BNWL-SA-1947

EVALUATION PROGRAM FOR PORTABLE RADIATION MONITORING INSTRUMENTS[a]

CONF-690103--20

by

L. V. Zuerner
R. L. Kathren

Battelle Memorial Institute
Pacific Northwest Laboratory
Richland, Washington

December, 1968

(a) For presentation at the Health Physics Society Midyear Symposium, January 29-31, 1969 at Los Angeles, California.

Work performed under Contract Number AT(45-1)-1830 between the U.S. Atomic Energy Commission and Battelle Memorial Institute.

DISCLAIMER

RECEIVED BY DTIE APR 1 3 1970

BNWL-SA-1947

EVALUATION PROGRAM FOR PORTABLE RADIATION MONITORING INSTRUMENTS[a]

L. V. Zuerner and R. L. Kathren

Knowledge of response and performance capabilities is of practical importance in selection and use of radiological measuring devices for health physics purposes. Instruments are desired which will meet prescribed performance specifications with the lowest overall cost per unit of time. In some cases, a high initial cost will be more than offset by lower operating and maintenance charges.

A well oriented and directed evaluation program should examine appropriate physical, electronic, and radiological characteristics of the instrument, providing data for performance and cost analysis. For portable instruments, weight, strength, and ease of handling and servicing are important physical characteristics. Human engineering features such as ease of meter reading, availability of controls, and physical stability must also be considered.

Among the electronic features to be considered are sensitivity, temperature and voltage dependence, stability, battery lifetime, response to electrical interference, noise and vibration, and extracameral radiation. Radiological factors include accuracy and stability of calibration, energy dependence, response to unwanted radiations, temperature dependence, and saturation effects.

A typical evaluation program is outlined for portable radiation survey meters and recommendations made for a standardized system of determining and reporting instrument performance.

(a) For presentation at the Health Physics Society Midyear Symposium, January 29-31, 1969 at Los Angeles, California.

This paper is based on work performed under Contract Number AT(45-1)-1830 between the U. S. Atomic Energy Commission and Battelle Memorial Institute.

1.0. INTRODUCTION

Proper selection of portable radiation monitoring instruments is as important as proper use. The ultimate objective, of course, is to procure instruments that will meet prescribed performance specifications with the lowest overall cost per unit.

Selection implies prior evaluation, and a meaningful evaluation must be based on knowledge of the performance characteristics, limitations, and economics of the instrument under consideration. Unfortunately, adequate and accurate data on which to base a meaningful evaluation is unavailable in most instances. Perhaps the best available are the published specifications of the manufacturer, but these are often incomplete or couched in language that is not wholly comprehensible, and may even be misleading. And, since each manufacturer may report or measure the same performance characteristics differently, the published specifications of various manufacturers may not be comparable. Many instrument purchases, however, are based solely upon the claims of the manufacturer or his representative, published or otherwise.

A second body of relatively accessible data is word-of-mouth from those who have had prior experience with a given instrument. In this case, the potential for misinformation is quite high; the spoken word gets notoriously garbled in transmission through several persons. And, even a direct two party contact may not always provide accurate information, either by accident or intent; some, we all realize, will not admit to purchasing a poor instrument.

What is needed is a well oriented and direct evaluation program to determine appropriate physical, electronic, and radiological characteristics on which a performance and cost evaluation can be based. A typical evaluation program for portable radiation survey meters is outlined in Table I. Obviously, no single program would fit all portable instruments now in use, or even those commercially available. However, the skeletal program in Table I should provide a sufficient body of information to enable the health physicist to make a sound selection, consistent with the needs of his operation, and the dictates of his budget.

As shown in the Table, the evaluation of a portable survey meter can be considered in the context of three broad areas: mechanical, electronic, and radiological. Each of these areas will be discussed in turn, and a series of specific evaluation and measurement procedures presented.

2.0. MECHANICAL EVALUATION

Evaluation of the mechanical features of an instrument can be divided into two overlapping areas: physical construction and human engineering. To a relatively large degree, this portion of the evaluation is subjective, and requires the sound judgment that is often acquired only through experience.

2.1. PHYSICAL CONSTRUCTION

Physical construction is evaluated by general appearance of both exterior and interior, paying particular attention to quality control and workmanship. Solder joints are of particular value in this evaluation; the presence of cold joints, excessive amounts of solder or flux, or the lack of good mechanical coupling are indicative of poor quality. Circuit boards are similarly useful indicators; the quantity of path conductor and

TABLE I

TYPICAL EVALUATION AREAS FOR PORTABLE RADIATION SURVEY METERS

I. MECHANICAL

A. Physical Construction

B. Shock and Moisture Resistance

C. Human Factors Engineering

II. ELECTRONIC

A. Power Supply

1. Stability

2. Temperature Dependence

3. Battery Life

B. Input Sensitivities

C. Linearity

D. Electromagnetic Interference

1. Magnetic Fields

2. AC Induced Fields and Transients

3. Radio Frequency

4. Electrostatic Fields

E. Switching Transients

F. Capacitance Effects

G. Geotropic Effects

H. Temperature Dependence

I. Extracameral Effects

J. Sound and Vibration Effects

TABLE I (continued)

III. RADIOLOGICAL

A. Range

B. Sensitivity and Detection Limit

C. Accuracy

D. Reproducibility

E. Saturation

F. Energy Dependence

G. Temperature and Pressure Dependence

H. Angular Dependence

I. Response to Unwanted Radiations

its path length, sharpness of the etching, and labeling of components are points to be considered. The examination of component layout should include consideration of heat dissipation and length of leads and connectors.

2.2. SHOCK AND MOISTURE RESISTANCE

While evaluation of structural strength is primarily subjective, resistance to shock and moisture can be objectively examined. Field instruments generally should have the ability to withstand a drop of three feet onto a hard surface and should function properly regardless of ambient humidity. Moreover, they should be able to survive a single, rapid total immersion in water without ill effects. These simple checks can reveal a great deal about the construction of an instrument; the detector, of course, should generally be exempted from meeting these requirements.

2.3. HUMAN ENGINEERING

An important aspect of portable survey instruments, often overlooked, is human engineering. Again, the evaluation is essentially subjective, and should include consideration of safety hazards, along with ease of handling, readout, and servicing. Typical safety hazards include sharp edges, inadequate grounding, and other shock hazards.

The shape, size, and weight of the instrument are important and obvious factors in ease of handling, and are seldom overlooked. However, other more subtle human engineering features also need to be included in the total evaluation--the location of switches, switching arrangements, meter size, location and readability--these are all points to consider. Even the general external appearance of an instrument can affect its acceptance by monitoring and other field personnel. Some consideration should also be given to use of portable instruments by personnel wearing gloves and other personal protective clothing, and to ease of decontamination.

Finally, ease of servicing should be evaluated. Batteries should be readily accessible without removal of other components or a large number of screws; this factor alone can save several maintenance man-hours per year. Plug-in circuit boards, accessible from both sides and with labeled components can also provide significant dollar savings in the maintenance areas. Circuit boards should also be keyed to prevent inadvertent erroneous positioning in the socket. This feature alone can sometimes save hours of trouble shooting, frayed nerves, and possibly components.

3.0. ELECTRONIC EVALUATION

Electronic evaluation is far more objective than the mechanical evaluation. Ten specific areas are evaluated; each is discussed in turn, and a specific testing procedure is cited.

3.1. POWER SUPPLIES

Most portable instruments use batteries as the prime energy source. The batteries may supply the power directly to the circuit, or in instruments of recent design, the batteries furnish energy to solid state supplies which convert the low voltage of several low cost, dry batteries to the high and intermittent voltages needed by the circuit.

3.1.1. STABILITY

Some power supplies have variable output, especially for the high voltage. With constant input voltage the output range is checked at the end points, and the stability noted. The measurements should include both voltage and current outputs. Generally, the circuitry of the instrument is used as the load, but fixed resistors can be used to provide loads of any desired value. The stability of the voltage and current output is observed as a function of load, output voltage, and input voltage. Modern power supplies should generally be capable of providing stable high voltages to within a few percent.

3.1.2. TEMPERATURE DEPENDENCE

Portable instruments are often used under field conditions with wide variations in temperature. Diurnal temperature variations of 50° F can be encountered, necessitating correction of instrument readings in many cases. Evaluation of the temperature dependence over the range of 0-120° is usually adequate, although extension of the extremes may be required.

Temperature dependence is determined by measuring the output over the desired range utilizing a constant input voltage. Generally, temperature effects are linear, and should be quite small. Battery voltage and current should also be recorded, for these may be limiting on the power supply.

3.1.3 BATTERY LIFE

For battery operated supplies, the output voltage and current are measured as a function of battery voltage. This test is best performed using the specific batteries designated for use in the instrument, since the proper operation of many power supplies is highly dependent on both battery voltage and resistance.

An instrument may be designed to operate with several types of primary or secondary batteries. Thus ordinary zinc manganese cells may be used for temperatures down to 0° F to 10° F. Below these temperatures zinc alkaline primary cells should be used. Battery life tests should cover those types of batteries which will be installed for these environments in which the instrument will be used.

Fresh, tested batteries should be installed in the instrument, and provisions made for measuring battery voltage, battery current drain, power supply voltages, power supply currents, and overall instrument response. The detector element of the monitoring instrument is placed in a radiation field which should provide a mid-scale reading on the most frequently used range. The instrument is turned on and the above variables recorded over the life of the battery. The end point of the battery is taken as that voltage at which the instrument response has decreased 10% from the response obtained with a fresh battery.

A battery test position is a highly desirable feature of any portable survey instrument. The battery voltage should be checked against the indicated position to ensure that it is properly located.

3.2. INPUT SENSITIVITIES

Most portable instruments are of the pulse type meter and aural output. The input sensitivity of voltage sensitive instruments (e.g. Geiger counters) is determined with a signal generator providing a voltage pulse similar to that given by the detector. The input sensitivity is expressed as volts or millivolts necessary to give a steady meter reading or aural output for a given pulse input repetition rate.

For current measuring instruments, such as ion chambers and proportional counters, a current source is used in lieu of the detector. The current necessary for full scale deflection is determined, and the input sensitivity expressed as the current for full scale deflection. If the active volume of the detector is known, the input sensitivity may be calculated in terms of R/hr required for full scale deflection. This calculated value can be checked by placing the instrument in a radiation field of the appropriate strength and measuring the current output of the detector. This technique can also be used to determine the linearity of the detector alone. Response in pulsed fields, which is daily assuming greater importance, can also be determined from this technique.

3.3. LINEARITY

Linearity of a rate meter is an important feature. It is easily and quickly checked by putting a signal similar to that provided by the detector into the detector input of the circuit. The signal generator should be initially set to provide a pulse rate (in the case of pulse detectors) or current (in the case of current measuring circuits) equal to about half scale deflection. In the case of charge sensitive input system, a voltage to charge convertor is put on the output of the voltage signal generator.

Linearity should be checked at several points over the range of 10 to 100% of full scale. It is important to watch the errors near full scale meter reading since some systems tend to saturate in this region. Linearity should be expressed in terms of the percentage deviation of meter reading from the correct value at any point on the scale rather than the full scale reading. Thus, an instrument that read 11% of full scale when the input signal was such as to give a reading of 10% of full scale, has a 10% deviation. A statement of ± __% is most useful to bracket linearity.

3.4. RESPONSE TO ELECTROMAGNETIC INTERFERENCE

Electromagnetic radiation of many kinds can cause unusual effects and spurious response. The circuitry, rather than the detectors, is more commonly affected. In most cases, well designed circuits with good electrical shielding will not be affected by electromagnetic fields.

3.4.1. MAGNETIC FIELDS

The meter is usually affected more frequently than other components by magnetic fields. The effect of magnetic fields can usually best be determined by actual observation under the specific conditions encountered in the field, orienting the instrument along an x, y, and z axis with respect to the direction of the magnetic lines of force. Differences in instrument response will usually be attributable to the magnetic field. The effects of magnetic fields can sometimes be negated by wrapping the instrument case with mu metal.

3.4.2. AC INDUCED FIELDS AND TRANSIENTS

Transients caused by interrupting an AC circuit under load are some of the worst offenders. This is especially true of AC line operated instruments, but also holds for battery powered instruments operated close to unshielded AC lines. Of course, in the case of battery powered instruments, radiated radio frequency (rf) is the cause of erroneous readings. Electric typewriters and calculators are frequently found in areas where monitors are used.

The effect of AC transients and induced fields can be crudely checked by using an electric drill or similar device. Transients and AC induced fields should not cause deflections greater than 10% of the meter reading.

3.4.3. RESPONSE TO RADIATED ENERGY (RADIO FREQUENCY)

The most common sources of radiated energy that interfere with monitoring instruments are:

1. Induction type heaters
2. Radio frequency welders
3. Radio frequency generated by AC line transients
4. Radar beams
5. Ignition systems.

Welding and radar apparatus may have x-radiation associated with it, and care must be taken to ensure that the response of the instrument was not elicited by stray x-rays. Interference from ignition systems can be particularly vexing. Errors greater than ± 10% of a given measurement have been noted at distances of 200 feet from the source of interference.

In general, instruments should be field tested for radio frequency response under the conditions in which they will be used. The untoward effects of R.F. can sometimes be alleviated by a metallic case, properly grounded.

3.4.4. ELECTROSTATIC CHARGES

As a rule, ion chamber instruments are the ones most sensitive to static charges. The effect of electrostatic charge is easily checked qualitatively by moving a charged comb or piece of plastic around the instrument and detector, and noting any deviation in meter reading. The deviation should not exceed ± 10% of the reading with static charge; meter deflection from zero should be minimal--not more than 1% of full scale.

3.5. SWITCHING TRANSIENTS

Switching transients refer to quick, violent, large excursions of the meter when the range switch is changed from one range to the next. Switching transients should not drive the meter pointer off scale ("peg" the meter). As a guideline, the pointer should return to the original zero reading in two seconds or less, without the aid of a meter reset switch.

When checking switching transients, the instrument should be allowed to warm up completely, and the range switch changed stepwise in both directions.

3.6. CAPACITANCE EFFECTS

Capacitance effects are changes in meter readings or instrument response from physical motion of parts of the instrument. Historically, the word capacitance is used, for in the early days of radiation monitoring instruments, case movements would cause capacity changes in the circuit, which would lead to changes in meter readings. A second type of capacitance effect--hand capacitance--is noted when the hand is brought near the case or detector.

In general, capacitance effects shall not cause meter deflections in excess of ± one minor meter scale division. To check for capacitance effects, the instrument is turned on and allowed to stabilize on the most sensitive range. Pressing on any part of the case, control knobs, lifting the control knobs lightly or any other manipulation which is associated with normal procedure shall not cause meter deflection in excess of that listed above. The test should be repeated on all ranges.

3.7. GEOTROPIC EFFECTS

Geotropic or position dependence effects are related to capacitance effects. In an ideal instrument the meter reading will not change regardless of the position in which the instrument is operated. Generally there is some position dependence due to gravity effects on the meter.

Position dependence can be quickly and easily determined by rotating a stabilized instrument through a full 360° in two planes normal to each other and parallel to the ground. Ordinarily, deviations of less than 1 or 2% of the full scale reading are acceptable.

3.8. TEMPERATURE DEPENDENCE

The effects of temperature on the total functional instrument package is of prime importance, since instruments may be used in thermal environments ranging from sub-freezing to in excess of 120° F. It is desirable that the temperature coefficient of the instrument be less than ± 0.1%/° F. Generally, the detector is the major contributor to temperature dependence, but other components may also contribute significantly. Occasionally, a single component such as a resistor may require replacement in order to minimize temperature effects.

Evaluation of temperature dependence requires an environmental or temperature test chamber. The instrument, detector, and source to give a constant meter reading are placed in the test chamber. The temperature is raised at a rate of about 20° F/hr until a maximum temperature of 140° F is reached. Meter readings are taken about every 10 degrees F, and a plot made of scale reading vs. temperature made. The temperature is then lowered at the rate of 20° F/hr until the lower limit of -10 degrees F is reached. Meter readings are taken every 10 degrees F. When the lowest temperature has been reached, the temperature is again raised at the rate of about 20° F/hr until room temperature is reached. As previously, readings are taken about every 10° F.

The test at lower temperatures is also a test for high humidity operation. At the start of the test, the air is at room temperature in the test chamber, and normally has a relative humidity of 30 to 50%. As the temperature is lowered, the air in the chamber will become saturated and moisture may form inside the instrument case. In most instances trouble is not encountered with moisture until the temperature is increased from the lowest point back towards room temperature.

In the above temperature tests there may be times when large calibration deviations occur. It will then be necessary to check sub-units of the system one or two at a time, until the temperature sensitive parts are determined.

3.9. EXTRACAMERAL EFFECTS

Extracameral effects are meter deflections caused by interaction of the ionizing radiation with part of the instrument other than the true detector or ionization chamber component. The effect is most prevalent in ionization chamber type instruments.

Obviously, it is necessary to check extracameral effects by shielding the detector or limiting the size of the radiation beam. By using a well collimated beam, 2 mm wide, a scan can be made across the instrument. The meter reading can then be plotted as a function of location. In general, extracameral response should be less than a few percent of the average reading obtained with the beam directed through the detector, regardless of range. As a rule, the extracameral effect will decrease proportionately as the instrument is switched to higher ranges.

3.10. SOUND AND VIBRATION EFFECTS

Response to sound occurs mostly in pulse type instruments. At times the speaker response may cause unwanted feedback, negating the use of the instrument. Ideally, noise effects should be checked in a sound chamber with variable intensity pure tones. The test is made by exposing the instrument to noises of various frequencies and intensity, and any abnormal response is noted. This is obviously impractical, and so random noise generators or general industrial noise sources can be used. Response to vibration or impact noise may result in temporary or permanent change in calibration. In addition, vibration may cause physical damage to the instrument. A shaker table is a good device for providing vibration for test purposes. One of the most satisfactory and practical vibration tests is to field test the instrument for a period of time. Ordinarily, noise and vibration should not noticably affect instrument performance.

4.0. RADIOLOGICAL EVALUATION

The radiological evaluation is perhaps the most germane and certainly the most meaningful to the operational health physicist. It is also the most objective, and requires an extensive amount of evaluation equipment. In general, the radiological evaluation is limited to the detector, or the response of the instrument as a whole.

Characterization of instrument response is rendered difficult by the problem, and one not unique to instrument evaluation, of terminology. In the succeeding paragraphs, as in the above sections, an attempt will be made to define or limit terms, in the hope of improving communication.

4.1. RANGE

The term range covers a multitude of features. The range is, of course, the whole of the instrument response. For instruments with linear readout, the range is ordinarily expressed in terms of zero to maximum full scale reading obtainable. For instruments with logarithmic readout, the range must necessarily be expressed in terms of the minimum and maximum scale readings obtainable.

In the typical evaluation, the range of the instrument is usually not specifically checked, for other aspects of the evaluation will adequately cover this area. However, a rapid check of the range can be easily made by simply varying the source to detector distance.

4.2. SENSITIVITY

The sensitivity of an instrument describes its capability in discriminating between two approximately equal quantities. Sensitivity should be constant over the entire instrument range, and is best expressed in terms of percent of full scale for instruments with linear readout. For instruments with logarithmic readout, sensitivity should be expressed as percent of the actual scale reading with the scale reading stated.

To illustrate, a portable instrument with linear response has a range of 0-10 mR/hr on a single scale. It is possible to read the meter to the nearest 0.5 mR/hr. The sensitivity of this instrument is $\frac{0.5}{10}$ X 100 = 5%. Similarly, an instrument logarithmic response has a range of 0.1 to 10 mR/hr. Near the low end of the scale, changes of 0.02 mR/hr can be determined, rising to 2 mR/hr at the high end. In this case, the sensitivity is 20% at both ends of the scale. If the minimum detectable changes were 5 mR at the high end, the sensitivity would be expressed as 20% at 0.1 mR/hr to 50% at 10 mR/hr. An expression of $\leq$ 50% for the sensitivity, although valid, would not be as descriptive as the previous method.

Sensitivity is determined with the instrument in an appropriate radiation field, utilizing a device such as a trolley or carriage to permit small and reproducible changes in the source to detector distance. In this manner, small yet accurate variations in dose rates can be obtained. Sensitivity should be determined at at least two points--one each near the maximum and minimum scale reading.

In the case of alpha monitoring instrumentation, sensitivity is expressed in the manner described above, but is determined with several sources, each having slightly different strength. A single source covered with mesh to absorb various fractions of the alphas, will suffice.

4.2.1. DETECTION LIMIT

The detection limit is the minimum (or, less commonly, the maximum) radiation reading which can be obtained, with the instrument. This value can be obtained from the sensitivity.

4.3. ACCURACY

Accuracy is, of course, the relationship of the instrument reading to the true value, and is expressed as a limit or range in terms of percent of the true value. Accuracy is the sum total of all factors which may adversely affect the reading of the instrument, including reproducibility (4.4), stability (4.10), and sensitivity (4.2).

Although correctly, accuracy is a statistical phenomenon, calculable from the known variance of the numerous factors that affect the reading of the instrument, such calculation (and indeed even securing the data on which to base the calculation) is impractical. Hence, the term accuracy generally refers to the total uncertainty ($\pm$ 3 standard deviations) in the instrument reading, with the measurement made under nearly ideal conditions, and with appropriate corrections made for such factors as temperature, pressure, energy, and geometry.

Accuracy is best determined with a calibrated source. Instrument readings over the entire range are compared with the "true" value as determined from the source strength. Presented on the following page are some actual data obtained with an ion chamber survey meter:

True mR/hr	Instrument mR/hr	Instrument Range
15	14	x 1
30	30	x 1
45	47	x 1
50	45	x 10
100	95	x 10
300	310	x 10
450	460	x 10
1500	1600	x 100
3000	3000	x 100
4500	4800	x 100

This instrument was rated as having an accuracy of ± 10%.

4.4. REPRODUCIBILITY

Reproducibility, or precision, is a measure of consistency of readings. It is determined by making at least five readings in a given field, removing the field between each reading. This should be done over at least three points on the range of the instrument. The following data were obtained with a GM survey meter on the x 10 range:

"True" CPM	Observed CPM
1,000	1,050; 1,050; 1,100; 1,050; 1,100
3,000	2,900; 3,000; 2,950; 2,900; 3,000
5,000	5,100; 4,900; 4,950; 5,200; 5,000

Reproducibility of better than ± 5% is indicated by the data.

Note that reproducibility is not the same as accuracy; an instrument that always reads exactly 1.50 the true value would be 100% reproducible, but would have an accuracy of + 50%.

4.5. SATURATION

When in radiation fields above their intended range, some instruments will saturate. The effect manifests itself in one of two ways: either the instrument reading rises to a fraction--usually about 80-90%--of the maximum full scale reading and remains there regardless of how intense the radiation level gets, or, the instrument is driven off scale but the reading drops back down to zero as the field intensity increases. Each of these conditions can result in a serious situation with possible overexposures to personnel. The former effect occurs most commonly in ion chamber instruments, and the latter in Geiger type survey meters.

Saturation is easily checked by placing the instrument in an appropriate radiation flux, and increasing the intensity until the effect is noted or a predetermined level--usually 100 times the maximum range of the instrument--is reached.

4.6. ENERGY DEPENDENCE

Energy dependence--also known as spectral sensitivity--refers primarily to the response of an instrument to X or gamma radiation of different energies. Energy dependence is caused by many factors, the two most important ones being photoelectrons (and, to a lesser degree, Compton electrons) from the detector wall, and self-absorption within the detector wall. These effects are, of course, competitive.

To evaluate energy dependence, the detector is placed in a field of known strength and energy and the response compared with the true exposure rate. Ordinarily, the instrument is calibrated with a source having an energy of approximately 1 MeV, and the instrument response normalized to this energy.

Several effective energies in the range of 10 KeV to greater than 1 MeV are necessary to achieve an accurate indication of energy dependence. An X-ray machine--preferably with 300 KVP capability--can be used to obtain effective energies in the 50-250 KeV_{Eff} region by means of heavily filtered spectra; a wide beam K fluorescent source can be used to conveniently obtain essentially monoenergetic photons in the region 8-100 KeV_{Eff}. The higher energies are provided with nuclides, commonly ^{137}Cs (662 KeV_{Eff}), ^{222}Ra + daughters ($\sim$ 800 KeV_{Eff}), and ^{60}Co (1.25 MeV_{Eff}). A typical series of energies for a cutie pie type instrument might be 8, 17, 23, 40, 60, 80, 100, 125, 175, 200, 662, 1250 KeV_{Eff}.

Energy dependence should be determined with both open and closed window, and often for other conditions, such as with the beam end--on or through a thicker side wall. Energy dependence should be reported as a +, - percentage over a specific energy range or a +, - percentage normalized to a specific energy. Graphical presentation, in the form of a plot of response per unit exposure as a function of energy, is a superior method of showing energy dependence.

4.7. TEMPERATURE AND PRESSURE DEPENDENCE

These effects are usually minor, and are commonly caused by changes in the mass of air within the detector. However, temperature effects on other components can also cause appreciable changes in instrument response, and a testing procedure similar to that described in 3.8 above is recommended.

Changes in atmospheric pressure should have minimal effect. If an appropriate environmental test chamber is available, the change in instrument response to a constant field should be determined in 10 mm increments over the range 720-780 mm Hg. A pressure coefficient, in terms of percent change per mm Hg will usually be apparent from the data.

4.8. ANGULAR DEPENDENCE

Because most detectors are not spherical, angular dependence may cause serious discrepancies in readings. In particular, angular dependence becomes significant when a fixed geometry or windowed detector is used in an ambient field or in such a manner that the window cannot be pointed towards the direction of the field.

Angular dependence is best checked through a full 360° in perpendicular planes, one parallel to the horizontal and the other to the vertical axis of the detector. Measurements should be made at 15° increments. If the detector is symmetrical about an axis, the determination can be made over 180° or 90°, as indicated by the geometry.

The statement of angular dependence should be expressed as ± a percentage from a fixed point, usually the so-called "normal" of the detector. However, a graphical representation is superior, as is true for energy dependence.

4.9. RESPONSE TO UNWANTED RADIATIONS

Portable survey meters are usually intended to monitor one type of radiation. Photon monitors such as ionization chambers, for example, should be relatively insensitive to other penetrating radiations, viz. neutrons. Similarly, alpha or neutron monitors should be insensitive to photon radiations.

Checking the rejection of unwanted radiations is often more art than science. For example, energy dependence must be considered, particularly when evaluating the rejection of photons by neutron or alpha scintillation instruments. Neutrons may show a similar energy dependence, with a response being elicited, say, only by thermal neutrons. And, the undesired response may not appear except in a mixed field. However, as a general rule of thumb, it is usually necessary to check response to unwanted penetrating radiation up to levels of about 10 R/hr in the case of photons, 10^7 n/cm^2/sec of fast neutrons, and 10^8 n/cm^2/sec of slow or thermal neutrons.

5.0. CONCLUDING REMARKS

The evaluation of portable radiation monitoring instruments is of prime importance if these devices are to be selected intelligently and used to maximum advantage by operating health physics personnel. Knowledge of appropriate correction factors, idiosyncrasies, and response characteristics are vital to proper application in the field.

Evaluation of a portable instrument should take into account relevant mechanical, electronic, and radiological response features, and should be oriented towards ultimate field applications. Both physical and psychological factors should be considered; personnel will not have confidence in an instrument that doesn't look as if it will work. Underlying all phases of the evaluation is economics; one must get the most for each dollar spent. Implicit in this is minimal maintenance along with low initial cost.

Proper evaluation requires time and a fair amount of expensive test equipment. The program outlined and briefly discussed above is by no means the ideal nor is it all encompassing. Rather it represents an attempt--perhaps more realistically, a start--towards uniform evaluation procedures and terminology, with a practical end result.