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Radiation Measurement Instrumentation for HPs – Looking Back at the Past and Looking Forward to the Future

CHAIR - Frazier Bronson

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ABSTRACTS

TAM C1 Pictures from an Exhibition - The Birth and Evolution of Field Instruments for Health Physics

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The birth and evolution of health physics instruments used in the field is traced with emphasis on portable survey meters and early developments along with a look into the future. The more or less exponential growth and advancement has been fueled by a number of activities and technical advancement and discoveries, including changes in the definition of radiological quantities, units, permissible dose levels and regulations over the years; programs such as the Manhattan District, Civil Defense and the development of consensus standards both by ANSI and international bodies; technological advances such as discovery of the transistor and development of solid state electronics, improved methods of digital display and the computer revolution; and most recently (and especially in the United States) international terrorism. Most interesting perhaps is to compare contemporary field instruments with their ancestral predecessors; while clearly their external appearance has by and large not changed radically, but what is inside has and the modern electronics permit a wide range of highly sophisticated measurements. On the other hand, the detectors, albeit somewhat improved, are by and large the same ones have been used for the past 60 years.

TAM C2 Portable Gamma Dose/Exposure Rate Instruments - What Does The Future Hold?

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The progression from past gamma dose/exposure rate measuring instruments to the current state of the art, and what the future might hold for new instruments, is discussed. Examples of the current state of the art are presented, including key features and how they arrived at where they are. Are the currently-available instruments serving all of the needs of the operational health physicist, or can we go farther and make them even more useful? We'll gaze into the crystal ball to see where they may be headed, including the ideas, needs, wants and dreams of operational health physicists. What features would the "dream instrument” of the future have if price was not a roadblock and technology could provide us with everything we wanted? What might such an instrument look like? Does the technology exist to manufacture such a “dream instrument,”, and if so, how soon might we be able to see one available for our use?

TAM C3 Field Neutron Instruments and Measurements

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Neutron detection depends on a number of interactions that produce charge particles, e.g. elastic scattering, fission and an number of specific endo- and exo-energetic reactions. Comparing the current crop of neutron instruments with those developed decades ago, it is clear that the underlying detection processes remain the same. However, progress is constantly made in novel applications of traditional detection schemes, miniaturization of electronics and increasingly more sophisticated on-board signal processing.

In the first part of this talk we will provide a quick overview of neutron detection methods, routine and specialized field measurement techniques, and discuss specific challenges in these areas. We will then feature a few selected instruments illustrating the progress and status quo of neutron instrumentation. The last section will contain a wish list of features that could be easily achieved in the near future, e.g. smarter counting algorithms or detector self-check without use of radioactive sources or natural background.

TAM C4 Contamination Measurements and Instrumentation

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Shonka Research Associates, Inc.

Contamination measurements form the core of operational health physics measurements at operating nuclear facilities and remain integral for decommissioning of nuclear facilities. Instruments to meet these needs have evolved from the first “Zeus” device (air ionization chamber used for alpha, beta, and gamma) developed during the Manhattan Project era to the microprocessor controlled devices used today. Over the last 60 years, electronics used for these instruments have steadily improved. However, the basic physics of the radiation detectors remains, to a remarkable degree, unchanging (with the exception of solid state devices). A review of available instrumentation and its application is made for both surface and volumetric contamination as a function of radiation type. Performance of a survey requires five elements: a sensor with electronics appropriate for the radiation type, a means for measuring location, a means for displaying and recording data, a platform that supports the equipment and moves it in the area of interest, and a means for analyzing and reporting the data. The developments in all five of those areas are highlighted. The trends in each of those areas are highlighted in order to show the current and future evolution of the state of the art.

TAM C5 Portable Gamma Spectroscopy - A Brief Look at the "State Of The Art" and a Vision of the Next Generation

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Westinghouse Savanna River Site

Currently portable gamma spectroscopy equipment utilizes solid detectors that can be categorized in two major classes based on the temperature at which the detector is operated. Generally the detection systems operate at ambient temperatures or are cooled either by a liquefied gas (usually nitrogen) or an electro/mechanical cooler. Packaging of the detectors that operate at ambient temperatures such as sodium iodide (NaI) are usually thought of as hand held instruments weighing only a few pounds making them truly portable. Cooled detectors used in portable spectroscopy systems are mostly high purity germanium (HPGe) detectors. The HPGe systems will include both detector with cooling medium and associated electronics that comprise an operational system. This combination of hardware will easily weigh over twenty pounds. When contrasting these two classes of spectroscopy systems you must understand that nuclide identification is the primary purpose of the equipment. What is the key attribute of a detector that plays a major role in accurate nuclide identification for complex spectra? That question can be answered with a single word, resolution. It's a well known fact that cooled (HPGe) detectors have superior resolution to that of detectors operated at ambient temperatures. Along with the hardware associated with these spectroscopy systems there is typically a host of software/firmware provided for the user interface. This software is used for system configuration, calibration, spectral acquisition, system diagnostics, and spectral analyses. One of the must useful additions to the software capabilities is the ability to quantify radionuclides via mathematically calculated efficiencies for complex geometries. Considerable software engineering has been focused in this area over the last few years which has resulted in a more intuitive interface for the users as well as being more portable across many computer operating systems. Looking to the future, anticipating what the next generation of portable spectroscopy equipment will encompass is certainly not clear. Many factors are currently influencing the development of spectroscopy systems which focus on the needs of the United States to minimize the possibility of a terrorist attack using radioactive materials. Portable spectroscopy equipment plays a fundamental role in the security of our homeland against this threat. For the most part portable equipment is used by personnel that respond to initial alerts based on intelligences or actual detection alarms. In this role, future ambient temperature detectors need to be developed so they have spectral resolution comparable to or approaching the current HPGe detector resolution. Another possibility is the future development of a light weight compact electro/mechanical cooling system for HPGe detection systems so these systems become more like the current hand held spectroscopy systems. In general, high resolution hand held spectroscopy systems are likely to be developed to enhance our Nations readiness. All of the future spectroscopy systems will be software driven requiring software development. Enhanced or smart software systems will have to be developed with capabilities to identify radionuclides with greater reliability, locate the radiation emission point, image the area about the emission point, reconstruct an unattenuated spectrum from the acquired spectrum, and auto efficiency calibrate in order to quantify the identified radionuclides.

TAM C6 The History and Direction of Passive Dosimetry

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Concern for the exposure of workers to radiation followed slowly upon the growth of the professions involved with the utilization of radioactivity and radiation producing machines. Photographic film dosimeters were one of the first to be widely deployed starting in the early 1930's. The transition to solids in the postwar era was convolved with widespread differences in opinion and influences by national interests. The path to the present, almost uniform, methodology is traced emphasizing some of the most critical forks in the decision tree. The place of photographic film, thermoluminescence, radioluminescence, and optically stimulated luminescence is discussed both from the viewpoint of their evolution and emplacement in today's monitoring programs.   A short list of "also rans" is presented along with critical minor players.

Possible future directions in both programs and material science is discussed with the aim of meeting developing requirements for ensuring accurate, sensitive and economical monitoring in an expanding use of radiation in industry, medicine, and energy supply. The possibility of ensuring overall accuracy in predicting risk discussed as a major shortcoming of the present methodologies. The characteristics of a possible rate and dose determining system are discussed with the intent of characterizing repair function in the event of acute exposure.

TAM C7 Current & Future Applications of Electronic Dosimetry

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Frederick P. Straccia, CHP, *RSCS, Inc.*

This presentation focuses on current state-of-the-art electronic dosimetry devices, including detection characteristics and data processing capabilities and applications. Potential improvements to existing technologies, plus new technologies for electronic dosimeters are discussed.

Technical details are presented on electronic dosimetry applications, including advantages and shortcomings, to detect and measure dose and dose rate for external gamma, beta and neutron radiations.   Considerations for ‘dose-of-record’ devices are presented, including applications of the Direct Ion Storage (DIS) dosimeter.

The presentation also describes some of the difficulties normally found during implementation of an electronic dosimetry program to be considered by new users.

Finally, the presentation contains data on use of telemetry systems. Advantages for maintaining exposures ALARA, as well as common problems with telemetry system applications are discussed.

TAM C8 Current and Future Biological Dosimetry - Tools for Health Physicists

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The current accepted generic multiparameter approach for biological dosimetry includes (a) radioactivity measurements and monitoring of the exposed individual; (b) observation and recording of prodromal signs and symptoms; (c) obtaining complete blood counts (CBCs) with white blood cell differential; (d) blood sampling for the chromosome-aberration cytogenetic bioassay, using the "gold standard" dicentric assay or alternatively the fluorescence in situ hybridization (FISH) translocation assay in cases of prior exposures for dose assessment; (e) bioassay sampling, if appropriate, to determine radioactivity contamination; and (f) use of other available dosimetry approaches. The Biological Assessment Tool (BAT), a radiation casualty management software application available at the AFRRI website (www.afrri.usuhs.mil), was developed to facilitate medical recording and bioassay dose prediction features of this function. Future developments in biological dosimetry are addressing national needs to provide suitable dose assessment and medical triage and diagnoses in the event of a large-scale radiological casualty incident. Use of automated instruments to accomplish sample preparation for the conventional cytogenetic-based bioassays is being developed along with the establishment of reference cytogenetic biodosimetry laboratories and network. Radiation-responsive molecular biomarkers (i.e., gene expression, protein) are being validated and optimized for rapid radiation exposure assessment applications. Use of electron spin resonance (ESR), ultrasound, and optically stimulated luminescence (OSK) technologies are being investigated to provide early-response indicators of radiation exposure. We are currently developing a First-responder Radiological Assessment Triage (FRAT) software application for use on hand-held personal digital assistant devices to analyze clinical signs and symptoms, lymphocyte counts, physical dosimetry, radioactivity, and location-based dose estimates. [Acknowledgement: AFRRI and the National Institutes for National Institute of Allergy and Infectious Diseases, National Institutes of Health (Bethesda, MD) supported this research under work units BD-02, BD-03, BD-06, and BD-10 and research agreement Y1-AI-3823-01 respectively.]

TAM C9 Personnel Contamination Monitors

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Bruce Power, Radiation Protection Programs

Personnel Contamination Monitors are an integral component of most Radiation Protection Programs. Such equipment is crucial in ensuring that both workers and members of the public are protected from low levels of radioactive material.

Existing technologies utilise some of the more common forms of radiation detection, including gas filled detectors and scintillators. The use of personnel contamination monitors is widespread and the technology has undergone considerable change over the years in terms of human factors engineering and data manipulation.

Increasing regulatory scrutiny along with a heightened public awareness for 'radiation' in general, leaves health physicists with little room for error in terms of hazard control and identification. Today's health physicists are in need of equipment that not only performs reliably in terms of detection capabilities, but can operate with high capacity factors and are amenable to incorporating modern technologies.

In this talk, we will examine some of the current designs, including their performance, and will take the liberty of speculating on what tomorrow's designs may look like.   In particular, what advances in detection technology and cost saving measures can be integrated into these devices.

TAM C10 Radiation Detection for Homeland Security: Past, Present, and Future

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Radiation detection equipment has been deployed at the U. S. borders to prevent the smuggling of a nuclear weapon, material for a nuclear weapon, or a radiological dispersion device. This equipment, along with other radiation detection equipment deployed outside the United States, is helping to prevent nuclear terrorism. There are different types of detectors used in this effort ranging from radiation portal monitors for screening moving vehicles to handheld detectors, personal radiation detectors, and x-ray imaging systems. The current installed equipment used on the U. S. borders will be reviewed with the advantages and limitations outlined. Next generation detectors with advanced technical capabilities including passive and active interrogation will be discussed as well as some possible entry process modifications to further increase the security of this nation.

TPM C1 The Evolution of Laboratory Instrumentation for Operational Health Physicists

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Canberra

Health Physicists take instruments with them for field measurements of the environment, but they also take samples of the environment back to the laboratory for more detailed analysis. These laboratory instruments that HPs use today mostly all had their start at one of the Manhattan Engineering District and subsequent Atomic Energy Commission facilities or their contract facilities in the '40s and early '50s. The same instruments were needed both for weapons design and for radiation protection measurements. Alpha/beta proportional counters came from Argonne, which also gave us the liquid scintillation counter, the Multi-Channel Analyzer, and whole body counting. Oak Ridge created the earliest MCAs and most of the analog signal processing electronics. Los Alamos created practical applications of liquid scintillation counting. Princeton developed NaI detectors and Berkeley created the first Germanium detectors.   Because of the importance of this instrumentation to the MED/AEC there was a very rapid influx of innovations to these devices throughout the ‘50s and ‘60s, due to the large amount of government funding for such development. During that time, there was also a rapid growth in the number of nuclear instrument manufacturers. Since that time both the amount of government investment into instrument development and the number of nuclear instrument companies has declined substantially. So has the rate of additional innovation. Today, the fundamental technologies used in laboratory instrumentation are not much different than they were in the ‘60s and early ‘70s. To be sure, today’s instruments are faster, smaller, lighter, more reliable, and after correction for inflation considerably less expensive than those of several decades earlier. That is the contribution of commercialization. This presentation will examine the evolution of these common laboratory instruments that HPs use and set the stage for the following speakers to discuss the present capabilities and to muse and perhaps amuse us about what the future might bring.

TPM C2 Alpha-Beta Counting Instrumentation*

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An overview of the available today commercial alpha-beta laboratory counting instrumentation as well as continuous air monitors (CAM) for operational health physics is given. Some of the key features of the current “state-of-the-art” alpha-beta counters presented and data processing and analysis are informative as to where the future might be. The health physicists’s instrument needs, the desired technological advancement and the fundamental detection physics constrains are discussed.

(UCRL ABS-218200)

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TPM C3 Liquid Scintillation Counters and Measurements Today

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The liquid scintillation analysis technique dates back to the late 1940s. The first commercial instrument became available in the early 1950s. Through the years, the technique has been refined with major advances in the areas of cocktail formulations and instrument versatility and sensitivity. Most notably, advances in cocktail formulations simplified sample preparation since many different sample matrices can now be measured with minimal preparation and increased counting reliability. In addition, the instrument performance has improved with much higher signal to noise response that allows liquid scintillation counters to be used for environmental radionuclide measurements. Routine environmental measurements are now possible because instrument background levels are now in the several counts per minute range. Today, the term liquid scintillation counter is often replaced by the term liquid scintillation analyzer since systems boast such features as a multi-channel analyzer(s), electronic background reduction techniques, and alpha/beta discrimination. Instruments have either a built in or external dedicated modern computer that allows for extensive data storage, networking and enhanced security. Today, there are a relatively few manufacturers. Current product offerings and the features/benefits of the each is discussed here with a look at the possible enhancements or instrument modifications that are likely in the future.

TPM C4 Two New Scintillators: $LaCl_3$ and $LaBr_3$

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Saint-Gobain Crystals (formerly Bicron)

$LaCl_3$ and $LaBr_3$, newly available Ce doped scintillators from Saint-Gobain Crystals (SGC), have unique and exciting properties making them ideal scintillators for general applications at this time.   They are denser and faster than NaI(Tl) which has been the workhorse and standard scintillator for many applications. $LaCl_3$ crystals have a relative density of 3.79 and light output of 29 photons/keV. Detector assemblies with PHRs (pulse height resolutions) below 4% are routinely available. $LaBr_3$ has a relative density of 5.29 and a light output of 63 photons/keV. Detector assemblies with PHRs below 3% are available. Both scintillators are about an order of magnitude faster than NaI(Tl) with decay constants of 28 and 16 nanoseconds for $LaCl_3$ and $LaBr_3$ respectively. Counting at extremely high rates is possible with minimal dead time corrections needed even at 1Mcps. Additionally, time resolutions equal to and surpassing that of BaF_2 are possible with coincidence resolving times below 300 picoseconds. Another nice feature of both scintillators is the retention of high light output at high temperature. $LaBr_3$ has double the light output of NaI(Tl) at 175ºC and $LaCl_3$ matches and exceeds the light output of NaI(Tl) above 120ºC. One negative: The natural presence of La-138 limits use in ultra-low background applications. These new crystals are available in increasing sizes as growth development continues, currently 3” dia. x 3” long and larger. They are being sold under the trade names BrilLanCe®350 and BrilLanCe®380 for the chloride and bromide, respectively.

TPM C5 Solid State Detectors

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Radiation Monitoring Devices

Solid state detectors are an important class of detectors for X-rays, gamma-rays, charged particles and neutrons. A number of detector materials starting from silicon and germanium to wider bandgap compound semiconductors such as cadmium telluride, cadmium zinc telluride and mercuric iodide have been investigated in past and are available commercially. Along with review of these detector materials, various schemes to enhance their performance (particularly, of compound semiconductors) will also be discussed. This includes various electron-only collection schemes that enhance the spectral resolution of compound semiconductors that have poor hole transport. Newer materials such as thallium bromide for gamma-detection will also be covered. Various solid state detector concepts for neutron detection will be covered. Finally, avalanche photodiodes and advances in this area will also be addressed. Implementation of position sensitive designs for silicon avalanche photodiodes will be discussed. In addition to bulk crystal form of detectors, thick films of solid state materials on crystalline or amorphous silicon read-out devices for large area imaging applications will be covered.

TPM C6 Multichannel Analyzers Based on Digital Signal Processing

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Yantel, LLC

This work presents an overview of the multichannel analyzers based on digital signal processing methods and algorithms. A comparison between the traditional multichannel analyzers and the digital multichannel analyzers is presented. This comparison shows the advantages of the digital signal processing algorithms in improving the throughput rate and enhancing the spectral resolution. Fast pulse-shape sampling and the use of real time digital algorithms allow pulse-shape analysis that was not possible with traditional analog electronics. Examples are shown illustrating the digital pulse-shape discrimination technique. The separation of neutron interactions from gamma interactions in liquid scintillators allows measurement of the dose due to neutrons only as well as the dose due to the gammas only. The application of the digital multichannel analyzers for environmental radiation monitoring is also discussed.

TPM C7 In Vivo Measurement Instrumentation

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The current generation of in vivo monitoring instrumentation for radiation protection purposes utilizes solid state detectors with high-purity germanium crystals and scintillation detectors with thallium-activated sodium iodide phosphors for most applications. Single detectors and arrays of detectors are used for the measurements depending on the radionuclides being measured and what part of the body is being monitored. A myriad of instrument configurations are used depending upon the application, funding level, available space and other facility specific issues. For routine monitoring applications the design is intended to optimize placement of the units in close proximity to the body. To illustrate some of the different designs, descriptions are provided of contemporary instrument systems in operation at different facilities around the world. This includes arrays of planar germanium detectors for measurement of low energy photons and coaxial germanium and sodium iodide detectors for measurement of high energy photons. A brief treatment is afforded other types of instruments including phoswich, room temperature diodes, and proportional counters. The salient features of the instruments and systems are highlighted as they pertain to the accurate detection and quantification of radioactive material in the body. After reviewing examples of the current instrumentation, some of the possibilities for what the future of in vivo measurement instrumentation might hold are discussed. Will technology allow even larger germanium crystals to be grown and further increase detection efficiency? Likewise, can room temperature diodes be manufactured with sufficient size and adequate performance characteristics? Can an array of small detectors be worn as a jacket to monitor lung activity and still be stylish? Are organ-shaped crystals viable? Will segmented detectors help improve detection capability for low energy photons? Or are there other modalities that may become available to help improve the sensitivity and accuracy of in vivo monitoring? Only time will answer these questions definitively but for now we can boldly prognosticate.

TPM C8 General Industry Developments that Affect HP Instrumentation

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Envirocare of Utah, LLC

Radiation detection technologies have changed little over the decades since radiation-liberated ions were first detected. The platforms to which the detection systems report have evolved. Today's microprocessor has been integrated into and has expanded the capabilities of instrumentation. Vast amounts of radiological data can be collected, stored, and then transferred to your desktop computer. Accompanying information can include what, when, how, where, and even the why of the measurements – should you so desire. Communication links like Bluetooth and cellular technologies have also expanded capabilities. Fountains of data can now stream into a computer from points afar. This data can be sorted, filtered, and analyzed faster than a pair of health physicists can agree on a method for calculating a detection limit. The ground rules that shape instrumentation needs have evolved. For example, prior to the License Termination Rule, which provides a uniform and reasonable approach to determining acceptable levels of residual radioactivity, sensitivity was exceedingly important. If there were three radioactive atoms in a sample, we wanted to know. The Bulk Survey for Release process (a.k.a. "green is clean"), which uses in situ gamma spectroscopy, can't reliably see the three atoms in a container of waste material. The survey process is, however, robust enough to meet the needs of the process and overarching regulations. Technology innovations outside of those related to specific detection methods, and the needs of our industry will likely continue to form the foundation of the next generations of instrumentation.