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MODEL 101HDC-3 MULTI-CHANNEL RADIATION DETECTOR

Rev. R

The model 101HDC-3 from Carroll & Ramsey Instruments is a radiation detector system intended for radiochemical synthesis and process monitoring applications in nuclear medicine laboratories, hot cells, etc.

TECHNICAL DESCRIPTION

The system comprises a set of up to three miniature detector probes, plus a three-channel transresistance (current-to-voltage converter) amplifier.

The maximum gain of the transresistance amplifier in each detector channel is nominally 5 x10^9 ohms, that is, a detector current of one nano-ampere can produce a voltage at the output of the amplifier of five volts. A multi-turn trim potentiometer on the output of each amplifier chain allows the user to adjust the overall transresistance gain of the system over a range of approximately 10:1.

Probe

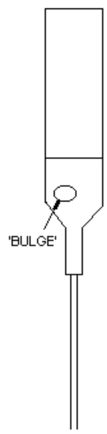
The active element in the 'standard' detector probe is a 7.6 mm^2 silicon PIN diode which is enclosed in a brass housing, and sealed with an opaque plastic resin to shield it against light and stray electromagnetic fields.

Each probe is connected to its amplifier unit through a length of small-diameter coaxial cable. The detector probes operate in "DC" mode and are intended to be used in close proximity to concentrated sources of gamma-emitting radionuclides.

Four sizes of probe are available; 7.6 mm^2 (standard), 25 $mm^{2,}$ and 90 mm^2 . Also available is a highly sensitive probe incorporating a 1 cu cm CsI(Tl) crystal coupled to a 1 sq cm Si PIN diode. This latter probe must be attached to its signal cable by means of a friction fit subminiature coaxial (type 'SMB') plug and jack. Press the male plug firmly but carefully until it seats in the jack.

Mechanical

The probes are mechanically robust and are not damaged by normal handling. However, the probe and its connecting cable will generate spurious signals ("microphonics") if moved or flexed during use. When making a measurement, the probe and its cable should be held in place and padded if necessary to minimize coupling to sources of vibration such as fans, pumps, motors, etc.

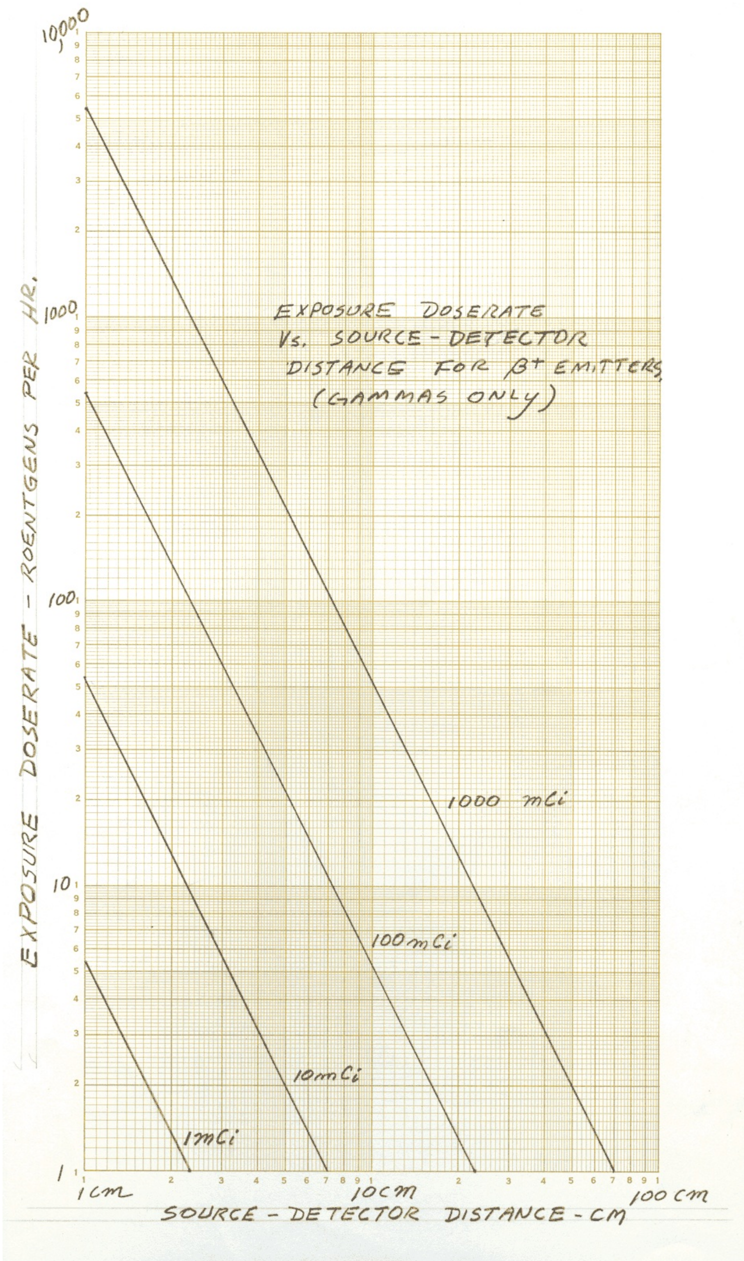


Note that the probes are *not* bilaterally symmetric in terms of response to a source of activity very close to – or in near contact with – the surface of the probe. On the smaller probes (2.7 x 2.7 and 5 x 5 mm) the active PIN diode element is closer to the face of the probe with a small 'bulge' under the heat-shrink tubing. On the 3 x 30 mm probes, the face opposite the 'bulge' is the more sensitive surface.

DC-Amplifiers

A small positive DC offset -- equivalent to ~ 5 pico-amperes or less (0.25% referred to full-scale), in the absence of radiation -- is normally present. Measurements at very low gamma radiation exposure dose levels are confounded to some degree due to this offset, and by slow changes in offset -- referred to as "drift" -- which are indistinguishable from changes in radiation intensity. Other sources of error are detector diode leakage and "dark" currents--all of which, in turn, are strongly influenced by ambient temperature. Offset drift is minimized by utilizing high-quality operational amplifiers with very low initial offset. Leakage current is minimized by operating the diode at zero bias into a low-impedance ("virtual ground") transresistance amplifier input.

However, the diode's dark current is still of the order of a few pico-amperes at 25^{o} C, and increases by a factor of 2 for every 5^{o} C rise in temperature. Thus, since the basic probe sensitivity is of the order of ~1 pA per sq. mm per rad / hr (Si), this detector system is best suited for applications involving gamma radiation fields of several roentgens per hour or greater exposure dose-rate, for example, in close proximity to concentrated sources of gamma activity of 1 mCi or more.



Source-Detector distance

See the attached graph to determine exposure doserate as a function of distance from a concentrated ("point") source of β^+ (i.e., 511 KeV gamma in this example) activity. For very close coupling to a point source of activity, the inverse-square law has a potent effect on detector response. This can be of some advantage in reducing the amount of shielding required against ambient activity away from the source relative to activity at the source.

However, if one is monitoring the amount of activity trapped in a column, for example, the exact place within the column where the activity is trapped can affect the observed doserate. Moving the detector a short distance away will mitigate this effect. The user should experiment with source-detector placement to find the best compromise between repeatability and minimum shielding.

Scale factor

Since observed doserate (and, consequently, detector current) is a function of source-detector distance, one may place the detector at a particular distance from the source so as to provide a convenient scale reading. For example, (refer to graph) a 1 curie β^+ source produces a field of 200 roentgens / hr at a distance ~5 cm from the source. A "standard" probe produces ~ 1.4 nanoampere at this exposure doserate, yielding a reading on the voltmeter display of 7. VDC at full sensitivity; once the source-detector mounting position is fixed, the amplifier gain control potentiometer may be adjusted so as to set the scale reading to “1.0".

INSTALLATION AND OPERATING ENVIRONMENT

The 3-channel amplifier box may be placed where radiation is present, but preferably away--or shielded-- from very intense sources of radiation.

The operating power for the 3-channel amplifier box is 12 - 24 VDC, well-filtered, at ~20 mA. Internal system operating voltages (+6VDC, and -6VDC) are provided by a built-in, regulated power supply.

The sensitive element in the standard or 4X detector probe is centered on the 'wide' face of the probe. The detector probes are connected to BNC coaxial receptacles in the 3-channel amplifier box marked **J 1, J 2, J 3,** respectively.

Wiring on the output connector is as follows:

Channel 1 signal out – pin 1
Channel 2 signal out – pin 2
Channel 3 signal out – pin 3
+power supply – pin 6
Power supply return and signal return – pin 9

The cable connecting the 3-channel amplifier box to the user's remote read-out or display unit should be (at least) a 4-conductor, shielded type, with wires distinctly color-coded. Three wires are used for the respective signal connections. The fourth wire carries + power supply potential. The shield is used as the signal and power common return. Alternatively -- and more conveniently -- a pre-assembled 9-conductor shielded cable with male/female DB-9 connectors can be purchased at most well-stocked computer or electronics supply stores. The output connecting cable may be any length up to ~30 meters

The gain for each channel may be adjusted by means of multi-turn, screwdriver-adjust, potentiometers which are accessible through the top of the preamplifier box. Channel 1 gain adjustment is closest to the front panel; channel 2 is next, etc.[1] Alternatively, the internal gains can be set at "max" and the gain for any channel can be adjusted lower by adding shunt resistance between signal output and ground for that channel. In this way, gain can be conveniently adjusted at a remote location. The signal levels, which are proportional to dose-rate, are monitored by a digital voltmeter, high-impedance chart recorder or computer data acquisition system (1 megohm or more input impedance).

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[1] Please do not try to change components or adjust other controls on the printed wiring board. Inside the chassis box.

Environment

The system is intended for indoor use. Components have not been characterized for operation outside the range 0ºC - 50ºC. The system components and system wiring must not be in close proximity to any flame, heating element, or exposed electrical terminals. The system components have not been characterized for operation in extreme neutron / gamma radiation fields such as encountered in close proximity to accelerator targets during irradiation. The system and its components should be protected from high humidity or condensation, or contact with solvents or volatile or corrosive reagents.

EMI and RF Susceptibility

Nuclear particle accelerators are used for the production of short-lived radio-isotopes. Such accelerators usually employ high-powered radio-frequency (RF) systems which have the potential to 'leak' RF energy into the environment.

These radiation detector systems are widely* -- *and successfully* -- *installed and used in PET / Radio-chemistry laboratories, which are almost always situated close to a cyclotron or similar type of 'RF continuous wave' nuclear particle accelerator.

However, the apparatus detects and amplifies very low-level input signals. Thus, there is a possibility that RF interference – either radiated or conducted through power or signal wiring – may occasionally cause spurious or false outputs. This may occur as a result of fast electrical transients or modulated RF signals -- for example -- from nearby digital cellular telephones or from electrically 'noisy' devices such as on / off (make-and-break) relay contacts, or from small 'universal' (AC/DC) motors often used in small electrical appliances.

For best results, signal cables should be shielded, with the shield braid or foil grounded to the respective equipment chassis at both ends. Signal cables which are longer than a few meters in length should be run in separate conduits or wire-ways -- away from facility power and control wiring. RF devices such as cellular telephones and electrically 'noisy' equipment should not be operated in the near vicinity of sensitive radiation detection equipment (or -- for that matter – near any sensitive electronic instrumentation).

TEST AND MAINTENANCE

Sensitivity

Sensitivity scale factor (numerical display reading) should be verified periodically against a known standard.

Analog Gain

Amplifier system gain may be verified by connecting a current source comprising a 1.5 VDC battery in series with a high-ohm resistor (1000 megohms or more) to the amplifier BNC input (negative polarity).

Probe

The detector probe may be tested in a gross manner as an ordinary diode using a good-quality ohmmeter with a "diode-test" setting; if it appears that a probe is not working properly check for a short- or open-circuit condition. A substantial increase in reverse leakage current due to radiation damage manifests as an equivalent drop in reverse resistance, which may, in turn, cause a noticeable increase in observed offset. However, the reverse resistance of a properly-working detector probe is of the order of a few hundreds to thousands of megohms, and cannot, in general, be read on a standard ohm-meter.

When in doubt, compare a suspected probe against another unit which is known to be sound.

WARRANTY

Systems are warranted against defects in materials and workmanship for a period of 1 year from date of shipment. Carroll & Ramsey Instruments' (CRI) sole obligation for products that prove to be defective will be repair or replacement. In no event shall CRI's obligation exceed the buyer's purchase price. CRI specifically disclaims any implied warranties or merchantibility or fitness for a specific purpose, nor will CRI be liable for any indirect, incidental, or consequential damages.

This warranty does not apply to products which have been subject to mis-use such as accident, severe mechanical shock and distress, over-voltage, immersion, exposure to volatile or corrosive agents, etc. The warranty does not apply to defects due to unauthorized modification, or which have been altered in such a way as to not be capable of undergoing functional test.

Performance specifications, physical dimensions, etc. are subject to change without notice.

Products sold by Carroll & Ramsey Instruments are not intended for use as critical components in medical devices or life-support devices or systems.