To Toss or Not to Toss—
That Is the Question

Minimizing Cost and Radwaste of Protective Clothing

A look at the "real" drivers and issues regarding the selection and use of protective clothing in the nuclear industry.

By J. Mark Price

Over the last several years, there has been a trend for nuclear power plants to either run trials with or switch to single-use protective clothing (SUPC) from traditional laundered protective clothing. In some cases, after trial usage of SUPC, plants have chosen to stay with SUPC. In other cases, after switching to SUPC for a period of time, some plants have chosen to switch back to laundering. Based on these observations, the author reviews the "real" drivers and issues regarding the selection and use of protective clothing in the nuclear industry.

Survey at Commercial Operating Plants

To better understand why some plants consider switching to SUPC, I conducted a survey of 30 SUPC users. Over a four-month period, I conducted telephone interviews, using a survey form to ensure consistency and quality. Interviews included questions in 10 topical areas involving the following key survey areas:

- Drivers for switching.
- Performance analysis.
- Economics (costs).
- Experience/results.

It was determined through the survey that there is no "Bill of Rights" for garments. Clearly, not all garments are created equal. Different plants have different drivers for switching to SUPC. One of the reported drivers for switching to SUPC was personnel contamination events (PCEs). However, it should be noted that there are numerous variables when recording, evaluating, and analyzing PCEs. Outage scope, outage length, system, and area contamination levels make PCE trending from one outage to the next extremely difficult. Typically, when plant management noted some improvement in the number of PCEs, they made the switch to SUPC. However, numerous oth-

Working on diamond wire in support of cutting reactor vessel muzzles (launderable protective clothing).

er changes had also occurred. This made it very difficult to isolate what caused improvement. Furthermore, looking at another driver, cost, I discovered that no plant surveyed could produce a cost study showing SUPC to be less expensive. The only cost analysis that I received concluded that laundering is less expensive. It is noteworthy that one major user of SUPC switched back to laundering because the additional costs of single-use garments were not justifiable. My conclusion, based on the survey, is that plants considering switching should perform an in-depth and rigorous cost analysis.

Table I summarizes the level of usage by the 23 plants surveyed.

Table I
Summary of SUPC Usage (23 Plants Surveyed)

SUPC Usage	Plants
No Trial – Benefit Not Evident	2
Trial – Did Not Prefer	2
Trial – Considering but Undecided	2
Gloves Only	1
Modesties Only	2
Outage Only	1
PC Only – Laundering Booties/Gloves	9
Full SUPC	3
Largest Fleet Selected Laundering after Trial	17

Decision Tree

Based on the survey results, one can determine that plants must consider many interrelating factors before deciding whether to use SUPC. Figure 1 depicts the key factors that need to be considered.

When evaluating the interrelating factors, plants undergoing decommissioning should consider the nature of their work compared to typical work at operating nuclear facilities. Workers perform demolition as opposed to disassembly/reassembly. There are heavy physical work demands compounded by heat (ambient air temperature). There are unique industrial safety aspects such as numerous sharp objects and the types of tools used, which create hazards as well. Cutting torches and saws are just two examples of tools that can quickly cause harm if not used correctly. Lastly, there is often the threat of exposure to radiation sources for long durations.

With this per-

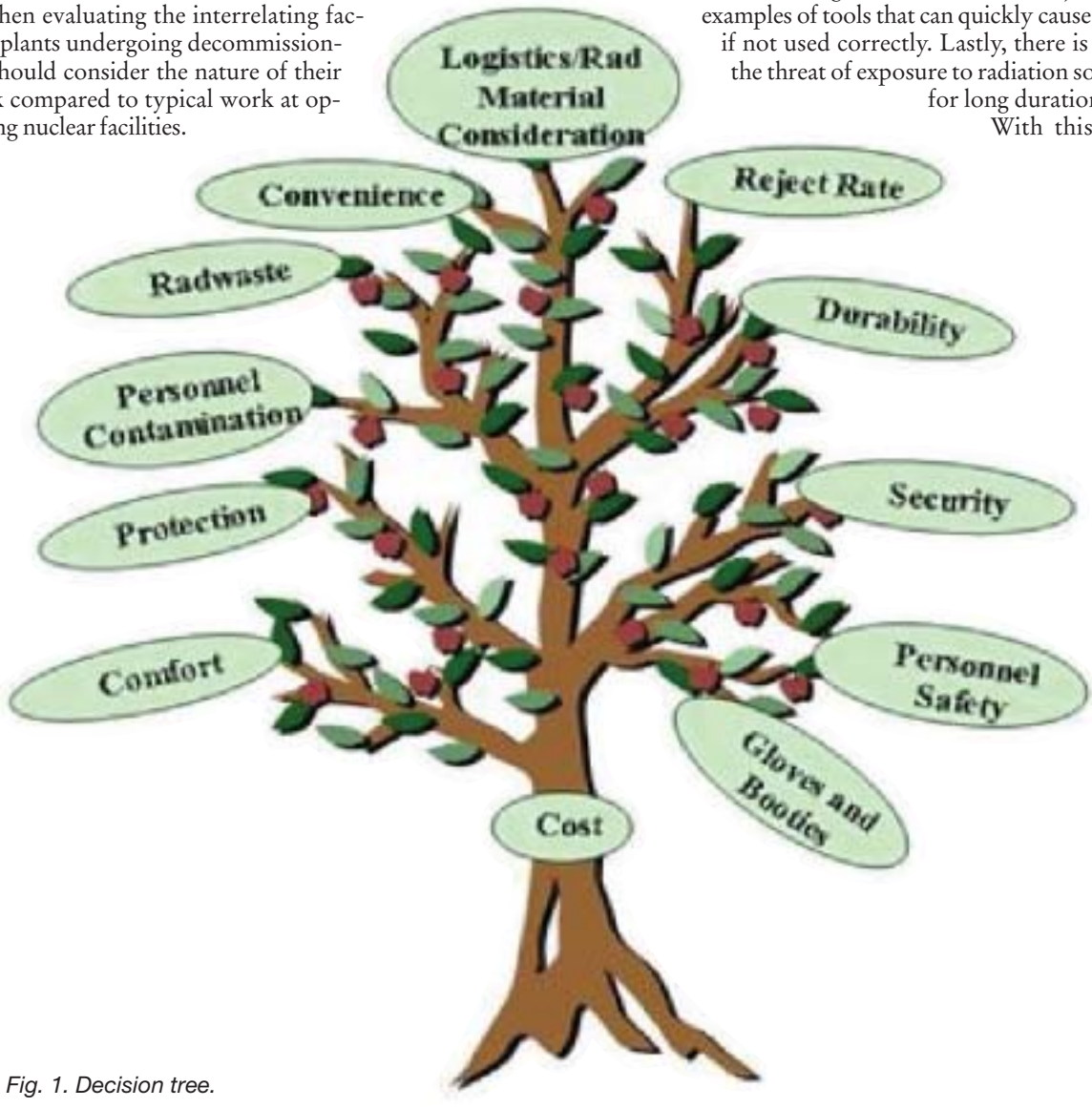

Fig. 1. Decision tree.

spective on the nature of decommissioning work, I can elaborate on the Decision Tree factors.

Cutting pieces of Unistrut using a reciprocating saw (nonflammable clothing).

Comfort

Physical demands/sizing are an important factor to consider because they affect the ease with which one can work in the garment. Garment design can be a limiting factor relative to comfort. Second, the possibility of heat stress should be evaluated, noting the product's (a) vapor resistance (air permeability—ASTM D 737-96) and (b) thermal resistance, including performance in both wet and dry conditions (Human Model Test ISO 11092 measures both vapor and thermal resistance).

Third, garment weight affects comfort and can be decidedly different when wet than when dry. There are a number of references from scientific sources that should be consulted (e.g., the Electric Power Research Institute's "Guidelines for the Optimization of Protective Clothing," Nov. 2003).

Protection

Protection issues include the following:

- Durability.
- Ability to avoid penetration.
- Performance in varying environments (wet/dry/hot).
- Ability to absorb or repel liquids.
- Performance when sweating occurs—capillary action.

The applicable standards that apply include the following:

- ASTM D 1683-04—Seam Strength.
- ASTM D 3786-01—Bursting Strength.
- ASTM D 3884-92—Abrasion Resistance.
- ASTM D 5034-95—Breaking Strength.
- ASTM D 5587-96—Tearing Strength.
- ASTM F 903-99a—Water Intrusion.
- IES RP.COO3.2—Particle Penetration.

I performed an evaluation to determine if results would or could be different based on the cause of the PCE. Table II shows this relative comparison.

My conclusion is that one should not think that a

Table II
Personnel Contamination Event Causes

Plant Conditions	Relative Comparison of Launderable vs. SUPC
Unknown Reason	Launderable/Single Use Same
Improper Undress	Launderable/Single Use Same
Improper Controls	Launderable/Single Use Same
Poor Work Practices	Launderable/Single Use Same
Airborne	Launderable typically better barrier vs. airborne (due to thickness)
Not Enough PC	Single Use better if you buy extra ($$) in right size distribution
Contaminated through PC	Do barrier testing; this can go either way based on type of single use or launderable.
PC Sweat Through	Greater with most single use, due to thinness. See if PC absorbs/repels water.
Contaminated from PC	Launderable greater – consider lower limit or different PC.
Torn PC	Greater with single use, 30 percent ripout report.

Table III How Many PCEs Really Caused by PC	
PCE Reduction of PC	**Cost Factor**
Better Housekeeping/Facility Decon	Cost medium
Improved Training	Cost low/medium
Radiological Work Permit Review/Right Protection for Job	Cost low/medium
Consider Single-Use over Launderable for Certain High-Contamination Jobs	Cost low/medium dependent on scope/size of job
Understand Your Processor's Laundering Cycle/Technique	Cost zero
Lower Reject Limits	Typically cost is low
New PC	Cost high/evaluate rental/lease
New Single Use	Cost high/almost double launderable on a cost-per-use basis

change to SUPC will reduce PCEs (see Table III). Real causes need to be well understood so that cost-effective mitigation can be implemented. After causes are identified, then plants can evaluate the most effective way to reduce PCEs.

Convenience

The convenience factor is addressed in Table IV.

Reject Rate

Reject rate is the limit at which laundering facilities reject laundry due to the amount of residual contamination that remains on clothing after laundering. The radioactivity in the garment is measured by monitoring equipment that is specifically designed for the application.

The following factors affect the reject rate:

- Type of fabric—synthetic, rubber, cotton, poly/cotton.
- Decontamination properties.
- Construction and quality of fabric—Velcro®, zippers, pockets, seams.
- Work environment.
- Set-point limits (level of detection).
- Monitoring equipment.
- Required mending.
- Age of the protective clothing.

The factor that has the greatest impact on the reject rate is the set-point limits (level of detection) of the monitors. Typically reject rates reported are less than 1 percent, so lowering the monitoring set point may indeed be an effective way of helping to further reduce PCEs at a minimal, if any, cost.

Durability

Durability of the garment should be considered in the overall analysis. Garment durability can impact cost in several ways. When a single-use garment breaks, an employee must exit the area and change into another garment. There is a loss of productivity and loss of the cost of the garment. A launderable garment may not become damaged under the same conditions. If it does, it may be

Table IV Convenience	
SUPC Process	**Launderable Process**
1. Shipment arrives at site (30 000 sets)	1. Shipment arrives at site (2000 sets)
2. Security screens	2. Security screens
3. Boxes moved to dress-out area (can be outside of RCA)	3. Move preloaded carts/mobile shelving to dress-out area
4. Boxes loaded onto shelving	4. Issue PC and other clothing out of carts/shelving directly
5. Personnel dress-out and use	5. Collect dirties in same carts
6. Dirties collected	6. Move to shipping area
7. Rad shipment prepared	7. Rad shipment prepared
8. Shipment sent	8. Shipment sent
9. Zippers/other waste returned	
10. Zippers/waste dispositioned with other radwaste	

Cutting pipe using a band saw (lauderable protective clothing).

able to be repaired, avoiding the cost of replacement. Consider the following areas when evaluating durability:

- Breaking strength (ASTM D 5034-95).
- Tearing strength (ASTM D 5587-96).
- Seam strength (ASTM D 1683-04).
- Bursting strength (ASTM D 3786-01).

Personnel Safety

Personnel safety ranks as the top priority in any industry. Careful consideration should be given to evaluate the safety implications of a type of garment. Heat stress could be an issue if a garment does not breathe well or causes sweating. Stocking and shipping activities have caused some back injuries in the industry. Fire protection of individuals is paramount when working around/with torches, open flames, sparkles, or energized circuits.

Although cost is important, certainly safety remains the number one factor when considering types of protective clothing.

Logistics/Rad Material Considerations

In some cases this is a key factor because of the space limitations and location of plants' storage areas. Designations of radiological controlled (RCA) or nonrad areas can affect efficiency and cost. Also, storage of protective clothing in dress-out locations can be a factor, as are the amount of space available and the shipment minimization. As an alternative to switching to SUPC, plants could work with their laundry service to minimize logistics issues. Consider prestaging, leasing, and specially designed carts and mobile shelving.

Security

In the post-9/11 environment, the level of security at nuclear installations has increased so that searches are required of all shipments prior to entry into owner-controlled areas as well as protected areas.

The logistics of material and dress-out location interrelate with these security issues. It is necessary to create processes that minimize the impact and associated costs of security searches.

Packaging SONGS-1 reactor vessel insulation (launderable protective clothing).

Cost

Cost is becoming the second strongest driver in decision making at operational nuclear plants, plants undergoing decommissioning, and U.S. Department of Energy facilities. A cost analysis should be performed to determine the overall comparative cost of laundering vs. using SUPC. Table V shows a possible format for doing a simplified cost analysis based on cost per use.

Based on a range of costs evaluated by the author, the following demonstrates the estimated savings:

- $1.30–$3.00 per dress-out multiplied by 200 000 dress-outs over a period of eight years equals a total savings of $260 000–$600 000 (€200 000–€500 000).

Survey of Decommissioning Plants

The survey to determine their protective clothing usage included the following plants:

- Maine Yankee.

Table V
Simplified Cost Analysis for Selecting Protective Clothing*

	Cost	Launderable Poly/Cotton	Single Use
A	Total Dress-Outs		
B	Required Inventory		
C	Existing Inventory		
D	Amount Required to Purchase (B - C)		
E	Garment Purchase Cost, including shipping (per unit)		
F	Number of Uses per Garment		
G	Cost Per Use (E ÷ F)		
H	Inventory Purchase Cost (D x G)		
I	Damage/Rejected/ Wornout Replacement Cost		
J	Garment Receiving Cost (12 shipment total)		
K	Shipping Cost (for laundry: 12 shipment total)		
L	Laundering Cost		
M	Radwaste Cost (includes all that applies: labor, shipping, dissolving, burial, etc.)		
N	Total Cost (H + I + J + K + L + M)		
P	Total Cost per Dress-Out (N ÷ A)		

**An explanation of the items/services included in each line item:*
A. Total number of dress-outs for the analysis.
B. Total required inventory to support workload.
C. Total existing inventory of items.
D. Amount of inventory that plant is required to purchase (required inventory minus existing inventory).
E. Total garment purchase cost, including shipping, handling, and applicable in-house stores charges.
F. Average total number of uses per garment (i.e., average life span).
G. Total cost per use (garment purchase cost divided by number of uses).
H. Weighted inventory purchase cost (required amount to purchase multiplied by cost per use).
I. Damage/rejected/worn-out replacement cost (includes all that applies: labor, shipping, dissolving, burial, etc.). For single-use items, this includes purchase for extra items to account for damaged items that must be replaced during use (e.g., worker rips out a coverall and must replace it).
J. Total cost for labor to receive goods into facility (i.e., security, health physics, worker, etc.).
K. Total cost for labor to prepare paperwork and coordinate laundry shipments to the processing facility (i.e., security, health physics, worker, etc.).
L. Total laundering cost for reusable items.
M. Total of all costs to disposition items as radwaste (includes all that apply: labor, shipping, dissolving, burial, etc.). This line item cost will vary depending on method of disposition selected.
N. Total costs for amount of dress-outs in analysis.
P. Total cost per dress-out (total cost of analysis divided by total number of dress-outs).

Individuals performing their own analyses are urged to request quotes from suppliers to confirm rates with respect to their application.

- Connecticut Yankee.
- Yankee Rowe.
- Saxton.
- Big Rock Point.
- Trojan.
- Rancho Seco.
- SONGS.

All these plants were using launderables, which they felt best met their overall needs.

Thermal cutting of metal (nonflammable clothing).

Zipping It Up

Individuals considering using SUPC should not jump to conclusions. The survey conducted clearly indicates that plants have different drivers for decision making. A facility should perform an evaluation to understand its true drivers for clothing selection. Consequently, I recommend that the facility form an interdisciplinary team including representatives from budgets and cost, safety, radwaste, and health physics to perform the analysis. For the plant to formulate a proper perspective and conclusion, they must ask the company providing the clothing the right questions. In the end, the individual making the recommendation should ask, "Is my decision emotional, logical, or economical?" ■

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