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Domestic Chimneys and Gas Vents

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This Digest describes three types of domestic chimneys, outlines the basic principles of chimney operation and the functions that a chimney must provide, and describes some common chimney problems with possible solutions. This subject is of current interest because the recent trend to convert furnaces from fuel oil to natural gas or to add wood-burning heaters has increased the potential for chimney problems. Chimneys designed for the specific maximum flue gas temperatures and the expected products of combustion from oil may be unsuitable for use with other fuels.

Chimney Types

Three types of chimneys are commonly used in Canada -- the masonry chimney, factory-built chimney and factory-built gas vent.

A *masonry chimney* is constructed of brick, stone, or concrete block and encases a liner that is made of material selected to withstand the effects of high temperatures and corrosive acids. Liners of clay pipe or tile are usually used in new construction. Where a masonry chimney is to be renovated without being dismantled, a steel liner can be inserted. A masonry chimney can be used with furnaces, stoves, fireplaces or any other appliances that burn gas, oil or solid fuels.

A *factory-built chimney* (commonly called a Type A chimney) is constructed of factory-made metal sections or lengths that can be joined together on site. It is intended for installation on the inside or outside of a building. The liner is usually stainless steel but the outer wall may be of a different metal since it is not subjected to corrosion or to the same high temperatures. The Type A chimney has a mineral-based thermal insulation between its walls to reduce the temperature at its outside surface. The Type A chimney is suitable for use with an appliance that burns gas, oil or solid fuel provided that the temperature of the flue gas does not exceed 540°C (1000°F).

A *gas vent* consists of factory-made metal sections that can be joined together on site. It may appear to be generally similar to the Type A chimney but it is not intended to withstand flue gas temperatures higher than 245°C (470°F); hence it is not suitable for use with oil or solid fuels. It is normally designed with only an air gap between the inner and outer walls to provide insulation. A gas vent is normally intended for installation inside a building (except the part that would protrude through the roof). The entire gas vent should not be installed on the outside unless each section has been specifically marked as being suitable for exterior locations.

Principles of Operation

Gases in a chimney usually have a higher temperature and, therefore, a lower density than household or outside air. This slight difference in density creates a theoretical draft or negative pressure inside the flue in comparison to the adjacent household or outside air.

Most appliances require a small, relatively constant negative pressure at their flue connection to assist the flow of air and smoke through them. The theoretical draft provides this necessary pressure at the flue connection and also overcomes any friction losses due to the movement of gases through the chimney. However, the theoretical draft is usually larger than necessary, fluctuating in response to changes in wind or temperature. To maintain a relatively constant negative pressure at the appliance outlet, a draft regulator is used to admit varying amounts of household air into the venting system. The additional air slightly increases the friction losses and cools the flue gases to reduce theoretical draft.

At start-up the average temperature of the gas in the chimney is relatively low; consequently draft is also low and some spillage of combustion products may occur until the chimney has become warm enough and the average temperature of the gas has increased to produce a sufficient draft. Spillage into the household air may occur through openings, such as barometric dampers, in the flue pipe or appliance. Because factory-built chimneys and gas vents have relatively lower thermal storage capacity than masonry chimneys, they heat rapidly and establish the required draft more rapidly than a masonry chimney.

Since higher outside air temperatures result in lower theoretical draft, inadequate chimney draft is more likely to occur in the spring and autumn rather than in the winter. In milder weather an appliance does not operate as long to heat a house; consequently the average temperature of chimneys, and of the gases in them, may be lower. The reduced average temperature of the gases, together with milder weather, results in reduced theoretical draft and may lead to spillage problems, especially if the chimney is designed with little reserve draft capacity.

An exterior chimney would have more heat loss than a chimney contained within a building. Therefore the temperature of the gases in an exterior chimney would tend to be lower and draft problems would more likely occur.

Two causes of inadequate chimney draft are: insufficient cross-sectional area in the chimney to conduct outdoors all gases from connecting appliances; and adverse wind pressure patterns at the chimney outlet caused by surrounding structures.

One solution would be added chimney height which would increase the draft and raise the outlet above the turbulence. A second alternative would be to add a draft fan or blower to the venting system to supplement the natural chimney draft and permit an existing chimney to vent the flue gases adequately and safely. Any draft fan or blower must be installed downstream from all appliance connections into the flue pipe or chimney to prevent back flow of the flue gases into the venting system of any other appliance.

Fire Safety

A chimney must protect any adjacent combustible material from the hot gases within it. The properties of cellulose-type materials, e.g. wood or paper, change when these materials are exposed to high temperatures for a long time. After such exposure, they may ignite at a temperature lower than that which would otherwise cause them only to char or discolour, thereby making a potential fire hazard difficult to detect. The maximum safe temperature for wood or other cellulose-type materials is about 90°C (200°F) following such exposure.

Standards for factory-built chimneys and gas vents require that a test chimney, located at the manufacturer's recommended clearance from combustible material, undergo extensive time-temperature tests. These will verify the integrity of the chimney during normal and abnormal conditions and also verify that during normal use, the temperature of adjacent combustible material does not present a fire hazard.

The minimum safe clearance between combustible material and a flue pipe that connects an appliance to a chimney can usually be found in building codes. The prescribed clearance may seem large but it can be reduced by the use of properly installed non-combustible protective materials. If not properly installed, heat conduction through the protective material may overheat the combustible material and cause it to char or ignite. Where protection is provided to use reduced clearances, the effectiveness of the protection should be verified by ensuring that surface temperatures of combustible materials do not exceed safe limits under maximum firing conditions.

During a period of continuous operation, more heat may pass through the walls of a masonry chimney than those of a factory-built chimney operating with the same flue gas temperature, and adjacent combustible material at similar clearances may reach a higher temperature. Thus a factory-built chimney may be safer under these conditions. However, with a short term, high temperature chimney fire, a masonry chimney may be preferable because its higher thermal storage capacity will delay the rate of temperature rise on its outside surface and may even result in surface temperatures lower than those of a factory-built chimney. During chimney fires, tile liners may crack but remain in place, and metal joints and liners of factory-built chimneys may weaken structurally or distort. Verification of damage is difficult unless pieces of fallen tile are found or unless significant distortion of a factory-built chimney can be seen. Other symptoms of damage such as reduced draft due to air infiltration through cracks or joints in the liner, or corrosion resulting from lower flue gas temperatures as a result of infiltration may not be readily apparent.

Corrosion

During combustion, sulphur in the fuel will be converted to sulphur dioxide or to sulphur trioxide, and hydrogen in the fuel will form water vapour. These gases will condense on cold walls of the chimney flue and react to form acids. Such acid formation will occur in any chimney until the liner has been heated enough by the vent gases that its surface temperature is higher than the condensation temperature of the gases.

A chimney liner must resist the corrosive action of these acids. Usually acid corrosion occurs near the top of a chimney where its operating temperature may be so low that condensation can occur. Factory-built chimneys and gas vents are designed so that any liquid running down the inside is conducted past the joint between sections and is not scooped into the joint. If the sections are installed upside-down, as may happen when a base section is not used and there is no other indication of which end should be up, acid will accumulate in the joints and will hasten corrosion. Mortar used to ensure tight joints between the tile liners of masonry chimneys should be a portland cement/sand mix to resist acid attack. Ordinary mortar contains lime which is particularly susceptible to acid attack and its use for joints between tile liners may lead to premature joint failure. This would permit air to infiltrate into the flue passage to cool the gases and increase condensation in the flue. Acids could also leak through the joint to the outside surface of the liner and attack the mortar of the masonry casing resulting in structural failure of the chimney.

Condensation increases with lower flue gas temperatures. Gas-burning appliances usually have lower flue gas temperatures than oil-burning appliances, so chimney deterioration may become more rapid if an appliance is converted from oil to gas. A chimney exposed for its full height to the outdoors will lose more heat, have lower vent gas temperatures and consequently more condensation than the same chimney located inside. Therefore an exterior chimney would be expected to deteriorate sooner.

Chimney Sizing

The required area of flue for a chimney can be calculated or may be specified in some building codes. The flue area must be large enough to exhaust all the vent gases when the lowest theoretical draft occurs, usually during mild weather. It must also be sized to allow for possible adverse effects of wind. An undersized chimney flue may be satisfactory during cold weather when theoretical draft is higher but in milder weather, it may cause spillage and recycling of flue gases, leading to incomplete combustion and the generation of excessive amounts of carbon monoxide. Carbon monoxide spilled and circulated to the occupied space can poison or asphyxiate the occupants.

A chimney flue can become undersized by accumulation of creosote and soot or, in extreme conditions, by the accumulation of frozen condensate. An interior chimney or a hotter fire would help avoid these problems.

Creosote and Soot

Many gases are produced during wood combustion. If the temperature in the combustion chamber of the appliance is not high enough or if there is insufficient combustion air, these gases will not burn completely and may condense as creosote on the cool surfaces of the venting system. Creosote is liquid when formed initially, but as moisture and volatile liquids are driven off by further heating, it becomes tacky and may eventually form a hard glazed coating. If not removed periodically, large quantities of creosote and soot can accumulate. Their ignition can result in a high temperature chimney fire that may last as long as 15-25 minutes and that can subject the liner to dangerous temperatures above 1100°C (2000°F). The high temperature may present a fire risk to adjacent combustible material or may structurally weaken the chimney. During any creosote fire in a chimney, the residue may curl, peal off the walls and obstruct the flue passage. After any chimney fire the chimney should be inspected to ensure that the flue passage is not obstructed, thermally distorted or otherwise damaged.

Creosote can never be entirely eliminated if wood is burned, but it can be minimized by using a high temperature fire to ensure that the maximum amount of gaseous products is burned before entering the vent system. The risk of a serious chimney fire can be minimized by careful scraping or brushing to remove any creosote or soot particles that have accumulated in the venting system.

Fireplaces

The theoretical draft created by the operation of a fireplace will cause a pressure depression in a house which has insufficient natural air infiltration. The pressure depression may exceed the draft at the base of an inoperative chimney serving another appliance and cause a downdraft of outside air in that chimney. When the other appliance does operate, the downdraft may prevent the proper venting of flue gases and they would be drawn into the occupied space.

The fireplace may consume the excess air normally required for complete combustion in the other appliance, with the result that carbon monoxide will form. Even without a fireplace operating, reducing the amount of air infiltration into the house or enclosing an appliance in a space with no air supply may have a similar air starvation effect on the operation of that appliance. Carbon monoxide poisonings and asphyxiations have been attributed to air starvation caused by fireplace operation.

Opening a window or door, or installing a combustion air supply from outdoors will reduce or overcome air starvation and the downdraft problem in the chimney serving the other appliance. Fireplaces designed for mobile homes have glass doors to prevent room air from entering the combustion chamber and have an out- door air supply ducted directly to the fireplace. These features isolate the fireplace from the air supply for other combustion equipment and provide some energy conservation by reducing the flow of heated room air up the chimney.

Water Damage

A weather cap sheds water from the liner and casing at the top of a chimney. A cracked cap or one whose mortar joints have deteriorated can allow moisture penetration into the casing of a masonry chimney. If the temperature of the masonry drops below freezing during the appliance off cycle, and rises above freezing during the on cycle, the freeze-thaw action may cause spalling and eventual disintegration of the masonry.

Vent Dampers

"Energy-saving" vent dampers reduce the flow of warm room air through the chimney during the appliance off cycle. This results in a lower chimney temperature at start-up requiring more time after start-up to establish adequate draft and possibly resulting in spillage of flue gases into the occupied space. It can also be expected that condensation will occur during a longer period of time following start-up, possibly resulting in more rapid deterioration of the chimney. No statistical information is available, however, to establish how this would affect the average life of a chimney.