PVC – Is it suitable for venting high efficiency gas fired appliances?

This "white paper" is intended to provide technical information substantiating the position that venting many of today's high efficiency, gas-fired, hot water heaters and boilers with common PVC (Polyvinyl Chloride) piping products may not be a good idea.

While PVC pipes and fittings are economical and therefore serve as an appealing, low cost method of creating a venting system, there are genuine risks involved in its use for these applications. The variety of potential health and safety risks that one assumes when using PVC should make one think long and hard as to whether the short term reward is worth the long term risk. Quite frankly PVC systems offer little or no factor of safety in these applications.

History of PVC as a venting system

Ever since ABS, PVC, CPVC or other commonly available plastic piping systems began to be used for venting specific high efficiency gas fired warm air furnaces, many users have assumed the relative factor of safety they provide is rather substantial or at least adequate. We would caution that such may not be the case for all applications.

While furnace manufacturers have been approving the use of PVC systems with many of their gas fired warm air furnaces for close to 30 years and experience seems to be positive (with very few problems), the history of the use of ABS, PVC and / or CPVC plastic vents on high efficiency water heaters and boilers is considerably shorter and the experience has not been nearly as good.

In order to better understand the situation, one needs to first understand something about plastic piping and venting systems in general, how they are evaluated (by the safety certification agencies) for use in venting various appliances, how the different appliance types and technologies differ and the consequences of same over the service life of an appliance and its venting system.

PVC piping systems:

PVC pipe and fittings are the most commonly used plastic piping for high efficiency appliance venting in North America. They have been around for decades, are most often used for sanitary plumbing applications at temperatures relatively close to or minimally above ambient and are produced per an ASTM product standard that describes the chemical (material) composition, dimensions, minimum material properties, etc. PVC pipe and fittings are joined in the field via use of a "solvent welding" technique whereby the plastic parts become chemically fused together to form an extremely strong bond – assuming everything is done properly in terms of cleaning, preparation, curing, etc.

PVC piping systems, like any plastics, have a certain range of temperatures and pressures in which they are capable of performing best and safely, providing a long and successful service life. While the internal pressures they experience in the venting applications rarely if ever approach any limits, the temperatures to which they are

subjected do – for many boilers and water heaters - often approach (and occasionally exceed) upper limits for what is considered safe exposure.

Environmental Stress Cracking - If and when PVC or other plastics begin to reach the end of their service life they often become more brittle and easier to crack or fracture. This process, known as “Environmental Stress Cracking” (ESC) is an aging / embrittlement process that plastics experience due to the combined effects of age, temperature exposure, chemical and (sometimes) UV exposure and / or stresses – both internal and externally applied. Elevated temperature usage and /or cyclic variations in stress have an effect of increasing the onset of ESC, thereby shortening its service life. Gas appliance venting applications commonly produce these combinations of factors, since the system is subjected to relatively high temperatures (for the particular plastic), varying chemistry of acidic condensation and cyclic stresses due to the thermal expansion and contraction (due to heating and cooling) and any restrictions placed on the system’s ability to expand and contract easily.

PVC venting system certifications:
With the exception of two manufacturers in Canada (where safety certification of plastic venting systems per a Canadian venting standard (ULC-S636 “Standard for Type BH Gas Venting Systems”) is now mandated as a condition of acceptance), there are no listed and labeled (safety certified) PVC or CPVC plastic venting systems available to the industry. (The requirement in Canada for these systems to be safety certified is based upon a number of well documented [near and actual] failures with certain plastic venting systems on water heaters a number of years ago.)

As previously stated, manufacturers of such plastic pipe and fittings certify their products per an ASTM product standard only; not (with the exception noted above for Canada) any type of product safety standard for an appliance venting application. Furthermore they specifically DO NOT make any claims that these systems are approved for venting of gas fired appliances. As a matter of fact, some are said to make specific reference to the fact that they do not recommend their PVC products for the application.

Unlike the many venting systems that are specifically produced and safety certified (Listed) for such application (in accordance with a nationally recognized safety standard for venting systems) generic PVC or CPVC piping used as a venting system on gas fired appliances are certified only by the appliance manufacturer (and their certification agency) as part of the certification of the appliance. Such approvals or “certifications” are based upon criteria found in the various, respective appliance safety standards – for gas fired warm air furnaces (ANSI/Z21-47), boilers (ANSI/Z21.13), water heaters (ANSI/Z21.10), etc.

During safety certification testing / evaluation of the appliance, in order to determine whether a PVC, CPVC (or other plastic) vent is an acceptable option for a particular appliance, a material property known as “Heat Deflection Temperature” is used as the pass / fail criteria for determining whether an appliance manufacturer is permitted to

reference various types of plastic venting system in the installation instructions accompanying the appliance.

The heat deflection temperature (also known as heat distortion temperature (HDT, HDTUL, or DTUL)) is the temperature at which a certain size and shaped plastic test sample deforms a certain amount under a specified load. HDT's vary from plastic to plastic. HDT is generally thought of as an indicator as to when the plastic is at a temperature at which it is beginning to soften and lose its mechanical strength characteristics.

According to the Standard for Gas Water Heaters (ANSI/Z21.10) the maximum allowable temperatures (HDT's) of typical nonmetallic (plastic) vent materials used are:

HDT	**^{O}F (^{O}C)**
PVC	157 (69)
ABS	180 (82)
CPVC	230 (110)

These are noted as being based upon the mid-range Heat Deflection Temperature (HDT at 66 psi). The same temperature limits for plastic vents appear in other appliance standards, as well.

The practice of approving plastic piping systems for appliance venting systems when they are being exposed to temperatures at or near their HDT (where they are on the verge of losing their structural integrity due to exposure to elevated temperatures) has been questioned by some. Permitting the system to be used at a temperature so close to the point where it begins to lose its structural strength seems to provide a very minimal and questionable factor of safety.

Those who question the factor of safety include many in the metallic vent industry where UL / ULC venting standards (for this and numerous other appliance venting applications) have provided a very substantial factor of safety for their respective applications over many years.

Factory-built, listed metallic vent system certifications:
Unlike generic PVC and CPVC piping systems, factory-built, metallic venting systems are thoroughly evaluated (per a nationally recognized, UL or ULC safety standard). (For this type of application, previously referenced ULC-S636 applies in Canada and UL1738 ["Venting Systems for Gas-Burning Appliances, Categories II, III, and IV"] applies in the USA.)

System evaluation consists of a variety of thermal and mechanical tests as well as a review of mandatory product markings (labels) and installation instructions – all of which taken in total provide for a very good and substantial factor of safety - FAR exceeding that provided by any plastics. (For instance, the thermal testing metallic systems undergo includes testing with flue gas temperatures 70^{O}F higher than the rating for which the system is being listed. Safe minimum clearances to combustibles are confirmed in such testing. Of course unlike plastics that have low melting points, metal

systems will not melt or lose structural stability until they reach temperatures approaching 2000^{O}F!)

These products qualify for an independent "Listing" (safety certification) as a complete system (with various required accessories) based upon demonstrated compliance with these safety standards for venting system applications. They are also supplied with specific markings and installation instructions providing detailed information and guidelines for safe and appropriate installation and use.

These products, known as "Special Gas Vents" (USA) and "Type BH Vents" (Canada) are typically fabricated from a special, highly corrosion resistant alloy of stainless steel known as AL29-4C. They have also been in use in the industry for close to twenty years – *in the more severe* boiler and water heater application - and their record of performance has been stellar.

Other considerations:
While it would seem that granting permission to use and reference PVC (when safety tests confirm the plastic vent system virtually reaches (but does not exceed) the HDT during testing) should be a cause for concern, there are other factors to consider as well:

1. Thermal expansion and stresses - These plastics all have relatively high coefficients of thermal expansion, meaning they literally "grow" in length when heated. (For example PVC has a coefficient of thermal expansion ($28x10^{-6}$ in./in./^{O}F) that creates approximately ¼" of "growth" in a 10' length, if heated only 80^{O}F above ambient [typical for this application].) This "growth" (which is about three times what metallic vents experience for the same temperature differential) must be accommodated (permitted to occur) without excessive restraint or the result will be additional (and potentially significant) stresses within the plastic vent and fittings.

   As noted previously, stress plays an important factor in environmental stress cracking (ESC) which reduces the service life of the product. Common practices of installing PVC systems include various generic supports and constraining devices that specifically impede the pipe's ability to expand and contract freely. All this can lead to premature ESC and possible fracture of the vent system which in turn could lead to a condition where flue gases vent directly into a dwelling or other structure, posing a potentially severe health and safety risk. Interestingly, the Canadian produced and Listed, PVC and CPVC systems come with installation instructions that make specific cautions and references to the fact that the system must be installed with care, insuring unrestricted thermal expansion is permitted. However, these very same manufacturers produce and offer few, if any, accessories that provide such function. Detailed instructions for providing the proper support without overly restricting thermal expansion are unavailable, so installers are left to make their own decisions on what is adequate and appropriate.

2. Flue gas temperatures during the life cycle of the appliance - One should also be aware that during the service life of hot water heaters and some boilers, it is not unusual for flue gas temperatures to rise appreciably higher than when the system is new (how it was tested) in a lab during the certification process. This is often caused by scale buildup (mineral deposits) on heat exchangers (which reduces the heat transfer to the water and sends more heat up the flue), but can also be caused by other factors, such as dirt buildup on fan blades, high return water temperatures, etc.

   Such higher flue gas temperatures can create a variety of safety issues including loss of structural integrity (sagging) of the vent and an advanced onset of ESC. In a worst case situation, surrounding combustibles (which are typically permitted to be at zero clearance to the pipe) may overheat and pose an eventual fire risk.

3. No safety shut offs - At present the appliance standards for water heaters and boilers do not (yet) mandate the inclusion of any type of safety shut-off in the flue gas stream at / near the appliance outlet. Such device is commonly required in Europe and would be a very useful safety precaution, since it turns the appliance off in the event something goes wrong and flue gas temperatures rise above acceptable, safe levels.

4. Product liability questions abound – If the manufacturer of the PVC piping system does not recommend, warrant or condone its use for venting applications, who do you suppose warrants the system and is liable in the event a failure occurs and property damage or injuries result? The appliance manufacturer? The certification agency? The installing contractor? Everyone in the chain (as is the typical posture of many Plaintiffs' attorneys when incidents occur)? (Depending upon the PVC manufacturer's posture, he may be the least liable!)

   If you are intrigued by these issues, you may wish to contact the manufacturer of the water heater or boiler (who's instructions permit PVC to be used) and ask them whether they warrant the vent system and assume any responsibility for any problems that occur. (It is highly unlikely they will respond affirmatively verbally - let alone in writing!)

5. Negative impact on the appliance - A few reports have been made of (long term) chloride leaching (from the PVC piping system) into the condensation within the vent system which has, in turn, run back into the appliance and caused problems (like corrosion) within the appliance. [The "C" in "PVC" stands for "Chloride" - one of its chemical constituents - and is a well-documented corrosion accelerant.] This could have a detrimental effect on the service life of the appliance heat exchanger and / or other internal components.

6. Combustibility - PVC is considered a combustible material by building codes. It produces toxic vapors when subjected to extreme heat and therefore requires

special considerations (like fire wraps) when run through plenum spaces for various installations.

7. Green – Unlike PVC and CPVC which is environmentally unfriendly and is restricted from use in certain areas, stainless steel is completely recyclable and produced in part from recycled steel.

Negative experience (overheating, cracking and actual fracture of plastic venting) on a number of water heaters caused Canada's move to ban the use of ABS plastic pipe and fittings and mandate the use of only Listed (safety certified) plastic venting systems for appliance venting. Unfortunately, whereas these (ULC-S636) listed venting systems are now more thoroughly evaluated and come with labels and installation instructions, they still fail to provide any significant factor of safety. This is because the appliance standards still permit the use / reference to PVC (or other) in installation instructions without any appreciable margin of safety relative to the heat deflection temperature, as noted above. At present ULC-S636 does not (yet) provide such margin of safety either. Further and as also noted above, the manufacturers do not offer any factory designed, tested and manufactured support accessories to insure a proper installation is achieved and therefore reduce the risk and premature onset of ESC.

Comparatively speaking, Listed, stainless steel venting systems (including those listed per UL1738 and ULC-S636 for wet condensing applications and having a stellar record in the industry) have an inherently large factor of safety with respect to temperature exposure and mechanical properties. As previously mentioned, they will not soften or distort until they reach temperatures close to 2000^{O}F! And unlike plastics they are not in any way subject to environmental stress cracking and fracture. Typically, these systems are designed, certified, produced and warranted for the application (by the vent manufacturer) and condoned (but not mandated) by the appliance manufacturer.

Based upon the above, one might logically ask – If all this is true, why do appliance manufacturers assume the risk of referencing / permitting the use of PVC systems with their high efficiency water heaters and boilers? The most common response from the product development engineering staff of these equipment manufacturers (who know the products and related safety standards best) includes an admission that they don't feel particularly comfortable with the situation, but they qualify it in order to be competitive with others in the market who do so for their appliances.

All in all, PVC and other generic, non-listed, plastic pipe and fittings used as venting systems for gas fired water heaters and boilers provide a very minimal factor of safety - at best. Unfortunately, unless interested parties take a more active role and insist upon a larger factor of safety in their appliance venting systems, it may require some unfortunate safety incidents before the industry comes to realize it and adopt appropriate revisions.

The above is presented from the perspective of Selkirk / Heatfab – a vent manufacturer. Additional information on this topic (from an independent expert with a variety of field

experience and history), can be found in a couple of very thorough articles that appeared in the “Plumbing Engineer” magazine. They can be viewed at: Plumbing Engineer - Columns: May 2011: Code Update[1] and Plumbing Engineer - Columns: May 2012: Code Update[1] We encourage the reader to do so and to consider whether saving a few dollars by venting these appliances with PVC is worth the long term risk and potential liability.

When choosing a venting system for today’s high efficiency gas fired water heaters and boilers one should consider all the various risks associated with the use of PVC piping (possible overheating – loss of structural integrity or overheating combustibles in direct contact, environmental stress cracking, etc.) versus the proven, safer, safety certified and warranted, stainless steel vent system alternatives available for the application.

[1]Official links
http://www.plumbingengineer.com/may_11/code.php

http://www.plumbingengineer.com/may_12/code.php