N196. Pilgrim's Progress Points the Way to Cobalt Reduction

The use of cobalt alloys is to blame for most of the occupational exposure at U.S. light water reactors (LWRs) -- and they can be eliminated, as experience at the Pilgrim boiling water reactor (BWR), and elsewhere, clearly shows. Most ALARA programs focus on time-distance-shielding, which is of limited value compared with removing the source of the problem: cobalt. The U.S. nuclear industry should set itself the target of cobalt elimination.

The choice of cobalt alloys for bearings and wear surfaces within LWR coolant systems was known from the beginning to be problematic. Wear, corrosion, and erosion products from the cobalt alloys would be transported by the reactor coolant through the reactor. Neutron irradiation of the natural cobalt-59 from the alloys would then become the source of the occupational radiation exposure experienced by workers in nuclear power plants.

At the end of 1989, cumulative occupational radiation exposure for U.S. LWRs was 644,200 person-rem. About 515,400 person-rem could be attributed to cobalt-60. Of that amount, about 464,000 person-rem (90%) is attributed to cobalt alloys that were designed intentionally into the plants. If operation of existing U.S. plants continues without substantial reduction of cobalt alloys, they could accumulate 1,500,000 more person-rem during their initial license period. The total cost for the remaining radiation exposure and disposal of the cobalt-60 generated from cobalt alloys in existing plants would be about $16 billion, or about $5.3 million per plant per year. Therefore, an aggressive cobalt source-elimination program is needed.

Cobalt alloys were developed in the late 1940s. Applications included weld-deposit hardfacings for severe wear (such as the wear edges of earthmoving machinery), and castings and wrought alloys for use in corrosive and high-temperature environments. In the early years of nuclear plant development, cobalt alloys were a ready alternative for high-wear components in reactor coolant environments.. Designers of equipment often decided they were the best materials, notwithstanding the expected detrimental effect on occupational radiation exposure. The expected exposures are continuing.

Concurrently, experience with various geometries, loads, operating regimes, and manufacturing controls showed that cobalt alloys are not the most wear-resistant material for many applications. This experience suggests that it is feasible, without development of new materials, to remove cobalt alloys extensively from existing nuclear power plants.

At Pilgrim, a 1998 MWT BWR, feedwater is pumped through flow-regulating valves directly into the reactor vessel. Estimates of the cobalt-59 input rates to the reactor fluid from such valves range from 38g to 114g of cobalt-50 per year, indicating that feedwater regulating valves are a major source of the total cobalt-60 inventory.

Pilgrim maintenance records show that the internals of the two 14-in valves were replaced four times in the first six years of station operation. In 1977, the cobalt alloy hardfaced parts were changed to type 420 stainless steel (420 SS). No materials development work was done; the procurement lead time was negligible compared to that for cobalt alloy replacement parts; and costs were about half those for cobalt alloy parts. Since then, the valve seats have been lapped once.

The Vermont Yankee experience with feedwater-regulating valves is similar in design to Pilgrim's. Recurring maintenance, coupled with an awareness of the relationship between cobalt and high occupational radiation exposures, prompted the utility to replace cobalt alloy valve parts with type 440C stainless steel (440C SS) in the fall of 1981. Vermont Yankee indicated that the same 440C SS internals have performed satisfactorily from January 1982 to the present.

BWR control blades designed in the U.S. contain roller bearings at top and bottom ends which guide the blade travel between fuel channels. The original designs specified cobalt alloys for both rollers and axles. These bearings are a major source of cobalt-60 in the BWR for two main reasons:

1. There are a large number of bearings performing a wear function in an aggressive environment. A reactor typically has 125 to 200 control blades with eight roller and axle sets per control blade.
2. By design the blades have a high residence time in a neutron flux, especially at the upper end. The continual residence in neutron flux of the cobalt-59 bearings causes these specific cobalt alloy parts to be the most concentrated in cobalt-60 of any parts in the plant.

In 1978, General Electric (GE) and the Electric Power Research Institute (EPRI) began a joint effort to find alternative bearing materials. After substantial research and testing, commercially available substitutes were chosen -- Inconel X-750 rollers and PH13-8Mo stainless steel axles. In-reactor tests began in 1981, and since 1987 GE has produced only control blades without the cobalt alloys. Once again, no new materials development was necessary.

In general, the operating lifetime of a control blade is dependent upon the neutron exposure to which the blade is subjected. Under certain operating regimes, many blades can remain in service for the full initial license period, as well as for an additional 40-year relicense period before reaching their neutronic end of life. Therefore, without accelerated replacement of original equipment blades, BWR operators will be faced with continuing radiation exposure and radwaste burden from this source until decommissioning.

Other Cobalt Contributors. A total of between 300 and 500 components (primarily valves) in typical LWRs contribute to the reactor coolant cobalt inventory. Many of these components may not (or do not) require cobalt alloys.

The degree of difficulty and the risk inherent in removal of cobalt alloys from these components varies. Risks associated with new developments must, of course, be controlled. The costs of eliminating cobalt alloys can be controlled by applying a program with the following steps:

- Identify all cobalt contributors in the plant.
- Identify and procure non-cobalt replacements for parts or components, and install at all opportunities arising during normal necessary maintenance.
- Evaluate major cobalt contributors, and replace on a case-by-base basis.
- Identify non-cobalt parts of components in drawings, manuals, maintenance instructions and inventory systems.

Impact on Exposures. Estimates vary, but cobalt-60 was credited for about 80% of accumulated occupational radiation exposure for U.S. LWRs up to the end of 1989. Cobalt alloys are responsible for about 90% of cobalt-60 inventory, with trace cobalt accounting for the balance.

Taken from "Why are We Still Using Cobalt? Pilgrim's Progress Points the Way," Ed Wagner and George Vazquez, Nuclear Engineering International, October 1992, p. 43.