Non-Destructive Testing and Radiation in Industry

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SUMMARY Non-destructive testing (NDT) is a little known discipline which uses non-invasive and passive techniques to investigate the condition of materials and structures. Some of these techniques employ the use of radioisotopes. The penetrating radiations produced by these materials are applied in various ways to obtain the required information. This presentation is an overview of the application of radioisotopes within the scope of NDT. Notwithstanding the well established use of traditional materials, new forms of radioisotopes are being developed which will extend their capabilities.

1. INTRODUCTION

The application of radioisotopes in Non-Destructive Testing (NDT) can generally be characterised by the underlying premise that the process for which they are used gathers information without adversely affecting the material under test. Furthermore, it usually causes minimal disruption to the plant or equipment undergoing the test. NDT in a broader sense uses other methods as well, such as ultrasound, electromagnetism, x-radiation and infrared radiation to perform in principle the same type of tasks.

Clear benefits of NDT to its users are that it can reveal information about the condition of a material or process without causing adverse damage or disruption to the material or process. The best analogy for people not familiar with NDT is to compare it to a medical clinic where a person may present for examination by radiography, MRI, ultrasound and the like. The information about the body is obtained (hopefully) without injury or damage.

2. HISTORICAL USES

One significant early use of radioisotopes in NDT in Australia was the use of radium for radiography of turbine blades in the early 1950s.This was undertaken by the then Electricity Commission of New South Wales under the direction of an innovative chief metallurgist, Alex Wilson. Early work such as this provided information hitherto unavailable, other than by disassembly and inspection. At this formative stage the isotope was handled at the end of a “fishing pole”, with obvious risks to the operators.

The use of medical sources such as radon capsules normally applied to treatment of cancer, was also employed until dedicated industrial material became available and useable in convenient transport and exposure containers. Leo Gallagher who also worked for the Electricity Commission around this time designed and built early isotope "cameras" for use with cobalt and other isotopes.

<u>Contemporary uses</u>: It was from somewhat risky beginnings where the application was proven in the field rather than in the laboratory, that the use of radioisotopes in non-destructive testing grew rapidly once radiographers and plant managers appreciated the convenience of a small, simple, "self-powered" source of radiation, which was suitable for the examination of fabrications, castings and forgings, and of both ferrous and non-ferrous materials.

The types of radiation sources commonly used in industry are:

Am-241:	Backscatter gauges - Smoke detectors; Fill height detectors; Ash content
Sr-90:	Thickness gauging - Thicker materials up to 3mm
Kr-85:	Thickness gauging - Thinner materials like paper, plastics etc
Cs-137:	Density and fill height level switches
Co-60:	Density and fill height level switches
Ra-226:	Ash content
Cf-255:	Ash content
Ir- 1 92:	Industrial radiography
Yb-169:	Industrial radiography
Co-60:	Industrial radiography

Radiography is dealt with in more detail later but it is appropriate here to note other uses such as soil density and water content. In this application an Americium/ Beryllium combination generates gamma rays and neutrons which are permitted to pass through a sample of soil to a detector to effectively quantify density and moisture concentration. Such gauges are essential for road construction and other earth moving projects.

Fixed and mobile gauging is also common throughout industry. Where the density of material flowing through piping or the level of product, in hoppers is to be monitored and controlled, it can be done with instruments containing radioisotopes. Sugar, petroleum, plastics, coal, raining, paper and cardboard manufacturing and many other process industries utilise fixed gauges for this purpose. Isotopes employed in these applications may be Krypton 85, Caesium 137, Thallium 204, Strontium 90 and Cobalt 60, depending on the type of material to be monitored.

Some modern portable "C" arm gauges now connect directly to computer programs, which analyse the amount of radiation detected to produce data and graphical displays. The display may represent cross sections through pipes for wall thinning, through telegraph poles or trees for termite damage, mooring posts for internal rot or the checking of product density in pipes or on conveyor belts. These determinations are carried out in real time, with digital storage of images and other data. Reports generated on site and direct comparison to previous inspection results can be used in trend analysis techniques.

Wear indicators in refractory linings are usually small sources of Cobalt 60, which are embedded at different depths from the outer surface of a furnace. Cobalt 60 is chosen because it continues to emit a detectable amount of radiation effective over the life of the furnace, which is four to five years. As the lining of the furnace deteriorates and collapses inwards, which is normal, so the radioactive sources are lost to the furnace product. By monitoring the position of the embedded sources and those sources which are lost, the remaining thickness of refractory lining can be indicated, around the circumference of the furnace. Accordingly a maintenance program can be implemented which ensures that the wear, of the lining is monitored and repaired before the safety and integrity of the furnace is compromised.

Industrial radiography does in many instances us x-ray generators but, as was noted above may employ radioisotopes as simple compact devices independent of external power. This facilitates the examination of pipelines, pressure vessels and even jet engines where access to the interior is difficult, or remote plant locations where availability of electrical power is not practicable.

The uses of radiography are many and varied. Crack and corrosion detection, foreign object detection and correct assembly checks being the major ones. Radiography has the advantage of producing a permanent record and has the ability to 'see through' things, which means there is usually no need to disassemble structures to inspect an individual component.

Radiography has two major disadvantages, the most important being the potential harmful effects of ionising radiation on living tissue. Industrial radiography, with high power settings and relatively long exposure times requires a strict adherence to safety procedures by all involved and periodic check on personnel exposure. Good safety practice is required for both the operational personnel and the public. The second disadvantage is that radiography requires a comprehensive facility for exposure, film processing, viewing and storage. These facilities can be expensive.

While x-ray generators emit a broad band of wavelengths, gamma -ray sources emit only one or at most a few discrete wavelengths. Gamma-rays are often specified in energy terms (keV and MeV) and not wavelength. Cobalt 60 for example has principal energies of 1. 17 and 1.33 MeV. Such energies permit the economic radiographic examination of steels up to 20 cm thick. If x-ray examination was used in these instances the equipment would be very high energy and very expensive. In combination with the correct type of radiographic film or recording device, good quality images can be produced repeatedly.

The purpose of much industrial radiography is to produce an image of joints in structures such as pressure vessels, plant and equipment, fabricated building structure, theme park equipment and amusement rides, elevated work platforms, transportation equipment, pipelines and many other devices which are welded, cast and extruded. The NDT can be part of the manufacturing quality assurance process or be applied in the field as part of preventative maintenance programs. In both instances it is cost effective in improving safety and reliability.

Petrochemical and power generation industries are major uses of this technology. The safety considerations of such large operations, which elsewhere in the world include nuclear power generation, are self-evident. Radiography using radioisotopes is a major contributor to the maintenance of safe plant.

There are many industry codes and standards, both international and domestic, industry specific and generic, which apply to the various items inspected by radiography, and to the methods of radiography itself. Compliance to these codes and standards ensures a degree of workmanship and product quality commensurate with acceptable safety requirements.

One recent development in gamma radiography is the improvement in Selenium 75 material as a viable alternative to Iridium 192. Earlier Selenium 75 products were too large for common projector devices and there were some safety concerns because of its high volatility and chemical reactivity. A thermally stable metal-selenide isotope with a longer half life (172 days) than Iridium 192 (74 days) has been developed. It has been particularly successful in replacing x-ray devices in some pipeline crawler applications.

The following is a brief summary of common uses of radiography using Cobalt-60 and Iridium-192, and the advantages and limitations:

Measures or detects:

- Internal defects and variations; porosity; inclusions; cracks; lack of weld fusion; geometry variations; corrosion thinning.
- Thickness, gap and position.
- Incorrect assembly and misalignment.

Advantages:

- Low initial cost.
- Permanent records; film.
- Small sources can be placed in parts with small openings.
- Portable.
- Low contrast.
- No disassembly.
- Self powered
- Acceptable image quality
- Variety of energy isotopes available

Disadvantages:

- One energy level per source.
- Source decay.
- Radiation hazard.
- Trained operators needed.
- Lower image resolution.
- Cost related to source size.
- Cannot be turned off.

Safety Precautions The use of radioisotopes in any setting has attendant risks and hazards, and their use must be justified on net benefit grounds. Industrial applications are no different. Occupationally and non-occupationally exposed persons are considered. Practical, operational codes of practice form the basis of work procedures using these potentially dangerous materials. In Australia, the National Health and Medical Research Council has provided a number of these codes of practice covering fixed gauges, industrial radiography and others. NSW radiation licences issued under the Radiation Control Act 1990 by the Environmental Protection Authority, typically note these codes. as conditions of licence. Other States follow similar guidelines. Licence holders are directly responsible for their safety, the safety of their fellow workers and those of the public, which may be affected by the use of radiation devices.

Additionally, the careful control of inventory of radiation sources is fundamental to their safe use; Loss of radioactive material does occur from time to time in industrial environments and the underlying cause, is in most cases traceable to lack of inventor y control. One activity which has a history of this problem is metal recycling where the demolition of plant may inadvertently contain derelict fixed radiation gauges. Other sources of radioactive materials are less frequent. Many scrap metal processing facilities now acknowledge this problem and the potential financial impost and disruption it may cause, by installing radiation detecting equipment at the reception point of the facility. These devices are capable of detecting small amounts of radiation coming from deep in loads of scrap in trucks and railway carriages. On detection of any radioactive materials, the load is immediately rejected and returned to its originator to identify the source.

Conclusion: The use of existing and newly developed radioisotope materials in traditional and innovative applications will continue in non-destructive testing. The benefits which they bring about, by additional plant and system safety, process control and productivity, genuinely contribute to the advancement of our modern society. The major costs of their use are in their regulation and management. NDT in all its forms permeates every aspect of our lives, often hidden or simply not acknowledged. The use of radioactive materials is an important segment of NDT and deserves to be recognised for the contribution it makes.