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July 30, 1998

Mr. Dale Ray
CPSC
430 East West Highway
Bethesda, MD 20814

Dear Dale,

Please accept the enclosed pages and use them to replace the original sheets in the Overview document from the Polyurethane Foam Association submitted for the Docket on the Flame Retardant Chemical Public Hearing of May 5, 1998.

These pages contain corrections, which were found on further review of the Overview.

The pages enclosed are numbered page 16, 23, 26 and 27. You should also remove the extra copy of page 17 from the Overview.

Thank you for your cooperation.

Sincerely,
POLYURETHANE FOAM ASSOCIATION

L.H. Peters
Executive Director

LHP/ld
Enclosures

073098dr

Form Equals Function

Polyurethane Foam Association
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July 20, 1998

Ms. Sadye L. Dunn
Office of the Secretary
Consumers Products Safety Commission
430 East West Highway
Bethesda, MD 20814

Dear Ms. Dunn,

The Polyurethane Foam Association (PFA) would like to submit the enclosed document "Overview of the Combustibility and Testing of Filling Materials and Fabrics for Upholstered Furniture" for inclusion in the Docket of Comments on the May 5, 1998 Public Hearing concerning Flame Retardant Chemicals That May Be Suitable For Use In Upholstered Furniture.

This overview was prepared for the Polyurethane Foam Association by Dr. Herman Stone. The overview deals with more than 25 years history of the subject of the flammability testing of flexible polyurethane foam (FPF) and other materials similarly used in the production of upholstered furniture, bedding, carpet underlay and automotive interiors. Dr. Stone has excellent credentials to provide this overview as reflected in the attached curriculum vitae.

Flammability testing is an extremely complicated matter under any circumstance. The ignition source for the combustibility can be either a smoldering ignition (i.e. cigarette) or open flame ignition (small and large open flame).The ignition source first "looks" at the outer covering material in most combustion instances. The reaction of materials can differ with regard to the type of ignition source. However, the resulting combustion action invariably involves the composite structure such as a particular piece of upholstered furniture. Unpredictable interactions between the covering fabric, possible interlayers and the filling material or cushioning system usually occur. Therefore, PFA believes that composite, small scale testing is appropriate only if it can be correlated with full scale results.

With respect to regulatory standards, the requirement for testing should be relatable to an identified risk, and the results should provide a positive response to that risk involving a particular end use product, like a piece of upholstered furniture. The Polyurethane Foam Association has espoused a strong position of Product Stewardship since 1980 when the Association was founded. This Product Stewardship has consistently

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taken the view that the flammability characteristics of end- use products, in which FPF is used, are a function of the composite structure characteristics. The overview explores this complex subject and provides insight into the difficulty of simplifying the combustibility testing of upholstered furniture.

I thank you in advance for adding the overview to Docket of Comments on the May 5, 1998 Hearing.

Sincerely,
POLYURETHANE FOAM ASSOCIATION

L.H. Peters
Executive Director

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072098sd

OVERVIEW
ON THE COMBUSTIBILITY AND TESTING OF FILLING MATERIALS AND FABRICS FOR UPHOLSTERED FURNITURE

PREPARED FOR CONSUMER PRODUCTS COMMISSION
BY THE
POLYURETHANE FOAM ASSOCIATION

JULY 1998

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1:INTRODUCTION

BACKGROUND AND HISTORY

The flexible polyurethane foam industry developed starting in the years following World War II. Although, over the years, many different products made by this versatile technology were developed for innumerable end uses, the market for flexible polyurethane foams (hereafter referred to as FPF) as a filling material for furniture remains a major one.

Almost from the beginning it has been recognized that flexible polyurethane foams can be ignited and, depending on conditions, can burn vigorously. This is an inherent property of materials of this type. The polymer is an organic material and any product based on carbon will burn. In the case of FPF this tendency is increased by the fact that foam has a very large surface area per unit weight and being open celled allows ready access to the Oxygen (air) required for combustion.

Recognition of these factors led to early attempts to measure the performance of FPF when ignited by small ignition sources and to attempts to reduce the tendency for ignition by including additives. In the early 1970's the US Testing Company collected a list of forty test methods mainly directed to performance of fabrics and filling materials under various ignition conditions. Test methods, primitive by today's standards, such as ASTM D 1692, were developed to measure relative performance of various products. The use of terminology such as "self extinguishing" and "non burning" that resulted from these tests led to charges against the polyurethane industry by the Federal Trade Commission. A consent decree (1972) was entered into by the named companies, the Society for the Plastics Industry (SPI) and the American Society for Testing and Materials (ASTM) with the FTC which prohibited the use of this type of description and required that a disclaimer be used in connection with any small scale flammability test such as "THIS FLAMMABILITY RATING IS NOT INTENDED TO REFLECT HAZARDS BY THIS OR ANY OTHER MATERIAL UNDER ACTUAL FIRE CONDITIONS".

As part of the consent decree the polyurethane foam industry agreed to spend five million dollars over a period of five years on sponsored research work aimed at increasing the understanding of the relationship of foam and fire.

Understandably the use of such a disclaimer has, in turn, led to misunderstandings and charges that the test results are meaningless and possibly misleading. The basic problem remains that there is no such thing as a "standard or real fire" by which performance of a material can be measured and projected to represent performance under all conditions. The following discussion explores the complexity of any fire and the difficulty of measuring the inter-actions of a variety of materials involved in any fire scenario.

2: VARIABLES IN PERFORMANCE TESTING

Any test for ignition and burning performance of a piece of upholstered furniture must take into account the many variables involved. It is obvious that it is impossible to cover all the possible variations in a single test and this limitation always must be kept in mind and clearly stated. As a result, over the years, a large number of test protocols have been proposed and in some instances established as standards. A number of these are discussed in more detail in later sections.

Some of the variables involved are outlined below:

Filling Materials - Foams, including various types of foam rubber and flexible polyurethane foams, fiber, feathers, rubberized horsehair, garnetted cotton, etc, have been used as filling material. In many instances more than one material is used, such as fiber over foam or several types of flexible foam in one cushion. For flexible polyurethane foams some of the factors to be considered are density (weight), composition, porosity, cell size, presence or absence of additives etc.

Fabrics - Variables associated with fabric include:

- Weight including tightness of weave and denier of the fiber
- Porosity
- Construction including weave, welt cords, presence or absence of raised fibers (pile or flocked fabrics)
- Presence or absence of back coating
- Presence or absence of fiber treatments for soil resistance or water proofing
- Composition (fiber content)

Composition includes:

Cellulosics - cotton, rayon, linen

Protein based - wool, leather

Synthetics -

Thermoplastic - Polyester
Nylon
Polypropylene
Polyvinyl chloride

Other - Acrylic -
Modacrylic

Inner liners -Layers of material between the fabric and filling material including fiber glass, Nomex, carbon fibers etc.

Mixtures - Mixtures of these are also used.

Furniture construction - variables include size and thickness of the seat, construction of the back (touching seat or not), presence of side arms, presence of full sides (which increase heat exposure by radiating heat to the seat) presence of flanges, skirts etc.

Ignition Source - In addition to smoldering ignition sources such as cigarettes, open flame ignition sources may vary as follows:

Size of flame
Length of contact
Configuration - point source or extended
Placement - top, side or bottom

Exposure conditions - room temperature or elevated
Ventilation conditions - free air flow or limited access to air (affecting production of smoke, Carbon Monoxide and heat evolution).
Presence or absence of secondary ignition sources (for example other furnishings in full scale room tests).

It is apparent from the above, why development of a single test protocol to cover the variables likely to be found in a "real fire" remains an elusive goal.

3: FLAMMABILITY TESTING

In principle any test should have as close as possible a relation to what is likely to be the real life challenge to performance. In practice this aim has not been completely met because of the complexity of materials and possible fire scenarios.

Another important distinction to be kept in mind is the difference between a qualification test and a quality control test. The general distinction between these types of test is that a qualification test usually is more complex, time consuming and expensive than a test designed for quality control. A qualification test may be highly sophisticated technically and require special facilities and instrumentation. As a consequence it can generally only be performed in a limited number of installations and tends to be expensive and is often used only for research purposes. It is usually not practical to require such elaborate testing for all possible combinations of filling and fabric materials. For any regulatory purpose, such as the requirement of certification for compliance, it is vital that a quality control test be available that can be done at the manufacturing site, on a small scale, quickly and does not require highly trained personnel or elaborate equipment. Almost by definition such a test should therefore only require simple numerical or "pass" / "fail" results.

A further important decision in test method development that must be made is whether to test performance of each component of a piece of furniture separately or to test the composite structure. Generally, a manufacturer of a component would prefer to test only that component, since that is the only product he controls and whose performance he can readily certify. However in the case of furniture (and many other end uses) neither the filling material (FPF or other) nor the fabric is used alone. Except during their respective manufacturing processes they are always present as a composite product. The recognized interactions between materials have made it clear that component testing alone is not sufficient for predicting performance of a finished product.

In the following discussion of available test methodologies it will usually be obvious, whether each method represents a qualification or a quality control test and whether it represents a component or composite sampling procedure.

4:SMALL SCALE TESTING

SMOLDERING TESTING

Smoldering is one of the two potential processes of combustion ignition and involves a source of sufficient heat without appearance of visible flame. Since the process is distinct from open flame ignition both the testing and the technical means to achieve resistance to smoldering ignition vary from those needed for open flame performance.

For furniture (and bedding), available statistics show that cigarettes have been the most frequent cause of home fires. Therefore, smoldering cigarettes have been the ignition source of choice for test protocols (although other approaches such as radiant heat have been studied also). Even for such an obvious ignition test source as cigarettes, it has been necessary to specify specific properties of the source including type of tobacco, tightness of packing, paper and additives. NIST has carried out extensive testing to define the effect of such variables on ignition performance.

A cigarette ignition test for mattresses became one of the first mandated standards for industry (FF 4-72, now 16CFR 302 part 1632). Two factors were recognized almost immediately. One is that performance of a fabric/filling composite depends largely on the fabric exposed to the ignition source. The other was that polyurethane foam alone generally is highly resistant to cigarette ignition. Indeed it was this property that led to rapid adoption of such foams in the construction of mattresses. Unmodified (without combustion modifying additives) flexible polyurethane foam is used in most mattress constructions to achieve the smoldering protection mandated in FF4-72.

For upholstered furniture several composite testing procedures have become standard for testing smoldering ignition of filling materials. One is California TB 117 which uses a small mockup wooden chair configuration (with only one horizontal and one vertical surface) and a standardized cotton fabric, with a smoldering cigarette placed at the intersection of the two surfaces. The "pass" criterion is no continuing smolder and a sample weight loss not exceeding 20 %. The voluntary standard by UFAC (Upholstered Furniture Action Council) is similar using a different fabric. It further utilizes a "standard" foam to test variations in fabrics. This standard foam is an unmodified, non FR, flexible polyurethane foam.

There have been a number of other proposed procedures notably those developed by NIST (formerly NBS) using larger samples, more complex constructions and more cigarettes.

The UFAC program has also involved periodic testing of actual chairs with multiple cigarette exposures, particularly in areas most likely to pose a problem

such as contact with welt cords. The fabric industry has helped in development of a special welt cord construction, which is heat conducting and serves to act as a heat sink for mitigating potential welt cord smoldering problems.

The large influence of fabric composition and construction on performance has been long recognized and it is generally agreed that natural fabrics such as cotton, particularly heavy weight and open weave are the most likely to fail the smoldering ignition test protocols. Unfortunately in the case of open flame ignition, synthetics, which generally do very well in smoldering resistance, tend to do more poorly than cotton fabrics.

There has been much concern about possible deleterious effect on smoldering performance caused by additives to improve open flame ignition performance. Except for a few notable examples this has not been a major problem. Manufacturers of both fabrics and foams have to avoid some contaminants which can promote smoldering tendencies particularly such things as salts of Sodium, Potassium, Calcium, Magnesium etc. Fabric treatments for soil or static charge resistance have to be evaluated for compatibility with the composite components. In actual use post production contamination of furniture by dust, ashes or spills can also radically affect smoldering performance. In home fire scenarios it is often possible that the initial ignition by the smoldering source may occur on material other than the piece of furniture, such as the presence of newspaper or other ignitable material on the seat.

In general the evaluation procedures for smoldering are well established, although there will always be some uncontrollable factors related to the actual use of furniture in a home. Additional studies in this area might include evaluating potential changes in smoldering performance when the material and smoldering cigarette are simultaneously exposed to a source of radiant heat such a lamp or other heat source. As the use of inter-liners (to be discussed later), becomes more common, the performance of fabric, liner and foam requires attention. For FPF, although it is generally highly resistant to smoldering ignition, there may be a need to look at end uses such as chair backs which contain shredded material rather than a solid piece FPF.

OPEN FLAME - COMPONENT TESTING

A large number of tests have been developed to screen the open flame ignition performance of components for various end uses. Although these tests provide some information on the behavior of materials they do not address the fact that materials in combination with other materials will perform differently than they do by themselves.

Such tests differ in prescribing sample size, sample orientation (horizontal or vertical), intensity (size and duration) of the open flame ignition source, location of ignition (top, side or bottom) and performance criteria (length of burning, burn damage, rate of flame spread). Although it is generally believed that vertical ignition represents a more difficult scenario than horizontal, this is not always the case. It cannot be assumed that a material passing a vertical test requirement will automatically pass the criteria of a horizontal test.

Probably the most commonly used test for FPF cushioning is California TB 117, which uses a vertical sample orientation, bottom ignition and a criterion for time of burning after ignition and maximum allowed burn damage. This test will invariably show large differences in performance between conventional FPF and those containing combustion modifying additives. This difference is much smaller and often disappears in larger scale composite tests with larger ignition sources or under conditions imposing higher than ambient temperatures (radiant flux) .

Other component tests, not generally used for furniture cushioning include the following:

1) MVSS 302 (automotive) is the prescribed test for materials used in the passenger compartment of automobiles. It uses a sample in the horizontal orientation with the ignition flame applied at one end. Performance criteria include "no ignition under these conditions", ignition followed by extinction, and continued slow burning (with maximum flame spread rate of 4" per minute). This test, like most of its type, is very sensitive to sample size. The prescribed thickness is one-half inch, and results vary dramatically with other thicknesses (those common to actual end uses).

2) UL 94 is Underwriters Laboratory test for materials in contact with electrical equipment and requires minimum damage after exposure (before and after accelerated aging test) of a half inch thick sample placed horizontally and ignited with a flame at one end for 60 seconds. Criteria are ability to cease burning before 1.5 inches of sample are consumed and no ignition of fluffed up cotton from flaming drops. This test also is very sensitive to thickness of the sample, which can be critical since actual use is rarely at the prescribed half inch thickness of the sample.

3) The flooring radiant panel test (ASTM E-948) for carpets and carpet pads is an example demonstrating the extent and the rate of flame spread as a criterion. The sample is exposed to a radiant heat source varying in intensity along the length of the sample. The open flame ignition source is applied at the hottest end and both extent and rate of flame spread are measured. It is well

recognized that performance of a carpet alone will not predict the performance of the same carpet with an insulating layer below it such as a carpet pad.

The variability of test performance depending on both test conditions and sample size dictate that component tests should only be used for screening purposes and cannot be relied on to predict performance in actual use. The use of composites (if possible in proportion to actual use) is much more likely to reflect actual performance.

FABRIC TESTS

Fabric tests use vertical (bottom ignition), horizontal (one end ignition) or fabric tilted at a specified angle such as 30 or 45 degrees (bottom ignition) with generally fairly short ignition periods and small ignition flames. For fabrics intended for use in furniture the choice of these tests or any other test is critical since the ignition and succeeding burning behavior determines whether the fabric is likely to become a secondary and possibly large ignition source for the filling material.

INDIRECT TESTS

One test method that has received a degree of acceptance as a general tool for measuring resistance to ignition is the Limiting Oxygen Index (LOI) (ASTM G 125) procedure. In this procedure a strip of test material is placed vertically in a glass chimney equipped to be filled with a stream of mixtures of Oxygen and Nitrogen. The sample is ignited at the top (burning like a candle) and the gas mixture required to produce a steady flame is reported as the LOI. By definition then, any LOI below 21% Oxygen (normal air) indicates the material is flammable and the higher the LOI presumably the better is the sample's resistance to ignition. This definition however is too simplistic. First of all ignition is at the top precluding preheating of the sample by the initial burning. Unfortunately, bottom ignition is not practical for melting material, such as many fabrics or filling materials. Another deficiency is the assumption that a simple number will classify materials for performance. Limited work has shown that two materials of equally high LOI values do not behave the same when heat is applied (as in a developing fire). It is reasonable to expect that a more meaningful rating might be the temperature at which a sample's LOI value decreases to 21% Oxygen (that is the sample will burn in normal atmosphere). There are significant technical problems associated with developing equipment capable of carrying out such an alternate procedure. One attractive other aspect would be the ability to investigate the fire behavior of materials at Oxygen concentrations below 21% in order to observe generation of smoke and Carbon Monoxide under conditions often found in actual fires.

OPEN FLAME COMPOSITE TESTING

As has been mentioned previously there are many compelling factors favoring testing of composites because of the many, often unpredictable, interactions between filling materials and cover fabrics.

Probably the best known and most widely used test in this category is the furniture standard test used in Great Britain (BS 5852). In the light of current work by CPSC it is important to keep in mind that BS 5852 is not a single test standard. The British standard involves two parts and includes one smoldering and seven different open flame ignition sources.

Part 1 describes a mockup smoldering ignition test and an open flame ignition source consisting of a small butane burner and short ignition time. This small butane burner is the ignition source used in current efforts by CPSC for determining ignition behavior of fabrics.

Part 2 describes two butane burner ignition tests using larger flames applied for longer periods of time. It also describes four wood crib exposure tests varying in size of the wood crib and therefore in increasing severity of exposure.

The protocol chosen for furniture using flexible polyurethane foam as the filling material is the Crib 5 test with larger ignition sources (crib 6 or 7) reserved for demands for high hazard locations.

The test involves a prototype chair as described in Part 2 for Crib 5. The test chair consists of a seating surface and a back, covered with a standard polyester fabric (note that a standard fabric is used and not all combinations of fabric and filling material have to be tested). The ignition source is Crib 5 (a wooden crib weighing 17 g (0.6 oz)) wetted with a small amount of isopropyl alcohol and placed at the back of the seat section. Failure criterion is a total weight loss exceedir g.(Note that the original test requirement was specific for flexible polyuretha. foam filling materials, with all other products exempted). It also does not address the problems of different covering materials which can drastically affect performance of the filling material.

Initially this test presumably directed manufacturers to the use of so called CMHR (combustion modified high resilience) FPF containing large amounts of melamine filler. Later developments allowed use of melamine filled FPF using special polyethers in the formulation and also use of FPF modified with special grades of graphite (acting as intumescents).

There have been a number of studies attempting to develop a small scale version of the test protocol described in California TB 133 (a full scale test described later) in order to have a quality control procedure. Such a simplified procedure does not generate all of the data of the full scale test but duplicates the visual performance (full involvement, cessation of burning etc) reasonably well. It has not been developed completely or accepted as an alternate approach to a full TB-133 test.

5: LARGE SCALE TESTING

The deficiencies in small scale testing have been recognized for a long time. A major problem not covered by small scale tests is measurement of the rate at which heat is evolved by burning materials and the effect of this heat on subsequent development of the fire. Another one is the measurement of amount of smoke generated and the change in that smoke during the fire. A third problem involved with smaller scale fire scenarios is the inability to determine the influence of large amounts of radiant heat on the combustion behavior of difficult to ignite materials. The radiant heat situation simulates the behavior of materials when the material under test is not the first item ignited. A number of instruments and flammability tests have been developed to partially address these problems. These include:

Rate of Heat Release - Several methods are available for this determination. The first was the Ohio State University Rate of Heat Release Apparatus (ASTM E 906) which exposes the sample to a large radiant heat source and measures both the smoke produced and the heat evolved versus time. This test was developed initially through a grant of the fire research program which was a part of the FTC consent degree with the polyurethane foam industry. A later more sophisticated approach is the Cone Calorimeter which measures heat evolved versus time by analyzing the products of combustion and the consumption of Oxygen in the gas stream.

Both of these methods provide some fundamental data on materials which have been used in developing computer models of fire behavior.

The deficiencies of the methods are that, although they have been used in composite testing of fabrics and foams, the data are not very reproducible between laboratories. A more basic problem is that the level of radiant heat used in the determination, which simulates what happens in a well developed fire does not replicate what happens during the vital early growth stage of the fire. Tests between various laboratories indicated that the level of radiant flux required for better reproducibility is of the same order of magnitude as the heat encountered during the last stages of a fire, the so called "flash over" stage. Basically the high radiant flux tests prove that all materials will burn when exposed to a sufficient amount of heat and the value that is determined is the optimum heat of combustion of a material.

The most important deficiency of these tests is the inability to provide reasonable information about the behavior of composites, such as fabric and cushioning materials in furniture, despite some claims in the literature to success in doing so.

Radiant Panel Test (ASTM D 3675) is designed to test burning behavior and heat evolution of materials that are difficult to ignite. It is based on exposing the sample to a large source of radiant heat (a gas fired radiant panel) placed so as to provide maximum exposure to the top of the vertical sample and decreasing towards the bottom. Ignition is by a gas flame at the top of the sample and the heat and smoke evolved is measured in the exhaust chimney. Most of the same problems discussed above apply to this method. It is not suited for testing of composites or for testing of materials which melt on exposure to heat.

Because of the intensity of the ignition source this test is suitable only for materials highly resistant to ignition and cannot be used for the vast majority of either fabrics or cushioning materials used for home furnishings. It can also not be used for testing of composites.

FAA Flammability Test (FAR Par.25.853) - This test was devised to measure behavior of airplane seats used in commercial aircraft. It uses a large kerosene burner (basically a furnace burner) with the flame applied to the side of a set of seats. The "pass" criterion is that the fire not spread to the adjacent seat. There is an obvious question whether the heat from the ignition source (something else burning in the aircraft cabin?) is not sufficient to compromise survival conditions even if the seat is not involved. Because of the intensity of the ignition source this test is also not suitable for general use in testing home furnishing composites.

NBS Smoke Chamber (ASTM E 662) - This test is specifically designed to measure smoke evolution. The chamber consists of a source of radiant heat directed to a sample which may also be exposed to a small gas flame ignition source. Measurement of smoke is by photoelectric measurement of light obscuration from bottom to top of the chamber.

Several variations of this test have been studied. One modification measures the gases exhausted from the chamber for presence of specific toxic combustion product, such as Carbon Monoxide, Hydrogen Chloride, Nitrogen Oxides or Hydrogen Cyanide.

Some studies have been reported on tests of the same material at different levels of radiant heat exposure to simulate the changing evolution of smoke during development of a fire.

None of the smoke tests available address the problem of smoke layering common in actual fires. They measure total amount of smoke and interpretation of the data only allows for assuming it is uniformly distributed and therefore not indicative of performance in real fire conditions.

6: FULL SCALE TESTING

ROOM FIRE TESTS - Although not practical as a test for quality control, full scale furniture tests are the most realistic means of checking performance of a composite piece of furniture under various fire scenarios. A number of room fire protocols have been developed by ASTM, UL, NIST and the California Bureau of Home Furnishings. They are all similar in specifying a room size, door opening, non-burning walls, placement of the test piece and placement in some instances of other materials, which may become involved . They are also similar in measuring smoke obscuration at various levels in the room (since smoke tends to layer) and levels of heat in the room. Measurement of heat evolved is by actual temperature measurements or, more frequently, by calculation based on measurement of Oxygen consumption The latter assumes a uniform amount of heat evolved by combustion of any organic material producing Carbon Dioxide and implicitly assumes that Carbon Dioxide is the only product of combustion of the Carbon content. In some instances other possible toxic gases are also sampled in the room exhaust stream. A variety of ignition sources and their placement can be tested.

One version tested extensively is California TB 133, which uses a T shaped gas burner impinging on the back of the chair to be tested.

The major draw backs of the full scale tests are the need for a large test facility, and sophisticated measurement capabilities and their cost. The tests are time consuming and present hazards from venting of combustion products to the atmosphere. The relationship between full scale tests and smaller laboratory scale test results is still not well established.

For evaluation of components of a piece of furniture it is obvious that it is impossible to test all possible constructions of a piece of furniture using the various material combinations as well as the other variables like construction of back, presence or absence of sides, size and placement of ignition source etc.

FURNITURE CALORIMETER - This method, originally developed at NIST, consists basically of a large weigh cell for the sample, a large cone shaped heat source and means of measuring exhaust gases. It suffers from some of the same problems of full scale room tests although it does not use the confines of a room.

COMPUTER MODELING - Although this category does not represent a test, computer models use data based on heat release rates, smoke development, evolution of toxic gases, etc from small scale tests to predict development of a fire and potential for spreading of a fire from the room of origin. As is true of any computer model they are limited by the availability and the pertinence of the available data, the assumptions made as to the ignition source the arrangement of the test piece in a room, the proximity of other potentially

involved materials and degree of ventilation. The model is very suggestive and influenced by data fed into it.

7: FACTORS AFFECTING TEST PERFORMANCE

It is easy to devise a test protocol to check the performance of any material under some specified ignition condition. However, there are many reasons why meaningful evaluation of burning behavior of materials, particularly composites, is so difficult. One of the main problems is the behavior of individual components and how that behavior is affected by contact with other materials in composite structures, which is of course the case in upholstered furniture. Some of these inter-action problems are outlined below.

MATERIAL INTERACTIONS

FILLING AND FABRIC - The filling material of upholstered furniture can be one or more products including cotton, wool or synthetic fibers, foam rubber of various types and the most frequently used material - flexible polyurethane foam. It is most important to keep in mind that there is no "standard foam" which represents the performance of the FPF product category.

FPF for furniture uses is produced in a large variety of types. These vary, among others, in density (weight per unit size), firmness, cell size, degree of cell openness, presence or absence of fillers, presence or absence of a variety of combustion modifying additives (flame retardants), use of co-additives with the combustion modifier and use of other additives including colors, antistatic additives etc. The means of achieving the desired specifications include use of variations in the two main ingredients composing the FPF - the polyol(s) and the diisocyanate(s) (discussed further below). An additional variable is the fact that FPF, at times, is not used as a single piece (either cut to shape or molded) but may be present in small pieces (chopped) such as in the backs of furniture or in the form of several different types of FPF glued together. All of these factors can and do affect the combustion performance of the FPF.

For the other cushioning materials, the same type of factors are present to a varying extent. Foam rubber may be made of synthetic or natural latex and contain one or more inorganic fillers in different amounts plus a number of other additives, including combustion modifying ones.

Fiber type fillers, usually used in conjunction with foam cushioning materials for seat cushions, by themselves in backs or arms will vary from cotton fibers either treated with a combustion modifier such as boric acid, or a synthetic fiber such as polyester, nylon, acrylic or polyolefin (such as polypropylene), or a mixture of any of these. Each combination will perform differently in an ignition or smoldering test, depending on whether they melt or char and how readily they burn once ignited. All of these fibers are organic materials and have high surface to volume ratios which influences their combustion behavior.

Predicting the performance obviously becomes even more complex when combinations of these materials are used, even before considering the effect of fabric coverings.

The picture for fabrics is at least as complex as it is for the cushioning materials. Fabrics will vary over the complete range of available products including the natural ones such as cotton, wool, leather and rayon. For synthetics, uses include nylon, polyester, acrylic, modacrylics and the polyolefins as well as PVC (polyvinyl chloride) and modified PVC. To complicate matters further, blends of these fabrics are used.

Most of these products can be made in a variety of weights, weaves, fiber denier (thickness), degree of openness, and with various back coatings which may be combustion modified or not. The fabric construction may also be a pile or flocked one, with varying thicknesses of the fibers and of the pile. Each of these variables will affect the ease with which each type is ignited by either a smoldering or flaming ignition source and how much heat it will generate, when ignited, that can lead to involvement of the underlying filling material. The performance of fabrics is also influenced by various dyes or pigments, impurities introduced during the finishing of the fabric and the use of after treatments such as soil proofing or water proofing.

To prevent the involvement of the cushioning or filling material in contact with the fabric, the use of some inter-liners has become popular in furniture systems designed to be more resistant to ignition sources (particularly more severe ignition scenarios such as those used for qualification for use in public areas or for transportation). A variety of products have been evaluated for this purpose including various types of woven fiberglass, intumescent treated fabrics, woven Carbon fibers and highly ignition resistant fibers such as Nomex (DuPont). The common feature of all of these is to prevent transfer of heat and/or flame from the ignition source or the secondary fire source, a burning cover fabric, to the filling material. Each of these, by themselves tends to perform well in fire tests maintaining its physical integrity for a significant time. It is however impossible to predict how any one of them will behave, when used in combination with a particular fabric and cushioning system. In actual tests there have been some totally unpredictable surprises in which a particular system with inter-liner has actually performed worse than the same system without inter liner.

All of this discussion is not intended to discourage but is designed to point out the hazard of relying on too simple a methodology for preferring any one filling or cushioning system and creating what may turn out to be a misleading sense of security. Some of the major interactions between fabric and filling material that can cause problems are discussed further below.

Predicting the performance obviously becomes even more complex when combinations of these materials are used, even before considering the effect of fabric coverings.

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or the rate of melting. Any of the fabrics can be constructed with a back coating which may or may not contain a combustion modifying additive, many of which are designed to favor the formation of a char layer. The fibers themselves can be treated with various ignition resistant additives, which can be fugitive or again designed to favor char formation. A further complicating factor is the fact that textile fabrics also tend to be treated with stain and soil resisting additives as well as additives to waterproof the product or to reduce static accumulation. Some dyes or pigments used in fabric coloration will affect the tendency to smoldering ignition.

The processes used in the production of the fiber and fabric or as post treatment can introduce impurities (particularly salts) which will affect smoldering performance unless they are removed efficiently prior to use.

MELTING AND CHARRING - Filling materials behave in one of two ways when exposed to flame or heat. They either melt or form a char layer, sometimes even an intumescent char layer. The char layers also differ in the degree to which they are continuous and how well they maintain their integrity on further exposure to flame. In some flammability tests the char or melt behavior will affect the results of the tests without necessarily reflecting real life performance. An example of this is a version of the California TB 121 mattress test which involved an ignition source of newspapers below the mattress. Furniture fillings and fabrics which charred tended to "pass" because the heat of the ignition source was contained under the mattress, while melting materials, without igniting, formed a hole which allowed the heat of the burning paper to exceed the allowed temperature at the ceiling. On the other hand tests which use a fixed location for an ignition source tend to favor materials which melt away from the source without igniting, while charring materials remain exposed.

The behavior on heat and flame exposure becomes even more important in formulating FPF designed to resist more severe ignition scenarios. Two major approaches to effect this type of performance have been used. One is the use of hydrated alumina together with combustion modifying additives to form a char layer with good physical integrity protecting the rest of the material below by acting as a heat insulator. Evolution of water from the hydrated alumina also reduces the heat available to support continuing combustion. The other approach consists of using combinations of combustion modifying additives and large amounts of powdered melamine. The prime effect of melting in the latter approach is the fact that the melt produced is very difficult to ignite. Addition of a filler such as hydrated alumina to a melamine containing system destroys the effectiveness of the system by interfering with the melting process. Methods

which measure rate of heat release also tend to penalize charring systems. since a definite amount of decomposition of the system is required for its effectiveness, and the presence of the char layer (often intumescent) keeps the foam in closer contact with the ignition source.

Fabrics also can be classified by their melting behavior. Cellulosics, particularly cotton fabrics, tend to form char on exposure to flame in many cases delaying ignition. This behavior becomes more pronounced as the weight of the fabric increases, but the negative aspect of this behavior is that such materials will generally smolder badly. Melting fabrics, including most of the synthetics, will generally melt and split away from the source of ignition thus exposing the filling to the ignition source. The end result is that the substrate becomes exposed to the ignition source. If the fabric is not burning and the substrate is not ignited by the ignition source the composite would exhibit satisfactory performance with regard to the situation. Small differences in the intensity of the ignition source will show large differences in performance of composites with nylon or polyester fabrics of equal weight. Fabric, such as the polyolefins , generally will melt and ignite and become a secondary and potentially large ignition source explaining the fact that such fabrics generally will perform poorly in composite tests. The currently proposed CPSC ignition protocol for fabrics is subject to large variations in actual performance in composites by relatively small variations in intensity and duration of the ignition source.

INTERACTIONS OF COMBINATIONS - One of the frustrating aspects of predicting performance of composites from the performance of the individual components, even if the same ignition source is used, is that the performance parameters are rarely additive. The current proposal by CPSC to use one ignition source for fabrics and possibly a much larger source for fillings (such as BS 5852 source 5) complicates this matter even more. As pointed out above, the behavior of melting fabrics on an FPF filling is generally much different from that of the behavior of the same fabric by itself. Differences are due mainly to the potential of the molten fabric to be ignited and become a secondary ignition source. Charring fabrics can also produce unexpected results not predicted by component testing. A charring fabric or inter-liner over a melting filling material can produce a cavity under the char layer which continues to burn and propagate because the heat of combustion is retained and reflected back to the interior. The same filling material under a melting fabric or one which produces only a thin and fragile char layer will not continue to burn because the heat from the burning material can escape.

A further complication is that there are individual materials each of which may be "good" by itself, which can behave poorly in combinations. In some of the British Standard furniture test, for example, it was found that combinations of PVC fabrics and some polyester fabrics with FPF containing large amounts of melamine failed the test requirements, while other much less flame retarded systems passed. There also have been some cases where leather, normally thought to be one of the best covering materials for burning performance has behaved poorly.

Such examples prove again that component test results by themselves should not be used as the absolute criterion for approving use of composites assembled from those components that individually pass combustibility requirements.

8: VARIABLES OF IGNITION AND FLAME SPREAD

As has already been implied any test of materials for their behavior in a fire should be directed to provide information allowing for an estimate of hazard to life and/or property even without going through a formal hazard analysis procedure.

Bearing this in mind the limitation of what any laboratory test can determine must be clearly stated and remembered. In the following section some of the variables of test procedures (in addition to the test material variables discussed previously) are outlined.

IGNITION SOURCE - The choice of ignition source is one of the most basic variables. It can vary from a small flame for a short period of time to an extensive source, such as a large wooden crib, burning for a long period time or to an ignition source applied simultaneously with a high radiant flux (simulating another nearby fire) and even possibly under conditions of higher than normal Oxygen atmosphere or pressure.

It has to be kept in mind that it is almost always possible to devise an ignition source that is so innocuous that almost any material will be safe from ignition. On the other hand it is equally possible to impose ignition conditions which will surely destroy virtually all organic materials.

In addition to size, the location of the ignition source also plays an important part in determining material performance. In general, ignition at the bottom of a vertical surface will present the most hazardous location, since the heat of the source and any incipient burning of the test material will preheat the remaining part of the test material. Since all materials will burn more rapidly and completely the higher their temperature, any preheating will usually produce the worst and the most rapid damage. Placing the ignition source at the intersection of a chair cushion and back in essence is an example of bottom ignition. Top ignition will generally be less severe, although it presents the easiest access to air required for combustion. It can also be argued that in many instances ignition at the top is most likely since it is the most readily accessible area of a composite structure. Ignition on the side is the intermediate case, since it is a location with ready access of air and presents at least a small vertical section. For furniture, ignition underneath the sample is probably the least severe and is also the least likely to occur in a real life fire situation.

In composite testing, when the ignition source is applied to the sample, close observation must be made to determine whether the component of the sample that first sees the ignition becomes a secondary and much larger ignition source in its own right. In the case of upholstered furniture it is most frequently the fabric which is directly exposed to the ignition source and can therefore become the secondary ignition source. In turn, if the fabric melts away from a

small ignition source without igniting, then the filling material is exposed directly to the ignition source.

FLAME SPREAD - If the ignition source does not cause continuing burning then presumably no hazard will develop. However, if the test material becomes involved a number of other considerations apply, since the way the fire develops will determine the degree of hazard.

The most important factor is the rate at which the fire grows by involvement of the test material. In particular the early rate of fire growth is vital to the time at which a room reaches untenable conditions. One of the important factors to consider is the way the fire spreads on a sample or finished product. Filling materials such as most flexible polyurethane foams, when burning, will generally produce a hot flame with melting but relatively slow lateral spread. The slow spread is important because it determines to some extent the likelihood of early involvement of adjacent materials. Burning with melting can very quickly produce burn through with flaming dripping, which can involve flooring materials. The behavior of fabrics whether by melting and burning or burning with charring will also play an important role in determining the rate of fire spread.

The rate of heat release is controlled by the rate of material consumption and the potential heat evolved, depending on chemical composition of the material. The rate at which heat is evolved determines the most important factors in hazard development. The first is that heat, unless very rapidly ventilated, will accumulate at the ceiling of a room and be reflected back to the sample increasing its burning rate. Depending on the amount of material burning and the size and ventilation in a room, the rate of burning will determine how rapidly Oxygen available for the fire will be consumed, which in turn will affect the amount of smoke and Carbon Monoxide produced and the time at which the phenomenon called "flash over" will occur. At "flash over" the spread of a fire outside the room of origin is most likely to occur.

TOXICITY - The evaluation of toxicity in connection with fire is probably the most complex of the many problems associated with fire. It is generally agreed that the greatest hazard is Carbon Monoxide gas, because it is the most rapidly produced product of combustion and is present in the largest amount, but that may be oversimplifying the case. All organic materials (materials containing Carbon) can burn consuming Oxygen to produce Carbon Dioxide (complete burning), Carbon Monoxide and Carbon (either in the form of smoke, soot or char). An additional factor, is that in the combustion of Carbon to Carbon Monoxide and Carbon Dioxide about two thirds of the heat evolved comes from the production of Carbon Dioxide. The combined hazard then comes from potential depletion of Oxygen, increase in Carbon Dioxide (affecting breathing rates) and Carbon Monoxide and presence of smoke which

may be disorienting and interfere with escape. To further complicate the matter the relative amount of each of the products will vary with time and the non uniform distribution of them in the room. The increasing temperature due to a growing fire alone can be rapidly disabling. The potential effect of the generated temperatures on survivability is generally ignored in laboratory scale toxicity tests. Consideration must also be given to the effect of combustion modifying additives. Since the method by which they work is to produce a less "efficient" fire with less heat evolution, these factors in general may lead to production of more Carbon Monoxide and smoke.

There are many other products of combustion in even the simplest fire scenarios. The ones that have received most attention are Hydrogen Chloride (or Bromide) from decomposition of either combustion modifying additives or such fabrics as PVC; Hydrogen Cyanide and Nitrogen Oxides. As will be discussed in a later section, the effectiveness of Chlorine or Bromine containing additives depends on the temperature and rate at which they decompose, so the presence of the Hydrogen Chloride or Bromide is to be expected. Any organic compound containing Nitrogen will also degrade in fire to produce either Hydrogen Cyanide or Nitrogen Oxides depending on the temperature at the time of burning. Some natural products, especially cotton produce Acrolein in small amounts. This compound is a very efficient nose and throat irritant and can interfere with breathing and therefore escape of occupants. Generally the amounts of all of these will be much smaller than the amount of Carbon Monoxide and also formation occurs later and more slowly, which is a part of the rationale for classifying Carbon Monoxide as the most significant hazard associated with a fire.

For all of the expected main toxic decomposition products it is extremely difficult to produce a realistic picture of the amounts and location of the gases since they are not uniformly distributed and the rate of generation is changing continuously. Even for Oxygen, Carbon Dioxide and Carbon Monoxide for which good and continuous analytical procedures exist, the testing is generally done in the exhaust stream of the test room, which at best gives a picture of the average concentrations.

There has also been much speculation about other highly toxic but unknown combustion products, but none have been demonstrated as having any effect in a "real" fire. In light of the usually high concentrations of Carbon Monoxide, even if presence of minute amounts of such other products were demonstrated , they would not materially change the toxicity picture. The Carbon Monoxide or the generated heat would undoubtedly be fatal to occupants of a room or structure long before other toxicants would come into play.

9: COMBUSTION MODIFYING ADDITIVES

Except for a few organic products which are inherently difficult to ignite, improved performance against various ignition sources is generally accomplished by use of additives. The type and amounts of additives will vary depending on the level of ignition resistance required. The highest performance requirement, in the category of upholstered furniture or specialty seats is usually specified for exposure conditions in locations which limit ease of escape or egress such as prisons, hospitals and mass transportation. Special performance levels are also expected in public areas where large numbers of people may make rapid evacuation difficult such as hotels, public arenas, college dormitories and similar situations. The combustion modifying additives include:

HALOGEN AND PHOSPHORUS CONTAINING MATERIALS - Compounds containing halogens (Chlorine or Bromine) and compounds containing Phosphorus (either in the same molecule or separately) are probably the most frequently used additives. Generally accepted theories of how combustion modifying additives work is that some generate "free radicals" which interfere with flame propagation in the vapor phase and thereby disrupt the continuation of the fire and that some perform in the solid phase by interfering with the formation of volatile and flammable breakdown products or by forming char which acts as an insulator for the remaining material. The halogen containing materials usually are classified as vapor phase agents and the phosphorus containing ones as solid phase ones.

Not all halogen compounds perform equally well. A simple picture of the process indicates that greatest efficiency is obtained if the decomposition of the additive occurs very close to the flame front. If the degradation by heat happens well before the flame front then the free radicals produced are no longer present when needed. If it occurs much later, as is possible with highly heat stable materials, then they are not present at the critical time required.

As was pointed out in the previous discussion on toxicity, the function of combustion modifying additives is to produce a less efficient fire generating less heat and therefore inhibiting and even stopping fire growth. A consequence of this performance often will be generation of larger amounts of Carbon Monoxide (for a shorter period of time) and possibly more smoke.

The same limitations apply to the phosphorus containing additives. Phosphorus compounds vary over a wide range in their ability to degrade and/or form char layers. One advantage of char formation may be that the degradation to Carbon instead of Carbon Monoxide or Dioxide is directed towards forming char instead of smoke.

In addition to flammability performance, a number of other critical requirements have to be met in order to make such additives useful in applications such as furniture fillings. In the case of FPF the modifying products, particularly the halogen containing ones, must be stable enough to remain undisturbed during the FPF manufacturing process and the heat involved in that exothermic process. Both the Halogen and Phosphorus containing products also cannot have deleterious effects on the diisocyanates used or interfere with the complex catalysis and foam stabilization required during FPF manufacture. Furthermore the volatility of the additives has to be low enough to assure that they will remain in the product for its expected life time. A number of flammability performance specifications include some type of accelerated aging test to assure this behavior. The same type of performance expectation relates to the potential for loss of the additives by water leaching (washing etc.) and, in the case of automotive applications, the low volatility is required to pass the requirements for non fogging.

The two most widely used systems at this time are tris(1,3-dichloropropyl) phosphate (one trade name for this product is Akzo's Fyrol FR-2) and a solution of pentabromodiphenyl oxide in an aromatic phosphate (one trade name for this is Great Lakes DE 60S). (Note: the prefix tris as shown above is part of chemical nomenclature and applies to a large number of chemical compounds containing three parts of equal structure. The "TRIS" of infamy as a flame retardant in synthetic fabrics is only one example of this type of chemical name and is not considered here).

Until recently it has been doctrine that both Halogen and Phosphorus are required for adequate resistance to ignition of FPF. More recently some newer products are appearing containing only Phosphorus with claims of adequate performance in some ignition tests.

OTHER ADDITIVES - For the most demanding fire scenarios for FPF the two major approaches have been use of hydrated alumina filler and use of melamine. Either of these is used together with one or more of the additives discussed above. The hydrated alumina acts as a char former and also is capable of releasing water vapor at decomposition temperature. This process absorbs a significant amount of heat and helps in suppressing the fire. The melamine decomposes and forms a highly ignition resistant melt with the additional performance of the other additives to suppress combustion. As pointed out earlier, the hydrated alumina and the melamine approaches are unique and cannot be combined. Both of these additives have the negative aspect that they are solids and have to be predispersed in the polyol component prior to foaming in order to assure uniform distribution in the FPF. This is not always easily accomplished.

Special forms of graphite have been used to a limited extent in Great Britain in order to meet the requirements of BS 5852 Crib 5 for upholstered FPF filling furniture.

Some cases require additional additives to be used to enhance performance of these systems . These include Antimony Oxide (generally to increase efficiency of halogen additives) and borates such as Zinc Borate (to reduce smoke formation). Another additive used occasionally as a secondary halogen is decabromodiphenyl oxide. The latter additive is too stable to be used as the primary flame retardant in furniture fillings.

Ammonium Polyphosphate has been used as an additive (char former) in a few cases but it is very difficult to use during FPF production because of the high viscosity of polyol dispersions and because of its tendency to interfere with catalysis. A further limiting factor, particularly for potential use in furniture fillings, is its lack of long term hydrolytic stability.

ALTERNATE PROCESSES - There have been many proposals to achieve good resistance to ignition by post impregnation of FPF with a variety of additives including borates, phosphates, various ammonium salts, etc. Aside from considerations of permanence to hydrolysis none of them has achieved commercial success. The main problem is the difficulty of achieving of uniform impregnation of an FPF cushion, which may be 5 or 6 inches thick. In addition many of these systems are water based, and the impregnated pieces then have to be dried which is a slow and expensive process. The drying process also tends to produce a thin crust of the additive on the surface of the FPF cushion.

A variation of this approach has been to surface treat the finished upholstered cushion. It is necessary to do that at the furniture assembly plant and most of these facilities are not equipped to do any chemical processing. The surface applications also tend to leave an undesirable harsh coating on the fabric cover of the cushion which is also subject to disruption by friction during use. The effect of those treatments on persons sitting on the treated surface is also unknown.

FABRIC TREATMENTS - Many of the treatments used for FPF also can be applied to textiles although the specific additives used may be different. There are several choices for application. One is to add the combustion modifier during the fiber spinning process to achieve uniformity. This approach has the same limitations to processability as was discussed for filling materials. Topical application to the finished fiber can be used. It is necessary that sufficient add on be applied and that such treatments do not interfere with other after-treatments such as stain or water repellents.This type of treatment also suffers from the potential of rapid loss of effectiveness due to abrasion during use. Currently the

most likely approach is via back coating because it produces the least interference with the desirable aspects of the face fabric and allows for the use of a fairly wide range of additives. Two major concerns are that the additive treatment to the back coating must not interfere with the soft feel and drape of the fabric and that it must not make the sewing operation more difficult. As is the case with cushioning materials, the additives used cannot be readily water soluble in order to insure permanence. In many cases the rate of leaching of water soluble products will be reduced but not eliminated when they are included in the back coating. Examples of such materials would be most of the water soluble ammonium compounds such as Ammonium Bromide and Ammonium Phosphates. Borates of various types are very efficient additives but many of them tend to slowly migrate and crystallize on the surface of the fabric or other material. This makes the additives subject to abrasion and loss of effectiveness.

For textiles in general the potential of migration and/or loss by wear due to friction is probably of more concern than is true for filling materials because the fabric is closer to potential skin contact with the user and because it is the first item exposed to the ignition source. The effect of any flame retardant additive on the smoldering performance of a fabric also will have to be evaluated.

10: SUMMARY

1) Fire is an extremely complex process, under the most simple circumstances. The performance of composite structures, such as upholstered furniture, in a fire adds to that complexity.

2) In the case of upholstered furniture there are many, often unpredictable interactions, between covering fabric, possible inter layers and the filling system, which in turn may also be a composite.

3) There are many factors, implicit in any test procedure which determine observed results including:

Ignition source size
Ignition source place of application
Ignition source duration

4) There are many factors in considering performance of a material and the test it is subjected to including:

Time to ignition
Rate of propagation
Direction of propagation - lateral or vertical
Rate of growth of fire
Rate of heat release
Temperature above the sample
Evolution and composition of products of combustion
Evolution of smoke

5) Regulatory Concerns

Any regulatory standard must be based on performance criteria not on a specified product and should be relatable to an identical risk.

Any regulatory standard, whether voluntary or by a government agency must, apply equally to all competing or future materials and equally to natural and synthetic products.

It must be recognized and clearly stated that any proposed test criteria do not and can not absolutely predict performance in a full scale fire.

6) Test Criteria

Performance of composites in fire testing can approximate the complexity of the fire problem. Component testing cannot achieve or define the complexity of a fire.

Both Smoldering and Open Flame Ignition performance criteria need to be covered.

A test protocol, suitable for quality control and acceptable for compliance certification, would have to be based, for example, on both of the following composite tests:

A procedure involving a fabric to be tested over a "standardized" filling material, such as a specific grade of FPF, similar to materials in current end uses.

A procedure involving a filling such as, FPF, fiber or combinations of any widely used materials in current end uses, covered by a "standard" fabric representing a compromise between a very ignition resistant one and one that is highly flammable.

Both of these procedures must clearly define the compromises and assumptions used.

Any developed procedure must demonstrate reproducibility between testing laboratories.

For initial qualification of a new combination of materials and/or construction a more elaborate test may have to be defined and then be required.

"Pass" and "Fail" criteria must be clearly stated and based not on subjective observations but on readily observable and measurable results.

A minimum sampling program and record keeping requirement is needed to assure compliance.

7) Test Procedure Requirements (suitable for quality control) have to meet, at a minimum, the following criteria:

Test setup must be small enough to fit into an average laboratory hood with means to control amount of ventilation used.

No elaborate instrumentation should be required.

Test should be rapid enough to accommodate production schedules so that compliance can be established before shipment of any component.

Test should be reproducible between laboratories as established by Round Robin Tests and the extent of variability should be stated.

8) Other requirements

Technology to achieve performance must be economically and technically feasible without affecting important other performance and life expectancy requirements for the finished composite article.

Performance criteria should not be based on a specified technology, since to do so would interfere with development of alternate or improved technology.

Specific construction requirements should not be imposed, since to do so would interfere with development of alternate or improved production practices.

CURRICULUM VITAE

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GENERAL BACKGROUND:

Administrative experience includes supervision of research laboratories, budget preparation and control.

Laboratory experience and supervision of research includes organic synthesis, process development, applications research and analytical research. Research work has resulted in numerous publications, presentations and patents.

Experience also includes work in long range planning, technological forecasting, technical audits and use of statistical design of experiments .

Background includes work in regulatory compliance, patents and trademarks, waste disposal, waste minimization, industrial hygiene monitoring, employee training and performance evaluation.

EDUCATION:

Ph.D. in Physical Organic Chemistry (1950)
The Ohio State University, Columbus Ohio.

B.Sc. Chemistry, Magna Cum Laude (1944)
Bethany College, Bethany, W. Va.

PERSONAL:

Born: November 3, 1924 , Munich, Germany
US Citizen - December 1945 (during army service).
Married, six children.

EXPERIENCE:

Current Position - November 1995 -

Semi-retired. Part time retained as director of environmental and legal affairs with General Foam Corporation as well as assignment on special projects.

Self employed as consultant specializing in polyurethane foam technology, flammability of plastics, technical aspects of patents, environmental and regulatory affairs and technical matters related to these subjects.

Have served as technical expert in legal matters relating to fire and flammability, liability resulting from exposure to materials and patent disputes.

Previous Positions - September 1974 - November 1995

Manager of Research and Development, then Director of Foam Development for Tenneco Chemicals Foam and Plastics Division, now General Foam, A Division of PMC, Inc. at Hazleton, Pa.

Responsible for all technical aspects of flexible polyurethane foam business including Research and Development, Technical Service/Customer Service, Raw Material Quality Control, Industrial Hygiene Monitoring, Waste Disposal and Minimization, Regulatory Compliance and Liaison with Regulatory Agencies and Technical Aspects of Patent and Legal Matters.

Particular emphasis on new products and specialty applications, emphasis on flammability and development of new combustion modified foam systems including development of test protocols.

Activities also included major participation in industry and trade associations such as The Society for the Plastics Industry (SPI), the Polyurethane Foam Association (PFA), the Upholstered Furniture Action Council (UFAC). Activities also involve standard setting organizations such as the American Society for Testing and Materials (ASTM) and the National Fire Protection Association (NFPA). Participation in the technical committees of these included development and test method standardization .

- 1972 - 1974

Director of Chemical Research, Malden Mills, Inc., Lawrence, MA.

Responsible for chemical aspects of applications to textile processing. Formulations and evaluation of backcoatings, fire retardants for natural and synthetic fiber fabrics, water repellents, napping assistants, screen print additives, antistatic additives and pollution abatement (air and water).
Laboratory supervision included standards, test methods, quality control of raw materials, production and cost control and technical support to the dye laboratory and engineering department.

- 1969 - 1972

Senior Research Associate and Project Manager, Corporate Research Laboratory, Allied Chemical Corp. (now Allied-Signal), Morristown, N.J.

Project Manager for technical aspects of flame retardant research including plastics, fibers, application studies and test method development.

Supervisory responsibility on research projects in catalytic oxidation, pesticide synthesis and new pigment research.

- 1963 - 1969

Director, Chemical Research, Specialty Chemicals Division, Allied Chemical Corp., Buffalo, N.Y.

Supervision of up to 40 professionals in laboratory research, process development and applications research. Areas of responsibility included:

CATALYTIC LABORATORY - Catalytic research mainly in Hydogenation and Oxidation.

ANALYTICAL RESEARCH LABORATORY - A service group for routine and non-routine analyses and method development for the division's research laboratory.

MONOMER PROCESSES - Process improvements, quality and alternate processes for caprolactam and its intermediates. Process development on terephthalic acid and its purification to fiber grade quality.

ORGANIC ACIDS AND ANHYDRIDES - New product development and applications on a range of products based on maleic anhydride.

AROMATIC AMINES - New product research and applications.

FOOD ACIDS - Process development, applications research and plant startup of a multi-million pound plant for malic acid.

SYNTHETIC DETERGENTS - Process development and applications research on biodegradable detergents.
DIISOCYANATES - Laboratory research on new products and process improvements on existing products. Studies on fire retardant systems.

- 1958 - 1963

Senior Scientist and Group Leader, Specialty Chemicals Division, Allied Chemical Corp., Buffalo, N.Y.

Responsible for all aspects of polyurethane applications research, including technical service and preparation of technical bulletins.

Particular contributions to development of flexible foam technology including fire retardant systems, process for molding foam and production of supersoft foams.

- 1954 - 1958

Chemist, Exploratory Research, Specialty Chemicals Division, Allied Chemical Corp., Buffalo, N.Y.

Exploratory research with major emphasis on approaches to new flame retardant systems including synthesis and test method development, polymerization studies and performance evaluations.

- 1951 - 1954

Chemist, Analytical Research, Specialty Chemicals Division, Allied Chemical Corp., Buffalo, N.Y.

Development of new analytical methods for chemicals and dye intermediates produced by the company.

- 1947 - 1951

Graduate student at The Ohio State University. Graduate teaching assistant in the department of chemistry. Part time position on US Navy sponsored project requiring security clearance.

- 1945 - 1946

US Army. Trained as medical laboratory technician. Main assignment to Separation Center at Ft. Dix in charge of medical laboratory.

- 1944 - 1945

Analytical chemist, National Aniline Division, Allied Chemical Corp., Buffalo, N.Y.

HERMAN STONE
OTHER ACTIVITIES

NONTECHNICAL

Temple B'Nai Or - Morristown, N.J. - Chairman Adult education
Temple Emanuel - Lawrence, Mass. - Adult Education
Beth Israel Temple - Hazleton, Pa. - Various committee chairmanships
President - 3 terms
Awarded Distinguished Service Award
Union of American Hebrew Congregations - Member of National Commission on Interreligious Affairs
Pennsylvania Region - Scroll of Honor
Jewish Community Council- Hazleton, Pa. - Member of Board and President (1 term)
United Jewish Appeal - Hazleton, Pa.- Chairman of annual drive
Lecturer on Holocaust - Pennsylvania State University Hazleton Campus
Bethany College
Various Public and Parochial high schools and grade schools.

TECHNICAL

AMERICAN CHEMICAL SOCIETY - National - Councilor and member of Professional Relations Committee
- Local Sections
Western New York - various committee chairmanships and president (1 term).
Northern New Jersey - executive committee
Susquehanna Valley - executive committee
Chair education committee

AMERICAN INSTITUTE OF CHEMISTS - Fellow

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE - Fellow

NATIONAL FIRE PROTECTION ASSOCIATION - Fire Test Committee

AMERICAN SOCIETY FOR TESTING AND MATERIALS - Several technical committees

AMERICAN HOTEL AND MOTEL ASSOCIATION - Safety Committee

(Herman Stone continued)

SOCIETY FOR THE PLASTICS INDUSTRY - POLYURETHANE DIVISION
Chairman of Technical committee

INTERNATIONAL SLEEP PRODUCTS ASSOCIATION - Flammability Committee

UPHOLSTERED FURNITURE ACTION COMMITTEE - Technical Committee

POLYURETHANE FOAM ASSOCIATION - Vice President and Chairman of Technical Committee
Lifetime Achievement Award

GUEST LECTURER PENNSYLVANIA STATE POLICE FIRE MARSHALL SCHOOL

SPEAKER AT MANY MEETINGS INCLUDING INTERNATIONAL MEETINGS -
Nice, France
Nagoya, Japan
Vancouver, Canada
Quebec City, Canada
Brussels, Belgium

JOINT COMMITTEES WITH GOVERNMENT AGENCIES ON REGULATORY MATTERS -

EPA- Environmental Protection Agency
OSHA - Occupational Safety and Health Administration
CPSC - Consumer Product Safety Commission

HONORARY SOCIETIES

PHI LAMBDA UPSILON

SIGMA XI

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