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**AN IMPROVED AIR-SUPPLIED PLASTIC SUIT
FOR PROTECTION AGAINST TRITIUM**

by

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A paper proposed for presentation at the
Second International Performance of Protective Clothing Symposium

and for publication in the proceedings

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INTRODUCTION

Tritium, the only radioactive isotope of hydrogen, can exist as elemental hydrogen or combined with oxygen (tritium oxide) as a liquid or vapor. Tritium gas and tritium oxide (HTO) are odorless, tasteless, colorless, and readily dispersed in air. Tritium is a low-energy beta emitter that presents no external hazard because the dead outer layers of skin will completely attenuate the radiation. Tritium that gets inside the body is hazardous because it irradiates the soft tissue. Exposure to HTO is considered to be 10,000 times more hazardous than exposure to elemental tritium. The general assumption is that HTO, whether entry is through the skin, respiratory system, or digestive system, is completely absorbed and mixes freely with body water. It permeates all tissues within a few hours and irradiates the body in a fairly uniform manner. Tritium and HTO exposures are possible in the following operations: light water and heavy water cooled power reactors, fusion reactors, nuclear fuel reprocessing, and tritium production for nuclear weapons.

Because HTO readily enters the body via the lungs and skin, total body encapsulation is required to prevent assimilation. In the 1950's, polyvinyl chloride (PVC) was chosen for the fabrication of air-supplied plastic suits for several reasons including: its advanced stage of development compared to other polymers; extensive industrial experience; and physical properties such as low flammability, good chemical resistance, heat-sealable seams, and good tear resistance (1,2).

Permeation testing conducted in the 1960's and 70's indicated that Saran® (Dow Chemical Company) provided up to 150 times more protection against tritium permeation than PVC (1,2). However, Saran® demonstrated poor performance in a number of areas including drape, flammability, tear resistance, and seam strength. Several unsuccessful attempts were made to produce a Saran® plastic suit by laminating Saran® to various substrates.

This paper will describe a Saran®/chlorinated polyethylene (CPE) plastic suit developed at the Savannah River Plant (SRP) for use in tritium and HTO atmospheres.

Saran®/CPE Plastic Suit

The plastic of the 9-mil Saran®/CPE suit is a lamination of two 4-mil DOW PVDC/CPE coextruded XU65505.07 films (Figure 1). Each of the 4-mil films is a laminate of polyvinylidene chloride (Saran®), chlorinated polyethylene (CPE), and ethylene vinyl acetate (EVA). The material is reinforced with a polyester scrim core for added strength and contains flame retardants to make it

self-extinguishing when tested per ASTM-D-568-77. The suit is a two-piece design consisting of a jacket and pants (Figure 2). The jacket has a 14" x 10-1/2" cylindrical 40-mil PVC head piece with a built-in plenum/noise suppressor to deliver air to the wearer's head. Jacket cuffs are constructed from rigid polyethylene to which butyl rubber gloves are attached. The jacket contains an air distribution system/noise suppressor that supplies air to the head, torso, and legs (Figure 3). The pants have attached boots and are held up with suspenders. The suit comes in two sizes; regular and small, the small suit fits people smaller than 5'8". The suit is supplied with 18 to 20 cfm of air.

Special techniques were developed to heat-seal the suit seams and allow for the heat-sealing of PVC to the Saran®/CPE material. These techniques were developed by the suit vendor and are proprietary.

Permeation testing was conducted on the Saran®/CPE material and 12-mil PVC that is used in the present tritium plastic suit. In addition, the Saran®/CPE suit was vigorously field tested at SRP and tested by the Personnel Protection Studies Section, Industrial Hygiene Group, of the Los Alamos National Laboratory (LANL) to accept it for use by the U. S. Department of Energy (DOE).

Permeation Testing Methods and Materials

Tritium permeation testing was done by Radian Corporation in accordance with ASTM test method F739-85. Test specimens were cut

from randomly selected areas. Each specimen was measured at three places to determine the average thickness. A dial gauge comparator was used to measure the thickness to the nearest 0.001 inch.

Specimens were mounted vertically between two halves of the test cell. Cells were bolted together to a torque of 25 inch-pounds. Because the cells were manufactured with high-tolerance machine faces, no gaskets were necessary to prevent leakage.

The 9-mil Saran®/CPE and 12-mil PVC materials were challenged with the followings mediums:

- Tritiated water (HTO), 10 millicuries per milliliter (mCi/ml);
- Ethanol/HTO, 1 mCi/mL;
- Freon® TF/HTO, 1 mCi/mL; and
- Duo Seal®/HTO, 1 mCi/mL.

The challenge solution was delivered via a five milliliter disposable syringe. Timing for the test began when the chemical contacted the material. The collection side of the test cell was swept with a stream of zero-grade nitrogen, N², at approximately 20 mL/min. The nitrogen flowed through a gas dispersion tube into the ethylene glycol collection medium. Samples of this medium were taken every 15 minutes for eight hours and every 24 hours for the neat tritiated water challenges. One milliliter samples were placed in a low-potassium scintillation vial with two milliliters of Aquasol-2, a liquid scintillant. Standards were prepared and a calibration curve generated ($\alpha = 0.9999$) to correct for possible quenching effects in the samples. The curve was used to

convert raw counts per minute to microcuries (μCi) per milliliter. All experiments were carried out in triplicate with a blank cell to check for cross contamination.

RESULTS

Breakthrough times and steady-state permeation rates for the 10 mCi/mL, HTO; and 1 mCi/mL, HTO in Duo Seal® vacuum pump oil, are summarized in the attached table. Tritiated water, 10 mCi/mL, permeated both materials; however, permeation was four times slower, and breakthrough was six times longer for Saran®/CPE. The relative effectiveness of the Saran®/CPE suit against tritium permeation is significantly better than the 12-mil suit: more than 75 times better after one hour; 17 times better after 2 hours; and 8 times better after 3 hours.

Tritium (1 mCi/mL) in Duo Seal® oil penetrated the PVC material in 100 min, but did not penetrate the "Saran®/CPE" during the entire 480 min test. Relative effectiveness against tritium was greater than 10 times better after 2 hours and greater than 28 times better after 3 hours for Saran®/CPE.

Both materials were challenged with tritium (1 mCi/mL) in Freon® TF and ethanol. No breakthrough was detected for either suit material during the 480 min tests.

DOE Acceptance Testing

The Personnel Protection Studies Section, Industrial Hygiene Group, of the LANL tested the SRP Saran®/CPE plastic suit in accordance with LA-10156-MS, "Acceptance-Testing Procedures for

Air-Line Supplied-Air Suits," for evaluation and acceptance by DOE (4). Suit test procedures examine quality of construction, ability to prevent penetration of aerosols, strength of hose, noise levels, performance in a loss-of-airflow emergency, and skin contamination during removal.

The SRP Saran®/CPE plastic suit proved to be of high-quality construction, provided a protection factor of >20,000 against a 0.3-micron polydispersed aerosol, and produced a noise level of 73 dBA inside the suit.

DISCUSSION

The newly developed Saran®/CPE plastic suit material offers significantly better protection against HTO penetration and permeation than the 12-mil PVC currently used at SRP and most other DOE and commercial sites where tritium and HTO are exposure hazards. Tritium permeation test results are in general agreement with the published literature. Breakthrough time is an important parameter when evaluating the applicability of protective clothing; previously published tritium permeation tests did not measure this parameter. Future studies should quantify steady-state permeation rate and breakthrough time to more fully evaluate potential tritium protective clothing.

Saran®/CPE has successfully been fabricated into a plastic suit because, in addition to its superior tritium resistance, it has all the characteristics required to construct a rugged, dependable, and comfortable suit. The use of the Saran®/CPE suit

at SRP reactor and tritium production facilities should be a major contribution to the site ALARA (As Low As Reasonably Achievable) program. In addition, several other DOE facilities have expressed an interest in this plastic suit.

Both Saran®/CPE have demonstrated excellent resistance to a wide range of chemical contaminants; therefore, this suit material may have applications in the general chemical industry and hazardous waste site cleanup operations.

ACKNOWLEDGMENT

I would like to thank all the people who contributed to the development of the plastic suit described in this paper especially Louis Contini of Rich Industries and Michael Ferguson of Dow Chemical Company.

The information contained in this article was developed during the course of work under Contract No. DE-AC09-76SR00001 with the U. S. Department of Energy.

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TABLE 1

COMPARISON OF SARAN®/CPE VERSUS PVC FOR TRITIUM PERMEATION

<u>Challenge</u>	<u>Material</u>	<u>Permeation Rate (μCi/cm²-hour)</u>	<u>Breakthrough Time (min)</u>	<u>Relative Effectiveness Against Tritium Permeation</u>		
				<u>1 hr</u>	<u>2 hr</u>	<u>3 hr</u>
10 mCi/mL	Saran®/CPE	0.02	95	>75	17	8
	PVC	0.07	15	1	1	1
1 mCi/mL in	Saran®/CPE	0.00	>480	1	>10	>28
Duo Seal®	PVC	0.05	100	1	1	1

Figure 1. Structure of SRP Tritium Suit Material

Figure 2. SRP Tritium Suit

Figure 3. SRP Tritium Suit Air Distribution System