Combustion Gas Venting:

The Dangers of Unlisted PVC and the Development of Safe Practices

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Executive Summary

One of the defining goals of almost any technology in recent years has been an increase in efficiency. In the field of heating and cooling, massive strides have been made in this respect. Gas-burning heating appliances such as boilers, water heaters, and furnaces have all been made increasingly efficient, leading to a reduction in gas usage and a lower need for the constant operation of the appliances in question. This, in turn, saves money for the user and works in tandem with broader sustainability and environmental goals. This improved technology has had other effects, however, including the necessity for a different venting material than what was used on less efficient appliances. This report will review these changes in venting practices, how they became unsafe, and the resulting developments that took place to address these unsafe practices.

The Rise of Unsafe Practices

An increase in appliance efficiency led to some side effects. The combustion products began to condense as so much heat was extracted from the combustion process that the gas passed its dew point. The resulting liquid is called condensate, which corroded the existing conventional metal vents. The joints in existing vents were also not sealed, which is a requirement for venting high efficiency appliances. These factors, combined with the mass availability of PVC, led to PVC becoming the default venting material. The problem is that standard PVC was and is listed to ASTM plumbing standards which explicitly state that they are not for use in combustion gas applications.

The result of misapplying this material in a dangerous application was venting failures, which generally result in the release of dangerous gases, primarily carbon monoxide (CO). These gases can cause severe injury and even be fatal.

The New Standards and Codes

Fortunately, there are venting standards which exist and can be applied in these situations. The sole venting standard in the United States is UL 1738. This standard is very extensive, and products which are listed to it are verified to be safe and tested for the application of venting. As more and more products were designed to meet this listing, code organizations began including it as a baseline standard in their codes, with even the PVC plumbing standard referring to it as the sole venting standard.

Commentary associated with these codes also make it very clear that these code organizations are aware of the danger, which is why they have taken the steps to add the standard to their codes. Some jurisdictions have already begun to enforce the standard, and it is now a process of educating building officials, contractors, and others in the industry on this matter so that this safety issue becomes one of the past.

Conclusion

UL 1738 is the only combustion gas venting standard of the United States and should therefore be the minimum required standard across the country for a material used in venting applications.

Introduction

There are many different forms of energy used in the home, with natural gas and fuel sources such as propane taking a center stage in much of the United States. The US Energy Information Administration reported that in 2022, about 60% of homes in the U.S. used natural gas in some capacity, with an emphasis on space and water heating (1). Another portion of American homes use propane as their primary heating fuel, coming in at about 5% of all U.S. households (2), with particular strongholds in New England and the Upper Midwest. These facts make any issue concerning this topic one which can be applied to a majority of the American public, heightening the importance of any potential safety concern.

Since this report deals with installations of high-efficiency (condensing) appliances, it is also relevant to note the increasing prevalence of these appliances relative to lower efficiency (non-condensing) appliances. Based on the 2019 BRG Heating & Cooling Market Report, it is estimated that in 2023, close to 60% of the total boiler market consisted of condensing appliances (3). The U.S. government is even incentivizing the installation of high-efficiency products via the Inflation Reduction Act of 2022, providing a tax break to Americans that install condensing furnaces through 2032 (4). These factors bring safety issues regarding condensing appliances to the forefront of safety conversations.

Background

Humans have been generating heat via combustion for thousands of years; it is, in fact, one of the benchmarks that we use to define humanity. Humanity began with fires in caves, then moved into homes with fireplaces and wood burning stoves. Eventually, in the 19th century, the first modern furnaces were invented, and then refined to provide central home heating in the first half of the 20th century. These were generally still quite simple appliances, all sharing a couple of basic qualities in common.

All of the aforementioned methods of heating operate via the combustion of a product, whether it be wood, coal, or a type of flammable gas (such as natural gas or propane). One of the products of this combustion process is heat, which is then transferred to air or water for the comfort or use of the occupant. Other products of this combustion of hydrocarbons are dangerous gases, one of which is Carbon Monoxide (CO). CO poisoning occurs when a person breathes in high levels of CO, which supplants the oxygen in the blood and can lead to extreme neurological damage and even death. CO is especially dangerous because it is colorless, odorless, and tasteless, making it almost impossible to detect without special tools or until symptoms are already experienced. This dangerous mix of gases is also known as “flue gas”.

It is necessary, therefore, to vent this flue gas out of the space occupied by humans. This is the reason that vents to the outdoors are needed. These vents took many forms, and the earliest vents were chimneys that would allow the harmful products of combustion to float up and out of the inhabited space. When stoves and then furnaces came to prominence, metal that could withstand the high flue gas temperature was used. Low to mid-efficiency furnaces, which had an Annual Fuel Utilization Efficiency (AFUE) of between 56-83%, were using a double walled metal that was known as B-vent, which was an ideal option due to its cheap price point and effectiveness.

Later in the 20th century, towards the end of the 1970’s, technological strides in the field were made which saw a second heat exchanger added to the equipment. This greatly increased the efficiency of the appliance, bringing the AFUE over 90%, as more heat was able to be extracted from the same combustion process. This had another effect though, being that so much heat was being extracted and applied to the air or water, that the leftover flue gas had a low enough temperature to condense into a liquid. This new factor is what led to the categorization of high-efficiency appliances as "condensing" and low to mid-efficiency appliances as "non-condensing"; this relationship between AFUE and temperature can be visualized in Figure 1.

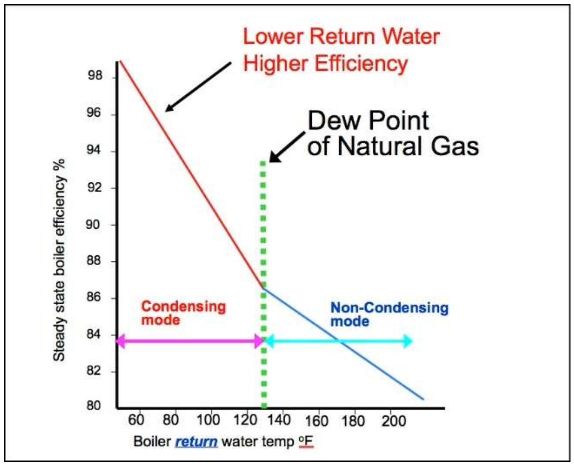

Figure 1: Chart showing the relationship between AFUE and the dew point of natural gas.

This new variable, temperature, could then be combined with another variable, being the pressure experienced by the vent system, creating four "venting categories". Below are the definitions of these categories as defined by the International Code Council (ICC) along with a chart showing the different categories (Figure 2):

Category I. An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that avoids excessive condensation production in the vent.

Category II. An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that is capable of causing excessive condensate production in the vent.

Category III. An appliance that operates with a positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.

Category IV. An appliance that operates with a positive vent static pressure and with a gas temperature that is capable of causing excessive condensate production in the vent.

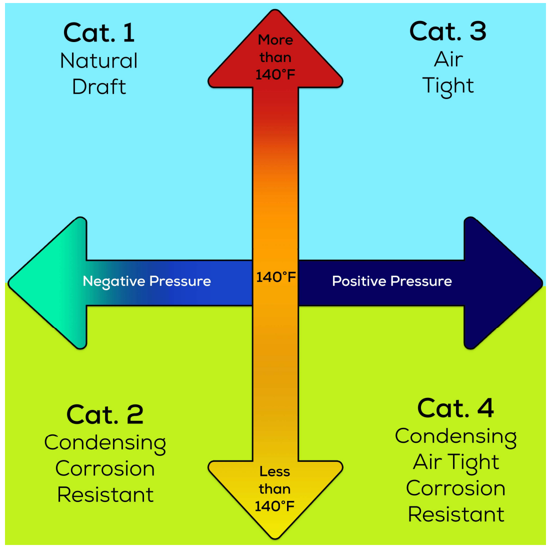

Figure 2: Chart showing the two different variables that create four categories.

As condensing appliances began to become more prevalent, a problem was quickly detected. It turned out that the condensate, which is highly acidic on account of it being a liquified version of the toxic flue gas, was able to easily corrode the galvanized metal vents that were being used on the appliances, a serious problem as it could create holes that would leak CO into the air and also potentially drip dangerous acidic condensate into the living space. Additionally, these venting systems were not completely airtight, and the transition from negative pressure to positive pressure systems made this a problem. An example of B-vent corrosion can be seen in Figure 3.

Figure 3: A B-vent that has been badly corroded by condensate (5).

The Use of PVC

With no immediately available venting technology, appliance manufacturers (OEMs) began the search for an existing material that could be used on their new condensing appliances. This was the beginning of the use of polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC), which were most commonly used for water transfer, in venting applications. These materials had many immediately apparent benefits, being that they were more resistant to corrosion in comparison to metal, were widely available, were inexpensive, and the industry was already familiar with the installation process. These factors were because of the fact that PVC and CPVC were widely used, and designed for, the DWV (drain-waste-vent) application.

The aforementioned factors led to OEMs citing PVC and CPVC as approved materials to vent their condensing appliances in their installation manuals. According to existing codes, such as NFPA 54/ANSI Z223.1, Section 12.5.2 (6):

> *"Where plastic piping is used to vent an appliance, the appliance shall be listed for use with such venting materials and the appliance manufacturer's installation instructions shall identify the specific plastic piping material. The plastic pipe venting materials shall be labeled in accordance with the product standards specified by the appliance manufacturer…"*

This clause, present in most major code books, gave the OEM full control over what material could be used to vent their appliances, so long as they cited a product testing standard for that material. In the case of PVC and CPVC pipes, they are most commonly listed to the ASTM D1785-21a (7) and ASTM F441/F441M-20 (8) standards, respectively. These are therefore the standards that are cited by OEMs in their installation manuals. Figure 4 shows a typical venting material identification table found in such installation manuals.

Approved PVC/CPVC Vent Pipe and Fittings		
Item	**Material**	**Standard**
Vent pipe	PVC Schedule 40, 80	ANSI/ASTM D1785
	PVC - DWV	ANSI/ASTM D2665
	CPVC Schedule 40, 80	ANSI/ASTM F441
Vent fittings	PVC Schedule 40	ANSI/ASTM D2466
	PVC Schedule 80	ANSI/ASTM D2467
	CPVC Schedule 80	ANSI/ASTM F439
	PVC - DWV	ANSI/ASTM D2665
Pipe Cement / Primer	PVC	ANSI/ASTM D2564
	CPVC	ANSI/ASTM F493
NOTICE: DO NOT USE CELLULAR (FOAM) CORE PIPE		

Figure 4: Typical approved material table found in condensing appliance installation manuals showing PVC/CPVC and their accompanying standards.

This led to PVC becoming the material of choice for venting installations. The problem at hand, however, is the question of what the ASTM standards test.

The ASTM Standards

While the ASTM standards are indeed testing standards, and so satisfy the base requirements of the existing codes, they were never designed to test venting conditions. If one examines the scope section of the ASTM D1785-21a standard, section 1.2 and NOTE 2 state the following (7):

"1.2 The products covered by this specification are intended for use with the distribution of pressurized liquids only, which are chemically compatible with the piping materials. Due to inherent hazards associated with testing components and systems with compressed air or other compressed gases some manufacturers do not allow pneumatic testing of their products. Consult with specific product/component manufacturers for their specific testing procedures prior to pneumatic testing…

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 these 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."*

The very first sentence of this reveals that, by using ASTM listed PVC in a combustion gas venting application, there is already a violation of scope, as flue gas is not a pressurized liquid. The ASTM F441/F441M-20 standard has identical wording in its section 1.2 (8). The following scope note then explicitly states that the D1785-21a standard does not contain testing provisions for the use of these products in the application of combustion gas venting and refers to the UL 1738 standard as the correct standard for this application.

What this declaration of scope reveals is a fact that makes sense when one considers the most common use case of ASTM listed PVC and CPVC pipe (henceforth referred to as "unlisted"); the ASTM standards listed above are plumbing standards which test for plumbing conditions and list for use materials suited for plumbing applications. With this in mind, one must consider the reality that the most common practice in the United States for the venting of condensing appliances is the use of a material which is neither tested nor listed for use in these applications.

Consequences of Misapplication

The consequences of misapplying a material, especially when dealing with something as dangerous as flue gas, are engineering failures, damages, injuries, and fatalities.

Carbon Monoxide (CO) Poisoning

Carbon monoxide poisoning would be considered the worst-case scenario for a vent failure. If vents were to be not assembled properly or the material unable to withstand the conditions, the results can be the leakage of the flue products into the air. This odorless, colorless gas results in unconsciousness, nausea, dizziness, weakness, and, if inhaled for a long enough period, death.

The Consumer Product Safety Commission in the United States notes that "heating systems were associated with the second largest percentage of non-fire CO poisoning deaths in 2019." (9). This associated figure is 28%, meaning that over a quarter of all CO poisoning deaths can be attributed to heating system failures. By using materials which are designed for the application of venting this dangerous gas, one can begin the mitigation of this unfortunate statistic.

Chloride Leaching & Hydrogen Chloride (HCl) Gas

The topic of the chemical makeup of PVC and CPVC also maintains an influence on the consideration of safer venting practices. These products are made of chemicals which are toxic to humans, with the principal element being chlorine. When exposed to heat, the pipes release heavily toxic fumes. A study on this fact (10) states:

"The use of PVC in construction (the largest overall use of PVC) doubled between 1980 and 1995. Because so much PVC is used in construction and household items, accidental building fires have become increasingly more dangerous for firefighters and building occupants. Although PVC is flame resistant, PVC products release toxic hydrogen chloride gas when heated. These corrosive gases can spread faster than flames, trapping building occupants before they have a chance to escape. Hydrogen chloride gas is lethal when inhaled.

According to fire experts, it is not unusual for people caught in building fires to be killed by toxic PVC fumes before the flames actually reach them."

These facts have been further acknowledged by some American jurisdictions which have actually banned the usage of these products for the venting application even if they were to be listed to the UL 1738 venting standard (which will be covered later in this paper). One such jurisdiction is that of New York City, whose department of buildings released a bulletin (11) stating:

"The 2014 FGC, Section 502.1 requires that plastic piping used for venting appliances be listed. ***Note that PVC piping, even when listed, is not allowed****."*

Though the reasoning behind this decision is not explicitly stated in the bulletin, it is believed that prior emergency incidents involving the FDNY (New York City Fire Department) may have contributed to the decision to outlaw the usage of PVC in these installations.

Modes of Failure

There are several ways that unlisted PVC installations may experience failures, which shall be covered in the following section.

Joint Separation

Joint separation accounts for a majority of PVC installation failures, an image of which is shown below in Figure 5. PVC is a material which is joined together using a multi-step process including the use of various tools, cements, glues, and primers. Combined with the fact that different products require different types of glues, primers, etc., the installation process is actually quite complex. This means that it is a product that can actually be very difficult to install correctly.

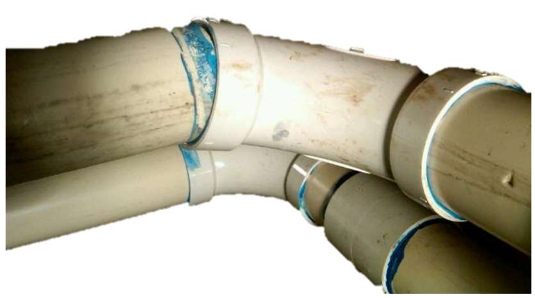

Figure 5: A separated PVC joint.

The difficulty of correct installation comes with a lower risk profile when one is dealing with the application which unlisted PVC is designed for, being the transmission of water. This risk profile increases greatly, however, when one applies the material incorrectly, such as the transmission of heated CO in a venting application. Any minor breach of protocol can result in a lethal gas leak.

Another factor to consider is the way that PVC is joined. The cements and glues which are used to join pieces of PVC are actually chemical compounds which solidify and create rigid joints. The problem with this rigidity is that these pipes, when used in venting applications, undergo constant temperature changes. Whilst the heating equipment is running, the vents are exposed to hot gas, and whilst it is not, the vents cool down. This results in the repeated expansion and contraction of the material.

Expansion and contraction are natural reactions to changes in temperature, which can be observed usefully in a thermometer, for example. The same amount of liquid is at all times in the thermometer, with the heat causing the liquid to expand upwards, and colder temperatures causing contraction downwards. This process can also be observed in more tightly packed solid materials. For example, as shown in Figure 6 below, rocks in the desert tend to crack as a result of the major temperature variations which occur in the desert between hot days and cold nights. These variations build up "thermal stresses" internally, which result in a split.

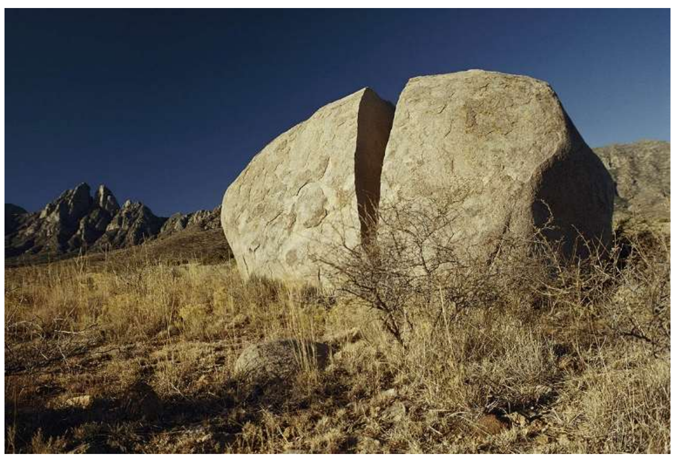

Figure 6: A rock which has split in the desert.

This same phenomenon can be observed in PVC venting, which targets the weak points in the installed systems (at the joints). The rigid nature of the cement is what creates these weak points, and unlisted PVC is not a material which can withstand these conditions.

Such conditions as these are why materials which are designed for the application of venting employ different joining systems, such as using gaskets (shown in Figure 7), which allow the expansion and contraction of the venting material without the associated internal stresses that result in failure.

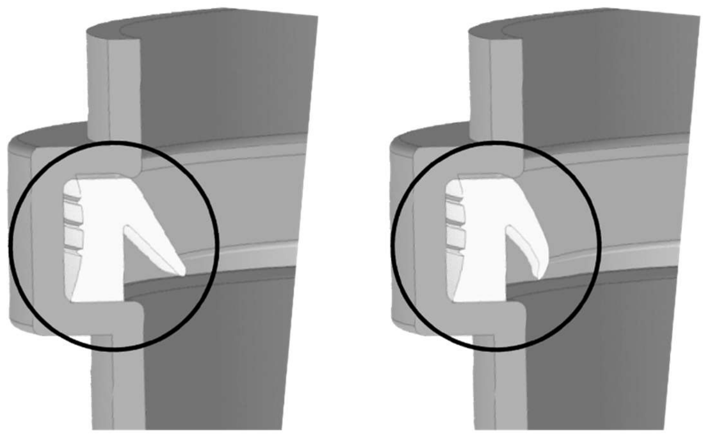

Figure 7: A vent pipe gasket, which is able to move with expansion and contraction, maintaining an airtight seal while not creating stress.

Material Failure

Another mode of failure that can be seen in unlisted PVC installations would be actual material failures on account of venting conditions. The most common of these would be in relation to temperatures. Unlisted PVC is listed, generally, at a temperature of around 140°F (12).

The heating equipment that the PVC is used on have stack temperatures which begin in the low hundred degrees Fahrenheit. Since this is within the operating temperatures of PVC, there is no immediate issue on the material side. This changes, however, over time.

Over the lifetime of heating equipment, impurities in the air and water, such as dust or dirt, build up on the appliance filters and heat exchangers, which decreases the efficiency of these heat exchangers. This causes the flue temperature to increase over time, which means that an appliance's stack temperature may be within the operating parameters of PVC to begin with but exceed those parameters after only a couple of years. Figure 8, below, shows a high efficiency appliance installation with PVC venting which has only been in operation for 2 years:

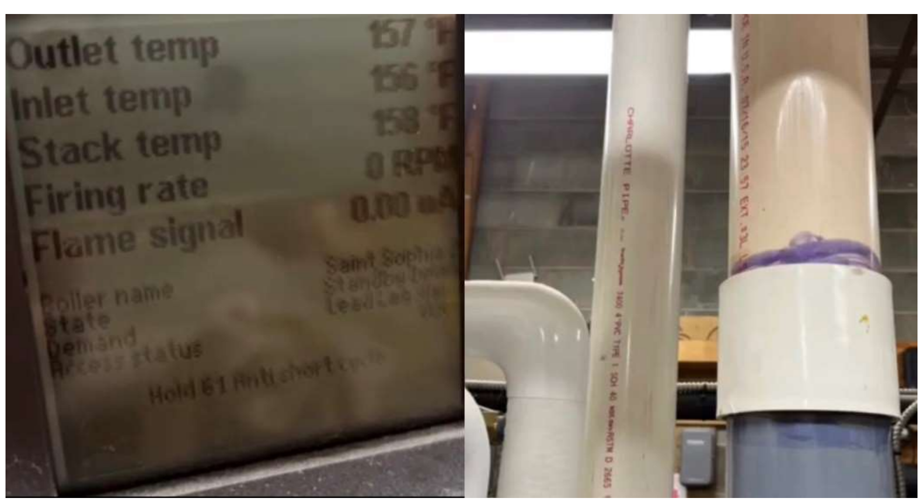

Figure 8: A 2-year-old high efficiency installation which has a stack temperature of 158°F and PVC venting, which can only tolerate temperatures up to 140°F. The PVC is beginning to show signs of failure via darkening.

One can see the effects of PVC's temperature limit being exceeded when the PVC begins to discolor. This usually takes the form of yellowing, browning, or blackening of the exterior of the PVC, shown in Figure 9. The pipe also begins to get more brittle and easier to break apart.

Figure 9: Unlisted PVC used for venting which has baked and turned dark due to high stack temperatures.

Another area of concern is that the ASTM plumbing standards contain no testing requirement related to UV resistance. This is acceptable when one considers the nature of plumbing materials, which generally never see the outdoors; this is unacceptable for the application of venting. The nature of the venting application necessitates that the vent goes outdoors, which means that the venting material will always suffer some amount of exposure to UV radiation. With relation to both general heating and exposure to light, a research article (13) regarding the chemistry of PVC found that:

> *"When subjected to forms of energy, such as heat, light, and ionizing radiation, PVC liberates hydrogen chloride, with accompanying discoloration and a general deterioration of mechanical and electrical properties."*

As discussed previously, hydrogen chloride gas has very harmful and potentially fatal effects when inhaled by humans, so these revelations are troubling as one can draw the conclusion that in order to use unlisted PVC in a venting application, one must accept some amount of HCl gas release.

The Application of Venting Standards

With the issue of venting failures becoming more prevalent in the industry, the question has become how does one vent safely? There is an answer to this question, being the application of a relevant and applicable testing standard. There are two particular standards in North America which were developed by Underwriters Laboratories (UL), being ULC-S636 in Canada and UL 1738 in the United States. A brief overview of their scope by UL states (14):

> *"UL 1738,* Venting Systems for Gas-Burning Appliances, Categories II, III, and IV, *and ULC-S636,* Standard for Type BH Gas Venting Systems, *cover vents in the USA and Canada for a subset of gas-fired products where flue gas temperatures are typically reduced. Energy conservation initiatives and principles intended to make more efficient use of resources require that certain gas-fired appliances operate with unique venting materials that are more resistant to corrosion and degradation. The unique conditions created by these products are the basis for two UL standards, intended to ensure that combustion gases, which may include carbon monoxide, are safely expelled to the outdoors."*

What is ULC-S636

The ULC-S636 venting standard was developed for application in Canada. The Canadian government adopted the standard as national law in 2007 in response to unsafe venting practices and the fact that the ASTM standard which most PVCs are listed to does not apply to venting.

What is UL 1738

The UL 1738 standard is the venting standard that is employed for use in the United States. This standard has existed for decades, but was generally associated with stainless steel products, as the rigorous testing requirements are exceedingly difficult for plastics to meet. As such, there are only a couple of plastic vent pipe products that exist at the time of writing which meet the stringent standard. Since this paper is being written primarily for consumption in the United States, this standard shall now be discussed in depth.

UL 1738

As previously stated, this is the sole venting standard for use in the United States. The major differentiator between it and the aforementioned ASTM plumbing standards are the material and installation qualities which it tests and requires. Some of the major test items which are not covered in the plumbing standards will be covered below.

Temperature Rating

One of the most important material aspects tested in this standard is elevated temperature relative to the material being tested. From the UL standard itself (15):

> *"17.7 A vent gas generator as illustrated in Figure 17.6, or equivalent heat producing assembly such as that illustrated in Figure 17.7, is to be used to achieve the vent temperatures at 70°F (38.8°C) above the temperature rating of the venting system."*

To reiterate, the standard requires temperature testing of the vent material at 70°F higher than its listing temperature. This would mean that in the case of Centrotherm's UL listed Innoflue PPs system, which is listed to 230°F, that it was actually tested and passed at 300°F. It would mean for IPEX's listed PVC system, listed to 149°F, that it passed at 219°F. It is important to note that the listing temperatures remain the same, lower number despite their passing at these higher temperatures.

The reason that this is such a crucial testing factor for a venting standard is because it considers the venting condition of appliances heating up over time. An installation may begin within the temperature parameters of the venting product but heat up so much over time that it exceeds it. What this testing factor does is make sure that there is a 70°F factor of safety automatically applied to each installation with a listed material, greatly decreasing the chances of system failure from a temperature standpoint.

Vertical Support Strength

In a plumbing application, it would be uncommon to find an installation that necessitates a tall vertical stack. Therefore, this is not something which is tested by the ASTM standards. This is a common find in venting applications, however, as venting straight up through a roof is one of the preferred termination methods. These vertical stacks can sometimes reach over 100 feet in height.

Figure 10: A tall vertical stack typical of a venting system.

The UL standard requires, therefore, that a static load which is equal to four times the load imposed by the heaviest assembly which the support will be required to sustain while in service is applied for a minimum of an hour. This is a massive factor of safety which makes sure that one of the most common venting assemblies will not be capable of failing under any normal condition.

UV and Cold Temperature

As previously mentioned, unlisted PVC is not UV rated, which is a problem when it is being used in an application that necessitates it being outdoors. The same principle applies to its handling in extreme cold temperatures. Venting materials, being outdoors, will need to be able to withstand extreme cold that may be found in the climates of locations like New England, Canada, Alaska, or the Upper Midwest.

One will find that UL listed products do meet UV ratings and also meet cold weather requirements, with the material being subjected to at least -31°F for a period of 24 hours and then making sure that there is no cracking, chipping, or degradation of joints after this period. This includes shear testing.

Installation Requirements

Perhaps the most important requirement of the UL standard is not a material requirement. This is because UL 1738 is not solely a material standard, it is a standard which also applies to a system. The particular system requirements are that the system is installed in accordance with all of the vent manufacturer's installation instructions. This would include proper support location, proper system pitch, proper joining method, etc. If a system was to be installed with a material that was listed to UL 1738 and violated even one of the manufacturer's installation instructions, then the whole system would not be considered UL listed. In the case of a jurisdiction which has adopted UL 1738 as a required standard, this gives the inspector leeway to determine that an incorrect installation does not meet code despite the fact that proper material was used.

One of the most noteworthy installation requirements is also that in a UL 1738 installation, only one material produced by one manufacturer may be used. This means that only one material may be used from the appliance all the way to the termination. This is in response to some contractors that would use higher rated material close to the appliance (where the flue temperature is highest) and then transition to a cheaper, weaker material later on in the installation in order to save money. An example of this would be using CPVC on the first few feet of the installation and then transitioning to PVC, something which some OEM's will actually recommend in their appliance manuals.

The problem with this recommendation is that it does not account for the fact that different materials have different material properties, one of which being the rate of thermal expansion. This means that PVC and PPs, for example, will react to temperatures at different rates. This makes creating a reliable airtight seal difficult, if not impossible. It also raises the question of liability; if a system were to fail, which vent manufacturer would be shouldering responsibility? It is due to these safety concerns that the UL standard mandates a single, UL 1738 listed material, made by a single manufacturer, to be used for a venting installation in order for it to meet its listing. This greatly enhances the reliability and the safety of the system.

Appearance of the UL Standard in Code

Beginning around 2018, the UL 1738 standard began to appear in the various relevant codes in the United States. Now re-citing the full 2018 edition of the NFPA 54, section 12.5.2 (6):

> *"Where plastic piping is used to vent an appliance, the appliance shall be listed for use with such venting materials and the appliance manufacturer's installation instructions shall identify the specific plastic piping material. The plastic pipe venting materials shall be labeled in accordance with the product standards specified by the appliance manufacturer* ***or shall be listed and labeled in accordance with ANSI/UL 1738****, Venting Systems for Gas-Burning Appliances, Categories II, III, and IV."*

This exact wording is located in the various different codes in the United States, such as the ICC Codes and IAPMO Codes, all appearing in 2018. The problem with this wording, however, is that it appears to be ambiguous due to its usage of the word "or". It appears to leave the choice up to the contractor, saying that one can either use something recommended by the manufacturer (such as ASTM listed PVC) *or* a proper UL listed system.

Some inspectors have interpreted this through the lens of accepting the UL requirement as the "stricter" requirement, and so have enforced UL 1738 in their jurisdiction despite the "or" statement. Most, however, have accepted that if an appliance manufacturer cites a material and an accompanying standard, a contractor may use this material despite the fact that the testing standard is irrelevant to the application. A majority of the time these officials are not aware of the fact that the ASTM standards are irrelevant, as the equipment manufacturers are trusted to put reliable materials in their manuals.

Code Commentary

The International Code Council (ICC), when they release a new version of code, also releases an accompanying commentary related to the changes made in that code. This holds true with their release of their 2018 edition of the International Fuel Gas Code. Some relevant excerpts from this commentary are below (16):

> *"503.4.1: … The definition of 'Vent'* ***does not include*** *plastic pipe, such as PVC, ABS, and CPVC, because such pipes are not currently listed as factory-built venting systems…* ***The PVC, ABS, and CPVC pipe manufacturers do not recommend that their pipes be used for appliance venting because such products are not currently listed for such applications.*** *There are polypropylene and possibly other types of plastic venting systems on the market that are* ***listed to UL 1738 as appliance venting systems, and they would fall under the definition of 'Vent'****.*
>
> *503.4.1.1: Experience has shown that plastic pipe and fittings used for venting appliances are not always joined together properly, and joint failures occur resulting in leakage of combustion products. Piping materials such as PVC and CPVC usually require the use of a primer in the solvent welding process…* ***The vast majority of reported vent pipe failures were caused by improper installation****…* ***Plastic venting systems listed to UL 1738 must be installed in accordance with the venting system manufacturer's instructions; such systems are listed as special gas vent.*** *Polypropylene special vent systems use proprietary mechanical joints…*
>
> *502.1: …The provision for unlisted plastic vents is necessary to allow for the venting systems commonly specified in installation instructions…****Unlisted plastic pipe (commonly PVC or CPVC plumbing pipe) vents are distinct from listed high-temperature plastic special gas vents****…*
>
> *503.6.10.3: …Because plastic pipes such PVC, ABC, and CPVC plumbing pipes are* ***not listed and labeled as appliance vents****, the code was silent on how to size such pipes..."*

There is a common theme among all relevant excerpts in the code commentary: unlisted PVC, CPVC, and ABS pipes do not fall under the ICC's definition of "vent". The commentary goes so far as to say that they are actually distinct from UL listed products which would be considered vents. Such information as this reveals the intent of the code organizations which have written the UL standard into their codes, and perhaps it is time for building officials to begin to consider this intent when they take a look at practices within their own jurisdictions.

Reactions to New Information

What have some jurisdictions done with this information? There have been multiple approaches to making sure that safety is made paramount in these situations. One such case is the change that was made by the state of Massachusetts in their 248 CMR Plumbing code. What is unique about this code is that it gives jurisdiction to the plumbing board of the state to allow certain manufacturers to operate within the state.

Notably, these additional safety restrictions introduced in Massachusetts have not caused market disruption, rather there is robust competition among the multiple approved manufacturers which operate within state borders. These vendors manufacture a variety of products, ranging from stainless steel venting to UL-1738 listed PVC options to UL and ULC listed polypropylene.

Another notable jurisdiction would be New York City, which was mentioned and cited earlier for the fact that it banned PVC as a material, even if listed to a venting standard. Another notable observation to make regarding the bulletin that was released by the city is their statement (11):

> *"The 2014 FGC governs the installation, alteration, maintenance, design, minimum safety requirements, repair and approval of vents and connectors serving gas-fired appliances. Section FGC 502.1 requires that vents, except as provided in FGC 503.7 (Single-wall metal pipe), be listed and labeled.* ***Since vents for Category II and III appliances must be tested in accordance with UL 1738, Standard for Venting Systems for Gas-Burning Appliances, Categories II, III, and IV, the Department accepts that vents for Category IV appliances also be tested in accordance with UL 1738****."*

This was not an alteration made to the code, rather an interpretation released in the form of a bulletin by the local Department of Buildings, mandating that a venting standard is required for venting applications.

Conclusion

There are historical reasons that the United States today finds itself one of the last industrialized countries to be without the enforcement of a venting standard. Europe has been using venting standards for decades, as has Canada. The statistics surrounding the resulting topic of carbon monoxide poisonings are astounding. Figure 11 from the National Institutes of Health (NIH) (17) is a collection of maps which shows a couple of these relevant statistics:

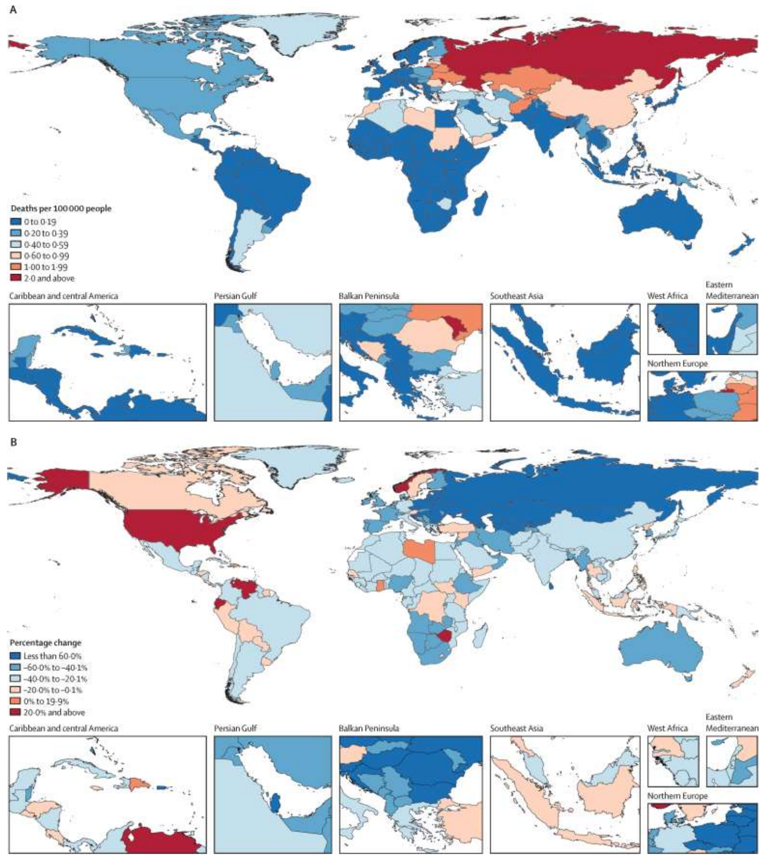

Figure 11: The top map shows country specific, age-standardized mortality rates due to unintentional CO poisoning in 2021. The lower map shows the percentage change in mortality rate from 2000 to 2021.

What this map reveals is an unfortunate truth. Not only is the United States behind its industrialized peers in this category, but it is also one of the only countries in the world which has seen an increase in its mortality rate this millennium, with a severe increase of over 20% at that.

The practices used in the United States must change. For too long there has been permittance of unsafe methods which are relics of an era when an immediate, band-aid solution was needed. ASTM listed plumbing PVC served as this band-aid at the time. Now, there is more information, and there are cost-effective, available solutions which do not have the associated safety concerns of unlisted PVC pipe.

Such safety concerns are numerous, whether it be material or joint failure. The results can be catastrophic, whether it be serious injury or even death as a result of CO poisoning or HCl exposure. These truths are what led to the development of safer venting products, listed to safer and relevant standards such as the sole venting standard in the United States, UL 1738.

Fortunately, the avenues exist now within code that allow for safer code enforcement, with the addition of the UL standard to the language of the fuel gas and residential codes. There are also useful sources which can assist in justifying certain interpretations, including the code organization's commentary itself, which are quite explicit in their definitions of what is and is not a vent. It is now the hope of this author that building officials take it upon themselves to take action in their jurisdictions for a safer future, whether that be through re-interpretation of code or the changing of the code to become even more explicit.

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