Guide to natural draught flueing

Introduction

This paper provides an overview of the principles of flueing for natural draught flue systems and the factors that contribute to good flueing practice. It is primarily aimed at gasfitting practitioners, from trainees to craftsmen.

Effective elimination of products of combustion is an important aspect of any gas appliance to ensure its safe and efficient operation. While so-called flueless gas appliances are designed to operate safely indoors under certain conditions[1], or to operate outdoors, many gas appliance types are intended to operate with a flue.

An effective natural draught (or atmospheric) flue will rapidly establish draught conditions that allow safe elimination of products of combustion, and avoid excessive spillage of products of combustion into living spaces. Flues, in particular powered flues, can also be important in purging the combustion chamber of some appliances on startup.

This guide is intended to complement, not replace, the mandatory requirements in the Gas Regulations and Part 1 of NZS 5261, and the means of compliance in Part 2 of NZS 5261.

This guide takes as a starting point that in New Zealand gas appliances are required to be:

- designed and constructed in accordance with NZS 5262; and
- installed in accordance with NZS 5261 – including:
    - reference to relevant manufacturers instructions,
    - existing conditions of installation, and
    - commissioning and testing to verify safe operation.

Powered or fan assisted flues are outside the scope of this paper. Such flues are used where the appliance is designed for fan assisted flueing or in cases where natural draft is not effective or adequate. Advice should be sought from the manufacturer and/or a specialist in installing powered flues when a powered flue is considered for a natural draught appliance.

Principles of flueing[2]

[1] While unflued appliances are not the subject of this paper, it is worth noting that typically they rely on dissipation of products of combustion into the space containing the appliance and air changes to effectively remove products of combustion. Unflued gas appliances that are designed to operate indoors rely on installation in an adequately sized space, with provision of sufficient ventilation for the fuel consumption of the appliance. Some are equipped with safety devices (eg flame failure or ODS) and some types of catalytic heater treat combustion products.
[2] Note: Americans tend to refer to 'vent' and 'venting', rather than 'flue' and 'flueing', and this terminology may also appear in product for export to or from the Americas.

In a gas appliance, after the flame has generated heat, for efficiency of heat transfer, the source of heat should be in contact with the medium to which the heat is applied for as long as possible to ensure efficient convective and radiant heat transfer.

To achieve this means having a significant resistance to flow of gas and combustion air within the appliance. In addition, draught is required to generate flow of combustion products. Resistance also means potential for spillage, in particular under cold conditions while the appliance and flue system are warming up and draught is being established.

Factors influencing good flueing include:

- establishing draught via temperature differential along the flue, so that the more buoyant lower density combustion products move upwards along the flue,
- flue height (vertical rise) and cross-section (diameter),
- minimum temperature loss along the flue to ensure effective draught, and
- minimal resistance to flow (minimising restrictions).

Factors that create resistance to flow, and therefore risk of initial spillage, include:

- inadequate height or equivalent cross-section,
- shape (cross-section) and shape transition (transition pieces),
- obstructions – including dampers and offsets,
- change of direction – especially sudden changes,
- multiple flues – causing back pressure due to convergence of flow), and
- horizontal sections of flue[3].

Factors for effective flueing

A properly functioning flue will:

- safely, reliably and effectively convey combustion products to the outside environment,
- establish appropriate draught quickly from cold starting conditions,
- minimise spillage of flue gases (products of combustion) into the room (or space where the appliance is located),
- incorporate components and design to minimise the effect of adverse draught conditions,

[3] Hence the requirement for the greatest possible vertical rise before any lateral extension.

- avoid hazards to the structure or its contents from excessive exposure to heat, and from points where the flue system penetrates the building envelope,
- avoid (or at least minimize) hazards of leakage of combustion products (flue gases) from the flue, and of the build-up of condensation in the flue, and
- incorporate an effective termination point.

Consequences of poor flue performance include:

- Spillage of combustion products into the living environment, leading to incomplete combustion and un-burnt gases,
- Flame lift,
- Flame lightback – for certain types of burner, and
- Inefficiency (too rapid loss of heat).

Effective flueing is an important aspect of good installation practice. It brings together a number of important factors in both the design and installation of flue systems, including:

- appliance design, ventilation and location,
- internal and external environments, and
- design of flue systems, including draught diverters and terminals,

Appliance ─ design ventilation and location

Design and installation of flue systems has to consider specific factors related to the type of appliance and its design and configuration, energy consumption, and location as well as any specific manufacturer's instructions.

In addition, the location, design and configuration of the flue needs to be related to ventilation and other mechanical and physical aspects of the building.

This includes ventilation requirements for the appliance, any other combustion appliances, and for users of the space in which the appliance is located, as well as the ventilation available and any mechanical ventilation that may be present, whether or not it is associated with the appliance.

Appliance design factors that allow them to operate safely and efficiently include:

- bringing gas and air into the appliance in adequate quantities and pressures, given the type of gas used,
- means of mixing gas and air and transporting the mixture to all burner ports, and
- burner design to ensure good flame characteristics ─ flame shape and colour, flame retention (avoiding lift and lightback), avoiding flame chilling (eg through impingement on cold surfaces).

Appliances that are designed to generate radiant heat from flames (eg natural draught flame effect heaters) are more prone to producing free carbon and exhibit poor combustion. This can lead to sooting, carbon monoxide (CO) and other products of incomplete combustion. Therefore flue systems for these types of appliance are more critical.

External environment

This includes the prevailing local climate variations, and the relationship to the structure that houses it, and to other structures. In some cases, vegetation or natural features, such as proximity to shelter belt or location in a gully, may have an effect.

Local knowledge may be useful, for instance in identifying prevailing wind patterns.

Internal environment

Flueing needs to relate to the ventilation and other mechanical and physical aspects of the building. This includes:

- the space in which the appliance is situated and its use,
- the availability and amount of permanent (fixed) ventilation,
- adventitious ventilation and tightness of the structure,
- intermittent ventilation,
- pressure patterns in the installation environment, including the effect of any mechanical ventilation in the structure, even in other rooms, eg range hoods and extractor fans that can cause negative pressure and upset natural draught flues,
- potential adverse climatic conditions,
- other combustion appliances, and not just gas appliances, as these will create draught (air movement) and consume oxygen,
- atmospheric contaminants – dust, spray, chemicals, eg hairdressers and drycleaners, and
- the effect of change in orientation of components within the appliance or flue system[4].

Obviously in many situations these factors may have little effect individually but the combined effect of these factors can be significant in critical situations.

Draught Diverters[5]

[4] Examples of this are (1) changing the position of buffers and trays in a baking oven that can lead to changes in circulation within the oven that will affect flue system performance, and (2) the positioning of coals, logs and particulate beds in flame effect heaters which is critical to combustion performance.

[5] Although draught diverters are discussed in this section it should be borne in mind that they are sometimes part of the appliance and sometimes installed separately as part of the flue system.

The purpose of the draught diverter (DD) is to ensure an appropriate pressure around the flame. This is achieved by diverting draught caused by changes in pressure within the internal environment or outside the building. It dampens the effect of any fluctuations in the air pressure inside or outside the building on the combustion chamber - see Figure A.

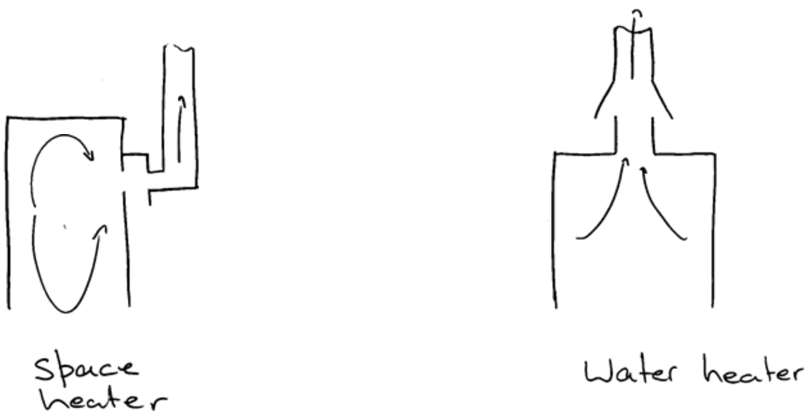

Figure A Typical draught diverter and flue arrangements: Purpose is to secure flame stability

In designing and installing the flue system the aim is to utilise the difference in temperature to create a pressure differential. This induces a flow of combustion products and free air through the flue, which draws cooler fresh air for combustion into the appliance. It also protects the flame. The effect of creating a pressure differential is often referred to by the observation that hot air is lighter than air and therefore rises.

The two forces that act through a draught diverter are downdraught pressure and lift or updraught presusure. In both cases the draught diverter acts as a bypass so that such forces are in balance and do not excessively act through the combustion chamber, and hence adversely affect combustion.

It is also important to avoid pushing the flame down by downdraught, i.e. excessive negative pressure, which can lead to spillage of combustion products into the room. In extreme cases it can lead to damage to appliance controls.

To ensure proper operation of the draught diverter there should be sufficient clearance around the diverter to ensure unrestricted air flow. In addition, it is important that the draught diverter is in the same space, and shares the same atmospheric conditions, as the appliance.

Flue design

It is important to ensure adequate temperature differentials within the flue to allow appropriate draught and to minimize the potential for condensation. It is also important to protect combustible surfaces from heat (temperature) hazards. These objectives are achieved by insulation using double skinning, clearances (air gaps) or insulating materials, and by height of flue.

Leak-proofing to ensure the integrity of the flue, the flue inlet and flue connections is also important. Seals have to be secure as any leaks or loose connections decrease the efficiency and effectiveness of the flue.

Flue dampers can provide for increased efficiency of some appliances. However, they should be avoided unless the maximum area closed would not lead to adverse operation of the appliance or to spillage of combustion products.

Manufacturers instructions must be consulted if a flue damper is contemplated.

Flue sizing [6]

Flues should be designed to ensure adequate draught under all operating conditions and have minimal restrictions throughout the system. In particular:

- there should be sufficient vertical rise to rapidly establish flue operation,
- the effective cross-section should never be less than the outlet cross-section of the appliance flue outlet, taking into account any offsets between transition piece inlet and outlet, and the size of the outlet,
- changes in direction should be minimized and should be even (ie not sudden)
- shape transition (ie rectangular to circular, elbows and horizontal sections, etc.) must not restrict the effective cross-section and hence the flow of combustion products, to minimise restrictions, see Figure B, and
- there should be a maximum vertical rise before any horizontal section.

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[6] As a general rule, for every cubic metre of natural gas consumed by a gas appliance, ten cubic metres of air is required for combustion, on top of any air required to ensure the safety and comfort of any occupants. This leaves eight cubic metres of nitrogen, two cubic metres of water vapour and one cubic metre of carbon dioxide to be returned to the atmosphere. If combustion is not efficient or is interfered with, other products of combustion may be present.

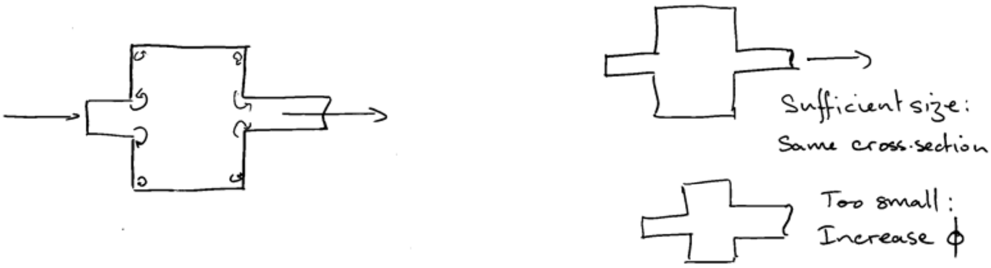

Figure B Transition: Corners (sharp angles) create resistance
Any transition or change in direction does this. Transitions may require specific attention, such as increasing cross-section or a properly-sized transition piece

Flue installation

To ensure good flue performance over the life of the flue, the installation of a flue should take into account the following:

- o elimination of slots or gaps to avoid the possibility of entrainment of air into the flue other than through draught diverters,
- o protection of combustible material by distance or insulation,
- o proper joining and mechanical integrity,
- o provision of adequate support and protection from potential future damage,
- o provision for removal of condensates, where applicable[7], and
- o provision for connection and disconnection of the flue from the appliance in such a way that it does not damage integrity of flue system.

The lapping direction for flue components should be downwards if the appliance produces condensation.

Masonry flues (chimneys):

In addition, installation using existing masonry chimneys should ensure:

- o the structural integrity and soundness of existing chimney for conversion to gas[8],

[7] This may be the case, for instance with high efficiency appliances or where the environment is such that condensation is likely. A mixture with any soot that may be present can result in a mildly acidic (and therefore corrosive) solution.
[8] There is potential for masonry structures to develop leaks over time due to the effects of ageing and movement of the structure.

- o removal of any moisture entrapped in an unlined chimney previously used with solid fuel or oil burning appliances so that it does not adversely affect its structural integrity,
- o provision for avoiding any hazards associated with falling material (debris), and
- o allow for the larger thermal mass of a masonry chimney, to avoid the possibility of spillage as such flues can take longer to heat up.

Single skin flues

Single skin flues are more prone to heat loss and, as there is no outer skin, soundness of joints is more critical. Therefore, design and installation of single skin flues has to ensure:

- o heat loss is minimised,
- o joints are sound and do not create restrictions, and
- o protection of combustible materials through isolation or insulation, for example when penetrating floors.

Double skin flues

Double skin flues have better insulation properties than single skin flues and have lower heat capacity than masonry chimneys. While arguably not as critical as in the case of single skin flues, attention to jointing, heat loss and protection of combustible materials are all important factors in good flue systems.

Flue Terminal

The flue terminal is an important component of any flue system in protecting against adverse pressure conditions and blockages caused by foreign materials.

Poor design and location of flue terminals can lead to poor flue performance, especially in adverse conditions. Therefore their design and location must:

- o avoid location in close proximity to openings in the building and in other structures, to avoid possible ingress of combustion air or impingement of hot products of combustion;
- o ensure flue termination provides clearance in all directions to avoid adverse pressure effects from adjacent structures usually by extending the height of the flue[9].
- o ensure draught has minimal effect on flue pressure– See Figure C,
- o protect against hazards due to activities of birds and vermin – eg by use of a properly sized mesh,

[9] Adverse pressure patterns and turbulence can readily arise from adjacent roofs, ridges, parapets or even adjacent structures),

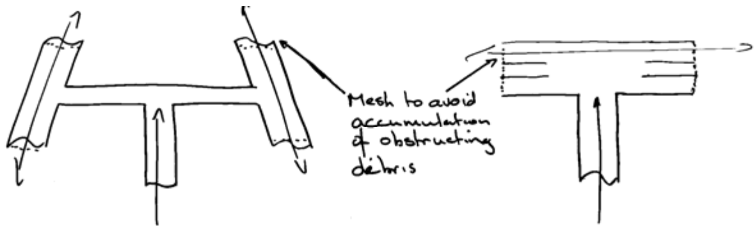

Figure D Flue terminals
Both types provide for adverse wind conditions – in effect providing downdraught protection.
A draught diverter on the appliance provides further protection in the case of high overall external air pressure.

- provide sufficient strength and support to the flue system, and
- provide adequate corrosion resistance.

Commissioning and Testing

Commissioning and testing procedures are important parts of the installation process.

The interface between design, installation and operation of the installation, flue and appliance must be clear and be able to be fully understood and applied by the installer. In addition to ensuring compliance of other aspects of the installation, the elements of commissioning that are directly related to flue performance include:

- Ensuring correct gas installation and appliance pressures (eg at the burner head), including pressures under operating conditions with all appliances operating,
- Spillage of products of combustion from appliance surrounds, front of appliance and any gaps around the flue system. It is useful to test on startup as well as normal operating conditions (after ten minutes continuous operation), and
- CO/CO_2 ratio test on startup (0-10 minutes operation) and under normal operating conditions (after ten minutes continuous operation)

Spillage test tests should be thorough and include checks for spillage from the draught diverter as well as from the front of the appliance. They should include any gaps around any closure plates that seal the flue or the flue connection from the room.

Care needs to be taken to ensure these are conducted thoroughly.

Equipment used to take measurements in setting up installations and in testing and commissioning should be suitable for the purpose and should be properly calibrated.

The aim is to be able to make a statement along these lines: On the basis of this test the flue operation is satisfactory and can be expected to be satisfactory under anticipated conditions, and should support any statements made in relation to certification.

Maintaining flue systems

Very often once an installation, including flue systems, is completed, little or no attention is paid to it until something goes wrong. However, sometimes the opportunity arises for maintenance. When it does it is a good idea to ensure:

flues are clean and free from corrosion and they are properly terminated and any protective mesh is not blocked,

Occasionally building alterations are found to have taken place since the installation of the flue system and openings or ventilation are too close to the flue, or structures encroach too close to the flue terminal and could affect its performance.

In some cases these can be resolved with the installation or building owner or operator. In cases where there is an immediate hazard to life or property, a licensed person has an obligation to notify the gas installation owner or operator and to notify the Secretary (ESS).