Safety and radiation emissions

In order for a system to be used in an industrial environment, it must meet strict regulatory standards in terms of operator safety. These requirements fall into three categories:

- Safety interlocks to protect operators when opening the machine
- Mechanical safety of the machine
- Emitted radiation levels

Safety interlock circuits

The interlock circuitry must, of necessity be fail safe. This means that it must have the following features:

- There must be two circuits passing through the interlocks, so that if one circuit fails in a way such as to compromise security, the other will still afford protection.
- There must be positive acting interlock (usually this means having a mechanical striker). Generally, inductive or magnetic interlocks devices are not considered secure.
- The two circuits should be wired through a safety relay. The purpose of the safety relay is to ensure that the two interlock circuits are made / opened within a short time interval of each other (20ms). This makes it virtually impossible to defeat the interlock circuits accidentally.
- The safety circuit is also responsible for control and shut-down of the mechanical devices in the machine. This includes disabling the conveyor, and dumping air from the pneumatic circuits.

Mechanical safety of the machine

In addition, the system should provide the following features:

- A monitored X-ray indication lamp, so that operators are aware when X-rays are being generated. If this lamp fails, the generation of X-rays is inhibited.
- A lock-out switch so that the system can be disabled from use by unauthorized personnel.
- Emergency stop control, accessible from both sides of the machine.

Emitted radiation

Emitted radiation is measured by means of a Radiation Survey Meter, which is usually a compensated GM (Geiger Muller) tube. The measurement units are in microsieverts/hour or millirad/hour (1 millirad = 10 microsieverts).

The regulatory authorities in various countries strictly control the level of the emitted radiations that are acceptable. A short summary of these standards is:

- United States: There are separate state and federal regulations, but the FDA federal regulations are, in general, the most stringent standards applied. FDA1020.40 mandates a maximum level of emissions from “cabinet” X-ray systems of 5 microsieverts/hour.
- European Union: The Euratom 1999 regulations, which are being adopted by most countries in the EU, mandate a maximum emission level of 1 microsievert/hour.
- Japan: The control of X-ray equipment id controlled by the Ministry of Labour which stipulates a limit of 2.5 microsieverts/hour.

What does this mean?

There are many sources of radiation, both naturally occurring and man-made. Typical of the naturally occurring ones are:

1. Background radiation. In regions close to certain rock deposits, and also in areas where there are certain types of clay, the background radiation level due to heavy elements of Radon gas can exceed 0.5 microsieverts/hour. People living in these areas are subjected to this permanently, and the accumulated dose received is likely to be very much higher than that received when working in the close proximity of a commercial X-ray system.
2. Cosmic radiation. Most people will encounter this, when flying a commercial jet. Typical radiation levels when flying at 35,000 ft (11,000m) would be 3-4 microsieverts/hour.

Man-made sources of radiation include medical and dental X-rays, and emissions from the nuclear power industry.

In conclusion, the radiation levels of an X-ray system which conforms to the regulatory standards will be extremely low. In general, a well-designed industrial X-ray system will have emission levels, which are virtually unmeasurable.

**Measurement of emitted radiation**

There is no such thing as a general radiation meter – different meters will respond to different parts of the energy spectrum. It is therefore important to select a radiation survey meter that is responsive to the part of the energy spectrum in which the system is operating.

Secondly, systems that are capable of generating X-rays at low energies (incorporating Beryllium window tubes) will require a compensation cap which is used to filter out very low energy emissions which could cause erratic readings.

The time constant of the meter should be long enough to average out momentary fluctuations in the readings. A typical time constant of 10 seconds is stipulated.

Radiation meters must be calibrated annually. At the time of calibration, a “conversion constant” for that meter will be calculated. The value displayed by the meter, should then be multiplied by the conversion constant, to give the actual radiation reading.

**Recommended radiation survey policy**

In most countries of the world, it is only mandatory to survey machines once per year. However, this does not mean that if a problem has occurred on a machine, that results in a higher than normal emission, which has only been picked up on an annual survey – the user does not know how long such a problem has been present.

The recommended procedure involves making a short survey at weekly intervals, recording the emissions at, typically 8 to 10 points around the machine, and recording the results on a log sheet. This would be performed by a member of the user’s plant personal, who has received training on the use and interpretation of the radiation survey meter. Such a survey takes less than 5 minutes to perform, but will provide re-assurance that the system is working within its specified parameters. This procedure follows the legislative requirements in the UK.
Irradiation of products

Products passing through the systems receive a small radiation dose. Many users of automatic on-line X-ray systems require that the level of irradiation is understood, and measured, so that it may be confirmed that the product is not adversely affected by the dosage. This is particularly true of users in the pharmaceutical industry, where it is important that the efficacy of the product is maintained.

There are two matters of interest here:

1) What is the total dosage received by the product?
2) What is the effect of the dosage on the product?

The total dosage received by the product can be calculated by measuring the accumulated dose level on a XXX device. The device would be passed through the system a number of times (typically 10 to 100 times) so that a measurable dose is recorded. It is then possible to estimate the period of irradiation that can be sustained before the dosage exceeds specified levels.

For pharmaceutical efficacy tests, samples of the product would be passed through a number of times (again, typically 10 to 100 times). These products would be then tested at various times in the future (1 month, 3 months, 6 months) to assure that there has been no deterioration of the product, attributable to the irradiation.

During normal operation, the degree of irradiation is very small. This is because the width of the X-ray beam is typically 1 – 2 mm. If the product is passing down the conveyor at, say, 30 meters/min. the time that it is under the beam will be 2 to 4 millisecs.

However, if the product is stopped, while the X-rays are still turned on, it is possible for part of the product to be irradiated for a long period. Precautions would have to be taken to guard against this condition. There are two main circumstances where this might happen:

- For pipeline systems, if the in-feed flow of product to the pump is stopped, the product will be stationary in the pipe. This could be quite a frequent occurrence in normal operation. Therefore, in this case, the collimator of the X-ray generator would be fitted with a shutter, and a signal from a pump encoder is fed to the system. The system will therefore monitor the pump speed and if the pump stops for more than a preset time, the shutter would be closed, thereby cutting off the X-rays from the product. The advantage, in this case of using a shutter, is that the X-rays can be re-enabled very rapidly.

- For conveyor systems, if the conveyor stops, a similar condition could exist. An encoder is attached to the conveyor, and which will indicate to the system that the conveyor is no longer moving. In this case, the X-ray system will have its own conveyor which would never normally be stopped – therefore a simpler solution is that the monitoring program would shut down the X-ray generator in the event of a fault condition.