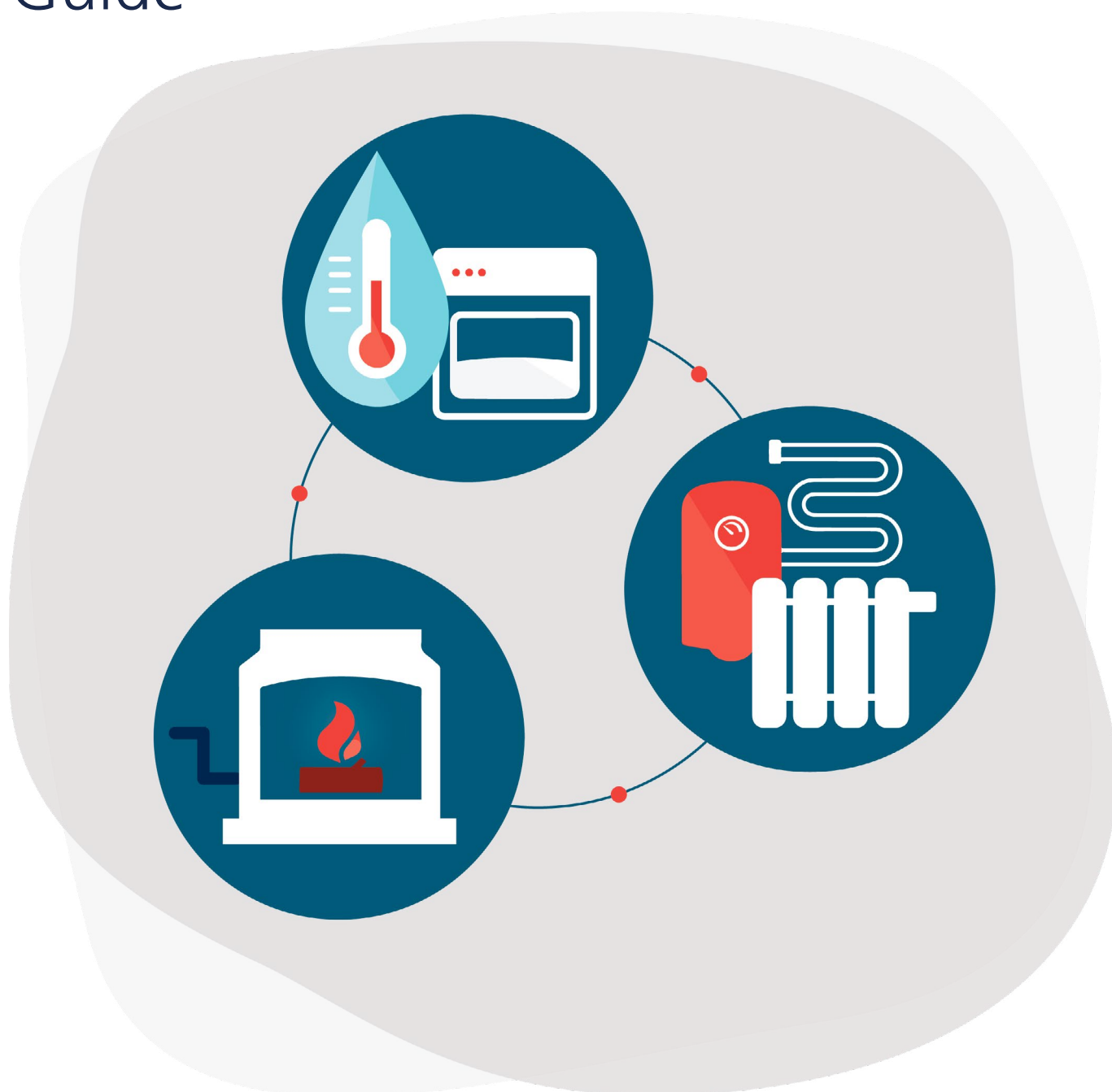


**PAS 4444:2020+A1:2021**

# Hydrogen-fired gas appliances – Guide



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# Foreword

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The guidance in this PAS is presented in Roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

*Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.*

Identified issues generating subsequent requirements and supporting tests are detailed and referenced to the relevant appliance standard/clause.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. “organization” rather than “organisation”).

Guidance in this standard is drafted in accordance with *Rules for the structure and drafting of UK standards*, subclause **G.4**, which states, “The wording of a guide is in the form of descriptive statements and recommendations, using the present tense and the auxiliary “should” for recommendations”.

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# 1 Scope

This PAS gives guidance on the development and construction of hydrogen-fired gas appliances, which are either purpose-built to use hydrogen or are designed to be converted to use hydrogen.

The PAS covers the functional specification of the appliance, including specific advice on the demonstration of safety, including reasonably foreseeable conditions to stress the appliance in excess of that which it is likely to experience in normal service. It also covers the setting of limit (upper and lower) hydrogen supply pressures and limit voltages. It discusses the possible arrangement of fittings and devices acknowledging the application to hydrogen-fired appliances.

The PAS also covers tests regarding both delayed ignition and unintended ignition of accumulated gas (which has leaked from the gas circuit) within the case of the appliance and/or its flue.

It also covers advice on manufacturer's instructions regarding installation of such appliances (including fluing) and their servicing requirements.

The PAS is intended to be used as a supplement to existing standards and generally assumes that any default performance requirements (for example, noise or pressure rating) align with those of an equivalent 2<sup>nd</sup> family gas appliance unless specifically stated otherwise.

The PAS also provides guidance on aligning with the essential requirements at the time of publication of the PAS of the Gas Appliance Regulation (GAR) for appliances burning hydrogen [1]. Annex A provides a list of these essential requirements and indicates where they are addressed in the clauses of this PAS.

This PAS has been developed with reference to the product standards given as normative references but might be applicable to other similar products (see Annex B).

This PAS is not applicable to industrial or process equipment.

This PAS is for use by the manufacturers of hydrogen-fired gas appliances and manufacturers of gas appliances that are designed to be converted to use hydrogen.

The PAS may also be of interest to Notified Bodies, other appliance test houses and anyone who might be engaged in testing these appliances.

**NOTE 1** *This PAS is intended to prepare the UK gas industry for "hydrogen ready" appliances, including appliances designed to be converted to use hydrogen.*

**NOTE 2** *This PAS has been developed on the basis that currently hydrogen limit test gases do not exist and are to be the subject of a wider discussion. Accordingly, other test means have been suggested so as to stress the appliance in excess of that which it is likely to experience in normal service.*

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions of this document.

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 7977-1:2009+A1:2013, *Specification for safety and rational use of energy of domestic gas appliances – Part 1: Radiant/convectors*

BS EN 26:2015, *Gas-fired instantaneous water heaters for the production of domestic hot water*

BS EN 30-1-1:2008+A3:2013, *Domestic cooking appliances burning gas – Part 1-1: Safety – General*

BS EN 30-1-2:2012, *Domestic cooking appliances burning gas – Safety – Part 1-2: Appliances having forced-convection ovens and/or grills*

BS EN 89:2015, *Gas-fired storage water heaters for the production of domestic hot water*

BS EN 203-1:2014, *Gas heated catering equipment – Part 1: General safety rules*

BS EN 203-2-1:2014, *Gas heated catering equipment – Part 2-1: Specific requirements – Open burners and wok burners*

BS EN 203-2-2:2006, *Gas heated catering equipment – Part 2-2: Specific requirements – Ovens*

BS EN 203-2-3:2014, *Gas heated catering equipment – Part 2-3: Specific requirements – Boiling pans*

BS EN 437:2018, *Test gases – Test pressures – Appliance categories*

BS EN 509:2000, *Decorative fuel-effect gas appliances*

BS EN 613:2001, *Independent gas-fired convection heaters*

BS EN 1266:2002, *Independent gas-fired convection heaters incorporating a fan to assist transportation of combustion air and/or flue gases*

BS EN 1749:2020, *European scheme for the classification of gas appliances according to the method of evacuation of the products of combustion (types)*

BS EN 1860-1:2013+A1:2017, *Appliances, solid fuels and firelighters for barbequing – Part 1: Barbeques burning solid fuels – Requirements and test methods*

BS EN 13278:2013, *Open fronted gas-fired independent space heaters*

BS EN 14438:2006, *Gas-fired insets for heating more than one room*

BS EN 14829:2007, *Independent gas-fired flueless space heaters for nominal heat input not exceeding 6 kW*

BS EN 15502-1:2012+A1:2015, *Gas-fired heating boilers – Part 1: General requirements and tests*

BS EN 15502-2-1:2012+A1:2016, *Gas-fired central heating boilers – Part 2-1: Specific standard for type C appliances and type B2, B3 and B5 appliances of a nominal heat input not exceeding 1 000 kW*

BS EN 15502-2-2:2014, *Gas-fired central heating boilers – Part 2-2: Specific standard for type B1 appliances*

## 3 Terms, definitions, symbols and abbreviations

### 3.1 Terms and definitions

For the purposes of this PAS, the following terms and definitions apply.

#### 3.1.1 burners

##### 3.1.1.1 aerated burner

component or assembly that operates with an air-gas mixture within the burner

**NOTE** An aerated burner can also be known as a “pre-mix” or “partially pre-mix burner”.

##### 3.1.1.2 burner

component or assembly that conveys the gas or air-gas mixture and ensures the combustion of the gas

[SOURCE: BS EN 26:2015, 3.6.2 adapted]

**NOTE** A burner can also be known as a “main burner” or an “ignition burner”.

##### 3.1.1.3 flame lift

movement of a flame away from the flame detector where the flame is not blown out, but the control system interprets a loss of flame due to the extinction delay-time being exceeded

**NOTE** Flame lift can only occur on aerated burner. “Flame blow out” is the unintentional extinguishing of any main burner flame by any factor, including external draughts and flue wind effects.

##### 3.1.1.4 flame stability

characteristics of flames that remain on the burner ports for aerated burners or in the flame retention zone for non-aerated burners

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.7.3, modified]

##### 3.1.1.5 ignition burner

burner intended to ignite a main burner

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.2.3]

##### 3.1.1.6 ignition device

any means (flame, electrical ignition device or other device) used to ignite the gas admitted to the ignition burner or the main burner

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.2.4]

##### 3.1.1.7 light-back

phenomenon characterized by the flame stabilizing upstream of the normal position of the main burner flame, with the resultant potential to cause damage to the appliance

##### 3.1.1.8 main burner

burner that is intended to assure the thermal function of the appliance

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.2.7, modified]

##### 3.1.1.9 manual ignition device

device by means of which the ignition burner is ignited following manual intervention

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.2.8]

##### 3.1.1.10 non-aerated burner

component or assembly that operates with no mixing of the air-gas mixture within the burner incorporating a fuel injector burner inlet nozzle

**NOTE 1** A non-aerated burner can also be known as a “diffusion burner”.

**NOTE 2** The fuel injector burner inlet nozzle is where the fuel is injected into the burner.

#### 3.1.2 combustion circuit

##### 3.1.2.1 combustion chamber

 unobstructed enclosure in the downstream of the burner, inside which combustion of the air-gas mixture and heat exchanger takes place 

[SOURCE: BS EN 26:2015, 3.7.1 adapted]

##### 3.1.2.2 combustion circuit

circuit from the air inlet to the combustion products outlet of the appliance

**NOTE** This includes the combustion chamber and heat exchanger and depending on the type includes the air supply duct, the fitting piece, the connection to the terminal, the inlet terminal, the outlet terminal.

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.3.1]

### 3.1.2.3 combustion circuit volume

internal volume of the appliance from air inlet to flue gases outlet (not including external air or flue ducts)

**NOTE** *In the case of a gas fire this is the volume of the fire enclosure to the flue exit or connection. In the case of cookers and catering equipment, this term is not applicable.*

### 3.1.3 flame supervision device

device that, in response to a signal from the flame detector, keeps the gas supply open and shuts it off in the absence of the supervised flame

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.4.13]

### 3.1.4 gas circuit

assembly of parts of the appliance that carry or contain the combustible gas between the appliance gas inlet connection and the point at which air is admitted

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.1.2, modified]

### 3.1.5 gases

#### 3.1.5.1 air factor ( $\lambda$ )

ratio of actual air volume for combustion divided by the stoichiometric air volume for the combustion with the nominal range to be declared by the manufacturer

#### 3.1.5.2 calorific value

quantity of heat produced by complete combustion at a constant pressure of 1 013.25 mbar, of a unit volume or mass of gas, the constituents of the mixture being taken at reference conditions and the products of combustion being brought back to the same conditions

[SOURCE: BS EN 437:2018, 3.12]

**NOTE** *A distinction is made between:*

- a) *the gross calorific value  $H_g$ : the water produced by combustion is assumed to be condensed; and*
- b) *the net calorific value  $H_i$ : the water produced by combustion is assumed to be in the vapour state.*

*The calorific value is expressed in megajoules per cubic metre ( $\text{MJ/m}^3$ ) dry gas under the reference conditions.*

[SOURCE: BS EN 437:2018, 3.13]

#### 3.1.5.3 equivalence ratio ( $\Phi$ )

ratio of molar (or mass) flows of fuel to air, divided by the stoichiometric ratio of molar (or mass) flows of fuel to air

#### 3.1.5.4 gas family

group of gaseous fuels with similar burning behaviour linked together by a range of Wobbe indices

[SOURCE: BS EN 437:2018, 3.18]

### 3.1.5.5 limit gas

test gas representative of the extreme variations in the characteristics of the gases for which appliances have been designed

[SOURCE: BS EN 437:2018, 3.5]

### 3.1.5.6 reference conditions

temperature and pressure for the correction of the measured gas volume fractions, referenced at 15 °C and 1013.25 mbar (101.325 kPa)

[SOURCE: BS EN 437:2018, 3.10, modified]

**NOTE** *Gas qualities can be given at conditions other than reference conditions by other sources and corrected accordingly to reference conditions.*

### 3.1.5.7 reference gas

test gas with which appliances operate under nominal conditions when they are supplied at the corresponding normal pressure

[SOURCE: BS EN 437:2018, 3.4]

### 3.1.5.8 test gas

gas intended for the verification of the operational characteristics of gas appliances

**NOTE** *Test gases can consist of reference gases and limit gases.*

[SOURCE: BS EN 437:2018, 3.3]

### 3.1.5.9 Wobbe index

ratio of the calorific value of a gas per unit volume and the square root of its relative density under the same reference conditions.

**NOTE 1** *Relative density ( $d$ ) is the ratio of the masses of equal volumes of dry gas and dry air under the same conditions of temperature and pressure: 15 °C or 0 °C and 1 013.25 mbar.*

**NOTE 2** *The Wobbe index is said to be gross or net according to whether the calorific value is used the gross or net value. Gross Wobbe index is expressed as  $W_g$ ; net Wobbe index is expressed as  $W_i$ .*

*The Wobbe index is expressed in megajoules per cubic metre ( $\text{MJ/m}^3$ ) dry gas under the reference conditions.*

[SOURCE: BS EN 437:2018, 3.13, modified]

### 3.1.6 operation of appliance

#### 3.1.6.1 nominal voltage

voltage assigned to the appliance by the manufacturer

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.9.3, modified]

### 3.1.6.2 thermal equilibrium

operating state of the appliance corresponding to a particular setting of the input, in which the measured value of the flue gas temperature remains steady within a tolerance of  $\pm 2\%$  over a period of 10 min

[SOURCE: BS 7977-1:2009+A1:2013, 3.5.3]

### 3.1.7 times

#### 3.1.7.1 appliance

appliance burning gaseous fuels used for cooking, refrigeration, air-conditioning, space heating, hot water production, lighting or washing, and also forced draught burners and heating bodies to be equipped with such burners

[SOURCE: EU 2016/426 [1] art.2, (1)]

#### 3.1.7.2 extinction delay time, $T_{IE}$

thermoelectric flame supervision device, the time that elapses between disappearance of the supervised flame and interruption of the gas supply

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.8.1]

#### 3.1.7.3 extinction safety time, $T_{SE}$

time that elapses between extinction of the supervised flame and the order to shut off the gas supply to the burner

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.8.2]

#### 3.1.7.4 ignition safety time, $T_{SA}$

time that elapses between the order to open and the order to close the gas supply to the burner in the event of ignition not taking place

[SOURCE: BS EN 15502-1:2012+A1:2015, 3.1.8.4]

## 3.2 Symbols and abbreviations

For the purposes of this PAS, the following symbols and abbreviations apply.

|                     |                                              |
|---------------------|----------------------------------------------|
| $^{\circ}\text{C}$  | degrees Celsius                              |
| $\lambda$           | air factor                                   |
| $\Phi$              | equivalence ratio                            |
| $A/F_{\text{mass}}$ | flue gas mass flow kg/s /fuel mass flow kg/s |
| $BLF$               | biomass label factor                         |
| $\text{CO}$         | carbon monoxide                              |
| $C_p$               | specific heat of flue gases                  |
| $\text{cmol}$       | centimole                                    |
| $d$                 | relative density                             |
| $daf$               | dry air-free                                 |
| $\text{dm}^3$       | volume $\text{m}^3/1\ 000$                   |
| $EEI$               | energy efficiency index                      |
| $g$                 | gram                                         |
| $H_i$               | net calorific value of fuel                  |
| $H_s$               | gross calorific value of fuel                |
| $\text{H}_2$        | hydrogen                                     |
| $\text{kg}$         | kilogram                                     |
| $\text{kPa}$        | 1 000 pascals                                |
| $\text{kW}$         | 1 000 joules/s                               |
| $l$                 | litre                                        |
| $\text{LPG}$        | liquified petroleum gas                      |
| $\text{mbar}$       | millibar                                     |
| $\mu\text{mol}$     | micromole                                    |
| $\text{MJ}$         | megajoule (1 000 000 joules)                 |
| $\text{mol}$        | mole                                         |
| $\text{m}^3$        | volume $\text{m}^3$                          |
| $\text{NO}_x$       | nitrogen oxide                               |
| $\text{O}_2$        | oxygen                                       |
| $\text{Pa}$         | pascal                                       |
| $P_n$               | normal test pressure                         |
| $P_{\text{max}}$    | maximum test pressure                        |
| $P_{\text{min}}$    | minimum test pressure                        |
| $\text{RH}$         | relative humidity                            |
| $s$                 | seconds                                      |
| $T_{IE}$            | extinction delay time                        |
| $T_{SE}$            | extinction safety time                       |
| $T_{SA}$            | ignition safety time                         |
| $V$                 | volt                                         |
| $W_i$               | net Wobbe index                              |
| $W_s$               | gross Wobbe index                            |