// Radioactive Isotopes in Process Measurement

An Objective Look at the Roles of Cesium-137 and Cobalt-60 in Nuclear Measurement Systems for Industrial Processes

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Level and density measurements in process control are performed by a number of technologies. When the process temperature, pressure, or chemistry is an issue, then nuclear measurement systems have the advantage. These are non-invasive to the vessel and unaffected by the process pressures and chemistries.

Overall, a nuclear measurement system used for process control consists of a gamma energy emitter and detector. An emitter is placed on one side of a vessel to broadcast a beam of energy to the opposite side of the vessel. The detector is placed in the beam on the opposite side of the vessel. The detector will scintillate in the presence of gamma energy and register counts proportional to the field strength. When the process value (level or specific gravity) is low, the detector will register a high number of counts since less gamma energy is blocked by the process material. When the process value is high, more of the gamma energy is blocked which leads to fewer counts.

The two most common gamma emitters used for level and density process measurements are isotopes of cobalt and cesium. The goal of this article is an objective comparison of the roles of cesium-137 and cobalt-60 in process measurement. This will be accomplished by reviewing the properties of the two materials and then comparing the use of the materials in process measurement.

// Property Review

Cesium-137 is a gamma emitter with a half-life of 30.2 years (Weast B-271). It is a by-product of fission in nuclear reactors. It will decay by ß decay into barium-137. Cesium-137 gamma rays have energy of 662 keV, about half the energy of cobalt-60 (Weast B-333).

Cobalt-60 is also a gamma emitter with a half-life of only 5.2 years (Weast B-244). It is a synthetic radioactive isotope produced by neutron activation of cobalt-59. To become stable, cobalt-60 also undergoes ß decay and emits two gamma rays with energies of 1.17 MeV and 1.33 MeV (megaelectron volts), becoming the stable element nickel-60 (Weast B-321).

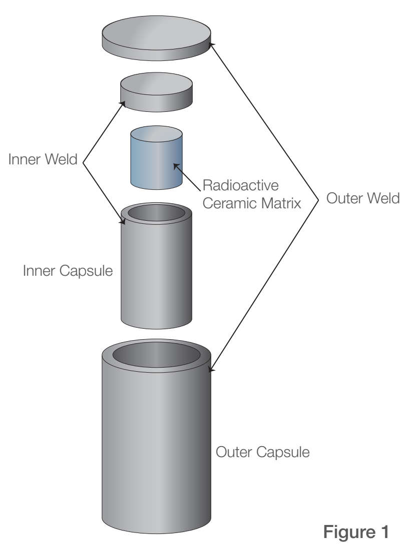

Figure 1

For process level and density measurements, whether the isotope is cesium-137 or cobalt-60, the radioactive materials are inside of a double encapsulated stainless steel cylinder, an example of which is shown in Figure 1. The gamma energy emitted from these capsules does not make an object or person radioactive due to the fact that gamma energy largely passes through objects and people. Some energy will be lost via Compton scattering as the rays pass through mass. The energy from these rays will be dissipated as they are deflected by atoms contained within the mass. However, this scattering does not make the object or person radioactive.

A person or object is only contaminated or made radioactive if the isotope itself leaks from the capsule and is either ingested by the person or comes in contact with the object. It is extremely unlikely that the material will leak from these capsules. The use of radioactive materials in industry is fairly commonplace and has been for over 60 years. These materials should be respected, but not feared.

// Choosing the Best Isotope

As discussed, there are key differences between cesium-137 and cobalt-60. These differences allow the choice of the best isotope to be made.

In nuclear level measurements, the level or density is inferred from the gamma energy field strength registered by the scintillation detector. If the gamma energy does not reach the detector, then there is no measurement. When selecting an isotope, the first decision factor is whether or not the gamma energy is able to pass through the process vessel and material, and register at the detector.

In the case of thick walled vessels, or where a density measurement is required on a dense process material in a large pipe, the largest available activity allowed in a cesium-137 source holder may not penetrate the vessel and reach the detector. In this case, cobalt-60 will be required. As discussed earlier, cobalt-60 gamma emission is twice as energetic as that of cesium-137. The higher energy of cobalt-60 allows it to penetrate more mass than the equivalent activity of cesium-137. Therefore, when cesium-137 cannot produce gamma energy at the detector but cobalt-60 can, the choice is easy.

In cases where both cesium-137 and cobalt-60 provide enough gamma energy at the detector, then one must look at other factors. This involves a look into the differences in characteristics of the two isotopes.

One of the key differences in the characteristics of cesium-137 and cobalt-60 is the half-life of the two isotopes. As discussed above, cesium-137 has a half-life of over 30 years, versus cobalt-60 at 5.2 years. One half-life is the time it takes for an isotope to lose half of its activity. For example, if you have a 100 mCi activity capsule of cesium-137, after thirty years that capsule will have an activity of only 50 mCi. The activity of all radioactive materials decreases with time as they naturally decay. A cesium-137 capsule will generally outlast the lifetime of the detector electronics, whereas a cobalt-60 capsule generally needs to be replaced every 5 to 8 years. The use of cesium-137 translates into cost savings to the customer over the lifetime of the measurement system.

Replacing the capsule involves removal of the source holder from the vessel, the services of a licensed specialist to remove the spent capsule from the holder, installation of a new capsule and remounting of the holder on the vessel. Also, there is the possibility of process downtime depending on turnaround time required and the process manufacturing requirements. In the case of cobalt-60 capsules, this expense will be incurred every 5 to 8 years, but for cesium-137, this process is relatively rare.

There have been several customer situations in which the lifetime of the ion chamber detector, a previous nuclear detector technology, had run its course and needed to be replaced with more up to date scintillation technology. Due to the fact that the scintillation detector replacement of today has increased sensitivity over the ion chamber, the cesium-137 source capsule did not need replaced. In some cases, shielding between the source and detector is needed because the field emitted by the original source capsule is stronger than ideal for today's scintillation detector technology. The cost savings here can be considerable.

A second difference to note is the energy associated with each isotope. The gamma rays emitted by cobalt-60 have nearly twice the energy of those of cesium-137, which presents two considerations. First, it allows cobalt-60 to have the advantage in applications with thick walled vessels, or heavy process materials in the case of density measurements, when cesium-137 does not have enough energy to penetrate the process vessel and material. On the other hand, for an equivalent activity of cesium-137 and cobalt-60, a cobalt-60 capsule requires a larger and heavier source holder to allow the field outside of the holder to meet the customer's radiation specification. Mounting concerns may arise here, as the weight of the source holders may be substantial.

The second consideration of the energy difference is the efficiency of the detector. Due to the increased energy of the cobalt-60 gamma rays, more of the rays will pass through the scintillator without interacting with it than those of cesium-137. When the same scintillation detector is placed in a 1 mR/hr field of gamma energy emitted by cobalt-60, the device will register only 60% of the counts as it will when in a field of energy emitted by a cesium-137 capsule.

In a density application, seen in Figure 2, where the change in counts between high and low specific gravities is typically

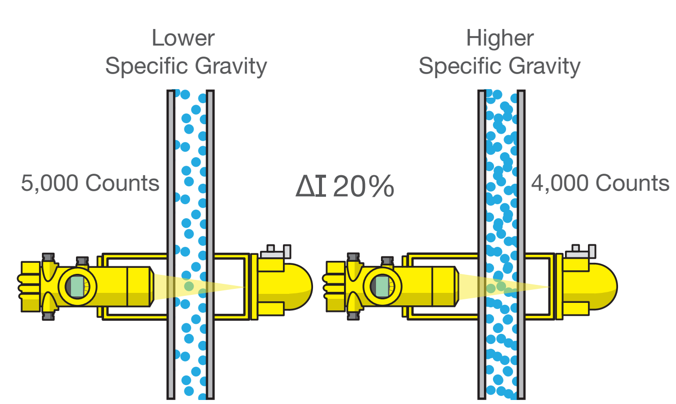

Figure 2

in the range of 20% to 30%, a cesium-137 source capsule will provide for an easier calibration and better measurement quality. As the specific gravity range of two materials gets closer, it becomes difficult to get satisfactory resolution for the measurement. In order to increase the resolution, the counts generated by the detector must increase in a given gamma energy field strength. Cesium-137, which provides 40% more counts per mR/hr, is a better choice of isotope for density measurements provided that its energy can penetrate the process vessel.

Another way to look at this topic is that in order to generate the same number of counts at the detector, the radiation field generated by a cobalt-60 capsule will need to be 40% larger than the field emitted by a cesium-137 capsule. In cases where the change-in-counts (ΔI) for an application is low, cesium-137 will provide a more reliable measurement at lower field strengths than cobalt-60.

// Conclusion

In summary, the two most common isotopes used for nuclear measurement are cesium-137 and cobalt-60. Deciding which isotope is the best depends on the application. Provided that cesium-137 can penetrate the process and generate a gamma energy field at the detector, it is typically the isotope of choice given its benefits over cobalt-60.

Comparison of Isotope Benefits

	Cs-137	Co-60
Low operational cost	Yes	No
	Half-life of 30 years minimizes replacement requirements	
Smaller size and weight	Yes	No
	Less shielding mass required	
Low ΔI applications	Yes	No
	Provides more scintillation for better measurement performance	
Thick-walled or large diameter vessels	No	Yes
		Cs-137 energy will not reach the detector
Heavy slurry Density measurement	No	Yes
		Cs-137 energy will not reach the detector

// Appendices

Appendix A — Authors

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Appendix B — References

Weast, Robert C., and Melvin J. Astle and William H. Beyer. CRC Handbook of Chemistry and Physics. 65th ed. Boca Raton: CRC Press, Inc., 1984. Print.