History of Radiography

X-rays were discovered in 1895 by Wilhelm Conrad Roentgen (1845-1923) who was a Professor at Wuerzburg University in Germany. Working with a cathode-ray tube in his laboratory, Roentgen observed fluorescent glow of crystals on a table near his tube. The tube that Roentgen was working with consisted of a glass envelope (bulb) with positive and negative electrodes encapsulated in it. The air in the tube was evacuated, and when a high voltage was applied, the tube produced a fluorescent glow. Roentgen shielded the tube with heavy black paper, and discovered a green colored fluorescent light generated by a material located a few feet away from the tube.

He concluded that a new type of ray was being emitted from the tube. This ray was capable of passing through the heavy paper covering and exciting the phosphorescent materials in the room. He found that the new ray could pass through most substances casting shadows of solid objects. Roentgen also discovered that the ray could pass through the tissue of humans, but not bones and metal objects. One of Roentgen's first experiments late in 1895 was a film of the hand of his wife, Bertha. It is interesting that the first use of X-rays were for an industrial (not medical) application, as Roentgen produced a radiograph of a set of weights in a box to show his colleagues.

Roentgen's discovery was a scientific bombshell, and was received with extraordinary interest by both scientist and laymen. Scientists everywhere could duplicate his experiment because the cathode tube was very well known during this period. Many scientists dropped other lines of research to pursue the mysterious rays. Newspapers and magazines of the day provided the public with numerous stories, some true, others fanciful, about the properties of the newly discovered rays.

Public fancy was caught by this invisible ray with the ability to pass through solid matter, and, in conjunction with a photographic plate, provide a picture of bones and interior body parts. Scientific fancy was captured by the demonstration of a wavelength shorter than light. This generated new possibilities in physics, and for investigating the structure of matter. Much enthusiasm was generated about potential applications of rays as an aid in medicine and surgery. Within a month after the announcement of the discovery, several medical radiographs had been made in Europe and the United States, which were used by surgeons to guide them in their work. In June 1896, only 6 months after Roentgen announced his discovery, X-rays were being used by battlefield physicians to locate bullets in wounded soldiers.

Prior to 1912, X-rays were used little outside the realms of medicine and dentistry, though some X-ray pictures of metals were produced. The reason that X-rays were not used in industrial application before this date was because the X-ray tubes (the source of the X-rays) broke down under the voltages required to produce rays of satisfactory penetrating power for industrial purposes. However, that changed in 1913 when the high vacuum X-ray tubes designed by Coolidge became available. The high vacuum tubes were an intense and reliable X-ray source, operating at energies up to 100,000 volts.

In 1922, industrial radiography took another step forward with the advent of the 200,000-volt X-ray tube that allowed radiographs of thick steel parts to be produced in a reasonable amount of time. In 1931, General Electric Company developed 1,000,000 volt X-ray generators, providing an effective tool for industrial radiography. That same year, the American Society of Mechanical Engineers (ASME) permitted X-ray approval of fusion welded pressure vessels that further opened the door to industrial acceptance and use

A Second Source of Radiation

Shortly after the discovery of X-rays, another form of penetrating rays was discovered. In 1896, French scientist Henri Becquerel discovered natural radioactivity. Many scientists of the period were working with cathode rays, and other scientists were gathering evidence on the theory that the atom could be subdivided. Some of the new research showed that certain types of atoms disintegrate by themselves. It was Henri Becquerel who discovered this phenomenon while investigating the properties of fluorescent minerals. Becquerel was researching the principles of fluorescence, wherein certain minerals glow (fluoresce) when exposed to sunlight. He utilized photographic plates to record this fluorescence.

One of the minerals Becquerel worked with was a uranium compound. On a day when it was too cloudy to expose his samples to direct sunlight, Becquerel stored some of the compound in a drawer with his photographic plates. Later when he developed these plates, he discovered that they were fogged (exhibited exposure to light). Becquerel questioned what would have caused this fogging. He knew he had wrapped the plates tightly before using them, so the fogging was not due to stray light. In addition, he noticed that only the plates that were in the drawer with the uranium compound were fogged. Becquerel concluded that the uranium compound gave off a type of radiation that could penetrate heavy paper and expose photographic film. Becquerel continued to test samples of uranium compounds and determined that the source of radiation was the element uranium. Becquerel's discovery was, unlike that of the X-rays, virtually unnoticed by laymen and scientists alike. Relatively few scientists were interested in Becquerel's findings. It was not until the discovery of radium by the Curies two years later that interest in radioactivity became widespread.

While working in France at the time of Becquerel's discovery, Polish scientist Marie Curie became very interested in his work. She suspected that a uranium ore known as pitchblende contained other radioactive elements. Marie nd her husband, French scientist Pierre Curie, started looking for these other elements. In 1898, the Curies discovered another radioactive element in pitchblende and named it 'polonium' in honor of Marie Curie's native homeland. Later that year, the Curies discovered another radioactive element which they named radium, or shining element. Both polonium and radium were more radioactive than uranium. Since these discoveries, many other radioactive elements have been discovered or produced. Radium became the initial industrial gamma ray source. The material allowed castings up to 10 to 12 inches thick to be radiographed. During World War II, industrial radiography

grew tremendously as part of the Navy's shipbuilding program. In 1946, man-made gamma ray sources such as cobalt and iridium became available. These new sources were far stronger than radium and were much less expensive. The manmade sources rapidly replaced radium, and use of gamma rays grew quickly in industrial radiography.

Health Concerns

The science of radiation protection, or "health physics" as it is more properly called, grew out of the parallel discoveries of X-rays and radioactivity in the closing years of the 19th century. Experimenters, physicians, laymen, and physicists alike set up X-ray generating apparatuses and proceeded about their labors with a lack of concern regarding potential dangers. Such a lack of concern is quite understandable, for there was nothing in previous experience to suggest that X-rays would in any way be hazardous. Indeed, the opposite was the case, for who would suspect that a ray similar to light but unseen, unfelt, or otherwise undetectable by the senses would be damaging to a person? More likely, or so it seemed to some, X-rays could be beneficial for the body.

Inevitably, the widespread and unrestrained use of X-rays led to serious injuries. Often injuries were not attributed to X-ray exposure, in part because of the slow onset of symptoms, and because there was simply no reason to suspect X-rays as the cause. Some early experimenters did tie X-ray exposure and skin burns together. The first warning of possible adverse effects of X-rays came from Thomas Edison, William J. Morton, and Nikola Tesla who each reported eye irritations from experimentation with X-rays and fluorescent substances.Today, it can be said that radiation ranks among the most thoroughly investigated causes of disease. Although much still remains to be learned, more is known about the mechanisms of radiation damage on the molecular, cellular, and organ system than is known for most other health stressing agents. Indeed, it is precisely this vast accumulation of quantitative dose-response data that enables health physicists to specify radiation levels so that medical, scientific, and industrial uses of radiation may continue at levels of risk no greater than, and frequently less than, the levels of risk associated with any other technology.

X-rays and Gamma rays are electromagnetic radiation of exactly the same nature as light, but of much shorter wavelength. Wavelength of visible light is on the order of 6000 angstroms while the wavelength of x-rays is in the range of one angstrom and that of gamma rays is 0.0001 angstrom. This very short wavelength is what gives x-rays and gamma rays their power to penetrate materials that light cannot. These electromagnetic waves are of a high energy level and can break chemical bonds in materials they penetrate. If the irradiated matter is living tissue, the breaking of chemical bonds may result in altered structure or a change in the function of cells. Early exposures to radiation resulted in the loss of limbs and even lives. Men and women researchers collected and documented information on the interaction of radiation and the human body. This early information helped science understand how electromagnetic radiation interacts with living tissue. Unfortunately, much of this information was collected at great personal expense.

Present State of Radiography

In many ways, radiography has changed little from the early days of its use. We still capture a shadow image of the sample with a detector opposite the x-ray source. Film is sometimes still used with procedures and processes technicians were using in the late 1800's. Today, however, we are able to generate images of higher quality and greater sensitivity through the use of higher quality films with a larger variety of film grain sizes. And, more recently, digital array detectors have largely replaced film in many industries.

Film processing has evolved to an automated state, producing more consistent film quality by removing manual processing variables. Electronics and computers allow technicians to now capture images digitally. The use of "filmless radiography" provides a means of capturing an image, digitally enhancing, sending the image anywhere in the world, and archiving an image that will not deteriorate with time. Technological advances have provided industry with smaller, lighter, and very portable equipment that produce high quality X-rays. The use of linear accelerators provide a means of generating extremely short wavelength, highly penetrating radiation, a concept only dreamed of a few short

Years ago. While the process has changed little, technology has evolved following radiography. Radiography has seen expanded usage in industry to inspect not only welds and castings, but to radiographically inspect items such as airbags and canned food products. Radiography has found use in metallurgical material identification and security systems at airports and other facilities.

Gamma ray

inspection has also changed considerably since the Curies' discovery of radium. Man-made isotopes of today are far stronger and offer the technician a wide range of energy levels and half-lives. The technician can select Co-60 which will effectively penetrate very thick materials, or select a lower energy isotope, such as Tm-170, which can be used to inspect plastics and very thin or low density materials. Today gamma rays find wide application in industries such as petrochemical, casting, welding, and aerospace.

Addressing Health Concerns

It was in the Manhattan District of US Army Corps of Engineers that the name "health physics" was born, and great advances were made in radiation safety. From the onset, the leaders of the Manhattan District recognized that a new and intense source of radiation and radioactivity would be created. In the summer of 1942, the leaders asked Ernest O. Wollan, a cosmic ray physicist at the University of Chicago, to form a group to study and control radiation hazards. Thus, Wollan was the first to bear the title of health physicist. He was soon joined by Carl G. Gamertsfelder, recently graduated physics baccalaureate, and Herbert M. Parker, the noted British-American medical physicist. By mid 1943, six others had been added. These six include Karl Z. Morgan, James C. Hart, Robert R. Coveyou, O.G. Landsverk, L.A. Pardue, and John E. Rose.

Within the Manhattan District, the name "health physicist" seems to have been derived in part from the need for secrecy (and hence a code name for radiation protection activities) and the fact that it was a group of mostly physicists working on health related problems. Activities included developing appropriate monitoring instruments, physical controls, administrative procedures, monitoring radiation areas, personnel monitoring, and radioactive waste disposal. It was in the Manhattan District that many of the modern concepts of protection were born, including the rem unit, which took into account the biological effectiveness of the radiation. It was in the Manhattan District that radiation protection concepts realized maturity and enforceability.

Future Direction of Radiographic Education

Although many of the methods and techniques developed over a century ago remain in use, computer imaging without the aid of film has replaced most radiographic inspections. The future of radiography will likely see many more changes.

Radiographers are now capturing images in digital form and sending them to the customer when the inspection has been completed. Film evaluation has given way to computer imaging systems. Systems will be able to scan a part and present a three-dimensional image to the radiographer, helping him or her to locate the defect within the part.