# Advanced Module 515

# Thin-film Intumescent Coatings for the Fire-Protection of Steel Structures

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**Summary**

This Advanced level module deals with thin film intumescent coatings used for the fire protection of steel surfaces. It commences with an explanation of what we mean by an intumescent coating and introduces the generic raw material types typically used in the formulation of both water-based and solvent-based coatings. This is followed by an indication of how these coatings are tested.

The application of these products is then discussed before proceeding to a comparison of various forms of fire protection. The final section of the module provides a summary of the subject of thin film intumescents.

This module is intended for anyone requiring an understanding of intumescent coatings whether they are the "formulator" or other laboratory personnel, raw-material supplier, applicator, salesperson, architect or specifier - or indeed anyone with interest in the subject!

The module is designed to cover a wide range of topics associated with thin-film intumescents and, depending on their needs and background; some students may find some sections more useful/appropriate than others.

As the module is set at an advanced level, we would expect the student to have some knowledge of chemistry and physics and some basic knowledge of intumescents.

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**Structure of the module**

The module consists of a theory block, a Computer Marked Assessment, and a written Assignment. The theory block is split into three sections, which are not of equal length, and a brief summary. The module is designed to take about 10 hours of study, excluding the time taken to write up your assignment.

For full certification, the CMA and the assignment must be completed satisfactorily.

| **Marks for this module** | |
|---|---|
| Computer Marked Assessments (CMA) | 20% |
| Assignment | 35% |
| End Test (TMA)* | 45% |
| TOTAL | 100% |

An overall mark of 50% or more is necessary for successful completion of the module, with students achieving at least 40% of the marks available in each element

*You may, if you wish, await the completion of three modules before sitting the TMA papers. By 'Stacking' tests in this way, you will only need to attend the test centre once instead of three times.

**Learning Objectives**

For each topic in the module, there are designated learning objectives. These objectives are listed in each section of the study material.

**Prerequisites**

Persons studying at this level will need to have a good understanding of physics and chemistry and considerable experience in the coatings, or a related, industry.

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**Module Objectives**

In the learning materials for individual lessons, you will find individually numbered sections; these indicate the specific objectives to which they relate.

After studying the module, you should be able to:

**Section 1. How intumescents work – and how they are tested**

1.1 Intumescent formulation–"common" ingredients.
Explain the individual characteristics – and give specific examples of each of the following:

(a) acid generator
(b) carbonific
(c) blowing agent
(d) binder

1.2 Typical Intumescent Reaction Temperatures
According to the text, what are the typical steel temperatures (in UK tests) at which:

a) the intumescent reaction commences
b) the intumescent reaction ceases
c) the steel (fully loaded ) collapses

1.3 Pigment Volume Concentration
Discuss the importance of pigment volume concentration (PVC) for thin-film intumescents.

1.4 Steel Section Factors
Discuss the section factor concept. Given certain information, you should be able to work through examples.

1.5 Market Research, Product Development and Fire-Testing
Briefly explain the steps involved in the development and testing of an intumescent product.

1.6 Intumescent Coating Systems
Discuss the importance of suitable primers and topcoats for intumescent paints and explain why certain primers must be avoided and topcoats always used in external environments.

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1.7 General comparison of solvent-based and water-based intumescents
Discuss the various advantages and disadvantages of both solvent-based and water-based thin film intumescent coatings

**Section 2. Application**

2.1 Application methods
Discuss the advantages and disadvantages of brush and spray application of thin film intumescents and compare costs, application rates, labour intensity etc.

2.2 Site Application
Discuss the advantages and disadvantages of "on-site"(2.2a) and "off-site" methods of application(2.2b).

2.3 Application-monitoring
Discuss the need for careful monitoring of wet and dry film thickness of intumescent coatings

**Section 3. Choosing a method of fire-protection**

3.1 Discuss the considerations made when choosing a method of fire protection
3.2 Discuss the advantages and disadvantages of the various forms of fire-protection

**Section 4. Brief Summary**

**Note:** In this module, we make several references to a publication known as the "**Yellow Book**" which can be obtained from the Association of Structural Fire Protection (ASFP). This publication is dedicated to fire protection and is, therefore, a very useful document. It contains fairly detailed information on subjects such as "section factors/Hp/A values" which are discussed briefly within this module.

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**Introduction**

According to the Oxford English Dictionary the definition of the term "intumesce" is "to swell up". Materials recognisable as intumescents have been around for many years. Carbonaceous intumescents were first observed with the "Fourth of July snake"- when heated to its "activation temperature" this novelty (a small pill) would swell, bubble and foam, and a snake-like body would begin to curl from it.

However, the first commercial reference to a bubbling and foaming fire retardant system did not occur until 1938. Early formulations gave up to "60 minutes" fire protection - but several companies have now achieved "120 minutes" fire protection. The time quoted is the duration to "failure" in a national fire test situation. We will expand upon this subject later in the text.

Intumescent coatings have really only become commercially viable in the last 30 years or so (In the UK, thin film intumescent coatings have been used to protect steel for over 20 years) when more robust coatings could be formulated because of the introduction/availability of improved raw materials used in intumescents -such as Ammonium Polyphosphate.

As a result of these improvements and on-going development work, it is now possible to formulate thin-film intumescents with very good durability characteristics along with excellent fire-resistance. It should be noted however that durability and fire-performance will vary significantly from one manufacturer's product to another, as this is very much dependent upon the actual raw-materials utilised.

Thin film intumescent coatings are now very widely used in the area of fire protection – particularly for the protection of structural steel used in the construction industry - one of their main advantages being their aesthetic appearance. They are used frequently on structures such as airports, universities and sports stadia.

In a normal environment, a dry coat of intumescent could be considered similar in appearance to many high build paints/coatings - they are often white in colour and have a matt appearance. However, should a fire develop, and the steelwork coated with intumescent reach a temperature above 200° centigrade (200°C), the coating expands rapidly to form a thick carbon char which helps insulate the underlying steelwork from the heat source. This phenomenon can significantly delay the collapse of intumescent protected steel members of a building.

It should be noted that "fully loaded" steelwork typically loses approximately half its strength around 550°C in UK tests, at which point it is liable to collapse. It is the intention of all fire protection material manufacturers to delay the point (i.e. the point of collapse) as long as possible, as cost-effectively as possible.

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The use of fire protective materials is considered essential in most modern buildings so that if a fire were to break out, valuable extra time would be gained to allow the possible evacuation of the building and for the fire service to arrive.

There are two basic types of fire-test:

1. The "hydrocarbon" test-this is designed for testing products for the "off-shore" market (e.g. as required for oil rigs etc.) Due to the extreme temperatures involved (1400°C reflecting the extreme temperatures possible in chemical/petrochemical fires), the type of coatings involved are often based on epoxy technology. As these are high build coatings, they are frequently referred to as "thick-film" intumescents.

2. The "cellulosic" test-designed for testing products intended for all other situations. Even so, the fire test temperature approaches 900 °C after about 30 minutes. The coatings materials often successful in this test are usually referred to as "thin-film" intumescents.

In this module, we will concentrate on the "thin-film intumescent" type of coating used on steel substrates, tested by the "Cellulosic" fire test rather than the type used for the offshore market.

It should be noted that the individual testing standards/testing conditions will vary slightly from one country to another and in this module there is particular attention to the British Standard method of testing and assessment. In future, however, there is likely to be some "harmonisation" of standards-particularly across Europe-and this is mentioned in the text. To provide a reasonably balanced module, we have also included some information on other types of fire protective materials.

Thin film intumescents for steel tend to be developed and manufactured by large paint/coating companies active in the area of protective coatings. Although they have certain unique properties, the principles involved in their formulation and manufacture are similar to those used for other coatings. However, the cost of testing intumescent coatings is very high.

It should also be noted that Intumescent coatings are used on both wooden and metallic substrates. The technology employed and the formulation principles used- are very similar. However, in this module, the emphasis is on the coating for steel substrates.

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