# FRHAM-TEX II Cool Suit Material Testing for Water (and Therefore, Tritium) Protection

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## Introduction

We studied FRHAM-TEX II, a new clothing material, to determine its effectiveness in protecting workers against water and water vapor, either of which may be tritiated. FRHAM-TEX II in a cool suit configuration is claimed by the manufacturer to provide more comfort than other materials because of its ability to transpire liquids, i.e., remove sweat. The manufacturer also intends that their cool suit protect workers by repelling water and chemicals. Cool suits (with caps) made of FRHAM-TEX II are being offered to workers at Los Alamos National Laboratory as an option to their use of Tyvek clothing.

As a result of this study, we intended to provide supervisors, users, and purchasing agents with guidance concerning the effectiveness of FRHAM-TEX II clothing for water repellence. Based on objective data rather than on manufacturers' claims or personal preference, potential users could then select protective clothing in place of or in addition to Tyvek clothing. Additionally, cost savings might be realized by potential users' having a choice among protective clothing materials that are shown to be equally effective, whether they are FRHAM-TEX II, Tyvek, or another material. Improved worker protection may also result from the users' ability to select better materials for the workplace.

After our work was underway, we received funding from Hanford to study six samples of protective clothing they were considering using. They requested that, among other properties, we study water repellence. Hanford's interest provided us with more materials to compare to FRHAM-TEX II and demonstrated another benefit of our study—having a procedure and equipment developed and available for future studies of this type, including studies of liquid and vapor organic chemicals.

## Method

The materials we used in these studies were cut from yellow or magenta FRHAM-TEX II protective clothing articles in the Laboratory's inventory, from a white sample of FRHAM-TEX II provided by the manufacturer, or from six brands of suits sent to us from Hanford. Normal (untritiated) water or water vapor challenged the test material.

To conduct water permeation measurements, we mounted fresh or dried samples in a standard permeation cell with either the outside (usually) or the inside on the challenge side of the cell. The permeation cell has one or more necks on the challenge side into which water can be poured or through which humidified air can be passed. The measurement side of the cell has one neck for a thermocouple and two more for air circulation. The cell is designed so that dry, sweep air impinges on the measurement side of the test material and swirls around before exiting to the analyzer. The area of material exposed to challenge water (or water vapor) and sweep air is 25 $cm^2$.

The water vapor analyzer we used is an EG&G Model-911 Dew Point Hygrometer. We measured the dew point or frost point and converted these measurements to water concentrations (mg/L) using the ideal gas law and correlations based on tabulated vapor pressures. We multiplied the air sweep rate (L/min) by the increase of water vapor concentration upon water or water vapor challenge to derive the water vapor permeation rate (mg/min).

We regulated and calibrated dry air from a cylinder to a 1.0 L/min flow rate through the test cell and recorded on a strip chart the analog output of the measured dew/frost point. At selected times, we also manually recorded digital dew/frost point and/or relative humidity (RH) readouts from the analyzer. A baseline, usually with less than 0.002°C/min frost point drift, was established before a test began. This corresponded to 3–5% RH of the sweep air. The initial frost point and cell temperature were recorded. We then quickly poured water into the challenge side of the cell or exposed it to a 1.0 L/min flow of humid air. In the latter case, we passed compressed air over a water bath, heated if necessary, to give the desired challenge water vapor concentration. Just before beginning the test, we monitored the dew point of the humid air until it stabilized.

We also conducted tests at above-ambient temperatures. We heated the cell with a voltage-controlled heating tape before and during the test and monitored temperature.

Two liquid water splash tests were done with a FRHAM-TEX II sample (outside contact). We rapidly poured 5 mL of water into the challenge side of the cell, immediately poured it out, and then inverted the cell to drain. We continued measurements to a maximum value and through the subsequent decrease.

## Results

One of the Hanford-supplied materials, Copiah Creek, immediately soaked up and passed liquid water through it; therefore, we discontinue using it for any further liquid water tests. All of the other materials repelled liquid water—we observed no drops on the other side—even though in most cases, vapor permeation was measured.

Table 1 shows a summary of the results of the liquid water challenge tests. Except for the Kappler Tyvek material, water permeation started within 10 seconds of adding the liquid to the challenge side. The vapor concentration increased so fast that the analyzer overshot and undershot the steady-state value several times until the signal leveled off, usually within five minutes. For the splash tests, table 1 presents the maximum permeation rates, rather than steady rates.

The best correlation we found for the effect of water vapor concentration on water vapor permeation is shown in figure 1. The "critical" water vapor concentration of about 12 mg/L at 20°C corresponds to 70% RH.

Table 2 shows a summary of the results of the higher water vapor challenge tests. Over the 65–75%RH range, we did not see a significant difference between permeation from the inside and the outside of the FRHAM-TEX II material. However, the permeation from the inside seems to be significantly higher than from the outside at the highest humidities. This may be the transpiration effect claimed by the manufacturer. However, the LANL Tyvek also showed this effect.

We also studied the temperature effect on permeation from the outside of FRHAM-TEX II material. We conducted a series of experiments in which water vapor challenge concentration was kept constant at 15.5±0.3 mg/L, while the cell temperature varied from 17–37°C. Figure 2 presents the results. Except at the lowest temperatures (17–19°C), permeation rates were essentially the same. We suspect that the highest rates in both figures 1 and 2 are due to liquid water condensation on the challenge surfaces at the lower temperatures involved.

***Table 1.*** *Water permeation for liquid water challenges*

| Material | Challenge side | Cell temperature (°C) | Number of tests | Water permeation Rate (mg/min) average | range |
|---|---|---|---|---|---|
| FRHAM-TEX II | Outside | 23 | 9 | 8.4 | ±0.7* |
| FRHAM-TEX II | Inside | 24 | 2 | 8.5 | ±0.4 |
| FRHAM-TEX II | Outside | 36 | 2 | 11.2 | ±0.1 |
| FRHAM-TEX II | Outside** | 23 | 2 | 3.2 | ±0.2 |
| LANL Tyvek | Outside | 24 | 2 | 5.4 | ±0.3 |
| LANL Tyvek | Inside | 24 | 2 | 4.7 | ±0.2 |
| TSO-150 | Outside | 24 | 2 | 5.1 | ±0.3 |
| Kappler ProShield 2 | Outside | 24 | 2 | 4.7 | ±0.1 |
| Kappler NUFAB | Outside | 24 | 2 | 7.0 | ±0.4 |
| Kool Cool Suit | Outside | 24 | 2 | 1.2 | ±0.0 |
| Kappler Tyvek | Outside | 24 | 2 | 0.0 | ±0.0 |

* Standard deviation estimate

** Splash tests (maximum permeation rates)

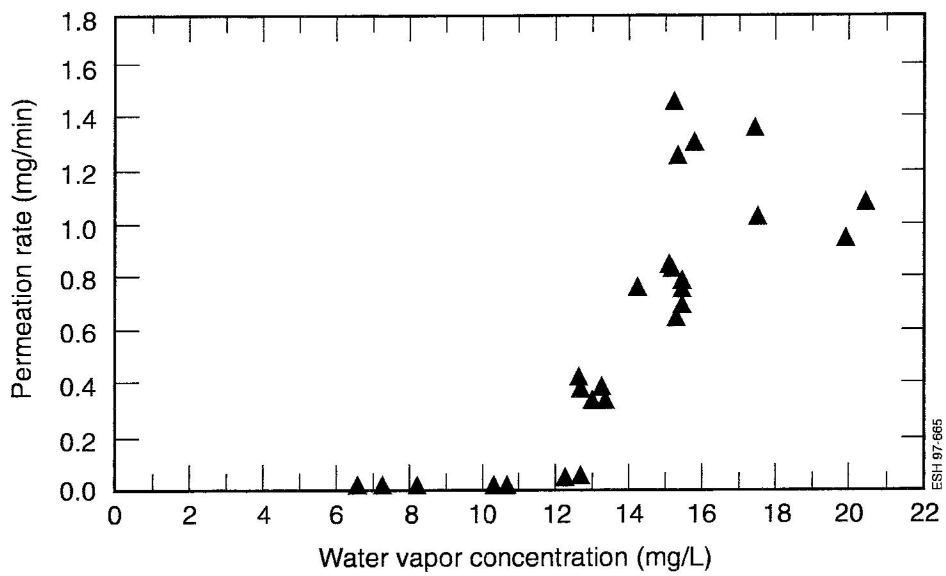


***Figure 1.*** *Effect of water vapor concentration on water vapor permeation of FRHAM-TEXII material. All challenges were to the outside of the material at 20 ± 3 °C.*

***Table 2.*** *Water permeation for higher water vapor challenges*

| Material | Challenge side | Challenge humidity range | Cell temperature (°C) | Number of tests | Water permeation Rate (mg/min) average | range |
|---|---|---|---|---|---|---|
| FRHAM-TEX II | Outside | 65–75% RH | 21 | 3 | 0.38 | ±0.03 |
| FRHAM-TEX II | Inside | 65–75% RH | 21 | 3 | 0.42 | ±0.02 |
| FRHAM-TEX II | Outside | > 93% RH | 22 | 4 | 1.1 | ±0.2 |
| FRHAM-TEX II | Inside | > 93% RH | 23 | 4 | 1.9 | ±0.3 |
| LANL Tyvek | Outside | > 98% RH | 22 | 2 | 3.15 | ±0.03 |
| LANL Tyvek | Inside | > 98% RH | 23 | 2 | 4.07 | ±0.01 |
| Kappler Tyvek | Outside | > 98% RH | 23 | 2 | Not detected | |
| Copiah Creek | Outside | 97% RH | 25 | 1 | 6.2 | |
| FRHAM-TEX II (white) | Outside | 78–82% RH | 25 | 5 | 0.7 | ±0.4 |

## Conclusions

Water repellence can be defined as the inverse of water permeation rate upon liquid water exposure. Of the materials studied, we found repellence to be the best for the Kappler Tyvek material and the worse for the Copiah Creek material. The latter was apparently an uncoated, woven cloth. FRHAM-TEX II and LANL Tyvek—the type currently used at Los Alamos—permeation rates fell between these extremes for both liquid water and water vapor challenges. Of these two Los Alamos samples, Tyvek was a little better for water repellence, but worse for water vapor permeation at high humidities. When exposed to liquid water, neither material is a very good water vapor barrier.

We saw no big differences between liquid water repellence for the two directions of permeation for FRHAM-TEX II or Tyvek. However, significant differences did appear for the highest humidity vapor permeation studies.

Temperature effects on vapor permeation occurred only at the lowest temperatures, when condensation on the outside surface could explain higher rates.

Splash tests showed that immediate water permeation occurs for even the briefest exposure of FRHAM-TEX II to liquid water. This was confirmed by the rapid permeations observed for the constant water exposure experiments.

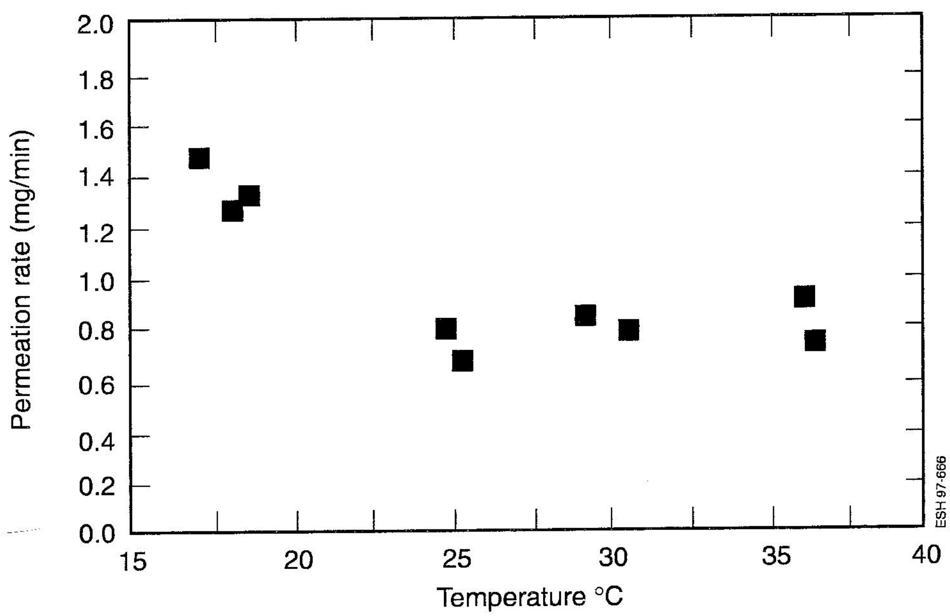


***Figure 2.*** *Effect of temperature on the water vapor permeation of FRHAM-TEX II material. All challenges to the outside of the material at 15.5 ±0.3-mg/L water vapor concentration.*

Figure 1 shows that for FRHAM-TEX II material, water vapor permeation increases rapidly above 12 mg/L vapor concentration (about 70% RH) at 20°C. Therefore, FRHAM-TEX II is not a good barrier for water vapor at high humidities.