

## The Science of Protection: The Chemistry of Coveralls - Permeation, Penetration, and Repellency

### Description

The primary purpose of a protective coverall is to protect the wearer's body. However, 3M recognize that different jobs require different levels of protection. This is why the range of 3M™ Protective Coveralls is diverse, and designed to provide options for your application and purpose.

In terms of Personal Protective Equipment, Body Protection normally refers to protecting the skin from the harmful effects of chemicals – either liquids or solids. This bulletin focuses on protection from liquid chemicals; first we will look at the three Types of coverall generally available for protection against different levels of liquid chemical hazards. Of the six Types of Chemical Protective Clothing, three are specific to liquid chemicals and are referred to as Type 6, Type 4 and Type 3. In each case the fabric is tested for various physical properties and chemical properties. The full suits are also subjected to different tests depending on the Type of protection they are intended to offer.

Type 6 Chemical Protective Clothing is intended to provide limited protective performance against light splashes of liquid chemicals. Type 6 coveralls are tested in a number of ways including undergoing a limited liquid spray test.



[3M™ Protective Coverall 4540+](#)

Type 4 Chemical Protective Clothing intends to provide a higher level of protection than Type 6 by having “spray tight” fabric and seams. Type 4 coveralls are subjected to similar tests to Type 6 but in the full suit tests a larger volume of liquid is sprayed on to them.



[3M™ Protective Coverall 4565](#)

Type 3 Chemical Protective Clothing is intended to provide an even higher level of protection than Type 4 by having “liquid tight” connections between different parts of the clothing. In the Type 3 full suit tests a powerful jet of liquid is sprayed at several points of the coverall to test for inward leakage.



[3M™ Protective Coverall 4570](#)

The full suit tests use a water based liquid to assess the overall performance of the fabric and the construction of the finished coverall. These tests look for any inward leakage either through the fabric or through the seams or zipper. However, the coverall is also subjected to more specific chemical tests depending on the Type of protection it is intended to offer. These tests are known as Permeation, Penetration and Repellency.

The fabric of all coveralls is tested for Penetration and Repellency, but in addition the fabrics and seams of Type 3 and Type 4 coveralls are also tested for Permeation. This document looks at each of these tests.

## Penetration and Repellency

Penetration is a test to see whether a particular chemical will go through the fabric. Repellency is a test to see whether the chemical being tested stays on the fabric or rolls off. Together, the Penetration and Repellency tests are often known as a “gutter test” because of the equipment that is used (Figure 1). The test method is described in EN ISO 6530 (Figure 2).

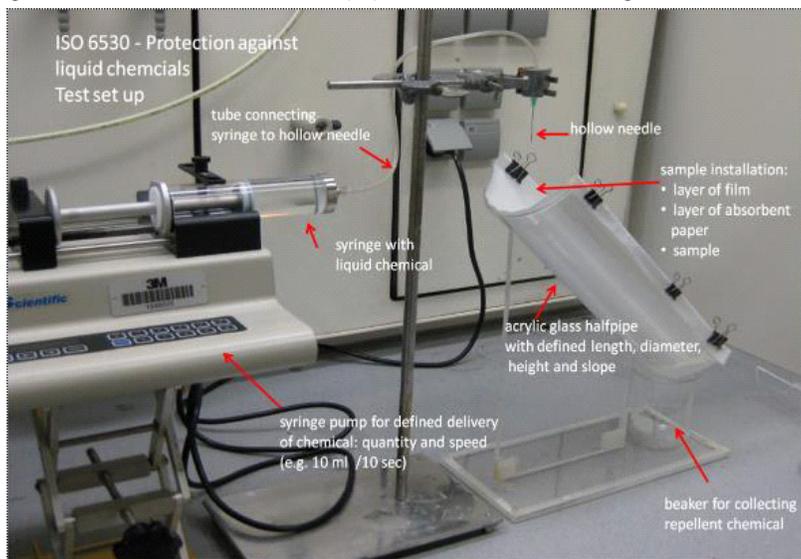


Figure 1

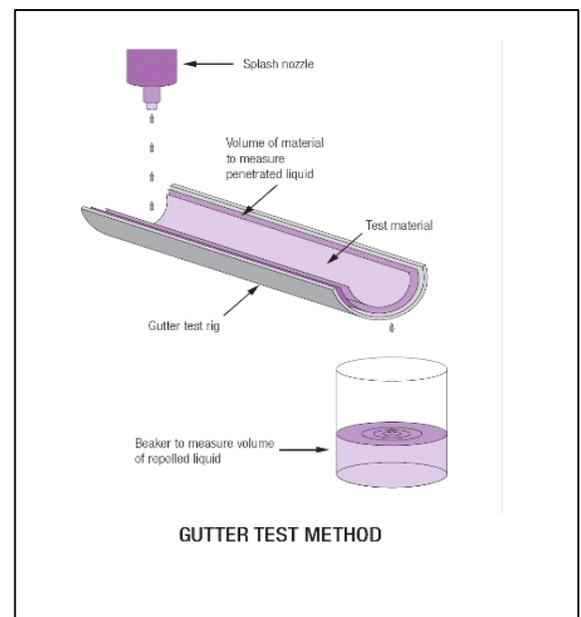


Figure 2

## EN ISO 6530 Penetration and Repellency

Penetration and Repellency are normally carried out at the same time. In this test the fabric being tested is weighed and placed in a semi-circular gutter at an angle of 45° on top of an absorbent piece of fabric, which is itself placed on top of a piece of film.

A beaker for collecting any chemical repelled off the fabric is weighed and placed at the end of the gutter. 10cm<sup>3</sup> of the challenge chemical is then delivered onto the fabric from a height of 100mm within 10 seconds using a syringe. After 60 seconds the levels of any Penetration and Repellency are measured.

Penetration is measured by deducting the weight of the absorbent fabric and film after the test from their original weight. The result will be zero if there has been no penetration.

Repellency is measured by deducting the weight of the empty beaker at the start of the test from the weight of the beaker at the end of the test – ideally this will be the weight of the challenge chemical i.e. it has all been repelled off the fabric into the beaker.

Typically, chemicals will be tested from families of chemicals to give an indication of the protective properties of a fabric. So, for example, Sulphuric Acid 30% may be selected to give an indication of how the fabric protects against acids, Sodium Hydroxide 10% as an alkaline chemical, o-Xylene as a solvent, and Butanol as an alcohol. However, when selecting a chemical protective coverall a full risk analysis should always be carried out to ensure the suitability of the product for protection against the hazards in question, including the specific chemicals the wearer may be exposed to.

Results are normally given in terms of classes based on the percentages of Penetration and Repellency, the higher the class number the better the performance. For example, the classification system in EN 14325 (the Standard which sets out the test methods and performance classification of chemical protective clothing in Europe) has the following classes:

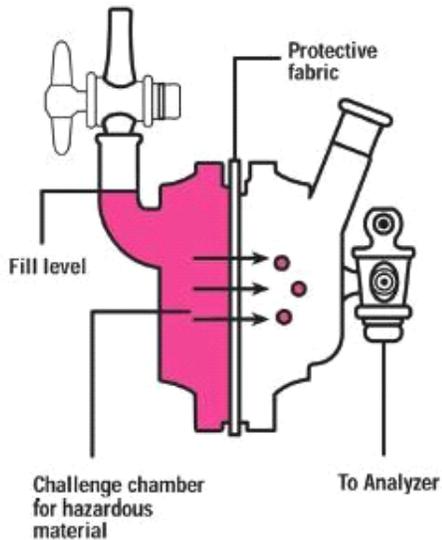
Penetration and Repellency Classes (EN 14325)		
Class Level	Penetration	Repellency
Class 3	<1%	>95%
Class 2	>1% and <5%	>90% and <95%
Class 1	>5% and <10%	>80% and <90%

## Permeation

“Permeation” is the process by which a chemical moves through a material on a molecular level. This is different to Penetration which could be described as the process by which a chemical moves through a material on a non-molecular level. To explain it more simply, “permeation” of a chemical through a fabric cannot normally be seen, whereas “penetration” through a fabric may be visible to the naked eye.

Permeation testing is required for all Type 3 or Type 4 coveralls because of the greater risk of being exposed to harmful chemicals either in a larger volume than a Type 6 splash, or for a longer time period. This test can take up to 8 hours, depending on whether there is any permeation, and may therefore be more suited to situations where a coverall is not replaced at the first sign of contamination.

Usually both the fabric and seams are tested for permeation. This is why the seams on a Type 3 or Type 4 coverall are normally covered with a special chemical resistant tape. If the seams were not taped it is most probable that any chemical would leak straight through, irrespective of how resistant the fabric may be to permeation. The test method for permeation is described in EN ISO 6529:2001.



**Figure 3**

Image courtesy of Quick Selection Guide to Chemical Protective Clothing, Forsberg & Mansdorf, Copyright 2007 John Wiley & Sons, Inc. Reprinted with permission from John Wiley & Sons, Inc.

## EN ISO 6529 Permeation

A sample of fabric is clamped between 2 permeation cells normally made of glass.

The challenge chemical is added to one of these cells such that it is in contact with the outer most face of the fabric i.e. the side of the fabric that is at risk of being splashed or sprayed.

On the other side of the fabric – the inner side - is a cell which contains a collection medium.

Throughout the test the side with the collection medium is analysed to detect any permeation.

The test is ended when the rate of permeation or breakthrough is detected at a certain level. This level is normally either when permeation is at a rate of  $1.0 \mu\text{g}/\text{cm}^2/\text{min}$  or  $0.1 \mu\text{g}/\text{cm}^2/\text{min}$ .

Results for permeation are normally given in terms of classes based on the time taken for the rate of chemical breakthrough to occur commonly known as Breakthrough Time or BT for short. Again, the higher the class number the better the performance. In Europe this is measured at a rate of  $1.0 \mu\text{g}/\text{cm}^2/\text{min}$  and according to EN 14325 there are 6 classes:

Permeation Classes (EN 14325)	
Class Level	Minutes
Class 6	>480 mins
Class 5	>240 and <480
Class 4	>120 and <240
Class 3	>60 and <120
Class 2	>30 and <60
Class 1	>10 and <30

Although it is essential to perform a permeation test of a chemical that a wearer might be exposed to in order to ensure the right overall for the application is selected, there are limitations to the permeation test. Many of these limitations apply to most of the tests carried out on chemical protective clothing and include:

- A limited numbers of samples are tested
- Testing is based on lab conditions which may not necessarily reflect work conditions
- Permeation rates increase with temperature
- Fabric may show variation
- Permeation testing does not assess degradation
- Breakthrough times are not safe wear times

3M has tested our fabrics against a large number of chemicals. The results can be found either on our Technical Data Sheets or by contacting your local 3M representative. If data is not available for a particular chemical, this could be arranged – please speak with your local 3M representative.

To find out more about the chemical protective properties of the fabrics used in our range, or which 3M™ Protective Apparel solution best meets your needs visit [www.3M.com/PPESafety](http://www.3M.com/PPESafety) or speak with your local 3M representative.

*Please note that, unless explicitly stated in product user instructions: data provided in this bulletin is for information only; it may be based on results from a limited sample size which may not be representative; it does not constitute official, quality-controlled product performance claims. The information provided is correct to the best of our knowledge at the time of publication but may be subject to change.*

*Customers should always read and follow the user instructions supplied with your 3M™ Protective Apparel in order to ensure correct operation. Final determination as to the suitability of these products for a particular situation is the employer's responsibility. If in doubt contact a safety professional.*

*For further information on the performance data of these garments, or for any other questions, customer should contact their local 3M sales or technical representative.*

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