Changing the Protective Clothing Paradigm

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INTRODUCTION

An important aspect of most radiation protection programs at nuclear facilities is the protection of workers from radioactive contamination while handling radioactive materials or working in radioactively contaminated environments. In this regard, protective clothing is used extensively to protect workers from contamination. Health physicists are faced with a variety of considerations and challenges when determining how to effectively manage a protective clothing program. Such considerations include:

- Selecting the type and style of clothing commensurate with the hazard;
- Evaluating safety considerations, such as heat stress, associated with the use of protective clothing and environmental factors;
- Managing the logistics associated with laundering, shipping, storing, stocking and issuance of protective clothing and other items;
- Minimizing radwaste;
- Establishing reasonable criteria for monitoring and re-use of launderable products; and
- Determining the use of disposable products vs. re-usable products.

All of these technical issues plus others not mentioned must be considered, while balancing the economic costs associated with coordinating the protective clothing program. Recently, new product technologies have been introduced in the industry, leading many facilities to re-think the management of their protective clothing programs. This article discusses some historical perspectives of protective clothing programs and examines actual field experiences with new technological options and approaches, and how they are changing the protective clothing paradigm.

HISTORICAL PERSPECTIVES

Every health physicist who has been charged with implementing a protective clothing program knows that such a program is a significant part of the radiation safety program at a nuclear facility. Considerable human and budgetary resources must be devoted to successfully managing such a program. The health physicist is challenged with providing effective protection to the workforce, while at the same time keeping costs at an acceptable level. This balance of cost vs. protection is not unique to managing protective clothing programs and is, in fact, similar to other operational health physics decisions based on the ALARA principle. This is an increasingly complex and difficult task in today's world of sustained emphasis to reduce staffing and operating costs, while desiring to maintain, and even improve, the level of protection and human performance.

Laundering, Monitoring and Re-Using Clothing

During the past two decades, conventional protective clothing programs seemed to have reached a reasonable balance through the use of re-useable, launderable protective clothing. As radioactive waste disposal costs have increased over those twenty years, and disposal options have become more limited, most facilities have migrated away from single-use, disposable products for the bulk of their protective clothing needs. It wasn't that long ago that many nuclear facilities operated their own laundry facilities or leased an onsite mobile laundry operation. But over the past ten years or so, most facilities have transitioned to utilization of offsite commercial nuclear laundry services and have been able to reduce their costs further through economy of scale.

Under this scenario, the use of launderable protective clothing is necessary to maintain costs. However, the myriad issues associated with the re-use of clothing do pose additional challenges for health physicists and should be addressed. The determination of acceptable methods for the radiological monitoring of laundered clothing and its criteria for re-use (e.g., the acceptable level of residual contamination for re-use on personnel) presents one of the most significant decisions required. While commercial nuclear laundry operations are capable of "decontaminating" the used protective clothing, not all of the contamination is removed from the fabric. Some level of residual contamination will remain in the garment and will be present during any subsequent use by another worker. "*Decontamination*" is certainly a relative term. Over the years, many facilities have looked closely into this issue because they had observed that the source of numerous personnel contamination events might have been from the protective clothing itself.

The issue of acceptable practices for laundry monitoring and determination of criteria for the reuse of clothing has been an ongoing challenge in nuclear facilities for many years. Prior to 1980, not much attention was paid to the proper laundering of protective garments. There was no general guidance and each nuclear facility had its own approach. Usually, clothing and other garments were sent to be laundered at an offsite facility and, when these items were returned to the site, they were assumed to be "clean." There was no uniform acceptance criterion as to what was considered clean and, facilities that actually checked the garments upon receipt used a number of procedures and various levels of "acceptable contamination." During the late 1970s and early 1980s, in NRC Region II, some sites accepted garments back from the laundry and considered them to be clean if the residual contamination was of the order of 0.5 mR/hr. Other facilities accepted clothing with readings as high as 2 mR/hr, when measured by wrapping the garment around a Geiger-Mueller (GM) detector probe. However, at the same time, some sites were using large-area, gas-flow proportional detectors to check the "clean" (i.e., decontaminated) clothing very carefully before allowing it to be returned to use.

One component of the problem was that the laundry facilities could mix garments from several sites or mix highly contaminated garments with cleaner garments from the same site, without much assessment of potential cross-contamination. Further, many sites did not require a specific decontamination factor (DF) from the vendors – their contracts just specified that the clothing was to be washed. Because of this, licensees sometimes received protective garments back from the laundry that were more contaminated than when they were shipped to the laundry. Later, it was common for facilities to require their clothing to be washed alone and mixing of clothing from different sites was discontinued, in general.

As a consequence of this level of control of "clean clothing," a considerable number of skin contaminations occurred at sites. This was especially true during outages, when the use of protective garments was high. In the hot and humid conditions existing in the southern U.S. and during heavy work conditions at many plants, perspiration would "leach" residual contamination from the garments resulting in contamination of the skin of the wearer. These skin contaminations have consumed an inordinate amount of manpower, because each such incident required a level of investigation and reporting. To further compound the situation, personnel contaminations were used as a performance indicator at most sites; with a high number of contaminations being an indication of a poor radiation protection program. Although the vast majority of these contaminations were of low consequence, staff health physicists were forced to take care of them, all the time knowing that many of the contaminations were related to the lack of decontamination effectiveness, an intrinsic weakness in the laundry process.

Although significant improvements have been made in laundry monitoring, and much more restrictive criteria for reuse are commonly used, many health physicists and radiation protection managers are aware that a significant percentage of the personnel contamination events can be attributed to the residual contamination in the laundered protective clothing. In addition to the laundry process itself, an inherent weakness exists with the technology most commonly utilized for monitoring of laundered protective clothing. Commercial nuclear laundry vendors typically use an array of large-area, gas-flow proportional detectors with an automated conveyor system that allows for monitoring large quantities of laundry. This type of gas-flow proportional detection system is primarily sensitive to beta radiation and, conversely, is relatively insensitive to gamma radiation. Alarm setpoints for these detection systems are normally in the range of 20,000 to 50,000 disintegrations per minute per 100 square centimeters (dpm/100 cm^2), with some utilities reportedly using setpoints as high as 100,000 dpm/100 cm^2. Since beta particles in the energy range of interest are easily attenuated ($E_{max} < 400$ keV), contamination on the inside of protective clothing or just covered by any fabric (e.g., a seam) would require an activity ten to twenty times greater than the monitoring limits to cause an alarm. Additionally, discrete radioactive particles (DRPs) are even more difficult to detect using beta-sensitive instrumentation. Not only is the beta radiation from a DRP easily attenuated, but its intensity is rapidly reduced with increased distance between the particle and detector. The common use of large-area detectors also creates additional detection inefficiency.

In the late 1990s, the Palo Verde Nuclear Generation Station re-surveyed all of their protective clothing onsite, after it had been monitored by their laundry vendor and returned for reuse. The onsite plant monitoring system was comprised of both beta- and gamma-sensitive detectors capable of detecting distributed activity as well as discrete, localized sources. More importantly, because of the gamma monitoring built into the site system, this ensured that the onsite monitoring limits were truly lower than the laundry vendor's alarm capabilities by the factor of 10 to 20. Contamination was found in locations where beta radiation was attenuated – collars, pockets, seams, and on the inside surface. This same contamination was not detected with the beta-sensitive monitoring instrumentation. Palo Verde reported that DRPs with activity ranging from 200,000 dpm to 4,000,000 dpm were found in 2% to 5% of the laundered protective clothing returned to their site from the laundry vendor. Similar reports are not uncommon throughout the U.S. nuclear industry.

Concerns such as these have led many health physics professionals to find ways to decrease the levels of contamination remaining in laundered protective clothing, or to evaluate other alternatives. One alternative is to convert to single-use, disposable protective clothing, thus ensuring a clean garment for every use. While that is a major shift in philosophy, the only other way to reduce the magnitude and general potential for personnel contamination events from protective clothing continues to be through improved laundry monitoring and more restrictive monitoring criteria.

But, as monitoring is improved and criteria for re-use become more restrictive, costs increase as the percentage of rejected protective clothing increases. Further, these rejected articles must be disposed of as radioactive waste and replaced with new garments to maintain adequate operational inventories.

Following the evaluations at Palo Verde, plant personnel worked with their laundry services vendor to construct and install new, state-of-the-art, beta- and gamma-sensitive laundry monitors at the vendor's facility and implement gamma monitoring for their protective clothing. Setpoints for the gamma monitoring system were consistent with the setpoints used historically for the beta-sensitive monitors based on the nuclides of concern. Data from the laundry vendor reveals the impact on the reject rate of additional gamma monitoring for laundered clothing. It clearly demonstrates that a significant amount of clothing was passing the beta monitoring process when it was, in fact, contaminated above the prearranged monitoring setpoints – because the betas were often attenuated. For the two laundry shipments prior to implementation of gamma monitoring, the reject rate for cloth coveralls averaged 8%. Immediately following implementation of gamma monitoring at the vendor facility, the reject rate for the next five shipments averaged 17%, more than double the previous reject rate. The laundry vendor conducted a test of the gamma monitoring for a second customer. A shipment of laundry from that customer was checked with the gamma monitors, resulting in a reject rate of 23%. That same customer's historical reject rate using only beta monitoring was 3% to 8%.

Even with improvements to the monitoring process, the fact remains that residual contamination will be present in laundered protective clothing. Therefore, it is inevitable that some percentage of workers wearing the laundered clothing will become contaminated from the clothing itself … the same anti-contamination clothing intended to protect them.

Logistics

Another important aspect associated with any protective clothing program is the logistics associated with receiving, stocking and issuing, collecting, transporting, servicing and the ultimate disposition of the clothing. These logistics vary greatly depending on particular facility operations, but maintaining adequate quantities of ready-for-issue protective clothing is critically important to the successful operations of every nuclear facility. Logistics are further complicated if an offsite commercial laundry service is used, as numerous shipments may be required to transport protective clothing to and from the laundry facility. Most nuclear power plants using a commercial laundry ship at a frequency ranging from daily to once every three or four days. Other licensees and Department of Energy sites may ship and receive clothing on a daily basis. The frequency of shipping must be balanced with the total protective clothing inventory to ensure an adequate inventory of protective clothing is maintained to support work activities.

Such a program requires considerable resources. Typical of a power-plant approach, several utility workers or decontamination technicians are required for handling and stocking of laundered clothing and collecting used clothing. The protective clothing inventory is turned around frequently and the handling required to restock the inventory in the plant may be quite intensive. When an offsite laundry is used, laundered items are handled multiple times to move them from the shipping container upon receipt into the field locations for issuance. This process is repeated frequently (sometimes daily) to maintain suitable inventories. Additionally, offsite shipments require specialized radiation protection resources to survey the shipment and prepare the shipping manifest. A typical laundry shipment may require two or three technicians, working for two to four hours, to complete the required shipment preparations and associated documentation. When laundry shipments return from the laundry vendor or facility, receipt surveys are required since the laundered items are also shipped as radioactive material due to the residual contamination in the clothing. The "clean" laundry must also be stored in a radiologically controlled area, which may limit options for storage. To effectively manage the logistics associated with the typical laundry program, a power plant may devote as many as 3 to 6 decontamination technicians or utility workers per shift to this activity.

Industrial Safety

Protective clothing handling and movement may also create industrial safety concerns. Personnel assigned these tasks are frequently required to lift bags of laundry when stocking laundered garments for issue and when collecting used protective clothing throughout a given facility. A 55-gallon size bag of laundry can easily weigh 40 to 50 pounds. Properly collecting and packaging protective clothing to limit the weight of each package and/or minimize the amount of lifting required poses additional challenges. Appropriately, considerable emphasis and training is directed toward the safety aspects of materials handling and proper lifting techniques. Nevertheless, back injuries and other muscle pulls or strains related to laundry handling activities often occur.

Heat stress related factors pose another significant industrial safety challenge to the health physicist when prescribing anti-contamination clothing requirements. Many work activities in commercial nuclear power facilities are performed in hot, humid areas, such as reactor refueling cavities, PWR steam generator platforms, and BWR dry wells and condenser hot wells. Workers in such areas are often exposed to risk of heat-related illness or injury. This risk may increase with additional layers of protective clothing when the work is performed in a contaminated area. Depending on the type of clothing prescribed, stay times for workers may be significantly reduced due to the protective clothing. Health physicists must diligently evaluate work activities to properly balance the risk of radiological contamination with the risk of heat stress and other physically limiting factors.

NEW TECHNOLOGY

With those aspects of radiation protection, safety, and cost in mind, OREX Technologies International has recently introduced a line of single-use, disposable protective clothing and other consumable supplies (see Figure 1) with an innovative, patented treatment system for the used products. These single-use products are unique in that they are fabricated from a polyvinyl alcohol (PVA) polymer, which is soluble in water above 190 degrees F. The solubility of the PVA polymer is the basis for the backend treatment system. Following use, the PVA products are processed in the treatment system that dissolves and decontaminates the PVA material. The resulting secondary waste volumes are very small. Further, the volume reduction factors from this decontamination process are far superior to existing processing and disposal methods for other

Figure 1. *PVA protective clothing and consumable products*

single-use products. This new processing technology eliminates the important waste challenges associated with the use of conventional disposable products. This unique combination of single-use products and specialized processing offers nuclear facilities a new option for use of disposable protective clothing without producing significant volumes of radioactive waste requiring disposal at a licensed radioactive waste disposal facility.

During the last two years, many commercial nuclear power facilities have taken a new look at the use of disposable clothing based on the PVA technology. Initially, some plants used PVA disposable protective clothing on a trial basis for the purpose of evaluating its effectiveness as a contamination barrier, and its general suitability for use in a nuclear facility, including the cost effectiveness. Following successful testing, numerous plants have transitioned their protective clothing programs almost entirely to the PVA-based disposable products. During the initial testing and subsequent full scale use of the products, many benefits related to use of disposable products were observed and reported. The remainder of this article will discuss these benefits relative to traditional, launderable protective clothing programs.

Personnel Contamination Event Reduction

One of the primary objectives in evaluating a protective clothing product is to determine its effectiveness as a contamination barrier. Although the manufacturer performed direct particulate transmission tests, there currently exists no laboratory testing protocol that accurately replicates the dynamics and mechanics of contamination in the field. Therefore, most initial users wished to evaluate performance under actual field usage conditions. To accomplish this, users monitored and tracked personnel contamination event (PCE) occurrences and compared numbers of PCEs associated with the activities where disposable products were used to historical numbers of events for the same activities under traditional reusable clothing programs. Users observed and informally reported significant reduction in the total occurrences of PCEs associated with use of the PVA disposable products. Most users reported reductions of at least 40%, with several reporting reductions as high as 60% to 80% as compared with historical data. These PCE reductions are significant and led the authors to collect data from users of the PVA disposable products and formally present the findings. The data were reviewed and evaluated to determine the apparent cause of the distinct PCE reductions.

Data were collected from five plants: Comanche Peak, Palo Verde, Catawba, North Anna and Surry. It should be noted that the data contained herein from participating utilities should not be construed as an endorsement of any particular commercially available products. All of these power plants had converted their protective clothing programs almost exclusively to the PVA disposable products. Prior to transition to single-use clothing, these facilities historically employed launderable protective clothing programs. Most nuclear power facilities categorize and track PCEs using guidelines developed by the Electric Power Research Institute (EPRI). The EPRI guidelines categorize PCE's into three levels based on risk significance. Level 1 events are low-level events with insignificant risk to the worker. These events are only documented. Level 2 events are intermediate risk, and tracking and trending of these events is recommended. Level 3 events are the most risk significant and require documenttation, tracking and trending, as well as skin dose estimates.

For purposes of this study, the total number of occurrences, categorized by EPRI Level, was reviewed. Also, the rate of occurrence for each level was calculated, when such data were available. The utilities furnishing data did not track the rate of occurrences in a common manner. Some reported the number of occurrences per outage day, while others reported the number of occurrences per work hours logged. A calculated rate of occurrence is useful because it normalizes the data and removes variability that could be attributable to the duration or scope of the work activities. Following review of the rate of occurrence for each level of PCEs, it was determined that there was no correlation between the observed reduction in the rate of occurrence of PCEs and the EPRI level. While some plants show the largest reduction for Level 1 events, other plants showed across the board reductions for all levels. For some plants, the rate of occurrence for level 2 and 3 events was so low (typically 0 to 3 events) per outage, a change of 1 or 2 events resulted in a significant change (increase of decrease) in the calculated PCE rate, but is not statistically significant relative to the total number of events. Therefore, the remainder of this discussion about observed reductions in the rate of occurrence of personnel contamination events will focus on the total rate of occurrences for each plant (e.g., the combined rate of occurrence for all EPRI categories).

Figure 2 shows data obtained from the Comanche Peak Steam Electric Station. The PCE rate for Comanche Peak is reported as events per 10,000 work hours. The data for this plant show five outages, including a Unit 1 and a Unit 2 outage prior to PVA use, another Unit 1 and Unit 2 outage when PVA clothing was used on a trial basis, and finally, a Unit 2 outage following full conversion to PVA disposable protective clothing. These data are particularly interesting because there is a noticeable decrease in the PCE rate, which occurred when PVA clothing was used on a trial basis, followed by another significant decrease following full conversion to PVA products. During trials of PVA products, the products were used primarily on refueling and steam generator primary side work activities. Historically, these work activities were the source of a significant percentage of the total contamination events and significant reductions in the numbers of PCEs which occurred during the targeted work activities were observed, contributing to an overall reduction in the PCE rate for those outages. For purposes of comparing the PCE rate prior to use of PVA disposable products to the rate following full conversion to the disposal products, the average PCE rate for the two outages prior to use of the PVA products was compared to the rate for the outage following full conversion. This comparison shows that the PCE rate was reduced by 79%.

Figure 3 shows PCE data from the Palo Verde Nuclear Generating Station. The data provided by Palo Verde show six outages, including two outages for each of their three units, prior to full conversion to one-time use products. Palo Verde converted to the disposable products for their Unit 2 outage in the fall of 2003. This outage comprised a significant work scope, including replacement of the steam generators. Over 100,000 dressouts were performed during this outage using the one-time use disposable products. Palo Verde completed this outage with a PCE rate per 10,000 work hours of 4.4, their lowest ever. Comparing this PCE rate to the average PCE rate for the previous 6 outages when launderable protective clothing was used shows a reduction of 60%.

Figure 4 shows PCE data obtained from the Catawba Plant. The data for this plant show two outages; one prior to use of PVA disposable products and one following full conversion to the one-time use products. The PCE rate for the Catawba data is also calculated in terms of events per 10,000 RCA hours. Although more historical data would be preferred to support a reduction at this plant, comparison of the two outages still shows a 47% reduction in the PCE rate from the prior outage.

Figure 5 shows PCE data obtained from the North Anna Nuclear Plant. The data for this plant show two outages prior to use of one-time use products and two outages after full conversion to the PVA disposable products. The PCE rates for each outage were calculated based on the outage duration in days. Comparison of the average PCE rate for the two outages where launderable products were used to the average PCE rate for the two outages when the one-time use products were used shows a 65% reduction in the PCE rate.

Figure 6 shows PCE data obtained from Surry. The data for this plant show two outages prior to use of PVA disposable products (Unit 1, Fall 2001; Unit 2, Spring 2002). The plant converted to PVA disposable products for the Unit 1, Spring 2003 and Unit 2, Fall 2003 outages. For this particular plant, the PCE rate was calculated based on the outage duration in days. If the average rate for total PCEs for the two outages prior to use of PVA disposables is compared to the average rate for total PCEs for the two outages when PVA disposables were used, a reduction of 63% is observed.

Figure 2. *Comanche Peak historical PCE data*

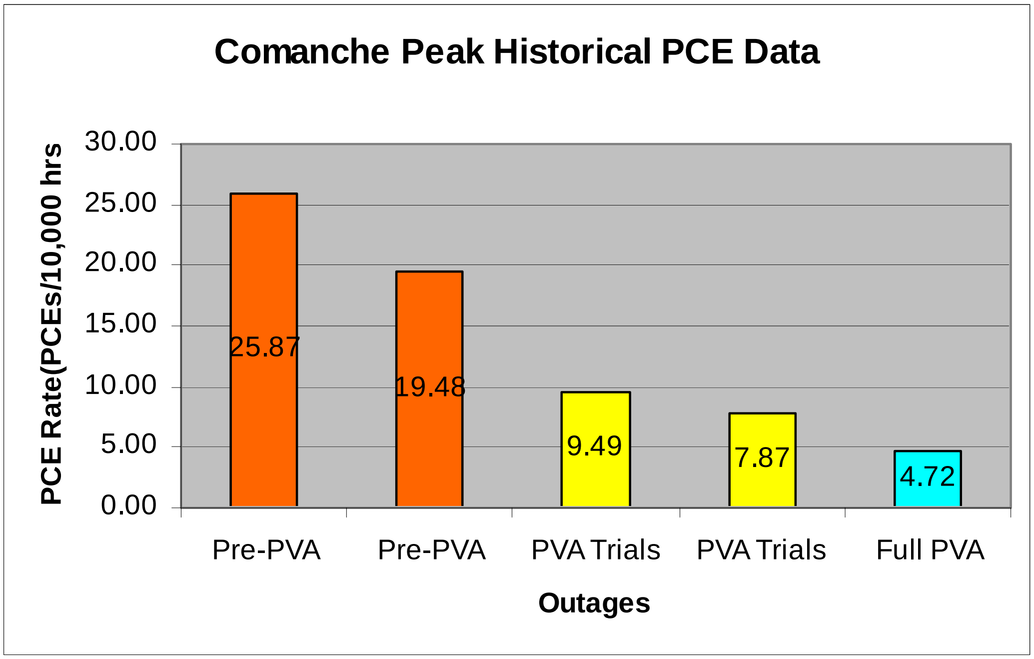


Figure 3. *Palo Verde historical PCE data*

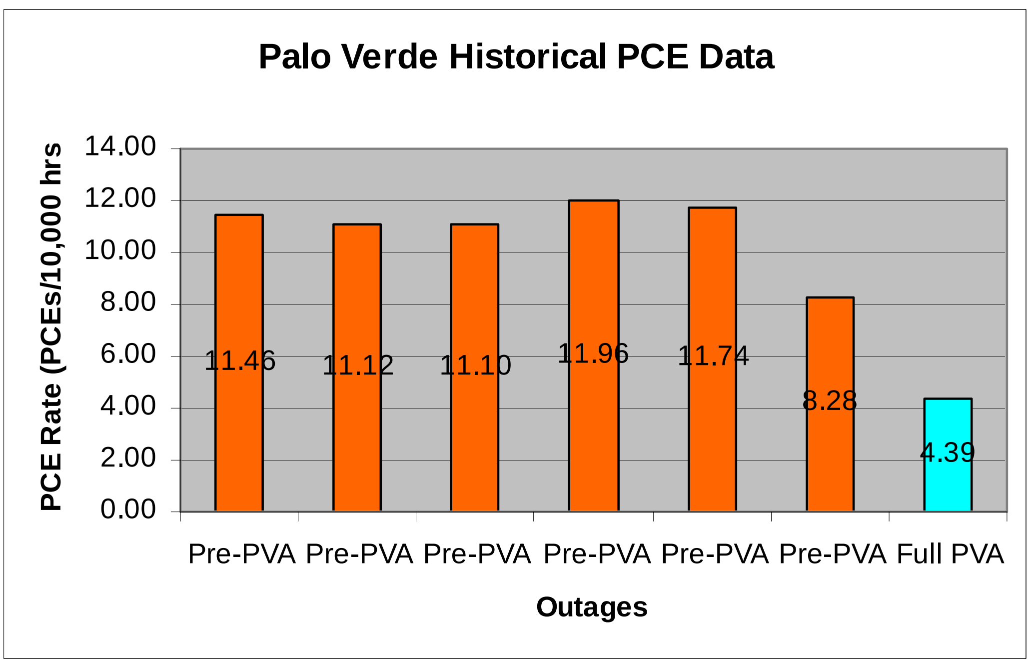


Figure 4. *Catawba historical PCE data*

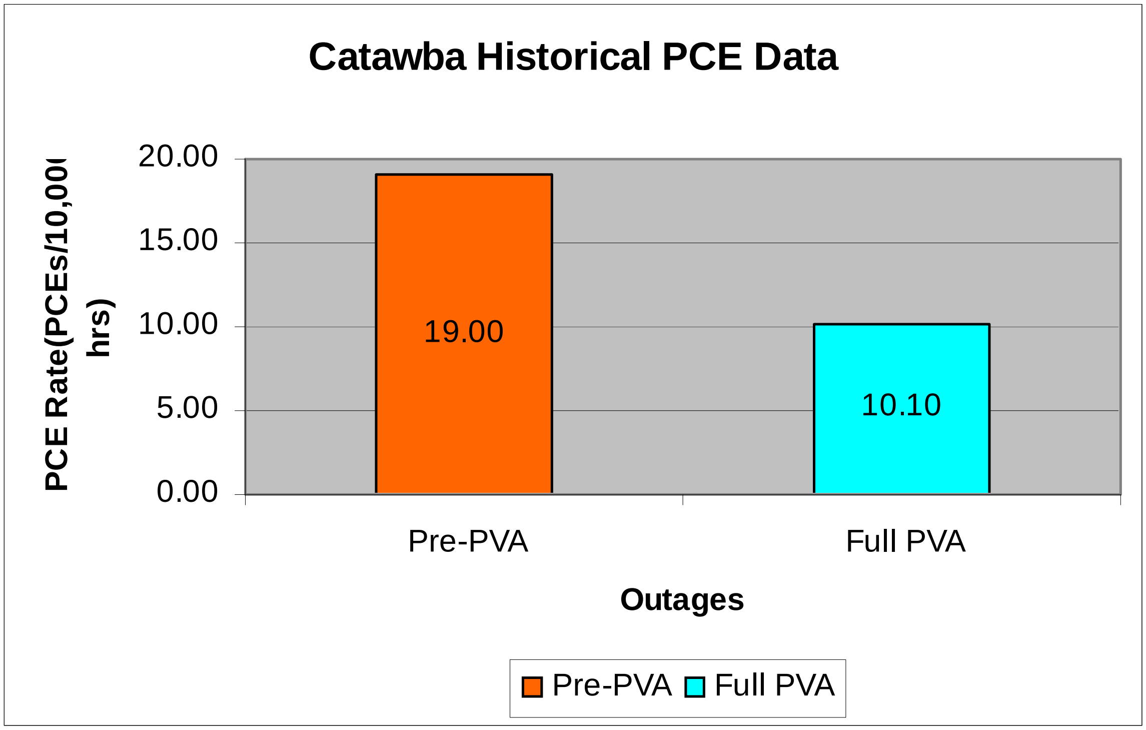


Figure 5. *North Anna historical PCE data*

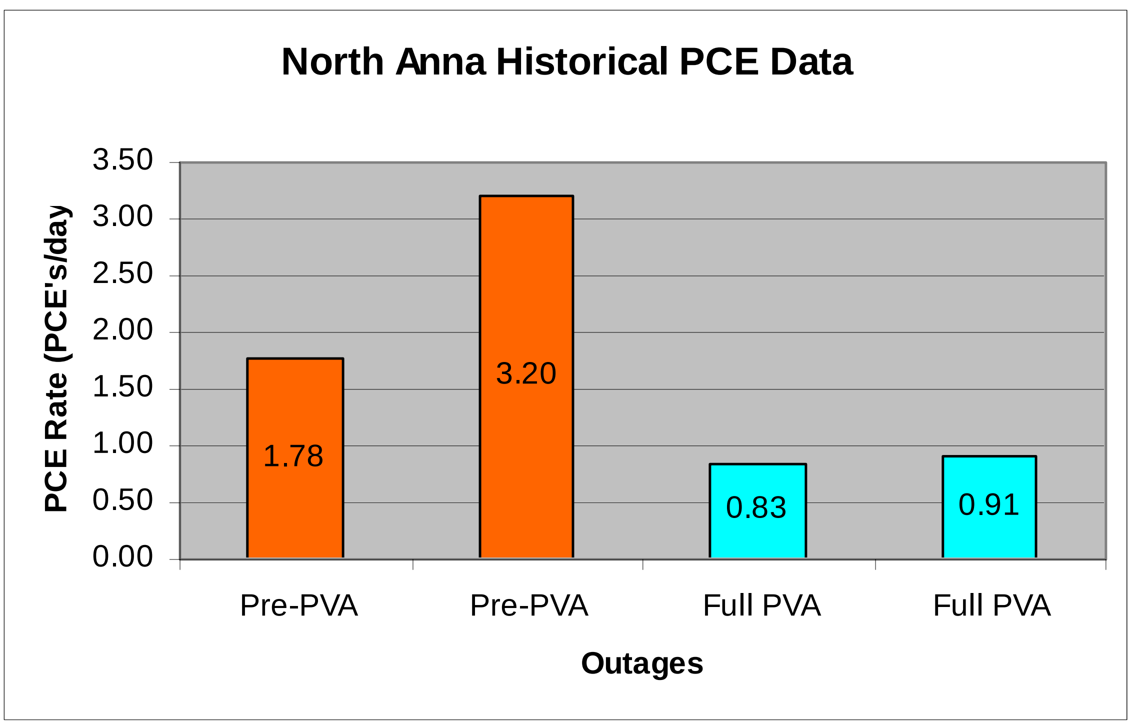


Figure 6. *Surry historical PCE data*

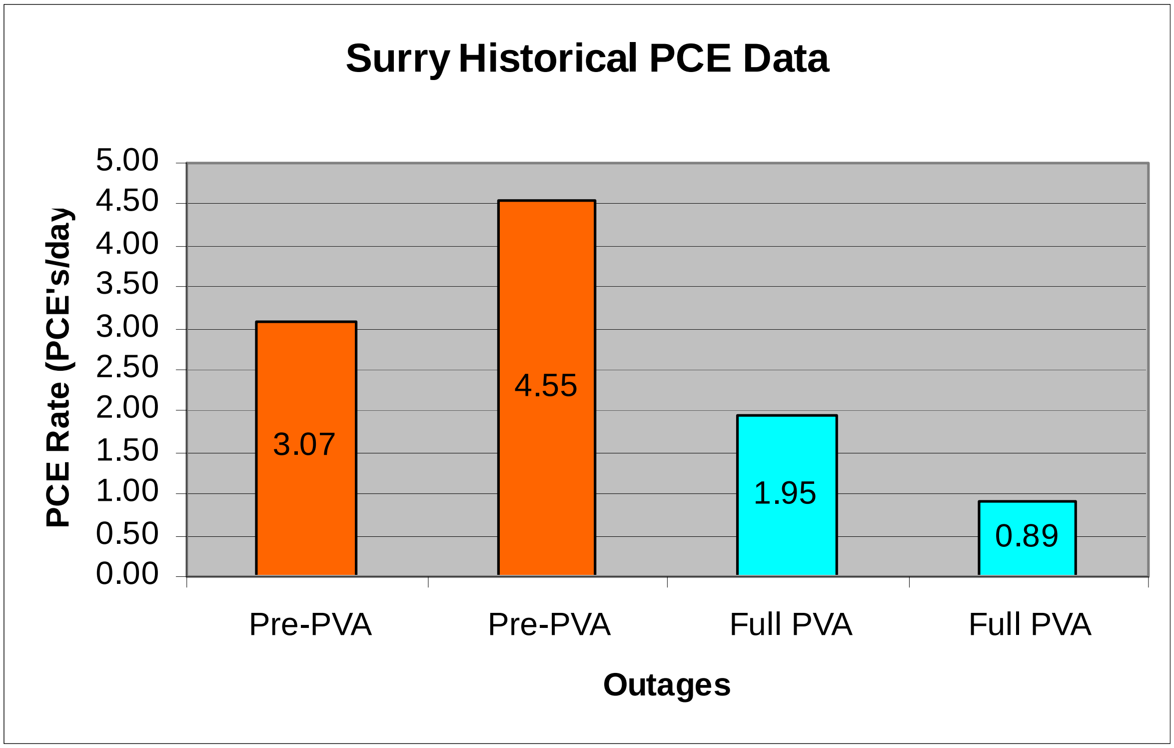


Figure 7. *Average PCE reduction for all plants*

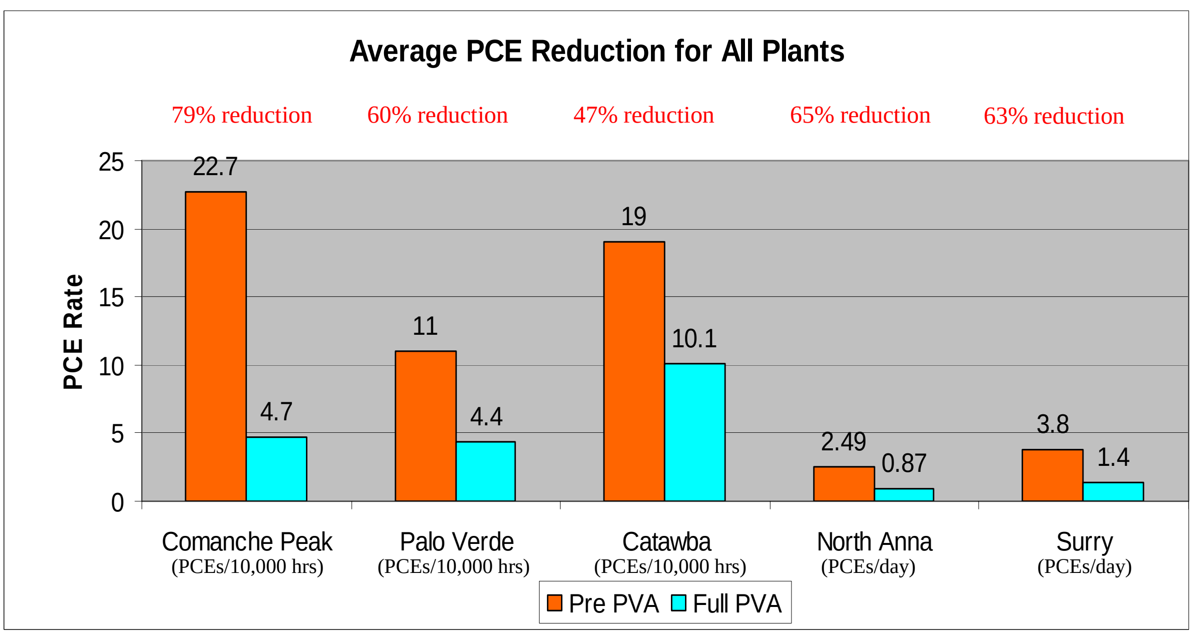


Figure 7 shows a summary of the data from the five plants. For each plant, the average PCE rates for the outages prior to use of PVA disposables and for the outages following full conversion to PVA disposables are shown. These data were then used to calculate the average percent reduction for each plant which coincided with full conversion to PVA disposable protective clothing. These reductions are significant.

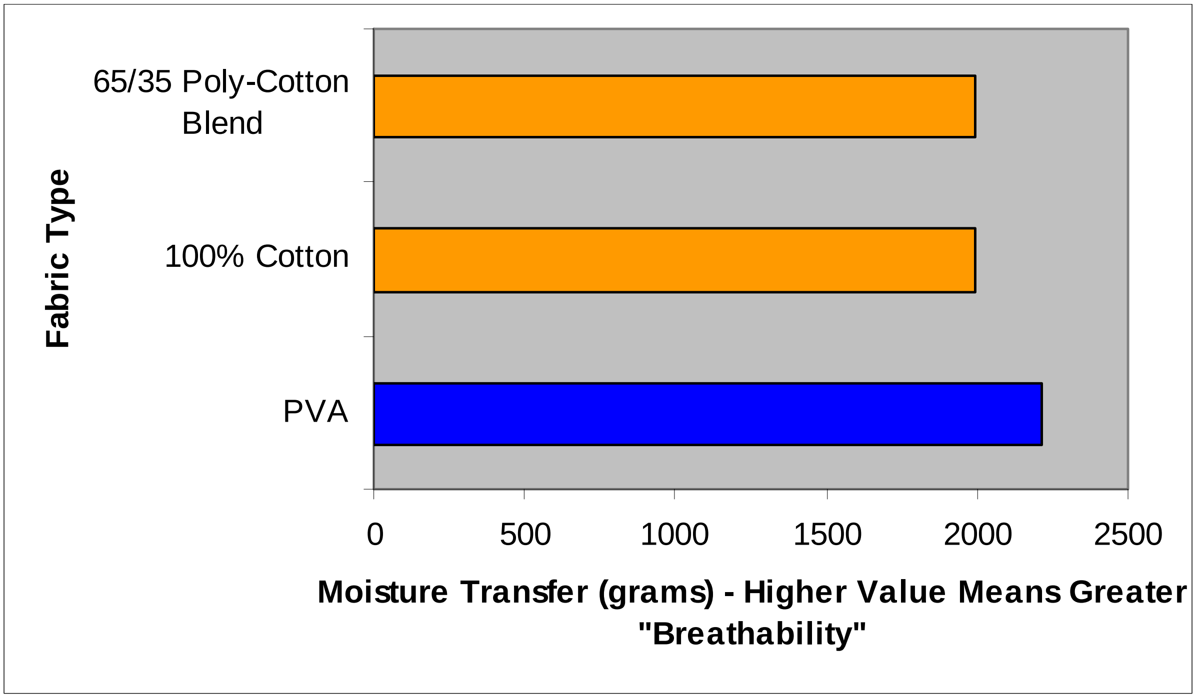
It should be noted that a detailed review of the PCE databases at these plants was not performed to evaluate the specific cause of each event. In general, the causes of personnel contamination events are varied and include poor worker practices, inadequate radiological and contamination controls, failure of engineered controls, failure or improper use of protective equipment, and many others, including those attributable to the residual contamination in laundered protective clothing. It is not the intent of this study to imply that *all* of the reductions that were observed at the plants which provided data can be attributed to use of one-time use disposable products. Plants continually implement actions aimed at reducing personnel contaminations, including radworker training focused on improving work practices, improved radiological controls, improved decontamination practices, engineered controls and many others. All of these play a role in the overall reductions observed, to some extent. However, plants have been implementing these types of actions for many years in an attempt to reduce personnel contamination events – and stepwise reductions such as those documented in this study have never before been achieved. If one embraces the belief that some percentage of personnel contamination events come from residual contamination in laundered protective clothing, then it is a logical conclusion that these events will be eliminated with use of a clean, one-time use disposable product. And clearly the data presented in this report show a correlation to a significant step change in the PCE rate at these plants coinciding with the transition from launderable protective clothing to one-time use disposable products.

Logistical Improvements

Many users have reported that the disposable clothing offers unique options for managing the logistics associated with receipt, storage, stocking, issue, and return of the products for processing which are not available with launderable programs. There are several differences with disposable products that present opportunities for logistical improvements. First, with disposable products the *entire* inventory of products needed for an outage can be delivered prior to the start of the outage. Second, all of the disposable products are new and clean. They do not have to be shipped, received, handled and stored as radioactive material, as is the case with laundered clothing because of the residual contamination. And finally, and possibly most significantly, frequent shipments to and from the laundry vendor are not required since all of the products are onsite and available prior to the start of the outage. The following is a list of logistical improvements reported by users:

- Radiological surveys of incoming materials are not required upon receipt;
- Additional onsite radiological monitoring of laundered PCs (for auditing purposes) would be eliminated, along with any potential contaminations of those technicians handling those PCs;
- Radiation protection support for security inspections is not required;
- The new material may be stored in non-radiologically controlled areas;
- Products can be stocked in bulk, ready for issue. Frequent restocking is not required. A greater volume of single-use clothing may be stored in a given space than launderable garments; and
- Outgoing and incoming radioactive shipments of used products may be reduced or eliminated during the outage. The protective clothing can be pre-staged onsite prior to an outage, removed from its shipping container, used by the workforce and then returned to the same container following use. The used products are collected in this manner and returned for processing in one or two shipments following the outage.

Figure 8. *MTRV comparison between OREX, cotton and poly-cotton blend fabrics*



Due to the logistical improvements that may be achieved, the number of personnel traditionally required to support laundry receipt, handling and shipping activities may be reduced or they may be reassigned to more radiologically significant work activities. For example, some plants have reassigned the radiation protection technicians who normally support laundry shipping to in-plant job coverage activities. Plants have also reduced the number of contract personnel who are assigned to protective clothing stocking and issue. The reassignment or reduction of personnel offers the opportunity for significant cost savings or improved efficiency in use of personnel, not to mention greater focus on more critical aspects of the Radiation Protection program.

Worker Comfort and Safety

PVA disposable products are different from most other available disposable products. The PVA fiber is actually converted into a non-woven fabric, versus the paper or plastic film common with other disposable products. When comparing the PVA fabric to conventional cotton or poly-cotton fabrics, some significant differences are noted. First, the PVA fabric is much lighter that conventional cloth garments. For comparison, a complete dressout (e.g., coveralls, booties, and hood) with cotton products weighs 2.4 to 3.0 pounds. The same dress-out with PVA disposable products weighs less than 1 pound. Measurements show that the PVA fabric weighs 70% less than cotton fabric typically used for fabrication of protective clothing. Additionally, testing has been performed to compare “breathability” of the PVA fabric to that of cotton and poly-cotton. Tests were conducted using a standard “Moisture Vapor Transfer Rate” test protocol (ASTM E96). Results of the test are shown in Figure 8 and demonstrate that the PVA fabric “breathes” about 20% better than cotton or poly-cotton fabric.

These test data are consistent with feedback from workers who consistently report they are more comfortable and cooler when wearing PVA disposable coveralls versus conventional cotton or poly-cotton products.

Another aspect associated with improved safety is related to materials handling. As previously noted, the PVA products are significantly lighter in weight than the conventional launderable products. PVA fabric density is about 65 grams/m^2 versus 220-240 grams/m^2 for 100% cotton or 65/35 poly-cotton blend launderable clothing items. Typically, a 55-gallon drum-sized bag of used launderable articles weighs 40 to 50 pounds. The same volume bag of used PVA products only weighs 10 to 15 pounds. Many plants have reported that workers who stock and collect the lighter, single-use protective clothing were at a reduced risk of materials handling related injuries, such as back strains and other muscle pulls and strains. Avoidance of even a single on-the-job injury can result in significant savings for a company as well as avoided pain and suffering for the employee.

Radwaste Reduction

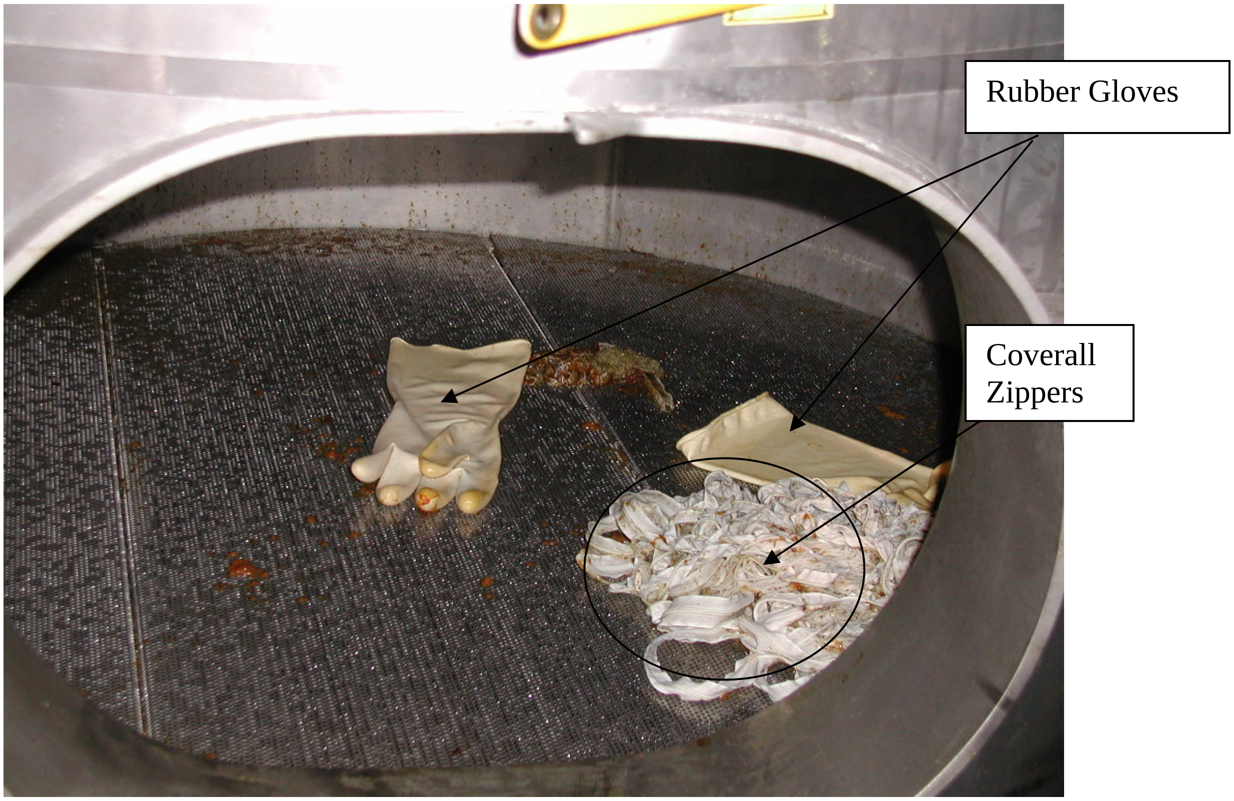
A key to the viability of any single-use, disposable product is the volume of waste produced and the associated of cost of processing and disposal. The PVA disposable products were "designed with the end in mind." The unique, backend processing system is licensed as a decontamination and release process. The PVA materials are dissolved and decontaminated. The radioactivity is removed by mechanical filtration and the dissolved PVA is discharged. The effluent is environmentally friendly and biodegradable, and is ultimately broken down to carbon dioxide and water. Figures 9 through 12 show the processing sequence for the PVA material.

Figure 9. *Before processing…seven drum-sized bags of OREX (120 pounds)*

Figure 10. *Seven bags loaded into the processor (view looking inside loading hatch)*

Figure 11. *After processing…view looking inside processor loading hatch*

Figure 12. *Close-up view looking inside processor at residual from 120-pound batch*



The PVA processing technology results in volume-reduction factors that are far superior to other existing methods for processing and disposal of one-time use disposable products. All non-PVA components of the products (e.g., zippers) and the radioactive material captured on filters are considered secondary waste and are dispositioned by the processing vendor. No waste from processing of the PVA single-use products is returned to or reported to the generator. Any other non-compatible waste commingled with the PVA products (e.g., tape, trash, gloves, etc.) is simply removed from the processor and returned to the generator.

CONCLUSION

Management of a protective clothing program is a necessary and vital aspect of operations at a nuclear facility and presents many challenges for a health physicist or Radiation Protection Manager and facility staff. Historically, launderable protective clothing has been used to balance costs and minimize volumes of radioactive waste requiring disposal. No other option has been reasonable in the past. Programs based on launderable products present numerous radiological, industrial safety, and logistical challenges that must be managed. One of the most significant tasks is developing and implementing methods and criteria for monitoring and reuse of launderable products to minimize the possibility that workers will become contaminated from the residual contamination present in the laundered clothing, while simultaneously keeping program costs in check.

Recently, many plants have transitioned away from traditional launderable products in favor of single-use products. Experience with single-use, disposable products has shown that they offer many unique options and features which are not available with use of conventional launderable products. Many of these options and features are based on the fact that the single-use products are clean, as opposed to the laundered products that contain residual contamination. Most notably, plants using PVA disposable products are experiencing significant reductions in the rate of occurrence of personnel contamination events. This, and the other benefits reported by users are significant and compelling!

In summary, new technology for PVA disposable products and backend processing offers nuclear facilities the opportunity for improved performance by reducing radiological and industrial safety risks, improving logistics and associated utilization of valuable resources, and minimizing radioactive waste generation. In short, this technology offers new options for managing existing health physics, industrial safety, radioactive waste, and logistical challenges that occur in nuclear facilities every day. The new single-use products and processing technologies are, in fact, changing the protective clothing paradigm!

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