Cook Unit 2 Refueling Outage ALARA Success: 34 Person Rem

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Abstract:

In October of 2010, DC Cook-2C19, a 4 Loop Westinghouse Ice Condenser PWR, is very close to establishing a new US record for the lowest collective work dose received during a 32 day refueling outage planned for 29 REM. In 1974, Pt Beach-1, a two loop Westinghouse PWR, performed a 28.4 REM refueling outage. The success is a culmination of a collaborative process designed to identify and execute changes to achieve a sustainable reduction in the impact of RCS corrosion products on DC Cook radiation exposure maintenance and operations, while simultaneously in improving RCS component reliability and fuel performance.

AEP DC Cook plant managers are constantly challenged to continuously examine the processes which impede maximizing the safe and economic operation of Unit 1 and Unit 2. Reactor coolant system erosion, corrosion and wear of components and piping systems is the primary cause for deposition of metal oxides throughout the reactor coolant primary system. These corrosion products are known to degrade fuel and RCS component performance, and when activated, elevate plant radiation levels and consequently, the costs of operations. Outage duration, radiation worker productive, low level waste costs, and worker radiation exposure were are also impacted. In 2002, AEP had identified an emerging new solution, first used at Turkey Point 3,4 in 2000, to reduce the impact of corrosion product transport and build-up in the PWR primary circuit. The new solution was derived 1) new technology from US Department of Energy National Nuclear Technology Research Laboratory and 2) the applied engineering experience of the technology licensee of world wide rights. AEP DC Cook in collaboration with the small business licensee, identified and implemented a series of actions which has resulted in a sustained reduced in radiation source term for Unit 1 and Unit 2 since 2002, which has culminated in setting US low dose record refueling outage.

The message of this paper is reducing radiation source term is not just good for worker radiation exposure, but good for the RCS fuel and component reliability, and good for outage performance.

Introduction:

In 2002, DC Cook had identified a new source term solution. Based on early success of this solution at FPL Turkey Point 3,4 and VC Summer, in 2002, DC Cook initiated a collaborative process with an engineering services company to implement the solution in Unit 1.

DC Cook just completed the 6th cycle for Unit 1 and 4^{th} cycle for Unit 2. Key to the solution is technology based on research performed by Los Alamos National Laboratory for processing of post Cold War nuclear weapons materials. The source term reduction engineered solution is comprised of 2 main parts:

1) An engineered solution for mitigation of source term transport and deposition based on review and revision of the shutdown/start-up sequence

2) Recently developed technology embodied in a surface modified ion exchange resin, or rather a uniquely enabled specialty media, for use in the CVCS purification demineralizers. Polymer filtration technology is exclusive licensed to the nuclear services company and includes world wide rights, for all fields of application, as assigned by the University of California, Los Alamos N. L. License fees and royalties are used to further nuclear research.

This technology, coupled with DC Cook excellent ALARA program, FME control program has resulted in U2C18 establishing a new low dose refueling outage record of 34.8 REM, for a 32 day refueling outage. DC Cook U1C23 has just finished a 34 day refueling outage at 37.0 REM.

Source Term Solution Description:

DC Cook in collaboration with nuclear services company revised the shutdown and start-up sequence designed to mitigate the transport and deposition of colloids (extremely small electrostatically charged insoluble iron oxyanions).

The second part of the solution was the use of a PRC-01 (particle removal cation) specialty resin uniquely designed to mitigate the formation, transport and deposition of colloids. These colloids and their chemistry during shutdown and start-up are in large part responsible for the Cook source term deposited in ex-core components and pipes. It should be mentioned that D C Cook always had CVCS removal efficiencies for Co-58 and Co-60 in excess 95% PRIOR to use of specialty media, but no improvement in source term during the use of conventional ion exchange mixed bed resins.

Quantitative Results of Source Term Reduction at Cook:

At DC Cook, in 2002 for Unit 1 and 2004 for Unit 2, the first use of the source term solution was accomplished with the revised shutdown and start-up sequence and specialty filter media in CVCS purification system. A significant sustainable decline in source term was achieved in each of the next 6 refueling outages, since first application in 2002 for Unit 1. The removal of the RTD by-pass lines eliminated a dose rate controlling crud trap in lower containment. This enabled the ability to more accurately measure the impact of the source term reduction solution in the area of the steam generators that had been used to reduce ex-core dose rates through the past 6 cycles. Dose rate reductions in other locations of the plant are well documented from Letdown Heat Exchange, RHR Heat Exchangers, RHR pumps, and others through the use of remote monitoring for each refueling outage.

Figure 1 shows the significant drop in the average hot leg and cold leg steam generator dose rates for the past 3 refueling outages for Unit 2. The RTD lines were removed in 2007. The engineered solution and PRC media has been in operation continuously since first implement. The data shows a significant 75% decline in average hot leg and cold leg of the channel head steam generator dose rates.

The U2C18 performance established a new US PWR ice condenser outage low dose record at 34.8 REM. DC Cook 1C23 will be the second lowest dose ice condenser record at 39 REM (EPD).

Quantitative measures of the source term reduction solution including PRC resin effectiveness are coupled with other RP variables such as good outage work management practices and good radworkers skills in the field. However, other quantitative measures of the specialty resin effectiveness include the following:

1. Lower dose rates in Unit 1 and Unit 2 containment have eliminated the need for 4 temporary shielding packages to be installed for the refueling outage. This was enabled by the lower dose rates that continue to decline inside containment. This permits the reallocation of critical outage resources from shielding installation/removal to other priority outage work activities.

2. Lower dose rates have also resulted in the reduction of the number of high (HRA) and the number of locked high radiation (LHRA) areas in both Unit 1 and Unit 2. As a result of lowering dose rates and down posting or elimination of LHRAs or HRAs, the Radiation Protection personnel coverage requirements and the risk of LHRA and HRA area entry challenges. This permits the reallocation of RP personnel to outage priority work activities.

3. Prior to the use of NPE solution, DC Cook use to generate 4 to 8 very high dose rate RCS filters and RCP seal injection filters during a cycle/refuel. Dose rates were in the 40 to 200 R/hr range. As a

result of the source term solution and PRC resin, DC Cook generates one RCS low dose filter and 1 RCP seal water injection filter a cycle, including refueling outage. That is changed procedural, not due to high dose rates or high-pressure drop. DC Cook routinely uses 0.1 um RCS filters. This has saved DC Cook an estimated $100,000 in filter disposal costs per fuel cycle.

4. RCS cleanup, following the hydrogen peroxide addition, was completed ahead of outage schedule and had no impact on critical path. Prior to implementation of NPE solution and PRC, DC Cook Unit 1 had 7.98 uCi/cc peak activity, which delayed critical path for clean up. It also delayed personnel from entering upper containment and lower containment due to very high dose rates. DC Cook U1 C18 had a 0.181 uCi/cc peak peroxide release. This low CRUD burst peak allowed immediate access to upper and lower containment. Bench mark data from no PRC plant, ice condenser plants, have peak releases that delay access to containment and critical path time, some 36 to 50 hours is required for RCS activity cleanup before containment is released for access. DC Cook Unit 1 has reduced critical path and work release restrictions by 24 hours per refuel.

5. Lower than projected general area dose rates were experienced in lower containment.

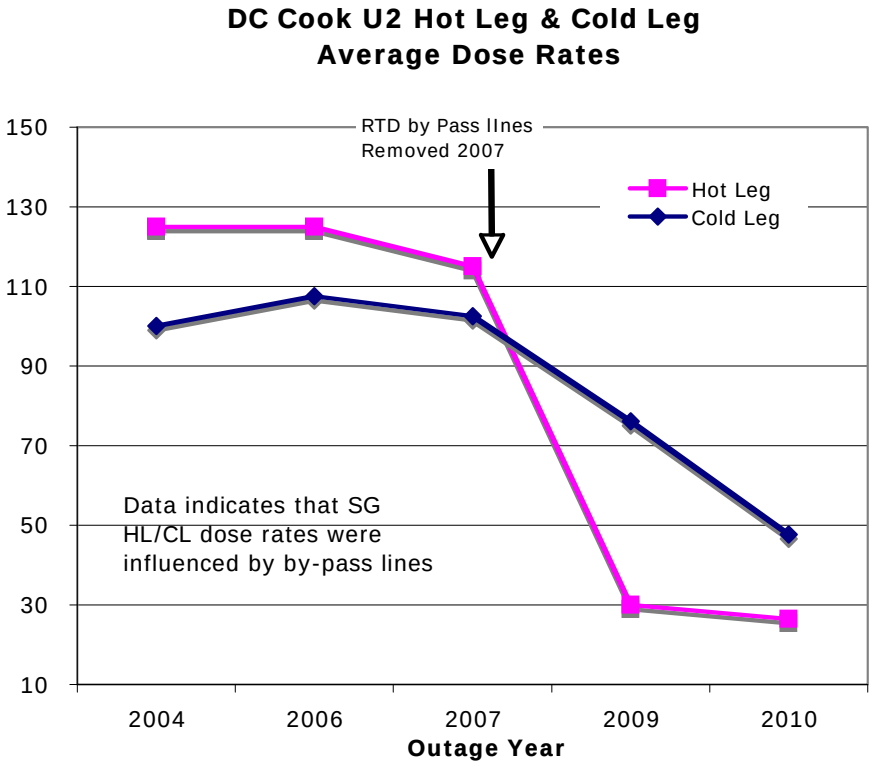
6. The reactor cavity water clarity was exceptional. This aided in fuel movement quality assurance.

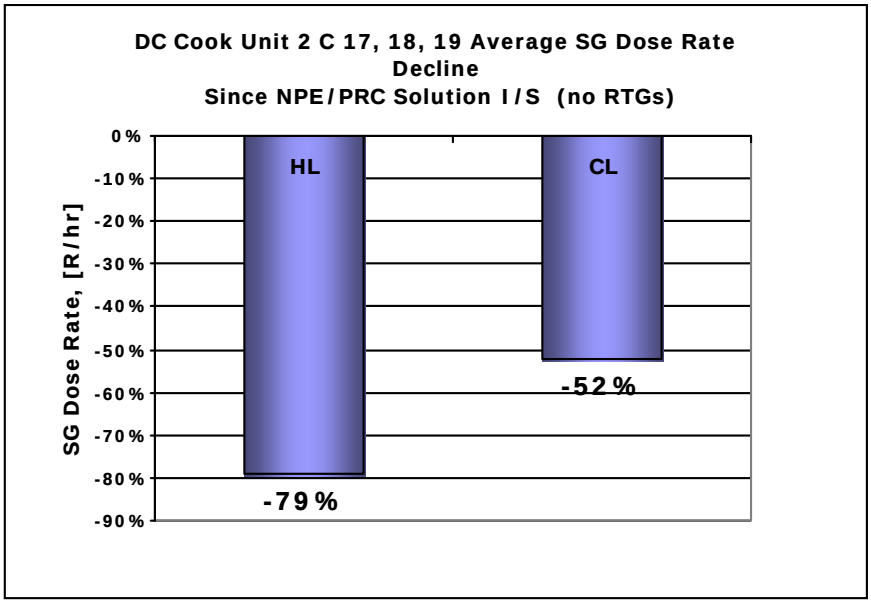
7. Few positive in-plant airborne monitoring results.

8. Reduced check valve and RCP pump debris issue due to low CRUD

9. The number of Locked High Radiation Areas was reduced. The next initiative is to have no high radiation areas in the Auxiliary Building at Cook.

Lower hot leg steam generator dose rates from previous cycles, see chart below:

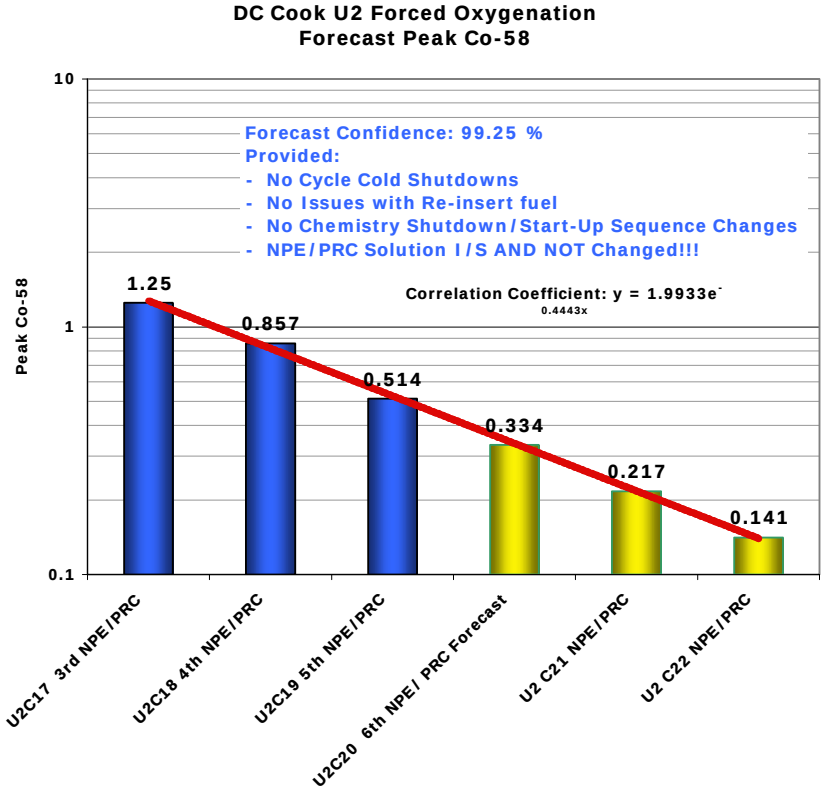


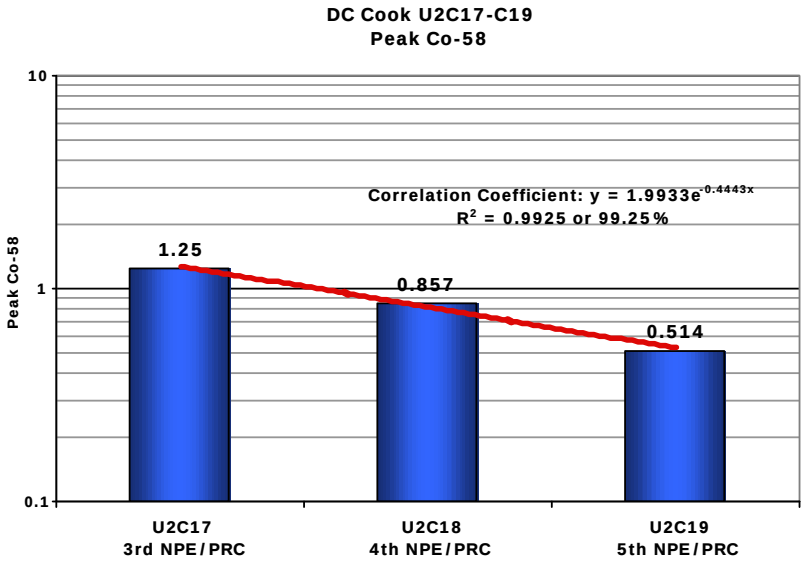

DC Cook Unit 2 C 17, 18, 19 Average SG Dose Rate Decline
Since NPE/PRC Solution I/S (no RTGs)
SG Dose Rate, [R/hr]
0%
-10%
-20%
-30%
-40%
-50%
-60%
-70%
-80%
-90%
HL
CL
-79%
-52%

Outage Performance Impact:

The benefits of mitigating of the formation, transport and deposition of corrosion products is reflected in the outage performance. Both Unit 1 and Unit 2 at DC Cook have declines in the quantity of activity being released from the core during shutdown and at the time of forced oxygenation of the RCS system with the injection of peroxide.

The U1C23 CRUD burst peak was 0.181 uCi/cc Co-58 (predicted was 0.75 uCi/c, and down substantially from 7.98 uCi/cc Co-58 in U1C18 (the 1st PRC-01 use). More importantly, the total curies released of Co-60 was less than 2.29 Ci in U1C23, compared to U1C18 21.6 Ci of Co-60 and Co-58 U1C18 3,372.7 Ci compared to U1C23 135.6 Ci of Co-58 shutdown release and removal. The decline in total curies released of Co-60 by a factor of 10X demonstrates that source term has reduced in a significant way. Co-60 contributes 3X the gamma radiation exposure per uCi, than does Co-58. It is the dominant dose controlling radionuclide. The below EPRI data demonstrates that Co-60 contributes 300% more dose rate in large bore pipes.





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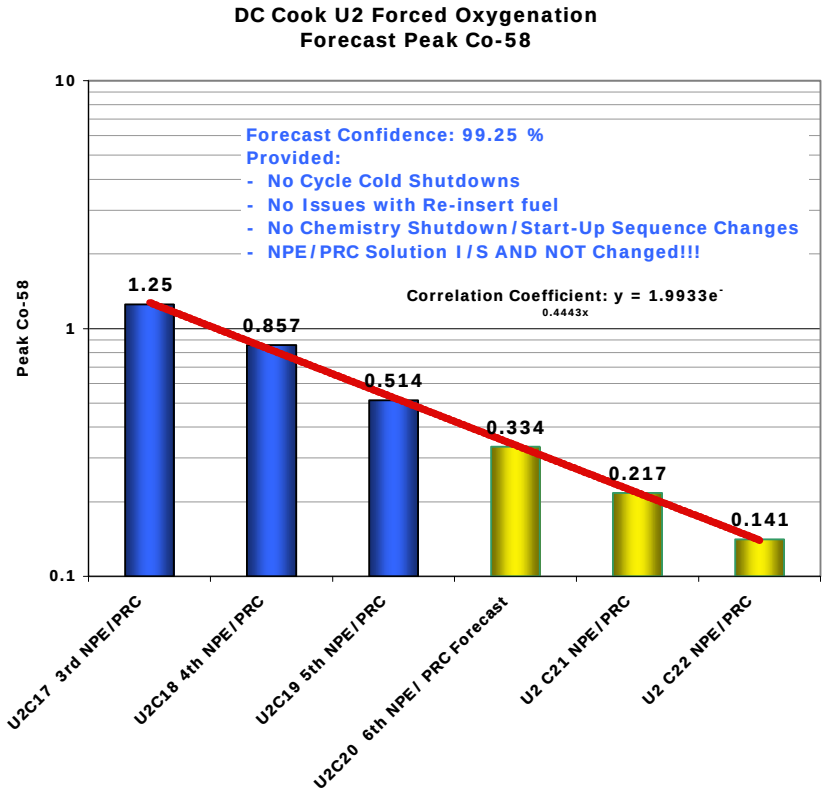
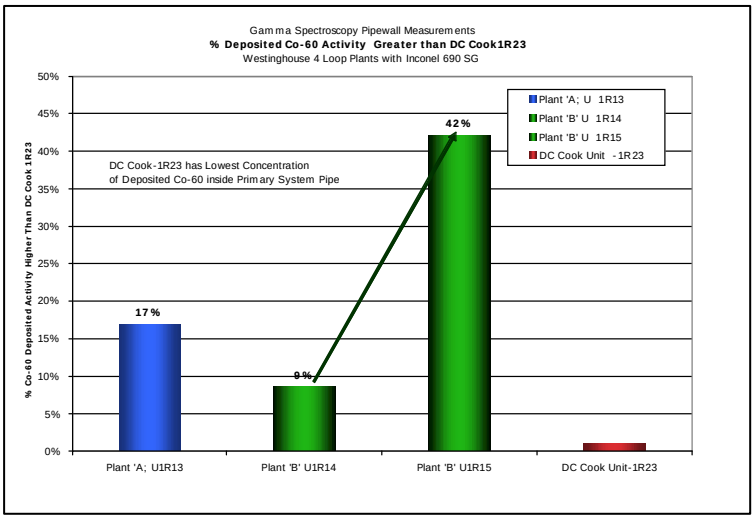


Table 4-1
Effect of Coolant Activity on Piping Dose Rates*

Isotope	Half-Life	Principal Kev	Gammas γ/d	Pipewall Dose Rate mR/hr per μCi/ml 3" Sch. 80	6" Sch. 80	28" (1.24" wall)
Co-60	5.27	1173	1	92	209	286
		1332	1			
Co-58	70.8	511	0.3	37	79	78
		810	0.994			
		864	0.0074			
		1675	0.0054			

* 3-inches from surface of 10-foot long pipe



Finally, the gamma spectroscopy pipe wall measurements on Unit 1 this spring, shown above, provided quantitative evidence of Cook's low Co-60 deposition on primary piping compare to other 4 Loop Westinghouse PWRs with Inconel 690 Steam Generators:

Conclusion:

DC Cook has concluded that the decline is attributed to the engineered solution implemented on both units since DC Cook did not implement any other source term reduction solution for Unit 1 or Unit 2. DC Cook has demonstrated a sustainable, and now predictable, decline in source term for 6 cycles on Unit 1 and 4 cycles on Unit 2. As a result, DC Cook is now ranked in the INPO top quartile for CRE and has set a low dose record for Unit 2C19 RFO. It is important to note that DC Cook did not invest $1 million dollars in plant modifications to inject zinc for source term reduction. Source term reduction has been accomplished without $200,000/ cycle – unit for zinc injection.

Cook will continue to collect and analyze in-plant source term measurements and compare the results with other Westinghouse PWRs. RP management's goal is to continuing improve the source term removal to achieve the lowest practical in-plant dose fields.