THE CHANGING ROLE OF THE HEALTH PHYSICIST***MASTER**

NOTICE

by
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Perhaps there has never been a period in history when a professional and scientific group had a greater challenge than has the health physicist or radiation protectionist at present. When our organized applied and research programs of health physics began during the early part of World War II, we were criticized and ridiculed for setting such conservative, "ridiculously low" and costly radiation protection standards. However, during this past quarter of a century, there has been mounting evidence that there is no truly "safe" level of exposure, that certain types of radiation damage increase more or less linearly with the accumulated dose⁽¹⁾ to the critical tissue and that all unnecessary exposure should be avoided. The number of sources of industrial and population potential exposure has increased manyfold; some sources of exposure are worldwide in scope, and the maximum permissible dose values have been lowered several times as indicated in Figure 1. When we set levels for radioactive waste disposal in White Oak Lake near ORNL at 0.1 R/day in 1943, some engineers and others criticized us and urged us to set these values at 100 R/day. Just this summer, the USAEC reduced population exposures from light water nuclear power plants from a maximum of 500 mrem/yr to 5 mrem and from an average to sizable population groups from 170 mrem/yr to 1 mrem/yr. This is an over-all spread in values of over seven orders of magnitude. As a consequence of these changes, some of us such as Fred Cowan, whom we honor today, have had many occasions to be thankful for our early conservatism. It is generally recognized that health physics has played a major role in helping to develop the nuclear energy industry such that it is unique among industries in planning ahead and attempting to estimate from many experimental studies (costing hundreds of millions of dollars) the radiation risks that might accrue to man from prolonged, low-level exposure. Maximum permissible exposure levels were chosen which are not based on sad experience and human misfortune that has been the usual industrial pattern for many other industries and other occupational and environmental vectors. As a consequence, the nuclear energy industry is one of the safest of all

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FIGURE 1

50,000,000- or 100R/day Urged by engineers and others in 1943

LEVELS OF POPULATION EXPOSURE

modern industries in spite of its tremendous innate potential for radiation damage.

Today, however, the shoe is on the other foot, and we are being placed on the witness stand and asked why we have been so reckless; why are our permissible exposure levels so high; why have we not maintained more careful control of radioactive materials that are released to the environment.

At the working level of applied health physics operations in national laboratories and large research institutions, the health physicist has conducted what I believe is a remarkably good job in assuring the safety of operation of reactors, accelerators, radioisotope production and research. This record becomes particularly impressive when we realize the magnitude of the radiation accident potential when working with some 80 different types of particles and anti-particles (leptons, mesons, baryons and resonant particles), some of them with energies in the gigavolt range and with many gigacuries of over 1700 presently identified radionuclides. Since the beginning of the nuclear energy program, there have been throughout the world only five nuclear accidents with reactors and critical assemblies that have resulted in fatalities⁽²⁾ -- four of these were in the United States; the fifth was in Yugoslavia. For the period 1943-67, only 3% of the fatal accidents⁽³⁾ in the nuclear energy operations in the U. S. Atomic Energy Commission are attributable to radiation, and only 0.4% of the serious injuries resulted from radiation.

The health physicist, however, has very little to be proud of from the medical applications of ionizing radiation. In most of the more advanced countries, a major portion of population exposure to man-made sources of ionizing radiation derives from medical diagnosis, e.g., greater than 90% in the United States. Yet it can be shown⁽⁴⁾ that with very little effort this exposure in some countries could be reduced to less than 10% of its present value without reducing the number of medical radiograms or diminishing the quality of medical radiological information; in fact, almost all of the measures suggested whereby this reduction in unnecessary exposure could be brought about would at the same time greatly enhance the quality of medical diagnosis. For example, G. M. Ardran⁽⁵⁾ stated, "If all radiological departments employed the techniques already in use in 25% of departments in 1958, the population gonad dose from diagnostic radiology would probably be reduced by a factor of about 7." This would mean a reduction of the average genetically significant dose in the United Kingdom

from 14 mrem/yr to 2 mrem/yr. The U. S. Public Health Service⁽⁶⁾ stated, "It was estimated that restriction of the x-ray beam to an area no larger than the film size would result in a reduction of the genetically significant dose from 55 to 19 mrad/person/yr." The Food and Drug Administration has just made the proposal that the general purpose diagnostic x-ray machines--including dental x-ray--be required to conform to a design that would limit the x-ray beam to the area of the body covered by the x-ray film. If such a proposal becomes law and if such a law is enforced, this is a great victory for some of us in health physics. Figure 2, taken from a paper presented recently by Dade Moeller, president of the Health Physics Society, emphasizes the increase in the number of x-ray machines and in the genetically significant diagnostic dose to the U. S. population during the past few decades. It indicates, also, the trend toward the end of the century unless health physicists can be more effective in their efforts to reverse the disgraceful, rapid increase in excessive diagnostic exposure of the U. S. population. By way of comparison, Figure 3 indicates the rapid increase in nuclear power. However, in Figure 4 it is observed that the genetically significant dose to the population from the entire nuclear energy industry in the United States has been estimated to be much less than 1 mrem/yr, and we believe this good record will continue. Some of us associated with health physics in nuclear energy operations sometimes feel we are partly wasting our energies and misapplying our talents in efforts to further reduce the less than 1% of population dose that is attributable to the nuclear energy industry when so little is being done and so much could be accomplished with very little effort to reduce the more than 90% of population dose from man-made sources which derives from medical diagnosis. The problem is primarily one of lack of proper education, training, certification, and motivation on the part of members of the medical and paramedical professions. For example, in the United States more than one-half of the x-ray machines are owned and operated by non-radiologists (practitioners, chiropractors, etc.), who have little or no training in radiation physics and radiation protection, and only in one of our 50 states (California) are there laws requiring the teaching of health physics and radiation protection in the medical schools. On the average, radiologists are able to provide more diagnostic information with less patient dose than other members of the medical profession. For example, surveys of the U. S. Public Health Service⁽⁷⁾

MEDICAL X-RAYS

FIGURE 2

NUCLEAR POWER

FIGURE 3

**AVERAGE IONIZING RADIATION EXPOSURE TO PERSONS
LIVING IN THE UNITED STATES**

	mrem/yr
<u>Medical Exposure</u>	
Gonad dose from diagnosis (1964)	55
Gonad dose from therapeutic use (1964)	7
Bone marrow dose from diagnosis (1964)	125
Thyroid dose from diagnosis (mostly dental) (1964)	1000
<u>Weapons fallout dose (1968)</u>	2
<u>Occupational Exposure</u>	
Nuclear energy industry gonad dose (1966)	0.2
All other occupational exposure gonad dose (1966)	0.4
<u>Other man-made sources (watches, television, shoe-fitting machines, radioisotope applications, etc.) gonad dose (1966)</u>	0.1

Figure 4

indicated the average diagnostic exposure to the abdomen of the patient was 636 mR when given by a radiologist and 1253 mR when given in private offices of other physicians. Only in New York, New Jersey and California are there laws which limit the operation of diagnostic x-ray equipment to the x-ray technologist who has had formal education, training and certification of competence for such use. The situation with dentists is just as bad. Surveys⁽⁷⁾ in the United States have indicated that more than half of the dental radiograms are taken where the cross-sectional area of the beam is equal to or greater than three times the area of the film. This situation persists in spite of the fact that there have been developed devices⁽⁸⁾ which may be attached to the end of the long, open-ended cone of the dental x-ray machine to provide precision collimation and reduce the cross-sectional area of the beam to the area of the film.

It has been encouraging during the past few years that a large number of colleges and universities throughout the world are adding courses in health physics. In a number of universities, graduate programs are given in health physics in which the major degree is in physics, nuclear engineering or biology with a speciality in health physics. Several schools are offering undergraduate as well as graduate degrees in health physics. There is considerable demand in the universities and colleges for health physicists not only to teach these courses and conduct health physics research but also to serve as radiation protection officers to assure the safety of the students, faculty and others who might be exposed to excessive radiation from university-owned and operated reactors, accelerators, x-ray machines, diffraction devices, isotope applications and all sorts of electronic equipment such as electron microscopes, voltage regulators, rectifiers, vacuum condensers, lasers, radar and microwave ovens. One of the more serious health physics education problems is the fact that there are many industries, laboratories, universities, hospitals, etc., where health physics programs are needed urgently, but those in charge of the operations are not sufficiently aware of the need or they are attempting to carry out health physics programs with untrained and improperly qualified personnel. I believe such operations with insufficient health physics coverage should be prohibited by state and federally enforced laws. The unawareness of health physics requirements is particularly

evident in some of the nuclear power companies in the United States that would rather "retread" some of their older and less gainfully engaged employees than to hire more competent and adequately trained health physicists. On some very crude assumptions, I have estimated that the nuclear power industry in the United States should have in its present employ approximately 400 health physicists; yet I estimate this number is only about 50. At this time when there is so much public concern about the possible risks from nuclear power plants, I know of no better investment the power companies could make than to strengthen their health physics organizations in order to develop a better understanding and appreciation of the problems and convince the public that radiation protection really is being taken seriously and provided for adequately by the power industry.

Likewise, radiation inspection programs in many cities and states are falling far behind for lack of proper financing and sufficient well trained health physicists. Many radiation-producing devices are surveyed and calibrated on a very infrequent basis, if at all. Mass chest x-ray programs are sometimes conducted where one might question the need in spite of the fact the U. S. Public Health Service has indicated that mass chest x-ray programs should not be given to all population groups⁽⁹⁾ but instead should be focused on groups within communities where the incidence of tuberculosis is high. Often, excessive use is made of chest x-ray surveys in spite of the fact that the World Health Organization⁽¹⁰⁾ has pointed out "attempts have been made to use mass radiography for detecting lung cancer at an early stage, but the results have been relatively poor and little if any improvement in the prognosis has been achieved." Often, techniques and equipment, such as the photofluorogram, are used which, as indicated in Figure 5, deliver 1,000 or more mR per chest examination when a well conducted, full-plate chest x-ray examination can be carried out with doses as low as 10 to 20 mR. In some cases, there have been toothpaste surveys among thousands of children in which toothpaste is supplied free to the children in a city school system for a year, and then the children are subject to a series of dental x-rays ostensibly to determine which toothpaste results in a lesser number of caries. Since these studies usually are not scientific in nature and since the equipment employed in x-raying the teeth often has not been properly evaluated, calibrated and inspected before use, it is my opinion that this risk of x-ray damage and

Common Diagnostic X-Ray Exposures (mrem to skin) in the United States

	<u>Range</u>	<u>Average</u>
Chest X-Ray at ORNL	10-20	(15)
Chest X-Ray (photofluorographic)	200-2000	(504)
Chest X-Ray (radiographic)	10-300	(45)
Dental X-Ray Series	1000-100,000	(20,000)

Figure 5

the use of young children as guinea pigs is unwarranted. It seems to me that frequently the primary purpose of such surveys may be to provide information for commercial TV and radio advertisements. One institution, ⁽¹¹⁾ North Texas State University, is using fluoroscopic x-ray equipment in the music department to observe the throat and jaw of the students to determine the progress made by the student in using various musical instruments. I would be strongly inclined to discourage such use of x-rays.

Radiation hazards of color television probably received more publicity than was deserved because in the vast majority of cases, exposures from these devices were extremely low. Although Rechen et al ⁽¹²⁾ have shown that the voltage regulator tube in some makes of color television sets can be selected and adjusted in such a manner as to give a dose as high as 800 R/hr at the bottom of the receiver, I doubt that there have been very many, if any, color television sets approaching this worst condition. The dose delivered by most color television sets is almost negligible. A survey of the U. S. Public Health Service in the metropolitan area of Washington, D. C., ⁽¹³⁾ indicated that only about 6% of these sets exceeded the maximum permissible level set by the National Council on Radiation Protection of 0.5 mR/hr at 5 cm from any accessible point on the surface of the receiver, and only two out of 1,124 sets inspected exceeded 12.5 mR/hr. However, in my opinion, even this low exposure is totally unwarranted because it represents unnecessary exposure and a potential for radiation damage to many millions of children who sit for hours each day only a few feet from the screens of the 20 million color TV sets in the United States.

During the past few years, there has been rapid expansion in the types and number of energy sources which produce exposure to ionizing radiation, and the health physicist in industry, the university, and in public health organizations must be on guard constantly to prevent misuse of such equipment. Many devices are not commonly recognized or clearly identified as potential sources of serious radiation exposure. For example, the high-voltage vacuum switch is commonly used as a convenient means of breaking the high potential side of an electrical circuit. These devices are used in industries, hospitals and universities. Auxier et al ⁽¹⁴⁾ have tested a number of these and found some delivering absorbed doses as high as 1 rad/hr at 10 feet. This terrific dose is delivered in the vicinity of these and similar electronic products in spite of the fact

that the specifications and literature furnished by the vendor mention nothing about the fact that these devices can emit x-radiation.

During the past few years, many health physicists have had problems associated with non-ionizing as well as ionizing radiation, and a number of health physics organizations have been given surveillance responsibility for microwave, rf, uv, laser and other kinds of radiation. As a consequence, the Health Physics Society in 1969 decided to extend the definition and scope of health physics research such that it now includes the study of the effects of all forms of electromagnetic radiation in both stationary and changing fields and all forms of particulates capable of producing ionization. It includes especially the protection of man and his environment from these radiations. For the present, it excludes mechanical forms of energy such as sound, ultrasonics and infrasonics. Thus, from this definition, health physics includes all wave forms of ionizing radiation (α and γ) and particulate radiations that can produce ionization (α , $\beta^\pm$, protons, heavy ions, neutrons, mesons, baryons, leptons, etc.) and, in addition, non-ionizing radiations such as uv, infrared, radar, TV, radio, microwave and rf radiations as well as the coherent radiation from lasers. In many cases, these non-ionizing radiations are intermingled with ionizing radiations; they present many of the same problems, and they require men with similar interests, background and experience to provide for their safe use. Thus, as indicated in Figure 6, many health physicists are required to broaden their horizons and extend their interests in balancing the benefits of various forms of electromagnetic radiation against the risks. For example, radiofrequency is used in communications, diathermy units and cauterizers, and microwave is used in ovens, dryers, heaters, spectroscopy, alarm systems, diathermy units, radar, TV transmission, communications and navigation devices, and some of these uses are reported to have resulted in human injury. Of the 100,000 microwave ovens in use in the United States, 40,000 are in homes. Secretary of the U. S. Department of Health, Education and Welfare, R. H. Finch,⁽¹⁵⁾ stated that a random survey of microwave ovens indicates one in three is leaking enough radiation to be a potential problem. The health physicist is concerned not only because of the rapid increase in use of these sources of non-ionizing radiation but also because of the uncertainty of the risks, the inadequacy of meters for estimating the dose and even some question of whether the properties measured are the ones most closely related to the

Figure 6

potential biological damage. For example, until recently the level of maximum permissible exposure to microwave radiation in the United States was $10 \text{ milliwatts/cm}^2$, whereas the level set in the Soviet Union is $10 \text{ microwatts/cm}^2$. Just this July our level was reduced to 1 microwatt/cm^2 for new cooking ovens--only $1/100$ instead of $1/1000$ of the level used in the USSR. The new U. S. standard would permit the level of old ovens to go up to $5 \text{ microwatts/cm}^2$. Apparently, most of the persons in the microwave field in the United States believe the principal damage is caused by the thermal effect. However, there are a number of publications from the Soviet Union and several observations in the United States indicating there are other energy exchanges and forms of damage which result in headaches, nausea, dizziness and general ill health from exposure to very low doses of microwave radiation. There are a few experiments which indicate that the electric component (E vector) rather than the magnetic component (H vector) of the energy field is responsible for most of the biological damage. Yet many of the measuring devices do not measure the electric component of energy or they measure some unknown fraction of it. Many of the instruments used are so large that it is difficult to estimate the dose at the point in question, e.g., at the lens of the eye or the gonads. Often the measurements do not take into proper account the near and far field, the reflected and standing waves, etc. There are a few experiments which indicate there may be biological damage caused by stationary electrostatic fields associated with high-voltage devices and with very intense stationary magnetic fields which can be produced over large areas by cryogenic conductors. Some of these devices may be introducing radiation risks which are now not sufficiently monitored by the health physicist. The risks of ultraviolet and laser radiation are limited primarily to skin burns, erythema and eye damage. With the rapid increase in use of these devices, the health physicist in a large industrial organization must be ever alert to see that employees do not receive serious radiation damage.

Although energy pollutants such as sound, ultrasound, infrasound, mechanical vibrations, airborne chemicals such as oxides of sulphur, oxides of nitrogen, hydrocarbons, particulates, etc., are not to my knowledge defined as a part of health physics, some of us already are developing some familiarity with these other occupational hazards, and I believe it may be only a matter of time until some health physicists must assume surveillance responsibility for these. (16)

During the past year, in the United States there has been considerable controversy relative to nuclear reactor siting and some of the standards set for this purpose by our national organizations and by the International Commission on Radiological Protection. A number of criticisms have been directed at the U. S. Atomic Energy Commission leading to intense arguments, some of which have become emotional in nature and have resulted in Congressional hearings. It is my belief, however, that in many cases the contesting parties are not arguing about the same things, and difficulties have arisen because of poorly written U. S. Atomic Energy Commission rules and regulations which have not stated clearly the intent and proper means of implementing these radiation protection requirements and leave room for implications and improper interpretations. It is my belief that as with all important energy sources there are some risks associated with nuclear power plants, but these are relatively small and should be acceptable in terms of the risks associated with fossil-fueled power plants. I believe the uncertainty of the probability of risk of a major accident with one of these power plants, however, is sufficient that at present they should not be located in densely populated areas unless one can guarantee the probability of rupture of the secondary containment at the time of a meltdown and partial release of fission products is almost zero, i. e., less than 10^{-5} per power plant per year. It is for this reason and because of the thermal pollution problem that I would like to see these large nuclear power plants located at carefully selected sites on the seacoast or in underwater caissons far removed from our big cities. I would like to see more extensive studies of underground siting and construction of the secondary containment so that it would withstand any conceivable type of explosion. I would like to see the development and extensive use of high-voltage transmission, both a. c. and d. c. I would like to see an acceleration in cryogenic transmission because with the use of coaxial cables circulating liquid helium, one could transmit underground into the center of big cities all the power needed on a few cables. Most of all, I would like to see greater emphasis placed on the development of the fused salt, thermal breeder reactors with continuous removal and solidification of the fission products so that these reactors would at no time have a large inventory of fission products and so that the potential of a major accident would be eliminated at the source. Furthermore, thermal breeders use ^{233}U as the primary fissile fuel, and this as an environmental pollutant would be two orders of magnitude

less biological risk to the population than the ^{239}Pu of the fast breeder. Finally, I would like to see the development of programs to make use of the waste heat from these power reactors for the desalinization of water, the processing of sewage, the making of fertilizers, the heating of greenhouses and space heating for homes. I believe if these developments are to be completely successful, they must at all stages involve the active participation of the second generation of health physicists, many of whom have been trained by Fred Cowan whom we honor today.

The greatest challenge to health physicists is the professional challenge to us as individuals to adhere at all times to the highest of ethical standards, to seek radiation risks wherever they may be found and implement ways to correct them at all costs and regardless of opposition and to maintain a proper perspective in our attempts to balance the benefits against the risks from the many applications of all kinds of radiation. Many of us work with contractors, government agencies and medical organizations that are dedicated to advancing and expanding the application and use of these radiations, and occasionally we may find it necessary to "apply the brakes" and insist that certain rather unpopular radiation protection measures be enforced. Usually, the health physicist and his management see "eye to eye" and work together in harmony and full cooperation in minimizing unnecessary exposure to employees and in keeping environmental contamination at the lowest practical level. At times, however, some managements have been known to put production schedules, economy and a flawless record before radiation safety. It is at these times that I have been proudest of some health physicists who have been willing to become the targets of criticism and even suffer demotion because of a stand contrary to the will of their management; some have even sacrificed their jobs by insisting certain radiation standards be maintained at considerable cost and with resulting delays in programs. It is easy to be a cooperative "yes man" and find ways to justify the wishes and actions of an erroneous management, but it takes fortitude, character and men of real stature to put radiation safety and the well-being of employees and the public even before the will of your employer or the future of your job. It is this kind of health physicist that has brought us dignity and professional pride and assures the future of our organization of which we are proud to be a part as we strive to make this world a happier and safer place where we and future generations may live.

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