RESULTS OF TESTING AND EVALUATING A HEALTH PHYSICS INSTRUMENT PERFORMANCE STANDARD

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INTRODUCTION

Pacific Northwest Laboratory, operated by Battelle Memorial Institute, is currently performing a 3-year project evaluating a draft ANSI Standard (N42.17) on the performance specifications for Health Physics instrumentation. This paper presents data taken during testing that provides information for the evaluation of the applicability and practicality of the proposed standard and the determination of the degree of conformance of currently available North American commercial instruments to the proposed standard.

The draft ANSI Standard N42.17 on performance specifications for health physics instrumentation was written in 1981 by a task group that included both manufacturers and users of these instruments as well as representation from regulatory bodies; the second draft of this standard is being evaluated. The draft standard attempts to establish minimum acceptable performance criteria for health physics instrumentation for use in ionizing radiation fields. Included are testing methods to evaluate the adequacy of several types of instrumentation for use under specified conditions. The requirements and testing methods discussed in the draft standard are related to five major areas: general characteristics (e.g., zero set, alarm threshold, battery status, AC and DC power requirements), electronic and mechanical requirements (e.g., stability, geotropism, response time), radiation response (e.g., accuracy, precision, energy dependence, angular dependence), interfering responses (e.g., non-ionizing electromagnetic radiations, ionizing radiations), and environmental factors (e.g., temperature, humidity, shock, vibration, ambient pressure.)

The instruments tested fell into one of the following categories: ionization chambers, Geiger Mueller (G.M.) detectors, alpha survey meters, neutron dose equivalent survey meters, or air monitors. Instruments were procured for testing by direct purchase of new production units or by loan from others. All units were calibrated before testing.

METHODS

Instrument test and evaluation procedures were developed with emphasis on the requirements and testing guidance stated in the draft ANSI standard and with additional criteria from other draft and current ANSI and IEC standards. Each procedure was verified prior to implementation of the testing phase. Initial data obtained with the testing procedures were carefully analyzed to determine that the data

represented the responses of the instruments under the conditions required by the draft standard and that those conditions existed for all of the instruments evaluated.

Instruments that have been tested and evaluated were procured by three methods: 1) direct purchase of off-the-shelf units, 2) loan of new or recently manufactured units from manufacturers, and 3) loan of units from DOE contractors. Approximately 80 instruments have been procured by these methods.

Twenty readings were taken for each data point for all tests to assist in obtaining statistically reliable data.

RESULTS

Initial results from eight tests will be discussed for G.M. and ion chamber type instruments. These tests include mechanical and electronic tests (i.e., stability, geotropism, response time), tests of radiation response (i.e., precision, accuracy, energy dependence), and environmental tests (i.e., temperature, humidity).

Stability

The standard evaluates the drift at constant temperature and pressure for a 3 hour period following a 10 minute warmup period. During this period, the readings are expected to remain with ±3% of full scale or decade on the most sensitive scale. The test is performed by affixing a source to the instrument which produces a mid-scale reading on the most sensitive scale and then recording readings every 30 minutes for 3 hours. Based on forty instrument tested, nine of 30 G.M. instruments and none of the ion chambers can be considered to have failed based on a greater than ±3% deviation at any one time.

Geotropism

Geotropism is defined by the standard as "a change in instrument response with a change in instrument orientation as a result of gravitational effects." The standard requires that a change in reading due to spatial orientation shall not exceed ±3% of the full-scale reading on the most sensitive scale. The instrument is tested by rotating it through two perpendicular planes and recording readings at 90° increments. During the testing, a source is affixed to the instrument which will produce approximately a mid-scale reading on the most sensitive scale. Again 20 readings are recorded at each point and the mean and standard deviation are determined. Of the 24 instruments tested to date, six of the instruments can be considered to have failed based on a greater than ±3% deviation in the reading at any one angle. However, it must be recognized that the statistical fluctuations are large due to inadequate precision of the instruments on the low ranges thus making it impossible to provide an unqualified judgement.

Response Time

Response time requirements in the standard are different for various dose rate ranges. These range from maximum response times of 30 seconds to 1 second for ranges of <0.01 mR/h and >1000 mR/h, respectively. Most instruments were tested against the response time requirement of 5 seconds for ranges of >0.1 to 100 mR/h. Instruments are tested by exposing them to a radiation field such that a response between mid and full scale is established. After equilibration, the radiation

field is removed instantaneously and the time is recorded to reach the background value. After equilibration at background, the source is re-applied and the time required to reach 90% of the initial equilibrium value is recorded. This is repeated on all ranges.

Twenty G.M.-type instruments were tested on a total of 55 ranges. Four of these instruments had selectable time constants and it was found that invariably the longer time constants failed to meet the requirements. On the instruments tested, 11 instruments failed to meet the performance criteria typically on high or very low dose rate ranges.

Precision

The standard requires that the instruments have a relative standard deviation of ≤2.5% on all ranges. A total of 21 instruments were tested on 49 ranges; 8 of these instruments were ion chambers and 13 were G.M. detectors. One ion chamber and all of the G.M. detectors failed the test. For ion chambers, only one range out of 18 tested failed; only 6 out of 31 ranges passed for G.M. detectors. The relative standard deviations of approximately 15% on the lowest ranges of the G.M. detectors complicates the interpretation of tests such as those for geotropism and stability which require readings on the lowest range.

Accuracy

For ionizing electromagnetic radiation, the response of the instrument compared to the conventionally true value is required to be within ±15%. This measurement is made at the 95% confidence level with ^{137}Cs radiation. The measurement must be made at approximately 25% and 75% of each range. Sixteen instruments (i.e., 4 ion chambers, 12 G.M. detectors) were tested on a total of 39 ranges. One ion chamber and 6 G.M. detectors failed the standard. Most of the failures were observed on the higher ranges.

Energy Dependence

For energy dependence, the standard states that the useful range shall be from 40 keV to 3 MeV. Over this range, the response of the instrument shall be within ±20% of the response for the reference energy. This permits selection of the energy to optimize the range of uniform response. To date, the energy dependence measurements have been limited to the low energy end of the range (ie., 23.7 to 248 keV) Sixteen instruments were tested with only five instruments (three from the same vendor) meeting the criteria in the standard. All of the seven G.M. type instruments failed.

Temperature

The standard states that instruments shall remain operational over the temperature range 0 to 40°C and should be operational over the range of -20 to 50°C. Instruments are exposed in an environmental chamber to an appropriate reference radiation source of sufficient strength to give a midscale response on any scale or decade. The temperature is raised at a rate of 10°C/h until the maximum test temperature is reached, and the results recorded at least at 10° increments. The temperature is reduced at a rate of 10°C/h until the minimum test temperature is reached, recording test item readings at 10 C intervals. Data was obtained at -20, -10, 0, 10, 20, 30, 40 and 50°C after an equilibration time at each level for all

instruments. Non-operational is interpreted as having mean instrument readings greater than 15% from the mean reading obtained at 20°C. Corrections for air density changes are made where necessary.

Thirty four instruments were tested (i.e., 15 ion chambers and 19 G.M. detectors). All G.M. detectors passed the test while 9 of the ion chambers were non-operational (i.e. failed). Five of the 9 ion chambers that failed were marginal failures; that is a mean instrument reading fell outside the ±15% criterion, but just barely.

Humidity

The standard states that instruments shall remain operational over the relative humidity range of 40-95% referenced to 0 and 40°C. The instrument is exposed in an environmental chamber to an appropriate reference radiation source of sufficient strength to give a midscale reading on any scale or decade. The instrument is allowed to equilibrate for 24 hours at 40 ± 2°C and 40 ± 5% relative humidity, and the reading noted. The relative humidity is raised to 95 ± 5% and held for 24 hours, and the instrument scale reading recorded. The relative humidity is lowered to 40 ± 5% while maintaining the temperature at 40°C. After 24 hours, the instrument reading is recorded. The above test is then repeated identically in all respects except that the temperature is 0 ± 2°C.

Twenty-two instruments were tested (i.e., 5 ion chambers and 17 G.M. detectors). One of the ion chambers and 4 of the G.M. detectors failed the test. Most of the failures were observed after the elevated-humidity phase of the exposure.

CONCLUSIONS

For the instruments tested to date, the G.M. detectors and ion chamber instruments fall into two distinct categories. Ion chamber instruments generally lack the sensitivity of the GM detectors but can meet the requirements of the standard. The G.M. detectors seldom meet the test of radiation response and electronic requirements of the standard, and their poor precision makes it difficult to make definitive statements concerning their performance on some tests.

Recommendations to the ANSI working group will include comments on: 1) obtaining statistically reliable data, 2) the precision requirement of the relative standard deviation of ≤2.5% on all ranges, 3) equilibration periods for the environmental tests, and 4) the need for quality assurance information in the standard.