ASSESSMENT OF THE EFFICIENCY OF PERSONAL PROTECTIVE EQUIPMENT FOR USE IN RADIOACTIVE CONTAMINATED ENVIRONMENT - RECENT IPSN CONTRIBUTION

Gilbert BRUHL ; J. CORBIÈRE ; J. CL. LABORDE ; J. VENDEL
Institut de Protection et de Sûreté Nucléaire , 92265 Fontenay-aux-Roses, France

Abstract

In all industrialized countries important studies have been accomplished with the aim of improving the personal protective equipment (PPE) performances, i. e. of minimizing the exposure to hazardous environment and other risks for workers attending to operate in a contamined area and, at the same time, to increase their physiological comfort.

In the same field, IPSN, in collaboration with other European laboratories, has achieved in the last four years, an important research program, in order :

- to determine the efficiency of protection of the different categories of PPE,
- to improve the design and to develop new material of construction of special type of PPE (e.g. ventilated-pressurized protective clothing, ventilated hoods,...),
- to optimize the time of use during routine operation or emergency situations, by considering both technical performances and physiological aspects such as heat constraints and health effects.

After a brief review of the main characteristics required for the different categories of PPE, the present communication will present the directions of research which were preferred in order to achieve the objectives specified here above. Then it will conclude with a review of the instructions of use, maintenance and wearer training, which are the essential factors to be considered by every responsible of operational health of the employers in a nuclear facility, in relationship with the PPE management program.

1 - PERFORMANCE LEVELS OF THE DIFFERENT CATEGORIES OF PPE

In order to evaluate the level of protection offered by a particular PPE, the following definitions are used :

- **Nominal Protection Factor (NPF)**

The ratio of the average concentrations of contaminant measured in the ambient atmosphere and inside the PPE, at the point where the wearer draws breath. The concentrations taken into account are the average concentrations recorded during a standardized test.

$$NPF = \frac{C\ \text{ambient}}{C\ \text{inhaled}}$$

- **Permeance or Total Inward Leakage (TIL)**

Quantity corresponding to the reciprocal value of the NPF. It is expressed in %.

$$TIL = \frac{1}{NPF}$$

According to these definitions and as usually admitted in the literature [1], [2], the efficiency of the different categories of PPE can be classified in accordance with table 1.

Categories of PPE / Definitions	Range of Nominal Protection Factor	Range of average leakage into the PPE (in %) during standardized test (Permeance)
Ventilated-pressurized protective clothing (Air feed impermeable suit)	10 000 - 100 000	0.001 - 0.01
Ventilated hood (Air feed impermeable hood)	5 000 - 50 000	0.002 - 0.02
Filter type respirator (Full face mask with filter)	2 000 - 10 000	0.005 - 0.01
Non ventilated protective clothing (Blouse or impermeable suit)	2 - 20	5 - 50

Table 1 : Efficiency of different categories of PPE

2 - MAIN RESEARCH DIRECTIONS

2.1 - Ventilated-pressurized protective clothing or hoods

- Improvement of the protection factor

For air feed protective clothing the protection factor level mainly depends on :

- the **static leaktightness** which in term depends on the intrinsic tightness of the clothing during normal working conditions; the studies have been focused on the improvement of the welding or seams and fasteners quality.
- the **dynamic leaktightness**, which is essentially dependant on the efficiency of the exhaust device(s) and on the aeraulic performances of the protective equipment.

Concerning this last field, both investigations have permit to increase namely the NPFs by a factor of 4 (i.e. from 20 000 to 80 000) by developing special high efficiency exhaust devices, and by increasing the internal air flow rate inside the equipment (see figures 1 and 2).

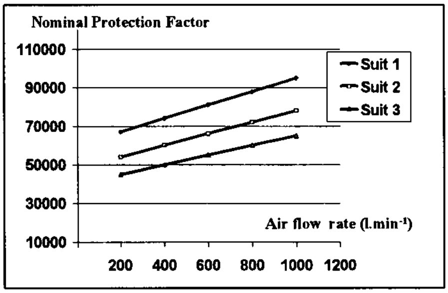

Figure 1 : Variation of NPFs by increasing air flow rate in ventilated-pressurized clothing

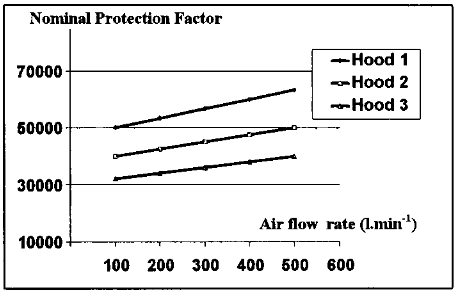

Figure 2 : Variation of NPFs by increasing air flow rate in ventilated-pressurized hoods.

- **Improvement of physiological comfort (new concept of ventilation of suits)**

The studies were carried out in cooperation with occupational physicians to the definition of a system of "direct skin or body ventilation" which allows a better thermal regulation of the wearers, particularly in case of intervention in hot environments.

The results have proved that for the same ventilation rate and the same physical work rate, the acceptability duration may be improved by 50 % by means of the refreshing due to the direct skin ventilation, in comparison with the traditional clothing in which the ventilation is fed into the suit, i.e. only over the underwear.

- **Studies concerning new material of construction of PPE**

In addition with efficiency against particle penetration, design of PPE must comply with other typical requirements, such as mechanical resistance, flexibility, flammability behaviour, suitability to disposal (by incineration), gas permeation, etc. Table 2 here after presents the compared performance of principal materials, replacing PVC, which has been so far the most common one.

PVC (standard or non flammable)	Low cost Easy welding Non flammable	Non incinerable High Cl content (36 %)
POLYURETHANE (standard or non flammable)	Incinerable Good mechanical & chemical resistance	High cost Difficult to weld
POLYETHYLENE (standard or non flammable)	Low cost No Cl content Incinerable	Flammable Mechanical resistance lower than PVC
PVC coated with polyester	Low permeability to gas (e.g. tritium), Excellent mechanical & chemical resistance	High cost Heavy material Non flammable
Polyethylene - Vinyl Acetate (EVA)	No Cl content Incinerable Acceptable mechanical & chemical resistance	Flammable, Difficult to weld and assembly, Higher cost than PVC
Non woven tissue (TYVEK) (polyethylene standard or non flammable)	Low weight, Incinerable Flammability depends on (Cl, Br, ...) content	Higher cost than PVC Mechanical & chemical resistance lower than for the previous material

Table 2 : Comparison between different material of construction of PPE

Airborne concentration	**Recommended personal protective equipment**	
	Continuous use	**Short duration use in special circumstances**
Less than 0.3 DAC	No requirements. Half face respiratory may be appropriate	No requirements. Half face respiratory may be appropriate
Greater than 0.3 DAC Less than 30 DAC	Full face respirator with particulate filter	Full face respirator with particulate filter
Greater than 30 DAC Less than 150 DAC	Air fed respirator, hood, blouse or impermeable suit	Full face respirator with filter, or air fed respirator, or impermeable suit
Greater than 150 DAC Less than 300 DAC	Air fed impermeable suit	Air fed respirator or impermeable suit
Greater than 300 DAC	Air fed impermeable suit	Air fed impermeable suit

Table 3 : Guidance for the selection of PPE (particulate hazard) for normal operations or emergency situations (IAEA Recommendations)

2.2 - Non ventilated-non pressurized protective clothing

Due to the fact that this kind of protective clothing does not provide the entire protection of the respiratory tract of the wearer, it was interesting to assess the different kinds of equipment in use (blouses, coveralls, 2 pieces suits,...) in order to determine the protection factor given by the protective suit without any additional respiratory protective device.

Two kinds of particle permeation test, using Na Cl agent test, with different particle sizes (respectively 0,6 µm and 1,4 µm of aerodynamic mass median diameter), have been successively performed :

- at first, the efficiency of the material of construction has been implemented. Figure 3 here after gives the results obtained for several types of non wowed materials.
- at second, the efficiency of the complete suit has been implemented (this test is called "whole suit test"). Figure 4 here after shows the results obtained on different types of protective clothing.

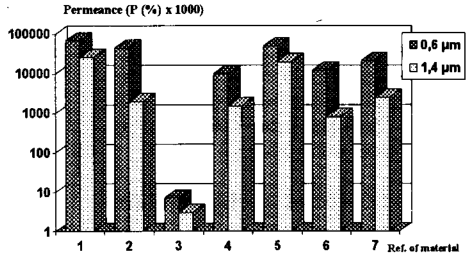

Figure 3 : Particle penetration test for material of construction of protective suits

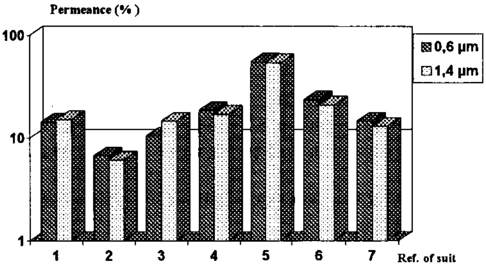

Figure 4 : Particle penetration test for protective clothing ("Whole suit test")

The conclusion of these tests are :

- Figure 1 : results depend on both particle sizes and permeability of material,
- Figure 2 : results depend only on the design of the suit (position of openings, straps on legs, neck, arms,...) and very little on material of construction. Total Inward Leakage can vary from 5 to 50 %.

These results have been confirmed by several European laboratories using the same test procedures, during intercomparison exercises [3], [4]. This means that the use of non ventilated protective clothing must be limited for very low contamined environment or combined with appropriate respiratory protective equipment in case of high or medium contamined environment for routine or emergency operations.

3 - CONCLUSION

Due to the different levels of efficiency, PPE should be chosen in accordance with the risk analysis. Table 3 here above could be a good help for the selection of the appropriate PPE. In addition other parameters should be taken into account, such as :

- examination of the means for removal or reduction of the sources of internal/external other than individual contamination or exposure (constructive provisions, confinement, ventilation or preferential extractions,...);
- evaluation of environmental parameters (toxic gases presence, fire risk, temperature, etc.) and of human factors (training and experience of operators);
- preparation of working protected areas (mobile or fixed tents with appropriate ventilation joined to equipment for radiological surveillance);
- choice of the most appropriate PPE for the intervention : reusable or disposable (disposal problems procedures);
- economics factors : equipment cost + decontamination cost/disposal cost (related to wastes volume);
- personal training, control and maintenance of equipment, etc.

4 - REFERENCES

[1] BRUHL G. and al.: Personal Protective Clothing for Hazardous Environment - Guide for the Selection and Use, Collection PMDS (Protection, Manipulation, Detection, Safety), Volume VII/2, 1990.

[2] IAEA Document : Safety Series Guide : " Use and Management of Personal Protective Equipment in Radioactive Contamined Environment " (final Draft, november 1994).

[3] BRUHL, G., BISCEGLIE, G.P., CAPOROSSI, G.F., MARANGIO, G.:" Progress made in the Design and the Use of Ventilated - Pressurized Protective Clothing against Radioactive Contamination ", International Conference on " Harmonization in Radiation Protection : From Theory to Practical Application", Taormina, Italy, 11-13 october 1993.

[4] To be published jointly by IPSN/BIA.