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INSTRUMENTS IN THE FIELD: USE, ABUSE, AND MISUSE*

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ABSTRACT

Advances in field instrumentation have been great over the past decade, providing the operational health physicist with a powerful armamentarium. However, even the most modern instruments have many limitations, and measurements must be made and evaluated in the light of these limitations, which include energy and angular dependence, response to pulsed sources, and effects of mixed radiation fields. The concept of surface dose rate, its meaning, use, and misuses will be examined in the context of operational health physics. A practical method of measuring doses close to the source--air interface will be discussed.

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I. THE EVOLUTION OF PORTABLE SURVEY INSTRUMENTS

Few professions are as dependent on field survey instruments as is health physics. While much can be done without instruments, operational health physics would be virtually non-existent without portable survey meters, for the operational health physicist needs to have meaningful measurements of conditions in the field in order to intelligently gauge the success of his efforts.

Although radiation protection efforts began shortly after the discovery of x-rays and radioactivity, development of field monitoring instrumentation lagged far behind other efforts. Photographic methods were the first to be applied to field measurements of ionizing radiation. Perhaps the very first attempts at field monitoring for protection purposes were those of William Rollins, an early ancestor of today's health physicist. In 1902, William Rollins described a method of shielding x-ray tube enclosures and prescribed the use of photographic plates placed against the housing to monitor leakage.⁽¹⁾ If the plate was not fogged by an exposure time of seven minutes, the tube housing was presumably satisfactory. A similar application for photographic film was described a year later by an American dermatologist who was concerned with limiting exposure to his patients.⁽²⁾ In this case, the film was placed on the patient to directly monitor the exposure.

Film badges for personnel monitoring evolved during the 1920's,^(3,4) but portable survey instruments were still lacking. What was quite possibly the first true portable survey meter was designed and built in 1929 by L. S. Taylor.⁽⁵⁾ This interesting device had three interchangeable spherical aluminum ionization chambers, each of a different size to provide

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several sensitivity ranges. Three small B batteries provided the 135 volt potential for the chamber. Charge was measured by a string electrometer, and full scale with the largest (most sensitive) chamber was 2 mR. Most significantly, this instrument was designed exclusively for protection purposes.

Through the 1930's, although x-rays and radium were in wide use, scant attention was paid to development and manufacture of portable radiation survey meters. However, at least one commercial manufacturer produced a portable ionization chamber, and the invention of the Geiger-Mueller tube in 1928 lead to the first commercial Geiger counters, available in the middle and late '30's.

However, it was not until the Manhattan District that any real attention was paid to the design, development, and application of portable monitoring instruments. The Health Division assumed principal responsibility for the development of pocket dosimeters and film badges, and cooperated with the Physics Division in creating portable survey meters, with one of the more notable efforts being "Pluto", an alpha contamination survey meter.⁽⁶⁾ Operational health physics, born along with the atomic bomb, brought with it a need for portable survey instruments, and the hiatus between protection efforts and portable monitoring instruments and development had begun to close.

The late '40's saw the birth of many new portable instruments. Big, bulky, and heavy by modern standards, these nonetheless were vital to those working in health physics. Serious development efforts were

were begun, with emphasis on miniaturization and improved response. The transistor, discovered in 1947, was swiftly incorporated into radiation monitoring instruments, and along with the more efficient batteries developed during the early 1950's, permitted great reduction in size and weight. A variety of new detectors appeared--thin metal walled Geiger tubes, pressurized ionization chambers, and neutron detectors of various types all appeared in commercially available instruments.

The flavor of portable survey meter evolution can be captured by a brief look at the history of a single instrument species. The Geiger counter, notable as one of the lay symbols of the nuclear era, might be a fitting choice. In the late 1940's, several Geiger counters were available commercially. Large and bulky, these featured glass wall tubes and were highly energy dependent. So much so that they were often considered detectors rather than dose rate meters. The vacuum tube circuitry required relatively high current, and big, heavy batteries were the order of the day. Saturation--or downscale reading in high radiation fields--was a severe bugaboo. These forerunners of modern day GM survey meters typically weighed in at 10-15 lbs., and displaced several hundred cubic inches. Typical of these early GM's were the Nuclear Chicago Model 2610, the Victoreen Model 263, and the first of the military AN/PDR27 series; those who have used any of these instruments cannot fail to recall their idiosyncrasies, weight, and size.

The early 1950's brought the application of the transistor to the Geiger counter, and the first metal wall GM tubes made their appearance. Energy dependence and saturation were still problems, but bulk and weight

had been cut in half. In these transitional years, vacuum tubes were still used, as were heavy B batteries, and instruments still weighed around ten pounds. Glass wall tubes were still prevalent, and many a high reading was attributable to a light leak. But the pattern for lightweight, small packages was beginning to emerge. Representative instruments for the early '50's include the Precision Model 107, and the early Civil Defense type units.

In the mid-1950's, the changes introduced in the early years of the decade became more prevalent. Metal wall, halogen quenched tubes were common and energy dependence was dramatically improved, partly by the use of low Z metal wall tubes, and partially by improved detector housings. Transistors made possible a very small package, and the lower current drain permitted the use of two D cells as the entire battery supply. Volume and weight were reduced even further--the typical GM survey meter of a decade ago weighed only a few pounds, and is exemplified by the Eberline E-112B, and the military AN/PDR 27J, a fully transistored light weight successor to the earlier models of the '27 series.

In the early years of this decade, the saturation problem appeared to have been licked, and an even more exciting development was current mode operation of a GM tube, which extended the range by two to three orders of magnitude. The detection versus dose rate controversy was, for all practical purposes, solved--most manufacturers labeling the meter scale in units of mR/hr. Miniaturization reached a practical limit and beyond, for now, GM survey meters seem to be getting larger.

II. USE, ABUSE, AND MISUSE

Survey meters have evolved over the years into highly sophisticated and useful devices. Transistors, integrated circuits, MOS-FETs--these, and other improvements have given the operational health physicist of 1969 tools beyond the ken of his forerunners of only a generation ago. Yet in spite of advances in instrument technology, many of the old problems are still with us, compounded by new nuclides and radiation generating machines providing unique energy and intensity spectra.

Use of field survey instruments is an easy task, since virtually anyone can turn an instrument on and read the meter response. But proper use is another story, and implies judgement as well as knowledge of instrument response characteristics.

Areas of misuse are many, and no short presentation could attempt to enumerate them. However, most instances of instrument abuse and misuse can be compartmentalized into four general areas:

- a. Energy dependence
- b. Mixed field effects
- c. Pulsed field response
- d. Angular dependence and other geometry considerations

Each of these will be briefly considered in turn.

With the exception of a few tissue equivalent chambers, virtually all instruments are energy dependent. The problem is neither new or is it limited to photon monitoring. However, most of the abuse occurs in the monitoring of low energy photons. Two anecdotes will illustrate.

About a decade ago, while a very junior health physicist, I witnessed the use of a high range scintillator for monitoring a laboratory

x-ray machine. The scintillator, held in the primary beam by a senior health physicist, hardly responded to the maximum output of the 50 KVP machine. Small wonder, for the detector was located behind a quarter inch of steel. On the basis of this measurement, the health physicist concluded that a frank x-ray burn on the hand of a chemist could not have occurred. The second event took place about a year ago, when I was astonished to see in a popular publication an evaluation of leakage radiation from color television sets.⁽⁷⁾ That there was leakage of x-rays was not surprising, but the mode of measurement was. Direct meter readings from thin end window GM survey meters was used to quantify x-rays in the region below 25 KeV.

These two anecdotes serve to illustrate flagrant misuse of an instrument--using it outside of its design capabilities, with no attempt at interpreting or correcting the readings. Moreover, the irresponsible practice of health physics in one case and the misleading of the public in the other is intolerable.

The problem of improper evaluation is not limited to low energy photons. Survey meters' readings are routinely used without interpretation for photons above 5 MeV, in flagrant disregard of electronic equilibrium conditions. Neutron survey meters, the accuracy of which is notably poor, are used with total and utter disregard of the neutron spectrum and detector response. Even the new "rem meters" are not energy independent.

Mixed field effects constitute a relatively minor area of misuse. However, as newer and larger accelerators are built, mixed field monitoring will become increasingly important. Although in most instances, the error

caused by a mixed field will be one of over-estimation, it is nonetheless an error, and could lead to unnecessary expense if used as a basis for, say, shielding design. Such use, while admittedly poor practice, is not unrealistic, for shielding design must ordinarily be verified by actual field measurement.

Pulsed fields are rapidly assuming greater significance. Pulsed reactors, accelerators, and x-ray generators are commonplace, and most field survey instruments cannot be used for monitoring the high intensity, short duration pulses associated with these devices. Even the venerable film dosimeter has its upper intensity limits.⁽⁸⁾

Most instruments will correctly respond to fields with frequencies greater than a few pulses per second. Many x-ray machines and cyclotrons are, in fact, pulsed, but the frequency is so great that the instrument sees essentially a constant field. At lower pulse frequencies, on the order of one or two pulses per second, most survey meters become virtually useless. However, ion chambers can be useful if the time constant is sufficiently long, for after a period of buildup, the reading will level out, and reflect averaging of the dose rate. A Juno, for example, was successfully used for surveying around a pulsed accelerator with repetition rates as low as 30 per minute. The validity of the Juno readings was verified with LiF thermoluminescence dosimeters.

The final area of abuse concerns the geometry of the chamber and source. Angular dependence of detectors is all but ignored, an abuse that could seriously underestimate the dose rate in an ambient field. Other geometry considerations relating to source and detector size will

be considered for a representative instrument in a later paper in this session.⁽⁹⁾ Suffice to say that the total solid angle intercepted by the chamber is the one of the basic criteria, and suitable corrections must be made to avoid underestimates of dose rate. But by far, the most prevalent and pernicious abuse of instrument capability relates to attempts to monitor surface dose rate.

III. WHAT IS SURFACE DOSE RATE?

Surface dose rate is, in simple terms, the dose rate at the interface of a surface emitting radiation and the air. Conceptually, it is the maximum dose rate that an individual could incur were he to handle a source--bare or packaged. Calculation and measurement of surface dose rate is difficult, at best; surface dose rates cannot be determined by the simple expedient of laying the detector on the surface, or in contact with the source. Yet to many, this is precisely how to obtain the surface dose rate. In this context, the terms 'surface dose rate' or 'contact dose rate' are meaningless; obviously, different instruments will give different fractions of the true value. Less obvious, but of great importance, is that distance alone is not the only factor affecting the response of the instrument. Even in the case of a large plane source, much greater in cross-sectional area than the detector, other factors will affect the measurement, including chamber wall material, average electrical field strength within the detector, shape of the detector, and source geometry and variations in uniformity.

Rather than give a 'contact' or 'surface' reading, a more pragmatic approach might be to determine the relationship of surface dose rate to

the dose rate at some convenient distance from the surface. Then, the instrument could be used to determine the dose rate at the convenient distance and a correction factor applied to give an estimate of surface dose rate. Preliminary experiments conducted in our laboratory with relatively large plane beta sources (diameter > 4") indicate that the ratio of surface dose rate to dose rate at 10 cm from the surface is constant and approximately equal to 25. Beta doses were determined with an extrapolation chamber, which enables the surface dose rate to be measured. Although, as yet, the data are too preliminary for general application, the concept appears to be promising. A similar ratio has been noted with large plane photon emitting sources.

IV. A RAY OF HOPE

As health physicists, we have a professional obligation to properly use our instruments. However, available information regarding instrument response is incomplete, and what is available is often inaccurate or only partially correct, encouraging misuse and error. Manufacturers of health physics instrumentation could help if they would establish and adhere to standard means of measuring and reporting instrument response. A comprehensive instrument evaluation program will be described later in this session;⁽¹⁰⁾ perhaps some of the ideas put forth will merit implementation.

In many respects, the problems of nuclear instrument specification statements is analagous to that faced by the high fidelity instrument manufacturers a decade ago. At that time, each manufacturer used his

own method of measuring and reporting the response of his equipment. Hence, one manufacturer's 25 watts was another's 100 watts, and each was correct in that he was reporting the results of his tests. However, power output can be measured in many different ways, and, over the years, the Institute of High Fidelity (IHF) has issued various standards prescribing measurement and testing techniques, as well as definitions. While not ideal, the current IHF Standards for audio amplifier tests and measurements (IHF-A-201 [1966]) and tuner measurements (IHFM-T-100 [1958]) do provide a common reference point. Manufacturers using these IHF Standards are required to present a specified minimum of published specifications, all obtained according to the IHF Standard. In this manner, the user has some knowledge of the performance of his instruments as determined by a series of standardized testing procedures.

Were a similar scheme established by the manufacturers of health physic instruments, misuse and abuse of instrument capabilities would be curtailed. While complete instrument evaluation is desirable, it may not be practicable. But, perhaps some common ground and self-regulation are indicated. The implications of an erroneously used and interpreted survey meter are indeed serious.

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