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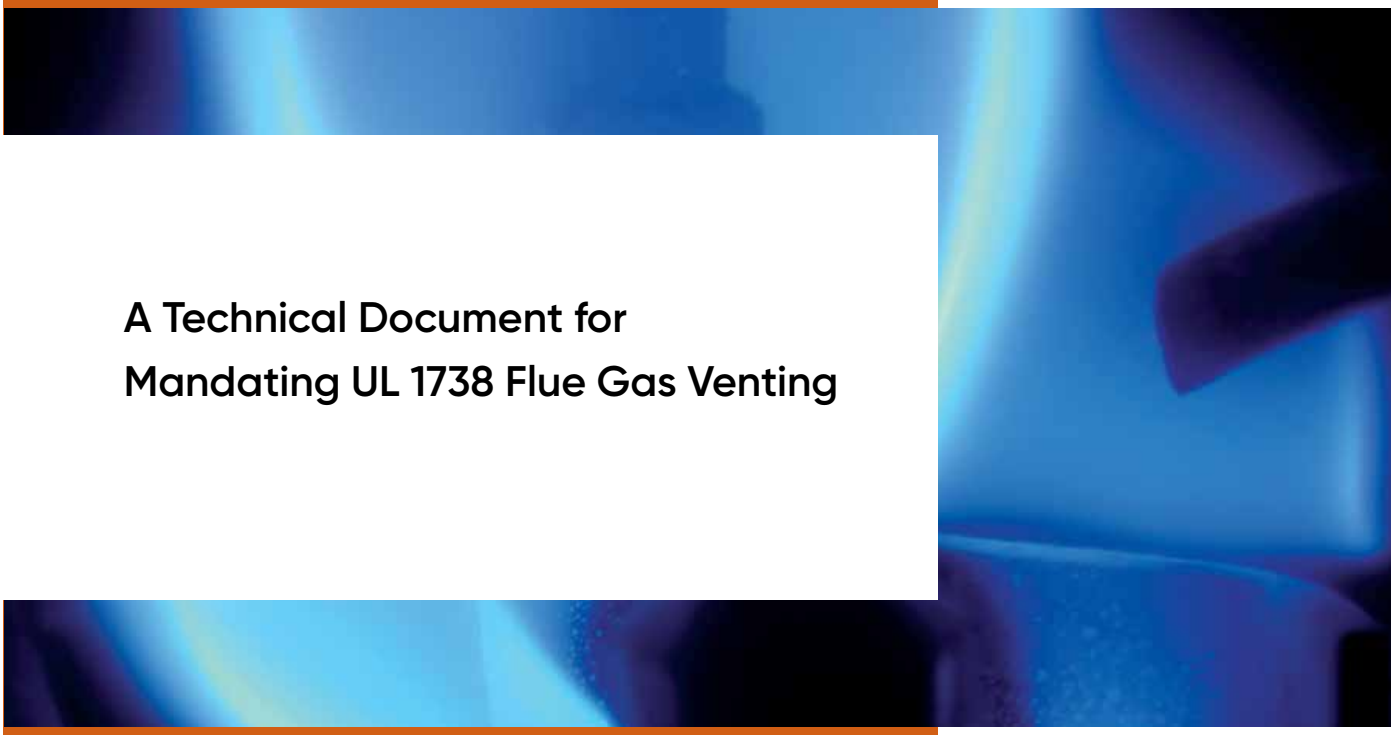

A Technical Document for Mandating UL 1738 Flue Gas Venting

Flue Gas Venting White Paper, 2021

Matthew Tucci, EIT
Market Development Specialist, Flue Gas Venting
IPEX USA LLC

Executive Summary

The Problem

Venting combustion gas is a life-safety application that can have severe consequences when failures occur. Historically, due to a lack of certified venting products, plastic products manufactured to plumbing standards have been accepted to vent gas-fired appliances. Despite proper installations, it is still commonplace to see these plumbing products fail in the field as plumbing standards do not qualify products for the conditions a venting system will experience.

The Solution

Through the use of application-specific product standards, such as UL 1738, which is designed specifically for gas-fired appliance venting systems, unlisted plumbing products are replaced with certified and listed venting systems. UL 1738 listed venting systems are qualified through more than 50 different material and system performance tests to ensure the venting system is suitable for use throughout the entire lifespan of the venting system.

Product Evaluation

When comparing the requirements of commonly used plumbing standards such as ASTM D1785, ASTM D2665, and ASTM F441 to the UL 1738 venting standard, it is clear that UL 1738 provides both safety and product benefits. Testing of typical venting conditions such as elevated temperatures, low temperatures, UV light, heat cycling, and exposure to acidic condensate is included in UL 1738 but is not found in the ASTM plumbing standards.

Additionally, UL 1738 requires the heat deflection temperature (HDT) of a listed material to be at least 18°F higher than the system temperature rating, ensuring there is a safety factor regardless of the application. As this requirement is not included in the ASTM plumbing standards, plumbing products are often used up to their heat deflection temperature instead of their temperature rating. This increases the potential for premature failures and carbon monoxide to leak into residential and commercial buildings.

Future Considerations

UL 1738 venting systems are manufactured and available across the United States. The standard continues to be included in many gas-fired appliance installation manuals as demand for certified, safer products increases. Unfortunately, in many regions, local and state fuel gas codes have not yet been updated to mandate UL 1738 listed products and still allow for a choice between unlisted and UL 1738 listed venting systems. If you are in a position to specify, install or inspect gas-fired appliances and their venting systems, insisting on UL 1738 listed venting products is the right thing to do.

Safety First

Introduction

Venting combustion gas is a life-safety application that can have severe consequences when failures occur. Although much is known about combustion gas and its dangers, it is still commonplace to see venting failures in the field

This white paper discusses the following:

- Why these failures are occurring and provides a solution to improve safety moving forward.
- How piping materials such as PP and CPVC, are used successfully in applications with vastly different requirements through application-specific product standards.
- The conditions a typical Category IV venting system will experience such as elevated temperatures, low temperatures, UV light, heat cycling, and condensate contact and how traditional plumbing standards do not account for these conditions.
- The UL 1738 Safety Standard and gives a comparison between the stringent requirements of UL 1738 and the requirements of common plumbing standards such as ASTM D2665, ASTM D1785 and ASTM F441.
- A material's heat deflection temperature and how it relates to a material's temperature rating, highlighting how the heat deflection temperature of traditional plumbing products is misinterpreted resulting in no safety factor when they are used to vent combustion gas.

This paper concludes that traditional plumbing products manufactured to ASTM standards are not suitable to vent combustion gases. If you are in a position to specify, install, or inspect gas-fired appliances and their venting systems, insisting on UL 1738 listed venting products is the right thing to do.

Background

Each year in the United States, approximately 50,000 people visit an emergency department due to accidental carbon monoxide poisoning[1]. What's more, from 2010-2015, these accidental poisonings resulted in over 2,000 deaths[2] with many of these taking place in colder fall and winter months, when gas-fired appliances such as furnaces and heaters are more likely to be used.[3]

For a gas-fired appliance to create incidents like the ones described above, two conditions are required. First, the appliance must be producing hazardous levels of carbon monoxide. Second, the hazardous carbon monoxide must be able to leak into the living space[4].

While the first condition can occur due to a variety of factors, many of which are well documented, this paper focuses on the second significantly less documented condition, specifically, why Category IV venting systems are failing. Despite proper installations, current venting materials are failing to deliver combustion gases to their intended destination. Both the problem at hand and a proposed solution will be detailed throughout this paper.

In piping applications that use similar thermoplastic materials, products are manufactured and listed to standards that are specific for their application. An example of this is clear when comparing polypropylene (PP) and chlorinated polyvinylchloride (CPVC) in potable water and corrosive waste applications. While the same material can be used for both applications, the conditions and parameters that each application poses are different, therefore, the products and standards differ as well.

PP & CPVC ASTM Standards in Potable Water and Corrosive Waste Applications:

Material	Applicable Standards	
	Potable Water	Corrosive Waste
PP	ASTM F2389	ASTM D4101
CPVC	ASTM F441	ASTM F2618

While the base materials in the above examples are similar, it is common practice to alter the compound, allowing the final product to better handle the requirements of its intended application. It is not uncommon to also see application-specific changes when examining the various fitting types and geometries that are used. In certain cases, specific manufacturing processes are used to provide not only application-specific benefits, but significant safety benefits as well.

The question then becomes: in a life-safety application such as venting combustion gas, why are products manufactured to plumbing standards still permitted for use in an application for which they are not designed?

Category IV appliances operate with a positive vent static pressure and with a vent gas temperature that may cause excessive condensate production in the vent.

How Are Suitable Venting Materials Determined?

Historically, fuel gas codes have deferred to the installation manuals of gas-fired appliances when determining suitable venting materials. This was due to a lack of readily available thermoplastic products manufactured to flue gas venting standards. As a result, the most common PVC product standards in these installation manuals are ASTM D2665 and ASTM D1785, while the most common CPVC product standard is ASTM F441, all of which are standards for plumbing and fluid handling applications.

A brief summary of each Standard's scope

ASTM D2665: Requirements and test methods for materials, dimensions and tolerances, pipe stiffness, crush resistance, impact resistance and solvent cement.

ASTM D1785: Requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening and extrusion quality.

ASTM F441: Requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening and extrusion quality.

While these requirements are necessary for plumbing and fluid handling applications, they have little value for products used to vent combustion gas. The application parameters experienced by Category IV venting systems differ substantially from plumbing systems, making the vast majority of these requirements inconsequential for venting combustion gas.

Furthermore, aside from a minimum cell class requirement, conditions that a Category IV venting system are likely to experience such as elevated temperatures, UV light, heat cycling and contact with acidic condensate, are not taken into consideration in any of the plumbing standards previously mentioned.

What is a Cell Class?

ASTM D2665, D1785 and F441 require specific cell classes as defined per ASTM D1784.

ASTM D1784 is a specification covering rigid PVC and CPVC compounds for general purpose use in extruded or molded form. The cell class of a material per ASTM D1784 is a six-digit number that defines select material properties. The cell class is commonly included in building specifications to ensure a minimum level of performance when specifying PVC and CPVC materials. Each digit of the cell class number represents a material property that is determined by an ASTM testing method based on the range the test result falls into. A summary of Cell Class requirements from ASTM D1784 is below.

Both ASTM D2665 and ASTM D1785 require pipe to be made of PVC compounds meeting or exceeding the requirements of Cell Class 12454 as defined in the table below.

Taking the fifth digit as an example, the minimum requirement is a '4', which corresponds to the material having a heat deflection temperature under load of at least 158°F.

Class Requirements for Rigid PVC and CPVC Compounds

The minimum property value will determine the cell number although the maximum expected value may fall within a higher cell

Designation Order #	Property & Unit	Cell Limits											
		0	1	2	3	4	5	6	7	8	9	10	11
1	Base resin	unspecified	poly (vinyl chloride) homo-polymer	chlorinated poly (vinyl chloride)	vinyl co-polymer								
2	Impact resistance (Izod), min: J/m of notch	unspecified	<34.7	34.7	80.1	266.9	533.8	800.7					
	ft·lb/in. of notch		<0.65	0.65	1.5	5.0	10.0	15.0					
3	Tensile strength, min: MPa	unspecified	<34.5	34.5	41.4	48.3	55.2						
	psi		<5 000	5 000	6 000	7 000	8 000						
4	Modulus of elasticity in tension, min: MPa	unspecified	<1930	1930	2206	2482	2758	3034					
	psi		<280 000	280 000	320 000	960 000	400 000	440 000					
5	Deflection temperature under load, min, 1.82 MPa (264 psi): °C	unspecified	<55	55	60	70	80	90	100	110	120	130	140
	°F		<131	131	140	158	176	194	212	230	251	266	284
	Flammability	A	A	A	A	A	A	A	A	A	A	A	A

[A] All compounds covered by this specification, when tested in accordance with Test Method D 635, shall yield the following results: average extent of burning of <25 mm; average time of burning of <10 s.

Heat Deflection Temperature

A material's heat deflection temperature is the temperature at which a material will deform under a specific load. This temperature is widely accepted in the thermoplastics industry as a temperature to avoid during service as approaching this temperature will result in significant breakdown of the material's mechanical properties. This is a significant factor behind PVC products manufactured to the ASTM D2665 and ASTM D1785 standards having a temperature rating of 140°F. The 18°F difference between the temperature rating of these PVC products and the heat deflection temperature is a safety factor. Using these products in applications above 140°F poses a substantial risk of material property breakdown including embrittlement, leading to premature failures.

In the same way that thermoplastic materials have product standards based on their intended application, gas-fired appliances also have their own product standards based on their intended application. Using water heaters as an example, the table below is from the ANSI Z21.10 Gas Water Heaters, Volume I, Storage Water Heaters with Input Ratings of 75,000 Btu Per Hour or Less Standard.

Maximum Allowable Temperatures of Typical Nonmetallic Vent Material used in Water Heaters

Material	Heat Deflection Temperature		Pipe Nomenclature	Standard
	°F	°C		
PVC	158	70	DWV	ASTM D2665 or CSA B181.2
			Sch 40, 80, 120	ASTM D1785 or CSA B137.3
			SDR Series	ASTM D2241 or CSA B137.3
CPVC	212	100	CPVC 41	ASTM D2846 or CSA B137.6
			Sch 40, 80	ASTM F441 or CSA B137.3
			SDR Series	ASTM F442
ABS	180	82	Sch 40 DWV	ASTM D2661 or CSA B181.1

The table above is commonly interpreted, as a result of the table's title, to list maximum allowable material temperatures.

In reality, it simply lists each material's Heat Deflection Temperature as defined per ASTM D1784. The result is PVC and CPVC plumbing products being used in an application that they have not been qualified for. Because they are operating well above their design temperatures, the safety factor is eliminated, increasing potential for premature failures and for carbon monoxide to leak into residential buildings.

Safety Always

In Summary

The use of plastic venting systems on gas-fired water heaters, furnaces and boilers has undergone a significant change. The NFPA 54-18 and IFGC-18 Fuel Gas Codes now recognize the UL 1738 venting standard across the United States.

The Solution

This paper has highlighted the fact that plumbing products, although used out of necessity in the past, are not suitable for venting combustion gas. The ASTM plumbing standards do not include provisions to qualify a piping system for venting flue gas and the appliance standards, which specify plumbing products have misinterpreted the heat deflection temperature. The combination of this lack of product qualification and misinterpretation poses dangerous potential in a life safety application like venting carbon monoxide.

To highlight that plumbing products are not suitable for venting combustion gas, the ASTM D1785, ASTM D2665 and ASTM F441 Technical Committees added notes to the scope of each standard in 2018. While the notes are similar in their intention, the note below is from the ASTM D1785 Standard.

> Note 2 – This standard specifies dimensional, performance and test requirements for plumbing and fluid handling applications only. It does not include provisions for the use of the products for venting of combustion gases. UL 1738 is a standard that does include specific testing and marking requirements for flue gas venting products, including PVC [5].

This note makes it clear that there is an inherent risk associated with using plumbing products to vent combustion gas, while referring to the UL 1738 standard as a solution.

The UL 1738 Venting Standard

UL 1738 is a Standard for Venting Systems for Gas-Burning Appliances, Categories II, III, and IV. It covers both metallic materials like stainless steel (SS) and nonmetallic materials like PVC, CPVC and PP making it easy to adopt, as one standard covers all venting materials.

It is a robust standard, which includes material testing requirements such as elevated temperature, low temperature, UV light, heat cycling and acid testing. It also includes testing of the entire assembled system of pipe, fittings, solvent cement and terminations. Importantly, the UL 1738 standard is stringent enough to prevent PVC and CPVC plumbing products manufactured to ASTM standards from passing the requirements.

A key test of the UL 1738 standard is the Heat Deflection Temperature Test 43, which stipulates that the heat deflection temperature of a polymeric material shall be at least 18°F higher than the system rated temperature, but not less than 158°F. Additionally, the UL 1738 standard requires that the system-rated temperature be printed on the product, something that is not a requirement of ASTM plumbing standards today.

The result is that UL 1738 listed venting systems always maintain a minimum 18°F safety factor between the system rated temperature and the heat deflection temperature. For example, System 1738® PVC manufactured by IPEX, has a temperature rating of 149°F meaning the heat deflection temperature of the product is at least 167°F.

Taking Action

UL 1738 PVC and CPVC venting systems are manufactured and available across the United States. The standard continues to be included in many gas-fired appliance installation manuals as demand for certified, safer product increases. Unfortunately, in many regions, local and state fuel gas codes have not yet been updated to mandate UL 1738 certified products and still allow for a choice between uncertified and UL 1738 certified venting systems.

If you are in a position to specify, install or inspect gas-fired appliances and their venting systems, insisting on UL 1738 listed venting products is the right thing to do.

References

[1] https://www.cdc.gov/dotw/carbonmonoxide/index.html

[2] https://www.cdc.gov/mmwr/volumes/66/wr/mm6608a9.htm#suggestedcitation

[3] https://www.cdc.gov/nceh/publications/spotlights/cospotlight.htm#:~:text=ATLANTA%20%E2%80%94%20Carbon%20monoxide%20(CO),Control%20and%20Prevention%20(CDC).

[4] https://www.federalregister.gov/documents/2019/08/19/2019-17512/performance-requirements-for-residential-gas-furnaces-and-boilers-advance-notice-of-proposed

[5] ASTM Int'l D1785-15 E1. Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.