THE BUSINESS OF HEALTH PHYSICS—JOBS IN A CHANGING MARKET

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Abstract—The health physics profession was born abruptly when once rare and precious radioactive materials became commonplace. The technological advancements that triggered an industrial complex and ended World War II demanded radiation safety on an unprecedented scale. Until then, protective measures against radiation were largely absent in laboratories. Over the subsequent decades, health physicists began protecting people and the environment in a wide range of settings including medical, research, and industrial. The use of radioactive materials and radiation-generating devices is prevalent today. Radiation doses occur continuously including during airline flights, in our homes, during medical procedures, and in energy production. Radiation is integral to numerous applications including those in medicine, dentistry, manufacturing, construction, scientific research, nuclear electric power generation, and oil and gas exploration. Activities that were once groundbreaking have now become routine and scripted. At higher doses, health effects are understood and avoided. Instruments for the detection and measurement of radiation are at times smarter than their users. Ironically, the same health physics community that has been successful in demonstrating that exposures to radiation and to radioactive materials can be effectively managed is shrinking at an increasingly rapid rate. This paper highlights the creation of past and current jobs, predicts the future opportunities in the profession, and makes recommendations necessary to protect the disappearing specialties.

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INTRODUCTION

There is a great deal of uncertainty regarding the future of the health physics profession as the number of professionals and students are decreasing rapidly. Significantly, the qualifications of those chosen to deliver radiation protection services are changing in concert. To predict where the health physics profession is headed, it is important to follow its evolutionary path, consider the economics of delivering services, and relate delivery to changes observed in comparable professions.

Any description of jobs in health physics benefits from an appreciation of its birth as a science, its development, and its role in protecting workers, members of the public, and the environment. While health physics is rooted deeply in science, its application as a standalone safety specialty was slow to mature initially and is eroding rapidly. Today’s reality is that the early legends of the profession have long since passed, and the first generation of the once-young health physics professionals and their jobs are now almost gone as well. Today, there is a new generation of health physicists challenged with the burden of continuing past traditions while remaining relevant to changing industries and global markets. Practicing health physicists are no longer the specialists, scientists, and educators who initially defined, established, and developed our profession. These professionals are caught in a changing market where most operations are considered procedurally routine, and once-prized niche specialists are considered an unaffordable luxury. This paradigm is now the business of health physics, and it impacts how jobs are evolving in a changing market.

ROOTS IN SCIENCE

The roots of the health physics profession sprang from laboratory experiments probing the fundamental sciences. The discovery of radiation and radioactive materials correlates directly with experiments designed to understand the atomic structure. These experiments tested ancient theories and ushered in a golden age of learning. Incredibly, the atomic hypothesis postulating that all matter is made up of a set of particles called atoms is ascribed to the ancient Greek philosopher Democritus of the fifth century B.C. Through the subsequent centuries, many philosophers pondered the ultimate structure of matter without experimental foundation. Early in the nineteenth century, John Dalton and Amedeo Avogadro conducted research to develop theories clearly distinguishing between atoms and molecules.

It was the discovery of x rays by Roentgen in 1895, radioactivity by Becquerel in 1896 (although the phrase was coined by Marie Curie 2 y later), and the electron by J. J. Thomson in 1897 that spawned the modern era of atomic physics (Evans, 1955). Almost immediately, x-ray techniques were applied as both diagnostic and therapeutic.
tools. Soon reports of injuries such as skin burns and epilation were reported among patients and x-ray workers. Many researchers resorted to using themselves as experimental subjects. Becquerel suffered unexpected burns to his torso due to his habit of carrying a small vial of uranium in his vest pocket (Boerner, 2005). Few scientists put forth recommendations to mitigate harmful deterministic effects. One notable exception was William Herbert Rollins, who may be called the first health physicist. Rollins developed and promoted new and improved x-ray tubes to improve safety.

Despite Rollins’ work and the apparent need, radiation safety as a profession did not take hold. More experimentation followed with the theoretical and experimental successes of H.A. Wilson, Barkla, Rutherford, Geiger, Marsden, Moseley, and Bohr. In 1911, Rutherford deduced that the atom was composed of a tiny central core, or nucleus, containing all the positive charge and almost all of the mass of the atom, and a nearly empty surrounding cloud region containing the light, negatively-charged electrons in sufficient number to balance the inner positive charge (Glasstone, 1950). In 1919, Rutherford produced the first transmutation of elements by converting nitrogen into oxygen (Shapiro, 1950). In 1941, the National Bureau of Standards issued a 15-page handbook providing general measures for handling radioactive materials, which evolved from radium worker studies. On the eve of World War II, however, there were no professionals devoted exclusively to radiation protection. This omission was about to change forever.

THE ADVENT OF RECOMMENDATIONS

In 1928, the forerunner of the International Commission on Radiological Protection was formed. It was immediately followed in 1929 by formation of the U.S. Advisory Committee on X-Ray and Radium Protection, which was later chartered by Congress as the National Council on Radiation Protection and Measurements. In the 1930s, along with the League of Nations, these organizations formulated radiation protection recommendations, although implementation in medical settings was at best secondary. In 1932, Chadwick proved the existence of neutrons, thereby concluding that the nuclei of all elements is composed basically of protons and neutrons packed very closely together. His work was critical to understanding the atom and radioactivity—certain combinations of protons and neutrons are stable and remain that way unless disrupted by nuclear collisions, whereas unstable combinations undergo one or more nuclear transformations through spontaneous disintegration processes that alter the proton-to-neutron ratio to achieve a stable state. Chadwick unlocked the fundamental science essential to developing radiation protection methods in the future.

More experiments followed with dramatic results and consequences. Experiments of Rutherford, of Cockcroft and Walton, of I. Curie and Joliot, and of Fermi challenged the existing hypotheses of atomic structure and investigated the nature and uses of radiations associated with nuclear transformations. While major developments in nuclear research were coming in rapid succession, interest in radiation safety was not prevalent. The quantities and uses of radioactive materials were still limited to medical applications and laboratories including those operated by academia, by private companies and for governments. Whatever measures existed to control radioactive contamination, intake of radioactive materials and radiation doses were typically developed by individual practitioners and rarely shared among users.

Broader uses of radioactive materials followed, and these created a more apparent need for radiation protection. Health concerns arose for radium workers and, in particular, radium dial painters, who were extensively studied during the 1930s. With a focus on addressing the needs of industry, the American Industrial Hygiene Association was formed in 1939 and included radiation safety as part of its area of practice. In the same year, researchers discovered uranium fission in the laboratory. In 1941, the National Bureau of Standards issued a 15-page handbook providing general measures for handling radio-luminous materials, which evolved from the radium worker studies. On the eve of World War II, however, there were no professionals devoted exclusively to radiation protection. This omission was about to change forever.

RARE BECOMES COMMON

On 2 December 1942 at the University of Chicago, the first self-sustaining nuclear fission chain reaction was started. With it, the release of atomic energy became a practical operation instead of an interesting phenomenon, and the world’s supply of precious and rare radioactive materials suddenly became almost too common for comfort (Ingraham et al., 1954). The ensuing scale of production was enormous within the Manhattan Project, the audacious and secretive research and development project conceived to produce atomic weapons. On 16 July 1945, the Trinity test in Alamogordo, New Mexico, marked the detonation of the first atomic weapon. A new workforce was engaged during the challenging time of World War II to build an industrial complex to design, test, and manufacture weapons containing radioactive and fissile materials. Protecting workers and monitoring releases to the environment became a large-scale priority. All work was conducted within the confines of national security.

Significantly, a group of workers within the Manhattan Project was assigned full-time to the task of radiation protection. Called health physicists (a moniker coined to conceal the weapons-related nature of their work), many of these original safety practitioners were physicists suddenly
responsible for protecting workers from health-related problems resulting from working with radioactive materials. It is from this group that the foundation of what would become the profession of health physics grew. Building the U.S. nuclear weapons complex resulted in broad applications for radiation protection, including programs for the workers, members of the public, and the environment. The number and diversity of health physics jobs during these times were vast.

With images published of the detonations of atomic weapons used to end World War II and their aftermath, researchers and members of the public alike developed a keen appreciation for the need for protecting people from radiation exposures. The technological advancements came in very rapid succession. Production of electricity by a nuclear reactor was achieved in 1951; the detonation of a thermonuclear weapon in 1952; and commissioning of the nuclear-powered submarine Nautilus in 1954. Each was a landmark event. The need for radiation safety was growing accordingly. These advancements facilitated the next group of radiation protection workers, operational health physics practices, and radiation dose standards. The jobs for those practicing radiation protection and their applications in this era were groundbreaking.

AN ESTABLISHED PROFESSION

The time period extended from the technological advancements in the early 1950s realized immense development of health physics practices. During these times, jobs were plentiful as a large number of standards were developed, regulations promulgated, and programs implemented. Instrumentation for detecting, monitoring, quantifying, and identifying radionuclides advanced purposefully. A priority for some professionals became quantifying the health effects and impact on members of the public and the environment of radioactive fallout from atmospheric weapons testing. The development of commercial nuclear power plants was also progressing rapidly.

A group including some of the original health physicists on the Manhattan Project is credited with creating a scientific community for radiation protection professionals in 1955 with the organization of the Health Physics Society. In 1958, a subgroup within the Health Physics Society organized the American Board of Health Physics to establish examination criteria to designate an individual as a Certified Health Physicist. The first examination was administered in 1960 (Moeller 1972). As the number of health physics jobs within industry grew quickly during this period, numerous university degree programs were created to provide degreed professionals. Training programs teaching basic radiation protection and related topics were becoming widespread.

GROWING NUMBERS

The health physics profession grew at a rate of more than 20% annually in the late 1950s and early 1960s (Boerner 2005). While still increasing, the growth slowed during the mid-1960s. The dramatic rise in the number of commercial nuclear power plants under construction in the late 1960s and 1970s fueled the demand for health physics professionals once more. In addition, with the increased demands for operational monitoring and contamination control, jobs for health physics technicians were expanding rapidly as well.

In 1979, the accident at Three Mile Island was shocking if not surprising in that progress was outpacing industry-wide controls, conduct of operations, training, and preparedness. The accident created a new niche within the health physics profession as efforts and funding increased dramatically to provide emergency preparedness and response planning, including more detailed modeling of source terms, release scenarios, atmospheric transport, deposition, and dose estimates. U.S. commercial nuclear power plants were now required to have comprehensive programs and to conduct annual drills. In 1986, the accident at Chernobyl highlighted internationally the need for such measures at all nuclear facilities and caused the largest environmental assessment since the cessation of atmospheric weapons fallout.

In the mid-1990s, the U.S. Department of Energy prioritized remediation of the nuclear weapons complex sites, and funding was measured in billions of dollars. Initially, new health physics programs and procedures were needed to address decontamination and decommissioning of these sites and facilities. Within years, numerous companies were performing cleanup operations successfully and safely, often working and teaming with and against each other. Working in the U.S. Department of Energy complex was now big business and highly competitive.

NO LONGER GROUNDBREAKING

The profession of health physics has successfully controlled and limited radiation doses to workers, members of the public, and the environment as radiation is easily detectable and quantified. Occupational radiation doses are controlled better today than at any time since the discovery of radiation. Although some degree of radiation injury may be inevitable given the significant doses delivered purposefully using radiotherapy, few patients treated with modern methods experience unintended severe or disabling radiation injuries. Modern facilities and safety practices have essentially eliminated radiation injuries due to excessive occupational exposure as were prevalent among pioneer radiation workers. Today, most radiation doses received by members of the public are low. Exceptions are doses
to the bronchial airways and lungs from smoking cigarettes and inhaling high indoor concentrations of radon (progeny), and whole-body or localized doses incurred during specialized therapeutic or diagnostic medical procedures. Radiation releases to the environment are monitored and controlled. Ecological and environmental surveillance programs are in place for radiological and nuclear facilities in developed countries.

Charting the full-time jobs in health physics since the discovery of radiation provides important insights into the periods with increases and decreases in employment opportunities. Fig. 1 presents a comparative representation of jobs through the decades based on historical accounts, the membership data of the Health Physics Society, and industry initiatives.

Once a major area of study, the human health effects from higher dose and higher dose-rate exposures are very well understood. Research-related jobs were prevalent in academia and at the national laboratories. Today, funding in these areas is very limited. In contrast, the effects from low dose and lower dose-rate exposures remain sources of controversies, public communications inaccuracies, and cancer-related fears. Although researchers worked to provide answers, all experimental data generated to date are insufficient to determine whether adverse health effects are caused. It is understandable that the public wants to know whether or not low doses of radiation do indeed cause cancer and whether all exposures should be avoided. A proposed study of over one million radiation workers in the United States (Bouville et al. 2015) sought to help answer those questions; however, it was suspected that it might prove insufficient due to the many confounding factors and the complexity of radiation dose and cancer causation (Mossman 2014). The study has been cancelled as any potential findings have been predetermined as inconclusive.

The vast majority of radiation protection professionals believe that all radiation exposures should result in a net benefit, that infants and children are the most sensitive to adverse effects, and that for healthy adults, low doses are safe compared to the multitude of risks we face in everyday life.

THE REALITY OF ECONOMICS

The business of health physics has changed significantly since the mid-1990s in response to a specific set of factors and conditions. These include dependence upon advanced technologies, constraints due to reduced budgets and competitive economic pressures, and the expectation that routine operations will always remain routine. Consequently, work once performed by health physics professionals is disappearing at an ever-increasing rate. Today, research projects are rarely funded. Radiation protection programs and protocols are already well established and documented. Those professionals with niche expertise in specialized disciplines of health physics are in demand only in unusual circumstances.

The specialties and markets provide insight into the source of health physics jobs. Survey information compiled from the members of the Health Physics Society provides such data. Fig. 2 presents the percentages of jobs arising from the following sources: government, industry, university, medical, consulting, national laboratory, and military. Analysis of data on specialties results in Fig. 3, which presents the percentages of jobs associated with applied health physics; reactors, fuel cycle and waste; medical applications; education and research; dosimetry; regulations and standards; environmental monitoring; instrumentation; and nonionizing radiation.
Many advocates for our profession, including the National Council on Radiation Protection and Measurements (NCRP), have warned that the numbers of health physics professionals have diminished alarmingly and that the nation’s industries requiring radiation safety are on the verge of a severe staffing shortfall. In fact, this pronouncement has been made for many years and has yet to be realized. If it were happening, the salaries for health physicists would be increasing dramatically as the incentives to attract a professional would be demand-driven. Given the recent flat salary history for health physicists, there must not be an immediate or alarming increased demand or severe shortfall. Simply put, the current economics do not support the forecasted condition.

A factor contributing to the lack of a staffing shortfall is the availability of generalists and technicians to advance and take positions once filled by health physics professionals. Such individuals are benefitting with jobs of greater responsibility, supervisory or management opportunity, and better compensation. Given the prevalence of such practices, there will be pressure from generalists to avoid a rollback. Unfortunately, the use of generalists has resulted in adverse impacts, and still the practice has not changed. The most common deficiency among generalists is to not identify disparate initiators, assess complex conditions, and respond appropriately to an unusual event. The consequences of such failures can be significant facility down time and rigorous scrutiny to restart operations. It could be easily claimed that more qualified and experienced health physics professionals can prevent such extensive and extended problems; however, the current focus on cost reductions across industry does not allow for such intellectual insurance against adverse impacts. It is apparent that the costs of greater expertise are not in the budget even when negligible compared to the costs of downtime, corrective actions, readiness, and restart.

Today’s reality is that generalists are conducting health physics programs and filling the majority of radiation protection jobs when costs are a primary consideration. Any proposed fix to maintain jobs or define career paths for health physicists must consider the economics and be sustainable. Such economics have played out in other industries. The most notable example is in medical care. Only a generation ago, medical doctors delivered a broad range of services to patients directly. Today, others with lesser education, qualifications, and experience deliver these services. The driver is economics. It is a reward versus risk equation. If the majority of services, whether taking a patient history, taking vitals, or providing a treatment, can be delivered at lower cost without undue risk to the patient, then it will be done accordingly. The risk is in an incomplete history, a limited understanding, a missed diagnosis, and an incomplete or incorrect treatment. We know these events happen, and yet there is little repercussion other than to the patient. The point is that, as a society, we accept some risk in order to lower costs.

The parallels to health physics are apparent with generalists conducting health physics activities and filling the majority of radiation protection jobs. Again, it is about economics. Health physics programs have been developed and implemented for virtually every type of operation including those for nuclear power generation, environmental monitoring and ecological surveillance, environmental cleanup, facility decontamination and decommissioning, research laboratories, radioactive source manufacturing, and those requiring a radioactive materials license. With established programs, individuals with lesser education, qualifications, and experience are filling the jobs to conduct programs. When operations remain routine, the programs are adequate and executed at lower cost.

One approach to filling jobs with health physicists is to improve their cross training to cover the broader areas of industrial hygiene and occupational safety. In effect, it is flipping the generalist approach. Rather than fighting the economics of a generalist of lesser qualifications filling a health physics job, change the economics by moving up and taking jobs covering more safety functions with greater health and safety responsibilities. Educational programs should focus on multidisciplinary, integrated occupational safety management training, including industrial hygiene, to allow a health physicist to gain more comprehensive safety qualifications and fill a larger role in an organization. This approach would likely be most effective among new students interested in the occupational health profession. Older, mid-career health physicists may be resistant to the...
new areas of responsibility unless their jobs are threatened. Training for all occupational safety professionals, new or old, would benefit from operational essentials such as integrated safety management and conduct of operations. The economics should support this approach.

PRESERVING THE SCIENCE

The most fundamental step that should be taken to maintain jobs for health physicists and to encourage new students to enter our profession is to establish comprehensive standards specifying the minimum education, training, qualifications, and experience necessary to perform the roles, duties, and responsibilities of practicing health physics technicians and professionals in today’s marketplace. A parallel example is the training and clinical experience requirements needed to be employed as a medical physicist or medical dosimetrist. Another example is in the engineering profession where the requirements for certification of calculations and stamped documentation by a Professional Engineer is commonplace. Governing regulatory drivers are typically the bases that dictate industry practices. When hiring or filling positions, many companies currently respond to regulatory drivers only when it comes to selecting the candidate. Comprehensive industry standards and the corresponding regulatory requirements for education, training, qualifications, and experience are essential if changes are to occur.

Many advocates for our profession want more money to support educational programs and attract students. Perhaps the real need is to increase interest in our profession. Students flock to the new, dynamic, and progressive areas of science. Whether these areas have been in medicine, aeronautical engineering, or the computational sciences, health physics is losing many of the best and brightest to those scientific disciplines that have growing and expanding needs. In many respects, health physics is in a maintenance mode, which gets back to generalists filling the majority of the health physics positions. The key to fixing the problem is likely in a more progressive and exciting future.

Absent the “exciting,” another fix could be to establish the discipline of health physics as a “strategic national need” or “essential to national security.” The argument can easily be made given the certainty that one day radioactive materials will be used in a terrorist act (“dirty bomb”). The need is to ensure that the professionals continue to maintain and enhance the numerous sub-disciplines or niche areas of expertise within health physics. While generalists are cost effective and may be sufficient for routine operations, without provisions to maintain professionals who understand the science, prescriptive procedures and smart instruments will continue to replace qualified people.

PREDICTING THE FUTURE

When assessing health physics jobs in the future, the impacts of public opinion and perspectives must be considered. It is an unfortunate reality that radiation is one of the most poorly understood concepts among members of the general public, while being one of the most studied and well understood hazards by scientists. Within general society, radiation is viewed as a malevolent manmade creation. Radiation’s association with atomic and nuclear weapons conjures up images of suffering and annihilation. Early in its discovery, radiation was thought to be the cure for certain health problems. The development and use of x-ray machines opened medicine to new heights of noninvasive diagnostics. The envisioned peaceful uses for the atom in the form of nuclear power generation were believed to make metering electricity unnecessary. With such a high bar, practices involving radiation have not met expectations. Faulty designs, poor application, and human errors have led to accidents, overexposures, and even death. Radiation is best accepted in medicine because of the understood benefit. It is either avoided or accepted with reservation in most other uses.

With opportunity, health physics jobs will be focused on: decommissioning U.S. nuclear power plants, commissioning and operating foreign nuclear power plants of new design, conducting environmental programs emphasizing virtually no emissions and therefore no harm, screening consumer products to detect inadvertent contamination, and supporting another generation of diagnostic and therapeutic medical devices. Health physics jobs may be created in emergency preparedness and response. The occurrence of a momentous event threatening to cause radiation exposures to members of the general public will create significant demands for health physics expertise, whether the event is the result of a dirty bomb or another shocking accident. Predictably, waste management, including waste processing and disposal, will continue to be an international concern. The role of the health physicist in all of these endeavors will need to evolve from what it is today.

Two areas will continue to dominate the use of radioactive materials. These areas are medicine and energy production. Ever advancing equipment for diagnostic and therapeutic medical devices continues to use radioactive materials or rely on the generation of radiation. Considering radiation was only first discovered in 1895, medical equipment has advanced with exceptional purpose and speed. Radioactive materials may continue to be the best electrical generators for spacecraft and may contribute to the success of new space missions. Nuclear power may be relied upon to contribute a portion of the overall energy supply both in the United States and internationally. Within the next few decades, smaller, modular reactors will likely produce local power both in developed
and developing nations, potentially transforming and reducing the extensive and overwhelming need for infrastructure. Such energy sources may be coupled with desalination plants to provide clean water, thereby improving living conditions, promoting agriculture and livestock yields, and reducing dramatically the prevalence of waterborne diseases. Our future perspectives on radiation will likely change dramatically. Imagine, for example, assessing the risk from radiation in 100 y if cancer were no longer considered to be a fatal disease due to available vaccines and treatments.

REFERENCES

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