Fire Characteristics of Rigid Vinyl

- **Rigid vinyl cannot be the ignition source of a fire.**
- **Rigid vinyl by itself cannot sustain burning.**
- **Rigid vinyl cannot cause a fire to spread.**
- **Rigid vinyl cannot conduct electricity.**
- **Rigid vinyl does not produce an unusual life safety hazard.**

Introduction

Vinyl describes a family of products based on polyvinyl chloride (PVC), an organic polymer derived from petroleum and salt. Its excellent ignition-resistance is responsible for many of its initial uses and for vinyl's phenomenal growth since the 1930's to the second most widely used plastic material in today's world market.

Initial applications for vinyl included electrical wiring, drain and water pipe, hose and acid tank linings. Proven resistance to ignition and low flame spread led to Underwriters' Laboratories, Inc., recognition for 600-volt building wire insulation. Those same properties made vinyl the U.S. Navy's choice to replace rubber for cable insulation at the beginning of World War II.

German rigid vinyl pipe applications for not only sanitary drainage but also water supply appeared as early as 1937. Although U.S. pipe installations evolved later (1952), vinyl's popularity spread. It's…

- low cost
- ease of installation
- resistance to corrosion and chemical attack
- and superior electrical properties

… make vinyl the largest volume plastic piping material in the country today.

Vinyl has found extensive use in electrical conduit, wire and cable insulation and jacket, water distribution systems, flooring, wallcovering, house siding, windows, irrigation systems, phonograph records, videodiscs and many more applications.

For more than 40 years, rigid vinyl's unique balance of performance properties combined with it's…

- Relatively high ignition resistance
- Low fuel contribution
- Lack of flaming drips
- High external heat necessary to maintain combustion

… have helped make it not only accepted but often preferred material for many uses in industry and the home.

I. Rigid Vinyl Cannot Be the Ignition Source of a Fire

Three factors are essential for "burning":

- Heat
- Fuel
- Oxygen

Remove any one of these and the burning stops.

A single match readily ignites newspaper, cotton drapes, a wool sweater or sticks piled in your fireplace. Once ignited, these materials continue to burn until totally consumed.

A flaming propane torch produces "spot" burning on rigid vinyl pipe – *but only while the flame is in direct contact with the pipe.* Remove the flame – the burning stops.

- ASTM Test D 1929. Ignition Temperature

The Ignition temperature is the lowest temperature at which sufficient fuel vapors evolve from a material to permit "piloted" ignition. If no pilot flame is present these gases must be heated more – giving rise to a "self-ignition" temperature. Rigid vinyl will burn while exposed to a continuous fire source. Wood, wool, cotton and paper are aflame – "feeding the fire"; contributing to the total fire hazard – *before* rigid vinyl ignites.

ASTM Test D 1929 demonstrates that wood and paper ignite at temperatures several hundred degrees lower than rigid vinyl (Table 1).

Thus, rigid vinyl's ignition temperature is too high for it to be an ignition source in an unwanted fire.

- Rigid Vinyl's Heat of Combustion is Lower than that of Wood

Heat of combustion is defined as the amount of heat released when a material is forced to burn to completion. The total amount of heat released by wood is between 8,200 – 9,400 Btu per pound (Table 2). Remember, sustained burning requires a constant supply of fuel vapors sufficient to produce a combustible fuel/air mixture. Heat generated from burning wood, paper or cotton products produces fuel vapors from those materials. These vapors, combining with atmospheric oxygen, perpetuate a combustible mixture which ignites, creating more heat and the burning process becomes self-sustaining.

Table 1

Ignition Temperatures of Various Materials

Material	**Flash-Ignition(1)**		**Self-Ignition(1)**		**Energy to Generate Combustible Fuel/ Air Mixture(2)**
	°C	**°F**	**°C**	**°F**	**(J/cm²)**
PVC	391	735	454	850	160
Douglas fir	260	500	----	----	65
White pine	228-264	406-507	260	500	----
Paper (newsprint)	230	445	230	445	----
Cotton	230-266	446-511	254	490	----
Nylon(polyamide)	421	790	424	795	----
Polyethylene	341-357	645-675	349	660	----
Polystyrene	345-360	650-680	488-496	910-925	----

Flash-Ignition Temperature
The lowest initial temperature of air passing around the specimen at which sufficient combustible gas is evolved to be ignited by a small external pilot flame.

Self-Ignition Temperature
The lowest initial temperature of air passing around the specimen at which, in the absence of an ignition source, ignition occurs by itself, as indicated by an explosion, flame or sustained glow.

Source: (1) Hilado, C.J., "Flammability Handbook for Plastics," Third Edition". Technomic Publishing Co. 1982.
(2) Tewarson, A.,"Physico-Chemical and Combustion/Pyrolysis Properties of Polymeric Materials", Factory Mutual Research Corporation, Report J.I. OEON6.RC, RC80-T-79, November, 1980

Table 2

Material	**Heat of Combustion (Btu/lb)**
Rigid vinyl	7,730
Cotton	7,950
Wood (average)	8,680
Newsprint	8,484
Douglas fir	9,040
Wool	10,210
Nylon 6	13,310
Polycarbonate	13,340
Polystyrene	17,850
Polypropylene	19,970
Polyethylene	19,960
Polyisobutylene	20,170

Note: Data prepared by Babrauskas, V., U.S. National Bureau of Standards. Data converted to Btu/lb from megajoules/kilogram.
Source: Fire Protection Handbook, 15th Edition, National Fire Protection Association, Section 4, Chapter 12, 1981.

Rigid vinyl alone cannot support burning. Its heat of combustion is only 7,730 Btu per pound. Heat produced by a flame from rigid vinyl is not hot enough to produce those necessary vapors which combine with atmospheric oxygen to create a combustible mixture. Because of its low heat of combustion and the lack of sufficient oxygen in the atmosphere, rigid vinyl by itself will not support combustion. Test results by A. Tewarson, Factory Mutual Research Corporation, indicate that two-and-one-half times more energy is required to create a combustible fuel/air mixture with vinyl than with wood. (Table 1).

II. Rigid Vinyl by Itself Cannot Sustain Burning

- ASTM Test D 2863. Limiting Oxygen Index

ASTM Test D 2863 measures the percent of oxygen in an oxygen-nitrogen mixture which barely supports burning. The oxygen content of the earth's atmosphere is about 21%. Materials with oxygen index values of approximately 26 and above should not continue burning after the flame source is removed because the normal atmospheric oxygen content is insufficient to support combustion.

Oxygen index values of rigid vinyl are 40 and above. Those of typical wood products are about 20 (Table 3). The significance is obvious: rigid vinyl cannot be the ignition source of a fire. It requires more oxygen than present in our atmosphere to ignite.

Table 3

Limiting Oxygen Indices (LOI) of Polymers (A low LOI value indicates high flammability)					
Below 22 (Material burns by itself)		**22 – 28 (May Burn Upwards*)**		**Above 28 (Materials Will Not Burn by Itself)**	
Polyacetal	15	Red Oak	23	Polysulfone	30-50
Cotton	16-17	Polyvinyl fluoride	23	Polyimides	31-45
Polymethyl Methacrylate	17	Polyphenylene oxide	24	Polyphenylene sulfide	40
Polyethylene	17	Nylon 6/6	24	RIGID POLYVINYL CHLORIDE	40-49
Polypropylene	18	Polycarbonate	25	Polyvinylidene Fluoride	44
Polystyrene	18	Nylon 6	26	CHLORINATED PVC	45-60
Filter paper (cellulose)	18	PLASTICIZED POLYVINYL CHLORIDE	22-32	Polyvinylidene chloride	60
ABS	19			Polytetrafluoroethylene	95
Cellulose acetate	19				
Styrene-acrylonitrile	19				
Polyrthylene terephthalate	20				
Birch	20.5				
Fir	21.5				

* For materials in the 22-28 LOI range, burning may continue if a vertical sample is ignited at the bottom. For materials in this range, burning may not occur if ignition is attempted at the top of the sample.

Sources: — Volume 1, "Materials: State of the Art", Report of the Committee on the Fire Safety Aspects of Polymeric Materials, National Materials Advisory Board, National Academy of Sciences, Washington, D.C., NMAB 318-1, 1977.
— Edgerley, P.G., "Toxic Gas Tests in Perspective", *Fire and Materials*, Vol. 6, No. 2, June, 1982.
— The BFGoodrich Company, Chemical Group.

III. Rigid Vinyl Cannot Contribute to Flame Spread either Directly – or Indirectly

- …Directly – Rigid Vinyl Demonstrates a Low Heat of Combustion

Materials with low flame spread become involved slowly in a fire situation. This means slower oxygen consumption, slower release of heat and slower production of carbon monoxide. These factors are critical differences in a life or death fire situation. Rigid vinyl consistently exhibits a slower burn rate than many wood-based products commonly used for interior finishes and building contents.

Two methods frequently specified by building code authorities to measure flame spread are the Steiner Tunnel (ASTM Test E 84 or Underwriters' Laboratories Test UL 723) and the Radiant Panel test (ASTM Test E 162).

— Steiner Tunnel Test. An approximately 5000 Btu gas flame ignites a 2-foot by 25-foot sample resulting in progressive surface involvement. The flame spread scale is set at zero for asbestos board and 100 for red oak wood. On this scale, most rigid vinyl sheet has achieved flame spread ratings between 15-35.

— ASTM Test E 162. This test involves an inclined sample where both high radiant heat and an impinging flame are applied simultaneously and remain for the duration of the test. Here, too, the scale is asbestos board, zero; and red oak, 100. By this test, typical rigid vinyl achieves an impressive flame spread rating of less than 10.

- Rigid Vinyl's Rate of Heat Release Is Lower than that of Wood

Materials which release heat slowly translate to: slower oxygen depletion, a longer time to "flashover" (if it occurs at all) but, most important, increased escape time for trapped occupants. A comparison of rigid vinyl to pine at end-use thickness shows that at a thermal exposure of 2.5 –2.6 Watts/cm², pine release 8,000 Btu/ft² per 10-minute exposure compared to only 1,500 Btu/ft² for vinyl (Table 4). Obviously, heat release from rigid vinyl is only 1/3 that of pine.

Table 4

Heat Release Characteristics of Materials as Measured by the Ohio State University Release Rate Test				
Material	**Applied Heat Flux (Watt / cm²)**	**Max. Heat Release Rate (Btu / ft² min)**	**Total Heat Release (Btu / Ft²) 3 Min**	**10 Min**
Rigid Vinyl	1.0	20	0	50
Hardboard, 0.25-inch	1.0	800	400	4,500
Exterior plywood, 0.5-inch	1.0	400	700	1,200
Rigid Vinyl	2.6	300	100	1,500
Pine, 1-inch	2.5	800	1,200	8,000

Samples vertically oriented to flame exposure.
Source: Hilado, C. J., "Flammability Handbook for Plastics", Third Edition. Technomic Publishing Company, 1982.

- Indirectly — Burning Rigid Vinyl Does Not Produce "Flaming Drips".

Some burning polymers produce molten, flaming drips which contribute to flame spread. Burning rigid vinyl produces a form-retaining carbonaceous char. This char totally prevents fire-spreading flaming drips.

IV. Rigid Vinyl Cannot Conduct Electricity

In electrical applications, rigid vinyl provides an extra margin of safety because it will not corrode or rust. But those properties fall secondary to the prime, obvious concern: "Can vinyl conduct electricity?" The answer, "No, vinyl cannot conduct electricity – nor can it promote 'arcing' between wire and conduit as does metallic conduit." The ignition source of the disastrous MGM Grand Hotel fire of 1980 was an electric short in metal conduit.

- Rigid Vinyl Achieves a V-O Rating by the Underwriters' Laboratories Subject 94 Procedure.

The UL 94 V-O rating indicates a high degree of resistance to flame. For that reason, it is frequently specified for materials which will be used in the manufacture of electrical appliances, power tools, business machines and some communications equipment. The procedure requires direct flame exposure to specimens which have been mounted vertically (most severe) and horizontally. To achieve a V-O rating, a material must conform to all of the following requirements:

— A material may not exhibit flaming combustion for more than 10 seconds after the flame is removed.

— After two controlled applications of flame, the test specimen may not have burned to the clamp holding the sample (approximately 4-3/4 inches).

— The material may not drip flaming particles capable of igniting cotton placed 12 inches below the specimen.

— And finally, a material may not exhibit glowing combustion for more than 30 seconds after the second application of flame.

When testing specific end-use products, manufactures find that rigid vinyl complies with all requirements of the Subject 94 procedure.

V. Rigid Vinyl Does Not Produce an Unusual Life Safety Hazard

- Rigid Vinyl Resists Flashover

The low flashover tendency of rigid vinyl is an outstanding property which is finally gaining recognition.

There are few disasters more frightening — or more totally destructive — than a raging, uncontrolled fire. "Flashover" is distinctive as the most critical event in unwanted fires. Rapidly burning materials are fuels producing plumes of hot combustion gases. These funnel upwards — then stratify across the ceiling — allowing room for oncoming volumes of gas as the fire gains momentum. Accelerated fuel combustion evolves intense heat which further accelerates greater fuel consumption; the burning process becomes self sustaining, self- perpetuating and uncontrolled.

As temperatures of the stratified gas layer reach 500-600°C (932-1,112°F), sufficient heat radiates towards the floor to ignite combustible contents in the room. Almost spontaneously, flashover occurs causing rapid raging flame involvement of the entire room. Survival is not possible under flashover conditions. Therefore, it is obvious that materials which minimize the possibility of flashover are highly desirable.

Laboratory tests determined that the wood and cellulosics are among the materials which go to flashover conditions most rapidly and produce the largest fires. *Flashover never occurred with vinyl* (Table 5, Table 7).

- In a Room Scale Test, Rigid Vinyl Produced Less Smoke and Lower Flame Spread than Wood.

When rigid vinyl is involved in an actual fire, its outstanding flammability characteristics…

- low flame spread
- high temperature necessary for ignition
- the necessity for an external heat source to maintain combustion

…have a pronounced effect on the amount of smoke produced. When exposed to direct flames as from a wastebasket fire, rigid vinyl burns

Table 5
Flashover of Selected Materials

Material	Height of Fire (Inches)	Time to Fire (Seconds)
Red Oak	26±0	34±2
Douglas fir	26±0	39±11
Southern yellow pine	26±0	33±8
Solid plastics		
Polyethylene	16±0	115±20
Polystyrene	8±4	160±37
Polymethyl methacrylate	26±0	61±18
ABS	7±2	127±32
Polycarbonate, 1	6±3	97±13
Polycarbonate, 2	none	none
Nylon 6	26±0	55±7
Nylon 6 / 6	26±0	97±37
POLYVINYL CHLORIDE	NONE	NONE
CLORINATED POLYVINYL CHLORIDE	NONE	NONE
Polyphenylene oxide, modified	none	none
Rigid foam plastics		
Polyester	22±7	91±8
Polyethylene	26±0	141±4
Polyurethane, no FR	3±1	92±4
Polyisocyanurate, urethane-mod., 1	2±1	72±5
Polyisocyanurate, urethane-mod., 2	none	none
Polystyrene	3±2	203±10
POLYVINYL CHLORIDE	none	none
Flexible foam plastics		
Polyurethane	26±1	44±4
Polychloroprene	none	none
Upholstery fabrics		
Cotton	20±3	36±16
Rayon	20±7	37±12
Nylon	21±6	83±8
Polypropylene	25±2	106±13
Cushioning materials		
Cotton batting	14±3	25±3
Excelsior	11±3	21±4
Kapok	13±2	27±5

Source: Hilado, C.J. and Cumming, H.J., "Screening Material for Flash-Fire Propensity," Modern Plastics, November, 1977 slowly, mildly and ceases burning when the ignition source is removed. The amount of smoke produced is low because only a small amount of vinyl has been consumed.

For both smoke and toxic gas generation data, recent emphasis has been placed on small scale laboratory tests. The correlation to unwanted fires has not been demonstrated. Naturally, this has led to confusion and misunderstanding regarding the realistic performance of materials under actual fire conditions.

For example, in the National Bureau of Standards smoke density chamber (ASTM Test E 662), wood produces far more smoke in the smoldering mode than under flaming conditions. The opposite is true for many thermoplastics including rigid vinyl (Table 6). By only considering data from the flaming mode, it could be incorrectly assumed that wood typically burns with very little smoke. Room size tests prove the inability of this small scale laboratory test to provide a meaningful prediction of the amount of smoke generated in a real fire situation. Important factors such as ventilation, fire source and the combustibility of involved materials are not taken into consideration.

Using a room size fire test facility, the flame spread and smoke generating characteristics of rigid vinyl under simulated fire conditions have been determined by BFGoodrich scientists (Table 7). Although unwanted fires span a wide variety of conditions, this room scale test helps demonstrate why numerous investigations for methods to reduce fire risk are demanding more ignition-resistant and burn-resistant materials such as rigid vinyl.

Table 6

National Bureau of Standards Smoke Chamber Density Ratings (ASTM Test E 662)

Material	Sample Thickness (Inch)	Maximum Specific Optical Density, DM	
		Nonflaming	Flaming
Rigid Vinyl	0.250	300	660
Red Oak	0.250	395	76
White Pine	0.250	325	155
Douglas Fir, Interior plywood	0.250	350	96
Polyethylene	0.250	526	NR
Polystyrene	0.250	372	660

NR: Not reported

Source: Hilado, C.J., "Flammability Handbook for Plastics, " Third Edition. Technomic Publishing Company, 1982.

In the room scale test, wood or rigid vinyl panels mounted in a corner are ignited by a wooden crib. Comparison of the results obtained when the wood crib alone was burned and when the crib was used as the ignition source for rigid vinyl, proves that rigid vinyl contributes negligible heat (only 17°C [30°F] above what was recorded when no vinyl was present). However, when approximately ¼-inch wood panels were burned, the temperature in the room increased to 558°C (1,036°F) — more than 2.5 times more heat (85,130 Btu) than from the wood crib alone or from the wood crib plus rigid vinyl (Table 7). Significantly, with rigid vinyl, fire did *not* spread beyond the point of origin nor was there any threat of "flashover".

Table 7

Room Size * Fire Test

Wall Lining Material	Sample Thickness (inch)	Temperature at door	Heat Generated During First 13 minutes (Btu)	Peak Smoke at door (OD/M)	Total Smoke Yield (Grams)
Wood crib only**	—	171°C (340°F)	30,900	1.6	106
Rigid vinyl	0.09	188°C (370°F)	30,050	8.3	384
Composition wood panels	0.23	558°C (1,036°F)	85,130	9.6	over 750

* Facility is 8-feet wide, 12-feet long, 8-feet high. Room lined with gypsum board over wood studs. Test material is in sheet form mounted in corner opposite 73-inch high by 3-foot wide door. Optical density through the smoke layer (OD/M) was measured vertically through a 30 cm (1-foot) path length located in hot gas layer near ceiling. Ignition source is 14.0 lb. wood crib.

** This test conducted to determine amount of heat and smoke produced by the wood crib alone.

Source: Dickens, E. D., Jr., "The Fire Performance of PVC, "*Journal of Vinyl Technology,* Vol.5, No.3, September, 1983.

The significance of low flame spread is further shown by the amount of smoke generated. Because wood creates a much larger fire, wooden panels generated more smoke than rigid vinyl. The room scale test demonstrates an important concept: *a large external fire producing heat, smoke and toxic gases must be in progress before combustion of rigid vinyl is possible.*

- Carbon Monoxide: The Primary Life Hazard in Unwanted Fires

Neither man nor nature has yet created organic materials which do not produce toxic gases upon burning. Carbon monoxide is present in all fires involving organic materials. Investigations examining human fire fatalities have proven carbon monoxide to be the primary toxicant in most fire deaths. It reduces the ability of the blood to transport life saving oxygen to critical body organs resulting in asphyxia (loss of consciousness).

Charges by metal pipe producers that plastics cause the majority of fire deaths are not supported by facts. Dr George Gantner, professor at St. Louis University School of Medicine and Medical Examiner for St.Louis, Missouri, extensively analyzed — then compared the autopsy slides from the 1977 Beverly Hills Supper Club fire and the 1942 Cocoanut Grove fire victims. He detected no difference in cause of death. The Cocoanut Grove fire occurred *ten years before* the widespread use of plastics.

- Hydrogen Chloride (HCl) Was Not Found at Toxicologically Significant Levels in Real Fires

Two independent studies were conducted to determine which gases were the major contributors to life hazard in a fire environment. The Harvard University study, in cooperation with the Boston Fire Department, concentrated on large multi-family dwellings. The study by Southwest Research Institute (in conjunction with San Antonio Fire Department) emphasized single family dwellings.

In both studies, firefighters equipped with air sampling devices entered actual building fires. Samples taken from the fire atmospheres were later analyzed (Table 8). HCl was not found at toxicologically significant levels. In the 260 fires monitored, the HCl median level was less than 5 parts per million (ppm). The maximum amount measured in any fire was 280 ppm. Atmospheric concentration of HCl immediately hazardous to life is 1,000-2,000 ppm.

Table 8

Analysis of Atmospheres in Building Fires
(Concentrations in parts per million except where noted)

	San Antonio Study %			Boston Study %		
	Samples	**Median**	**Maximum**	**Samples**	**Median**	**Maximum**
Carbon monoxide	90	50	7,450	>90	23	4,800
Acrolein	6	—	4	>50	0.4	98
Acetaldehyde	19	—	7	NA	NA	NA
Benzene	100	2	17	92	0.7	180
Hydrogen chloride	53	4	232	36	<1	280
Hydrogen cyanide	89	0.2	9	11	<0.2	4
Nitrogen dioxide	NA	NA	NA	—	<0.2	8
Carbon dioxide (%)	93	0.07	1.6	100	<0.2	7.5
Oxygen depletion (%)	100	<1	1.3	NA	NA	NA
Particulate (g/m³)	69	0.04	0.9	—	0.03	18

NA: Not analyzed
< means less than; > means more than.
Source: Kaplan, H.L.; Grand, A.F.; Hartzel, G.E., "A Critical Review of the State of The Art Of Combustion Toxicology," Southwest Research Institute Project Report No.01-6862, Pg.117, June, 1982.

The Boston study concluded that carbon monoxide and acrolein (a common toxic combustion gas from burning wood) were the most hazardous air contaminants in actual structural fires.

Types and levels of combustion gases depend on many variables. Large concentration of wire or cable confined in a small space are situations where high levels of specific combustion gases could accumulate. High concentrations of an individual material in a warehouse represents a similar possibility. Regardless which combustible materials are present, these types of installations require close attention to proper fire stops and automatic detection and suppression systems.

- Rigid Vinyl: No Additional Combustion Toxicity Risk Compared to Other Organic Materials

Vinyl is one of the world's most thoroughly tested materials. It has been evaluated in every major combustion toxicity test. Although no universal test for classifying toxicity of burning materials has evolved, worldwide studies by academia, government and industry indicate the toxicity and hazard of rigid vinyl is neither unique nor extreme. In fact, combustion products from many common materials cause incapacitation or death in test animals more quickly than combustion products from vinyl.

The most advanced laboratory test has been developed by the National Bureau of Standards (NBS). The NBS method is the only one which has been extensively cross-checked for interlaboratory reproducibility. In addition, it is closest to guidelines established by the national Academy of Sciences for screening materials for unusually toxic combustion products. Results from the NBS method prove that combustion gases from rigid vinyl are no more toxic than those from Douglas Fir (Table 9).

Table 9

"Normalized" Toxicity Value*
National Bureau of Standards (NBS) Method — 30 Minute Exposure

	"Times as Toxic as Douglas Fir"	
	Flaming	**Nonflaming**
Douglas fir	1.0	1.0
Wool	0.8	1.1
PVC	< 1	< 1
Polyurethane (flexible)	< 1	< 1
Polyurethane (rigid)	2.4 (2-3)	< 1
Urea-formaldehyde	< 3.2	< 21
PTFE	18 (10-59)	25

*LC50 (Material)/LC50 (Douglas fir)
< means "less than"
Interpretation: Using this method of comparison, a value of 1.0 is assigned to Douglas fir as a reference "standard". Materials with values greater than 1.0 are "more toxic" than Douglas fir while materials having values less than 1.0 are "less toxic".
LC50 is the concentration producing death in 50% of the test animals exposed for 30 minutes and observed for 14 days.

Source: Clarke, F. S.; Benjamin, I. A.; and Clayton, J. W., "An Analysis of Current Knowledge in Toxicity of the Products of Combustion", for National Fire Protection Association, by Benjamin/Clark Associates. August, 1982.

Generation of HCl is temperature related: evolution begins in the 250-300ºC (482 -572ºF) range. Yield of HCl in a fire environment depends on size and intensity of the external fire source and how effectively it heats exposed vinyl. Since rigid vinyl by itself cannot support combustion, HCl yield and toxicity of the gaseous fire environment *cannot* be assessed independently. Small scale tests ignore the tremendous contribution of the fire source.

- Hydrogen Chloride: Only One of Many Gases Produced in Real Fires

A contrast to carbon monoxide, frequently referred to as the "silent killer" because of its odorless and tasteless nature, hydrogen chloride has a pungent, irritating odor. The odor threshold for HCl is recognized to be 1 – 5 ppm. Thus, it acts as a warning indicator above 5 ppm. At concentrations between 10 – 50 ppm, work becomes difficult and continued inhalation results in irritation to the respiratory tract.

Burning wood evolves as many as 175 different gases including corrosive acrolein, a severe eye and respiratory tract irritant. Smoke from burning leaves, a campfire or cigarettes produce this same irritating sensation. Another irritant, acetaldehyde, is also produced (Table 10). Many cancer causing substances are also present in the combustion products of wood smoke (Table 11).

Irritating, corrosive, sometimes carcinogenic and lethal gases are produced as *all* organic materials burn. Their composition and amount depend on:

- heat of the fire atmosphere;
- chemical composition of combustibles;
- and volume and concentration of fire gases involved.

These comprise only a fraction of the total life hazard present in an uncontrolled fire.

Table 10

Summary of Human Reactions to Exposure to Acetaldhyde, Acrolein, Carbon Monoxide and Hydrogen Chloride

Acetaldehyde

PPM	**Response**
0.07-2.3	Odor threshold
50	Detectable eye irritation
200	Excessive eye irritation
> 200	Injury to corneal epithelium, persistent lacrimation, photophobia

Source: "Occupational Health Guidelines for Chemical Hazards". NIOSH/OSHA. Publication No. 81-123, January, 1981.

Acrolein

PPM	**Response**
0.1	Threshold Limit Value (ACGIH)
1.0	Immediately detectable
5.5	Intense irritation
10.0 and over	Lethal in a short time
24.0	Unbearable

Source: "Documentation of the Threshold Limit Values", American Conference of Governmental Industrial Hygienists, 1971.

Carbon Monoxide

PPM	**Response**
50	Threshold Limit Value (ACGIH)
100	Allowable exposure for several hours
400-500	No appreciable effect after one hour
600-700	Appreciable effect after one hour
1,000-1,200	Unpleasant after one hour
1,500-2,000	Dangerous when inhaled for one hour
4,000	Fatal when inhaled for less than one hour
10,000	Fatal when inhaled for one minute

Source: Kaplan, H. L., et al, "A Critical Review of the State-of-the-Art of Combustion Toxicology", Final Report, Southwest Research Institute Project No. 01-6862, June, 1982.

Hydrogen Chloride

PPM	**Response**
1-5	Odor threshold
5	Threshold Limit Value (ACGIH)
10	Irritation
10-50	Work is difficult, but possible
35	Throat irritation after short exposure
50-100	Work is impossible
1,000-1,300	Dangerous
1,300-2,000	Lethal in a few minutes

Source: Stahl, Q. R., "Air Pollution Aspects of Hydrochloric Acid", National Air Pollution Control Administration. Prepared byLitton Systems, Inc., 1969.

Summary

The fire elements projecting emphatic threats to human survival – excessive heat, oxygen depletion and increased carbon monoxide content – are direct results of materials which ignite first and are consumed rapidly. Quantity and rate of heat release determine the rate of flame spread and the temperature of the total fire environment. These are critical factors in life or death fire situations (Table 12).

Rigid vinyl's low heat of combustion, low flame spread and resistance to flashover will not allow it to contribute to those conditions which present unusual hazards to human life.

Table 11

Toxic Characteristics of Wood Smoke				
Combustion Product	**Irritation / Pulmonary Edema**	**Neurotoxic**	**Carcinogenic**	**Mutagenic**
Carbon monoxide		+		
Carbon dioxide		+		
Acrolein	+			
Benzene			+	
Formaldehyde	+		+	+
Acetaldehyde	+		?	
Butyraldehyde	+		?	
Dimethylbenzanthracene			+	+
Benz(a)anthracene			+	+
Dibenzanthracene			+	+
Benzophenanthrene			+	
Benzofluoranthene			+	
3-methylcholanthrene			+	+
Benzopyrene			+	+
Idenopyrene			+	
Dibenzopyrene			+	+
Dibenzocarbazole			+	
Chrysene			±	+

Note: This does not represent an all inclusive list. Amount of toxicants present will vary depending upon fire conditions. Absence of a + does not necessarily mean no effect. Effects listed are based upon readily available information.

Table 12

Maximum Limits of Humans to Exposure of:	
Carbon Monoxide(1)	
1,500 – 2,000 ppm	Dangerous in 1 hour
3,200 ppm	Unconsciousness in ½ hour
6,400 ppm	Unconsciousness in 10 minutes
12,800 ppm	Unconsciousness in 5 seconds, death in 1 minute
Heat(2)	
140°F	Heat Stroke
212°F	Rapid skin burns in humid air
220°F	25 minute tolerance
248°F	15 minute tolerance
264°F	5 minute tolerance
300°F	Temperature limit for escape
320°F	Rapid unbearable pain
360°F	Irreversible injury to dry skin in 30 seconds
Oxygen Depletion(3)	
16-12%	Pulse quickens
14-9%	Numbness, fainting
10-6%	Nausea, paralysis, unconsciousness
3-2%	Death within 45 seconds

(1) Henderson, Y., Haggard, H. W., *Noxious Gases and the Principle of Respiration Influencing Their Action*, 2nd Rev. Ed., Reinhold, N.Y., 1943.
(2) Volume 3, "Smoke and Toxicity, (Combustion Toxicology of Polymers)", Report of the Committee on the Fire Safety Aspects of Polymeric Materials, National Materials Advisory Board, National Academy of Sciences, Washington, D.C., NAMB 318-3, 1978.
(3) Sollman,T., *A Manual of Pharmacology*, W. B. Sanders Co. Philadelphia, PA., 1948.

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ACCREDITATION Standards Council of Canada, Registration #1B.

REGISTRATION ISO 9002-1994, registered by QMI, Registration #001109.

SPECIFICATIONS OF ORDER

Determine the Flame Spread and Smoke Developed Classifications based upon a single test conducted in conformance with ASTM E 84, as per your letter dated January 16, 1996.

SAMPLE IDENTIFICATION

The sample submitted for testing was identified as:
Blind vanes manufactured with Royal PVC compound 9005,
3.5" wide x 96" long x 0.035" thick.

(ORTECH sample identification number 96-J52-S0001)

TEST PROCEDURE

The method, designated as ASTM E 84-94, "Standard Method of Test for Surface Burning Characteristics of Building Materials", is designed to determine the relative surface burning characteristics of materials under specific test conditions. Results are expressed in terms of flame spread Index (FSI) and smoke developed (SD).

Although the procedure is applicable to materials, products and assemblies used in building construction for development of comparative surface spread of flame data, the test results may not reflect the relative surface burning characteristics of tested materials under all building fire conditions.

SAMPLE PREPARATION

The sample was conditioned to constant mass at a temperature of 23°C and a relative humidity of 50% prior to testing.

SUMMARY OF TEST PROCEDURE

The tunnel is preheated to 150°F, as measured by the floor-embedded thermocouple located 23.25 ft. downstream of the burner ports, and allowed to cool to 105°F, as measured by the floor-embedded thermocouple located 13 ft. from the burners. At this time the tunnel lid is raised and the test sample is placed along the ledges of the tunnel so as to form a continuous ceiling 24 ft. long, 12 inches above the floor. The lid is then lowered into place.

Upon ignition of the gas burners, the flame spread distance is observed and recorded every 15 seconds. Flame spread distance versus time is plotted ignoring any flame front recessions. If the area under the curve (A) is less than or equal to 97.5 min-ft., FSI = 0.515-A; if greater, FSI = 4900/(195-A). Smoke developed is determined by comparing the area under the obscuration curve for the test sample to that of inorganic reinforced cement board and red oak, arbitrarily established as 0 and 100, respectively.

TEST RESULTS

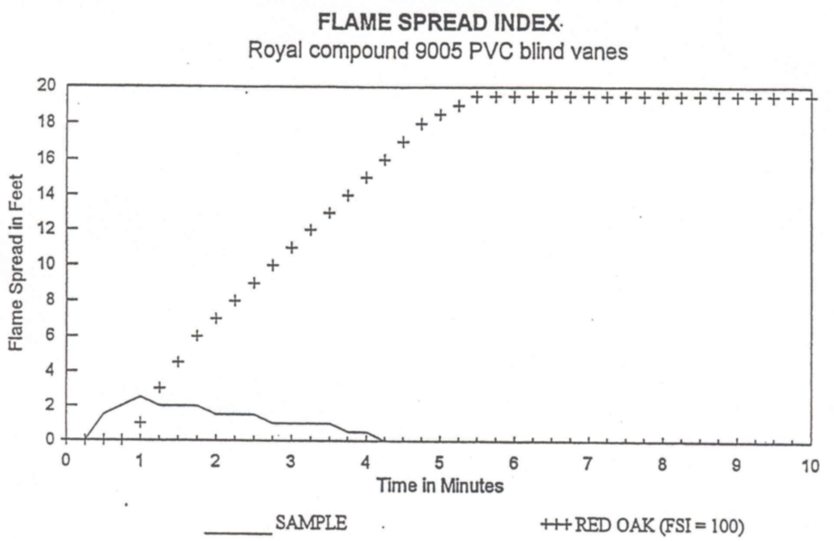
SAMPLE	FSI	SD
Blind vanes manufactured with Royal PVC compound 9005, 3.5" wide x 96" long x 0.035" thick.	12	149

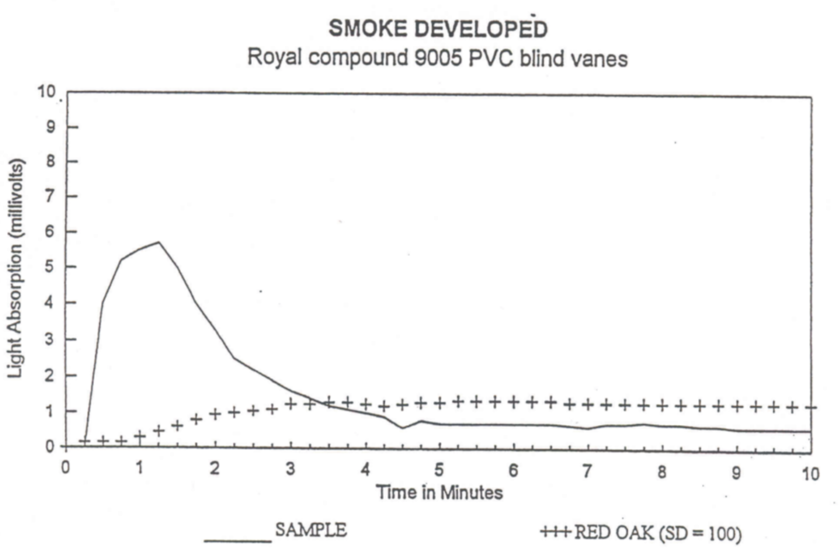
Observations of Burning Characteristics

— The sample was observed to begin to melt, ignite and propagate flame after approximately 15 seconds exposure to the test flame.
— The flame front propagated to a distance of 2.5 feet during the first minute of test and then slowly receded to the baseline.
— The flame propagation was accompanied by a rapid increase in smoke developed. Maximum amounts of smoke were recorded coinciding with maximum flaming involvement of the sample. Smoke production then began to decrease as burning activity subsided (see accompanying charts).

Authorities having jurisdiction usually refer to these categories:

	Flame-Spread Index	Smoke Development
Class 1 or A	0 – 25	450 Maximum
Class 2 or B	25 – 70	450 Maximum
Class 3 or C	75 – 200	450 Maximum





FSI	SD
12	149