth, these correspond to ranges of atmospheric electric field of ±0.1, ±1, ±10 and ±100 $kV.m^{-1}$ for ±2 V output. In this arrangement the JCI 131 can form a key part of a system for the advance warning of lightning activity [5].

The fieldmeter circuit includes facilities for automatic selection of sensitivity range and the range selected is available externally as 2 logic level signals. A step down of sensitivity is made at a signal level close to the full scale output of ±2.0 V, and a step up in sensitivity at an output level around ±0.15 V. The internal sensitivity selection can be overridden remotely by forcing the range signal lines high or low (5 V or 0 V) as appropriate. <u>Range input settings must not be applied until the JCI131 is running to avoid damage to the unit.</u> The zero reading can be adjusted remotely by applying a regulated positive or negative signal. Setting the zero requires that the sensing aperture of the fieldmeter is placed in a large clean metal zero-check chamber (for example a JCI 152).

Measurement of quasi-continuous electric fields has been made immune to mains frequency (50/60 Hz) electric fields up to x10 full scale of the DC field operating range. If this is exceeded the operating range will auto-change down to the next less sensitive range. This ensures reliable measurements even in the presence of large mains frequency fields. This is relevant when, for example, making measurements of atmospheric electric fields near or under high voltage power lines.

A fast response version of the JCI 131 (the JCI 131F) is available for investigations where it is necessary to measure mains frequency alternating electric fields in combination with quasi-continuous electric fields. This is relevant for measurements of atmospheric electric fields near high voltage power lines. The fast response version has a flat frequency response to about 70 Hz. Separation of the alternating and quasi-continuous signal components is available using the JCI 234 Base Unit.

An optional facility to ensure continued confidence in measurements during long term continuous operation of JCI 131 fieldmeters in adverse environmental conditions is 'operational health monitoring'. This is provided by the JCI 133, a development of that used for the JCI 501 Lightning Warning System [5]. This comprises an additional circuit board within the JCI 131 and a shield unit around the outside of the fieldmeter.

The JCI 131 head unit can be operated directly from a single supply of 20 - 30 V with a 1.5 A current capability. This current is sufficient to ensure satisfactory start-up, though a higher initial transient (up to 4 A) will be drawn if the power supply has that capability. Once normal running is established the current should not exceed 450 mA, so taking all things into consideration a 1.25 A fuse on the power supply output has been found to be suitable.

The JCI 134 Base Unit (and the JCI 234) provides for operation from 100 - 240V 50/60 Hz mains supplies or from a 12 V battery. The arrangement also allows a 12 V battery to be used as battery back-up in the event of a mains supply interruption. The JCI 134 and JCI 234 include displays of fieldmeter readings, and when the operational health facility is fitted, the operational health drive and sensed signals can also be displayed.

Fieldmeter observations are presented both as direct values of electric field as measured by the fieldmeter, and as interpreted atmospheric electric field values when the fieldmeter is mounted on a pole in a potential probe configuration.

Analogue output signals are provided from the JCI 131, and also via a JCI 134 or JCI 234, so raw observations may be recorded for analysis and re-display using computer-based signal processing systems. A convenient approach in this respect is the Picoscope attachment (www.picotech.com) which turns a PC into a digital storage oscilloscope or datalogger.

2. PRACTICAL DESIGN FEATURES

The JCI 131 is based on a proprietary JCI design of 'field mill' electrostatic fieldmeter which does not need earthing of the rotating chopper [1, 2]. This design, together with use of an electronically commutated drive motor, is appropriate for long term continuous measurement of electric fields.

Immunity from adverse environmental conditions is achieved using large gaps from the sensing surfaces to other nearby surfaces, long insulation surface tracking paths and a sealed region for the signal processing and other circuit boards [5]. The large gaps (7 mm to nearby stationary surfaces) prevent bridging with water or other contaminants, and these and the long tracking paths can be seen in the photographs in Figures 1 and 2 (page 5).

Low noise and good reading and zero stability are achieved by ensuring key components are made from exactly the same material to minimise electrochemical potential differences. To this end units may either be gold plated or use an all stainless steel construction. Either approach ensures that when surfaces are cleaned they return to well defined surface conditions.

Operation is immune to the presence of ionized air up to the point at which the rotor assembly becomes charged above about 20 V. Immunity is achieved because signals from ionization currents are in quadrature to electric field signals and so can be, and are, removed by phase sensitive detection.

The response for the standard JCI 131 is -3 dB at about 3 Hz. Response has been made immune to operation in 50/60 Hz alternating fields of up to x10 of the current full scale DC operating range. For the fast response version the frequency response is flat up to about 70 Hz, such that mains frequency fields can be measured.

Figure 1: General View of the JCI 131 Electrostatic Fieldmeter

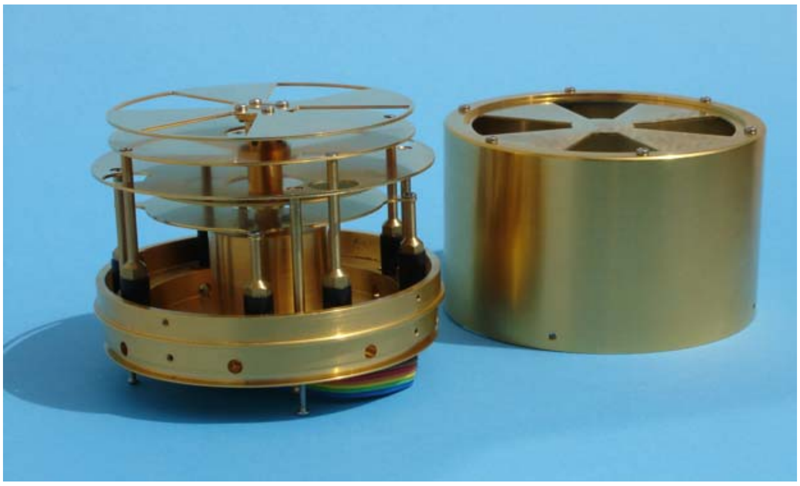

Figure 2: Internal features of the JCI 131 Sensing Region

High measurement precision is achieved by using rigid structures for the sensing surfaces and for the rotating chopper assembly. The sensing surfaces and chopper parts are electrochemically machined hard brass and gold plated, or stainless steel. The rotating chopper assembly is mounted on the motor shaft with an alumina insulator and the electronically commutated motor is free of end float. The motor shaft is well shielded to minimise capacitive coupling from the motor commutation signals. With the large gaps between chopping and sensing surfaces to avoid water bridging (as seen in Figure 2), a rather large instrument diameter is needed to provide good signal modulation and achieve good signal to noise ratio at low signal levels [1].

The electronically commutated motor provides a once per revolution logic output signal. This signal is used in conjunction with digital multiplication and a phase lock loop circuit to provide the signals needed both for motor speed stabilisation and for phase sensitive detection of the sensing surface signal. This arrangement permits the opportunity to generate the phase

related operational health signal and its phase sensitive detection. The basic chopping frequency is set close to 275 Hz, deliberately chosen to be well away from harmonics of possible 50 or 60 Hz mains power supply signals. For the fast response version the chopping frequency is 512 Hz.
The standard sensing head unit includes two circuit boards, one for providing regulated power supplies and the other for running the fieldmeter. Where operational health facilities are provided, an additional circuit board is fitted, along with a special back plate to provide connection to the operational health shield located around the fieldmeter body. There is also space within the JCI 131 body for a fourth circuit board, which is used to accommodate a radio signal observation board for the JCI 501 lightning warning system [5]. In this case the mounting pole is isolated from the bottom spike and used as the radio antenna.

A major application of the JCI 131 fieldmeter is for monitoring atmospheric electric fields. A stainless steel tube of 47.5 mm internal diameter and, for example, 2 m long will provide a suitable mounting for the sensor unit. The JCI 137 is such a support pole with an earth mounting base and attachment ring for guy lines. A diagram of this arrangement is shown in Figure 3. The fieldmeter sensing head unit can be lifted off the top of the support tube and replaced without disturbing the support pole or the stabilising guy lines. The cable linking the fieldmeter to its power supply source and signal recording and display equipment passes up the inside of the mounting tube.

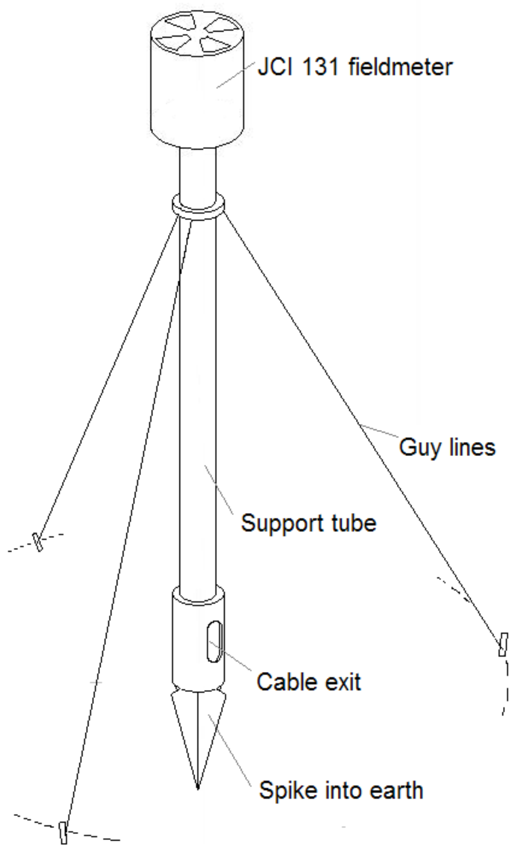

Figure 3: Diagram of JCI 131 Mounting

3. POWER SUPPLY REQUIREMENTS

The JCI 131 fieldmeter can be operated directly from a single supply of 20 - 30 V with a 1.5 A current capability. This current is sufficient to ensure satisfactory start-up, though a higher

initial transient will be drawn if the power supply has that capability. Once normal running is established the current should not exceed 450 mA, so taking all things into consideration a 1.25 A fuse on the power supply output has been found to be suitable. The power supply should preferably be floating relative to earth.
The wide range of supply inputs makes it easier to work with long cables and less well defined supply sources. Where long cables are used, the voltage drop along the lines needs to be accounted for to ensure the above supply criteria are met at the fieldmeter. For that reason, where long cable are used it may be better to use a supply close to the top end of possible supply voltages.

A switched mode power supply unit inside the fieldmeter head generates the supply voltages actually used within the instrument.

4. CONNECTIONS

Power input and signal output connections are made via a sealed 19w Mil socket connector on the back of the fieldmeter (Pattern 105: Socket: AB05 210014-19SN00, Free plug: AB05 602714-19PN00). A suitable cable is DEF Stan 61-12 Part 4: 7/0.2 PVC insulated, overall braid screened, PVC sheathed type 7-2-20C. The following table lists both the connections at the 19w cable socket of the JCI 131 and also connections at the 25w D type diagnostic port on the JCI 134 or JCI 234 Base Units. It is advised that the power supply lines (C & D) are doubled up in the cable as shown to reduce resistive voltage drop in the cable and are not linked to the 0 V earth line (B) of the fieldmeter itself. The signals indicating and controlling the sensitivity range and external zero adjustment are all relative to the instrument 0 V: the black lead, connection B.

Cable Feature	19w Cable Connector	25w D Type Diagnostic Socket
Cable sheath & case	A green/yellow	
0V	B black	1
+ve power supply	C red & yellow/blue	2
- ve power supply	D blue & blue/white	3
Fieldmeter 0V	E green	4
Fieldmeter signal	F white	5
Range bit 0 (field x10)	G yellow	6
Range bit 1 (field x100)	H brown	7
Zero adjust	J violet	8
Field over-range	K orange	9
Noise signal	L pink	10
Noise x10	M turquoise	11
Health inhibit	N grey	12
Field health drive	P red/blue	13
Noise health	U green/red	14
Impulse signal	V yellow/red	15
Impulse x10	R white/red	16
Impulse health	S red/black	17
Field health signal	T red/brown	18
Field DVM		19
Field range +1		20
Field range -1		21

The cable should include a shielding braid and this should be earth bonded at both ends.
For good quality analogue signal observations over long cable lengths it is best to use a unity gain differential buffer amplifier between the fieldmeter signal 0 V and the signal line at the

signal processing end. This is included within the JCI 134 and JCI 234 Base Units. Experience indicates that compliance with all of these guidelines ensures fieldmeter operation will be satisfactory with cable lengths to at least 100 m.

5. SAFETY AND PROTECTION

Warnings

The operator of this equipment must ensure that, especially in remote operations, appropriate warning signs are posted in conjunction with suitable protective measures (e.g. fencing) to ensure as far as is reasonably practicable that unauthorised and untrained personnel cannot come into contact with JCI 131 fieldmeters, for the following reasons:

- Allowing fingers to enter the sensing aperture when the chopper is running could cause severe injury.
- In use the Operational Health Shield is energised with a potentially lethal power supply, which could cause injury.
- Any foreign object entering the sensing aperture, especially when the chopper is running, could cause severe damage to the unit necessitating its return to the manufacturer for rebuilding.

Although designed for use in adverse conditions, parts of the fieldmeter are delicate. Hence, care should be taken in handling the unit, and a special warning is given against dropping or hitting the fieldmeter sensing head, as this is known to be the cause of damage to the alumina sleeve insulator that mounts the rotor assembly on to the motor shaft. This will require a manufacturer's rebuild to repair.

6. OPERATION IN FLAMMABLE ATMOSPHERES

This equipment is not suitable for use where hazardous flammable atmospheres are or may be present (hazardous areas as defined in IEC 60079-10-1 and IEC 60079-10-2) inside or outside the equipment. Furthermore, even in the absence of designated hazardous areas, this equipment should not be used in close proximity to flammable substances without first conducting a risk assessment which is the responsibility of the end user company.

7. OPERATING ENVIRONMENTAL CONDITIONS

The full extents of the operational environmental envelope for the JCI 131 and JCI 131F fieldmeters have not been investigated. However, an operating range is suggested of 0 – 40 °C and 20 – 100 % RH, including direct rain precipitation into the sensing aperture. There is no reason to suppose the JCI 131 fieldmeters would not operate satisfactorily below 0 °C, though if snow, freezing rain or sub-zero temperatures after precipitation are expected, it is recommended that the JCI 131 is kept in continuous operation, and so kept warm, to avoid clogging of the rotating chopper assembly.

8. ZERO READING AND ADJUSTMENT

The zero reading of the JCI 131 is set internally at manufacture. This setting should remain stable over an extended period of operation. Nevertheless, provision is included in the external connections (pin J, violet) for remote adjustment of the zero setting. The zero reading should be checked from time to time and particularly before any application where it is critical to measure low values of electric fields with accuracy. The zero reading is checked by placing a Zero Check Chamber (for example JCI 152) over the sensing aperture end of the instrument. This large clean metal chamber is electrically bonded to the case of the JCI 131 and has no surfaces closer to the sensing aperture than about 100 mm. Because the JCI 131 is a high sensitivity instrument it is desirable that the zero check chamber is of the same material as the JCI 131 itself to avoid the possible influence of electrochemical potentials on the chamber surfaces. All values measured with the JCI 131 are relative to the zero reading as set. Zero checking and any zero setting adjustment must be done with the JCI 131 fieldmeter operating on its most sensitive range.

When the JCI 131 is fitted with the operational health monitoring facility (JCI 133) the JCI 152 Zero Check Chamber is aligned over the health shield by the 3 studs in the top plate. The operational health facility needs to be turned off and the JCI 131 set to operate in its most sensitive range.

When the JCI 131 is used in conjunction with a JCI 134 or JCI 234 Base Unit a potentiometer is provided for remote adjustment of the zero setting.

If the zero reading becomes unstable, or noisy, or is appreciably different from zero then it is probably desirable to clean the instrument sensing region (see Section 9 below) and then recheck the zero.

9. CARE AND CLEANING OF JCI 131

Although the JCI 131 is of robust construction its operation and/or performance may be impaired if it suffers mechanical impact damage or if the sensing aperture or the internal parts becomes dirty or debris enters the sensing region. The following checks and cleaning may be safely undertaken by the user without adversely affecting instrument performance or sensitivity. If satisfactory operation is not restored by these operations then the instrument should be returned to JCI-Chilworth for repair or servicing. DO NOT attempt any adjustments to the circuits as such actions will, almost certainly, adversely affect instrument operation.

If there is any visual evidence of dirt or contamination on any of the sensing aperture or the sensing region surfaces, or if the zero reading has drifted or become unstable, then the first action is to remove the front cover of the instrument. (For instruments fitted with the operational health facility the health shield needs to be taken off first. This requires removal of the 6 x M4 retaining screws). There are two sets of 4 x M2 screws around the middle of the instrument casing. Carefully remove the four M2 x 6 mm stainless steel screws nearest the sensing aperture end of the casing, leaving the other four untouched. Carefully remove the front casing to reveal the sensing surfaces and rotating chopper assembly (as shown in Figure 2).

The sensing surfaces and rotating chopper assembly should be inspected for any signs of physical damage, dirt, hairs or debris. Any debris should be carefully removed. Contamination of the surfaces should be removed by gently washing in warm soapy water and rinsing well, or alternatively by using a residue-free aerosol spray cleaner (some aerosol cleaners leave a film of conductive oil and are therefore quite unsuitable). The same actions should be applied to the inside of the front casing. (DO NOT undo the grub screws securing the rotor assembly to the motor shaft. DO NOT undo the 6 x M2 screws around the front edge of the sensing aperture. Such actions will necessitate full resetting of instrument operation at JCI-Chilworth. When the internal structure of the sensing region is clean the front cover may be replaced and re-secured with the four M2 x 6 mm screws.

Instrument operation and the zero reading should now be checked before returning the instrument to normal operation.

10. OPERATIONAL HEALTH MONITORING

To give continued confidence in operational performance during long term continuous observations an operational health system is available as an option.

Operational health monitoring was originally developed as part of the JCI 501 Lightning Warning System [3]. In that system the whole fieldmeter sensing head unit was modulated with a low frequency square wave alternating signal of some 50 V peak to peak amplitude. This modulated the observed electric field signal and the amplitude of modulation was compared to the level expected. The present facility involves an additional shield mounted around the casing of the JCI 131 fieldmeter sensing head (which is earthed) and it is the shield that is driven with a sinewave voltage relative to earth at a frequency and phase locked to the chopper rotation signal.

The voltage swing of the shield is set appropriate to the fieldmeter operating sensitivity, and is about 2.2 V rms on the most sensitive range, 22 V rms on the next range and 220 V rms on the top two least sensitive ranges. Feedback arrangements aim to keep the health signal constant despite any expected leakage losses that may be present. *Hence, the current capability is such that in some circumstances the supply could be considered potentially lethal. Therefore, if the operational health shield is fitted and operational, measures must be in place to ensure as far as is reasonably practicable that unauthorised and untrained personnel cannot come into contact with the shield. (See also the warnings at the front of this manual and in Section 5.)* Provision is also included for direct monitoring of the level of the operational health shield's drive signal so positive monitoring of the operational health facility itself is possible.

Phase sensitive detection enables the health modulation signal observed by the fieldmeter from the shield to be selectively extracted. Phase sensitive detection is also used to monitor the level of the health drive signal. There is no influence from the health monitoring signals on normal ambient electric field measurements. Both health and health drive signals are made available via the output connector as nominally 1.0 V signals. The levels of the health drive signal can be expected to remain very stable with time, unless there is serious contamination of the shield mounting. The health signal may vary by a few % in normal operation. This variation can be due to rainwater droplets on the primary sensing surface changing the gap spacings slightly.

11. CALIBRATION

All JCI 131 fieldmeter instruments are carefully set up in manufacture with the sensitivity set using the same arrangements as for formal calibration to BS 7506: Part 2: 1996 Annex 1 [3, 4]. Instruments can, optionally, be formally calibrated to this Standard at JCI-Chilworth, with measurements whose accuracy is traceable to National Standards. In that case appropriate calibration documentation will be supplied.

12. APPLICATIONS

12.1 Introduction

The JCI 131 electrostatic fieldmeter measures the strength of the electric field at its sensing aperture. If this aperture is mounted flush with a large surrounding plane conducting surface then the fieldmeter reading relates directly to the electric field at the surface of this plane. This is the mode in which the instrument is set up and calibrated [3, 4]. In many situations, however, it may not be practical to mount the fieldmeter in a large plane conducting surface, or the electrostatic conditions of interest will be some way away from accessible positions of measurement in a more or less complex earthy structure (for example for measurements in silos and in the cargo tanks of large crude oil tankers during tank washing [9, 10]). In such situations it is necessary to relate measurements at the fieldmeter sensing aperture to conditions elsewhere by some modelling action. This may be appropriately done by computer solution of Laplace or Poisson equations in two or three dimensional models of the practical situation [6, 7, 8].

A particularly useful application of an electrostatic fieldmeter is as a 'potential probe' [9, 10]. So long as the size of the fieldmeter sensing head unit is small compared to its structural environment and well away from nearby conducting structures (more than 5 or 10 diameters) then the electric field observed by an earthed fieldmeter depends upon the local potential which was at the fieldmeter mounting position before it was introduced. This is approximately described by the following equation:

$$E_f = \frac{V}{d} \qquad (1)$$

where E_f is the fieldmeter reading ($kV.m^{-1}$), V the local potential (kV) and d the effective sensing head diameter (m). There will, of course, be a contribution to the measured electric field that is dependent on the alignment of the sensing aperture relative to the ambient electric field, but this effect is usually small.

The actual sensitivity of fieldmeter measurements can be checked in situ by having the fieldmeter assembly insulated from the main earthy structure at its mounting and applying a calibration voltage to the fieldmeter assembly. With zero electric field at the fieldmeter sensing aperture the applied potential is the same as the local voltage. Opportunity for such checking is provided with the JCI 137 Support Pole, as the pole is mounted in a Delrin socket in the tube socket on the ground spike.

However, before attempting this voltage sensitivity check, it must be ensured that all connected instruments are disconnected from earth. This includes both JCI 131F, any Base Units (JCI 134 or JCI 234) and any mains power supplies. To ensure a JCI 134 or JCI 234 Base Unit is disconnected from earth, it should be powered only by a battery (which is isolated from earth), with its mains power supply disconnected. **Failure to comply with this instruction may result in serious damage to the instruments and power supply, necessitating their return to the manufacturer for repair.** It is also recommended the voltage used to float the instrumentation is kept as low as possible consistent with the requirements of the test, and that only low current power supplies are used.

Fieldmeters have been used as potential probes in studies of tank washing on large crude oil tankers [9, 10] and in food product silos [10]. This is also an appropriate approach for measurement of ambient atmospheric electric fields with the fieldmeter mounted at the top of a metal mounting pole. A suitable arrangement is illustrated in Figure 3 (Section 2). Notes on such applications are described on the JCI Website [11].

The atmospheric electric field, E_a ($kV.m^{-1}$), may be measured using the fieldmeter mounted on a support pole at a mounting height, h (m), with the fieldmeter earthed. In this mode the fieldmeter is operating as a potential probe and the atmospheric electric field is given by:

$$E_a = \frac{V}{h} \tag{2}$$

where, as before, V is the local potential in the absence of the fieldmeter in kV.

From Equation 1:

$$V = E_f d \tag{3}$$

and substituting Equation 3 into Equation 2 gives:

$$E_a = E_f \frac{d}{h} \tag{4}$$

where E_a is the ambient electric field in the absence of the fieldmeter ($kV.m^{-1}$), E_f is the indicated electric field ($kV.m^{-1}$), d the effective sensing aperture of the fieldmeter (m), and h the height of the sensing aperture above ground (m).

There will be a contribution to the measured electric field that is dependent on the alignment of the sensing aperture relative to the ambient electric field. If for example the two field components are in directions to add (e.g. the fieldmeter looks upwards on the top of the mounting pole), then the atmospheric field can be more precisely given as:

$$E_a = E_f \frac{d}{h\left(1 - \frac{d}{h}\right)} \tag{5}$$

though as d/h is normally small, the influence of this effect is small.

Where a fieldmeter is mounted other than above a large-scale flat ground area, and well clear of any buildings or earthy projections, there will be a need to interpret electric field measurements in relation to the geometric arrangement of the surroundings. In principle this can be done with computer modeling, although this is not easy and may lack conviction in complex three dimensional arrangements. An easier approach to tackle this problem is to normalise readings in relation to measurements of ambient atmospheric electric field values made in an area that is nearby, plane and free of interfering structures and features. Such normalising measurements may conveniently be made using a JCI 140 Static Monitor held at arm's length above the head. It will be best to match observations between the two instruments at the same time in clear "blue sky" conditions and with the reference site not too far away. (Although it is stated that the ambient atmospheric electric field in clear "blue sky" conditions is typically around 100 $V.m^{-1}$ this is susceptible to fine atmospheric pollution, so cannot be relied upon in practical observations).

If the sensitivity of a fieldmeter to the local voltage (or an applied calibration voltage) is S kV.m^{-1} per kV, and at a height h (m) above the ground in a local atmospheric electric field E_a, the relationship between the ambient electric field and the fieldmeter reading, E_o (kV.m^{-1}), is as follows:

$$E_a = \frac{E_o}{Sh} \tag{6}$$

If at the same time measurement of the atmospheric electric field in a nearby large flat area is E* then there is a shielding (or gain) factor, F, at the set measurement location given by:

$$F = \frac{E^*}{E_a} \tag{7}$$

In this case the true atmospheric field at the set observation location is given by:

$$E_a = \frac{FE_o}{Sh} \tag{8}$$

For a JCI 131 without the operational health shield fitted: S ≈ 10.0 kV.m^{-1} per kV
and with the operational health facility fitted: S ≈ 7 kV.m^{-1} per kV.

Hence, for a mounting pole height of, say, 2.0 m, with the operational health shield fitted:

$$E_a = \frac{E_o}{7\times 2.0} kV.m^{-1} \tag{9}$$

If the shielding factor at the test location is, say, 1.5, then:

$$E_a = \frac{1.5\times E_o}{7\times 2.0} \approx 0.107\,E_o\; kV.m^{-1} \tag{10}$$

12.2 Pole Mounting

To mount the JCI 131 fieldmeter on the JCI 137 mounting pole the spike is first driven into the ground at the required location. If necessary the driving may be by a collar tube (not supplied) fitting over the socket housing for the bottom end of the mounting tube so that impact is direct to the top of the spike. The mounting tube may be used to check verticality from time to time during driving. With the spike in position and the mounting tube laid on the ground, the cable connector may be passed through the side hole in the housing and then though the length of the tube and left free at the far end. There are then two options:

i) The fieldmeter may be connected to the cable and mounted on the top end of the mounting tube. This assembly is then raised upright and socketed into the insulator in the bottom housing, and the guy lines secured.

   Or

ii) More conveniently for service inspections, the tube may be mounted into the housing and the guy lines attached and secured. The fieldmeter head unit can now be connected to the cable and socketed into the top of the mounting tube.

Care is needed to ensure easy movement of the cable in and out of the side hole in the bottom housing.

The pole mounting arrangement provides insulation between the earthed pole socket housing and spike and the mounting tube. This permits in situ calibration of the voltage sensitivity of the fieldmeter by operation of the fieldmeter from an isolated power supply, or battery, and application of defined voltages to the fieldmeter assembly. At all other times the fieldmeter should be connected to earth using the earthing terminal near the bottom of the mounting tube to connect to a local earthing rod driven well into the ground.

JCI 131 fieldmeters without the operational health facility fitted have a brass back plate. This will provide direct electrical connection between the fieldmeter and its mounting tube. When the operational health facility is fitted (and/or the radio system for the JCI 501) then the back plate is insulating and spring loaded connectors are included to link the internal circuits to the mounting tube (antenna) and to the operational health shield. Two spring loaded connectors are provided for each facility.

13. JCI 134 / JCI 234 BASE UNITS

The JCI 134 and the JCI 234 Base Units provide an easy solution for powering JCI 131 fieldmeters, displaying readings, and relaying signals to other equipment such as dataloggers. The JCI 234 Base Unit is specifically designed for use with the JCI 131F. A separate manual describes the use of the JCI 234 in more detail.

Using the Base Units the JCI 131 fieldmeters can be powered from a 100 – 240 V 50/60 Hz mains power supply or from a 12 V battery. When operating from mains, a battery connected at the same time provides back-up for uninterruptible operation in the event of mains supply failure. The low voltage supply to the JCI 131 fieldmeter from the Base Unit is 24 V, which is sufficient to ensure reliable operation of the fieldmeter even when allowing for the voltage drop along 100 m of the recommended cable. The Base Unit's top cover display includes LED indicators to show power supply sources actively available. The layout of the JCI 134 top cover can be seen in Figure 4.

Figure 4: JCI 134 Base Unit

Operational power is switched on with a key switch. This provides protection against accidental interruption of long term monitoring operations.

Fieldmeter readings are displayed on a 3½ digit LCD, with 6 sensitivity ranges. LED indicators show if the current range should be read as $V.m^{-1}$, $kV.m^{-1}$ or $MV.m^{-1}$. Ranges can be selected and held using the two range selector buttons, or auto-ranging selected by pressing both buttons simultaneously.

When used for atmospheric electric field measurements the observations can be displayed as ambient electric field values (see Section 12), though the local electric field as measured by the fieldmeter can always be viewed by operating the appropriate push button on the Base Unit. As shown in Section 12.1 above, when the fieldmeter is pole mounted at a height, h (m), the local ambient atmospheric electric field E_a ($kV.m^{-1}$) is related to the electric field measured by the fieldmeter E_o ($kV.m^{-1}$) by:

$$E_a = \frac{FE_o}{Sh} \quad (8)$$

where F is a shielding factor and S the sensitivity of the fieldmeter assembly in $kV.m^{-1}$ per kV.

The JCI 134 and JCI 234 provide opportunity to match the displayed values of electric field to actual values of atmospheric electric field. Where the fieldmeter assembly is mounted in a large flat area with no shielding from nearby buildings or structures then atmospheric electric fields are determined simply from the voltage sensitivity of the assembly and the height of mounting. If the JCI 131 has to be mounted in a position where there may be some enhancement of ambient atmospheric fields by mounting on a local hill or reduction by shielding from a nearby building or structure then the true ambient reading can be normalised by direct comparison to readings from a portable fieldmeter (for example a JCI 140) held aloft at a location somewhere nearby but where the shielding/enhancement effects are negligible.

A potentiometer and a 3 position slide switch are provided in the back plate to enable the display to be adjusted to show the ambient atmospheric electric field. A push button in the back plate provides easy switching of the display between the ambient atmospheric electric field and the actual fieldmeter reading from which it was derived.

Ambient electric field values can be obtained in two ways:

1) Using the voltage sensitivity of the fieldmeter. This is about 10 $kV.m^{-1}$ per kV for a JCI 131 by itself, and about 7 $kV.m^{-1}$ per kV for a JCI 131 fitted with the operational health shield. This can then be combined with the height of the pole mounting and the actual fieldmeter reading to determine the ambient atmospheric electric field using Equation 8.

2) Using the value of ambient electric field from measurements made at a nearby flat area of ground to set the Base Unit display to read ambient atmospheric electric field directly:

    a) Turn the ‘gain’ potentiometer fully clockwise to show maximum value and select auto-ranging operation by press the two range control push buttons simultaneously.

b) Move the range switch in the back panel so the reading is between x1 and x10 of the target ambient field value (as determined by the nearby field reading).

c) Adjust the gain potentiometer until the displayed reading corresponds to the target ambient electric field (from the nearby field reading).

As ambient electric field values may change relatively quickly in anything but “blue sky” conditions, it may be most convenient to establish the ratio between the ambient and local field values so this can be used to set the gain while toggling between local and ambient displays. It is important that any comparisons between the nearby plane area and the JCI 131 location are made at the same time, so at least two people in radio or mobile phone contact will almost certainly be required.

A potentiometer is also provided in the Base Unit back cover for adjustment of the zero reading of the JCI 131. This needs to be adjusted with care when a suitable Zero Check Chamber (for example a JCI 152) is placed over the sensing end of the fieldmeter. The fieldmeter needs to be operating in its most sensitive range with the display showing direct readings of electric field at its sensing aperture.

The JCI 131 is connected to the Base Unit via a 19w connector in the front plate. A 25w D type connector is provided for external linkage of all signal channels from the JCI 131 for external display and recording of observations. For all connections see Section 4.

The operational health of the fieldmeter can also be shown on the LCD using the two buttons just below it. Pressing the top button shows the operational health signal as a % of the expected level. Pressing the lower button shows the operational health drive signal as a % of the value expected. Operational health can be toggled on and off if it is desired to check for lack of interaction between operational health and fieldmeter observations.

14. COMPUTER DATA PROCESSING

Earlier versions of the JCI 131 fieldmeter offered the optional facility of an integral and proprietary RS 232 serial interface PCB within the head unit. This could be linked directly to the serial port of an IBM PC or a compatible microcomputer for display and numerical recording of observations using JCI LOG proprietary software.

This approach was superseded some time ago as Windows operating systems advanced and off-the-shelf data logging solutions became readily available. Hence, for most applications data recording using a Picoscope digital storage oscilloscope (www.picotech.com) and PC or laptop is recommended.

15. REFERENCES

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SPECIFICATION

Sensitivity ranges:	±2, ±20, ±200 & ±2000 kV.m^{-1} full scale output of ±2 V.
Accuracy and linearity:	JCI 131: Within 1.5 % of operating range fsd. JCI 131F: Within 1.5 % of operating range fsd.
Zero stability:	Within ±50 V.m^{-1} over extended periods. Within ±10 V.m^{-1} over short periods.
Zero noise:	JCI 131: <10 mV pk-pk (<10 V.m^{-1} pk-pk on Range 1). (20Hz – 1MHz) Bandwidth JCI131F: <40 mV pk-pk (<40 V.m^{-1} pk-pk on Range 1) (20Hz – 1MHz) Bandwidth
Zero adjustment:	External adjustment by potentiometer from ±5 V regulated supply via zero adjust connection.
Controls:	Auto-ranging sensitivity. External selection of range by holding range indicating signal lines low (earth) or high (+5 V) relative to signal earth or cable sheath.
Signal output:	±2.0V for ±2, ±20, ±200 or ±2000 kV.m^{-1} FSD for ranges 1, 2, 3, 4. 2 logic level indication of sensitivity range (0 V or 5 V LO/HI)
Mounting:	47.5 mm diameter by 75 mm long plug on backplate of head unit provides mounting by socketing into 51 mm diameter (1.6 mm wall) support tube. (Cable connector on axis within 39mm dia.).
Operating environment:	0 – 40 °C, 0 – 100 % RH including direct rain precipitation.
Power supply:	20 – 30 V 1.5 A capable power source. Running current 450 mA.
Earthing:	Via mounting of sensing head unit and/or cable braid.
Dimensions:	102 mm dia. x 250 mm long. Weight: 3.5 kg. (170 mm diameter with operational health shield fitted).
Calibration:	Sensitivity is set up in manufacture on the basis of measurements with accuracy traceable to National Standards. Option for formal Calibration to the principles of BS 7506: Part 2: 1996.

***JCI Chilworth** manufactures a wide range of high quality, state of the art electrostatic instrumentation. We also carry out servicing and repairs for JCI instruments, and where appropriate calibration traceable to national and international standards. **JCI Chilworth** is part of **Chilworth Global**.*

***Chilworth Global** brings together leading expert consultants in the fields of electrostatics and process safety, and GLP compliant laboratories, to provide a single point of contact for all electrostatic and process safety needs. Our laboratories provide material properties data for electrostatic problems and hazards, fire and explosion hazards (including liquids, vapours, gases and powders), chemical reaction hazards and regulatory testing. Our consultant engineers are all experienced in process safety, with individual expertise that includes electrostatics, chemical reaction hazards, and other particular aspects.*

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