Designation: E2778 – 14

Standard Specification for
Custom Tiled/Mortared Masonry Heaters (Stoves)[1]

This standard is issued under the fixed designation E2778; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification contains specifications for the dimensioning of custom tiled/mortared masonry heaters (stoves). The custom tiled/mortared masonry heaters (stoves) are individually technically calculated and constructed. This information can be used for log (cordwood) wood-fired masonry heaters that burn one fuel load per storage period with a maximum load between 10 and 40 kg and a storage period (nominal heating time) between 8 and 24 h per EN 15544.

1.2 This specification is valid for masonry heaters equipped with fireclay as interior material with an apparent density between 1750 and 2200 kg/m³, a degree of porosity 18 up to 33 % by volume, and a heat conductivity from 0.65 up to 0.90 W/mK (temperature range 20 to 400°C) per EN 15544.

1.3 This specification is valid for masonry heaters with sidewise combustion air supply of the combustion chamber.

1.4 This specification is not valid for masonry heaters combined with water heat exchangers for central heating or other heat-absorbing elements such as glass plates greater than ⅙ of the combustion chamber surface, open water tanks, and so forth. It is also not valid for masonry heaters combined with heating/fireplace elements in accordance with EN 13229. Furthermore, this specification is not valid for mass-produced prefabricated or partly prefabricated slow heat release appliances according to EN 15250.

1.5 The calculation method of this specification is used to establish emissions and energy efficiency when burning log wood or wood briquettes according to the manufacturer's or builder's manual.

1.6 *Clearance to Combustibles*—When a masonry heater is constructed according to this specification, the clearance to combustibles shall be in accordance with TRVB 105 or other appropriate standards.

1.7 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions

E1602 Guide for Construction of Solid Fuel Burning Masonry Heaters

2.2 *EN Standards:*[3]

EN 13229 Inset appliances including open fires fired by solid fuels—Requirements and test methods

EN 13384–1 Chimneys—Thermal and fluid dynamic calculation methods—Part 1: Chimneys serving one appliance

EN 15250 Slow heat release appliances fired by solid fuel—Requirements and test methods

EN 15544 One off Kachelgrundöfen/Putzgrundöfen [tiled/mortared (*sic*) stoves]: Calculation methods

2.3 *Austrian National Fire Service Association Standard:*[4]

TRVB 105 Fireplaces for Solid Fuels

3. Terminology

3.1 *Definitions:* Terms used in this specification are defined in Terminology E631.

3.2 Masonry heaters are also known by the following words and terms and are further explained in Guide E1602; Kachelofen, Kakelugn, grundofen, Kachelgrundöfen, Putzgrundöfen, and slow heat release appliance.

4. Classification

4.1 *Nominal Heat Output*—The nominal heat output shall be specified.

4.2 *Load of Fuel:*

[1] This specification is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.54 on Solid Fuel Burning Appliances.

Current edition approved Oct. 1, 2014. Published October 2014. DOI: 10.1520/E2778–14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Deutsches Institut fur Normung e.V.(DIN), Burggrafenstrasse 6, 10787, Berlin, Germany, http://www.din.de.

[4] Available from Österreichischer Bundes Feuerwehr Verband (ÖBFV), Voitgasse 4, 1220 Wien, Austria, http://www.bundesfeuerwehrverband.at/shop/contact.

4.2.1 *Maximum Load*—The maximum load of fuel is calculated per EN 15544.

4.2.2 *Minimum Load*—The minimum load is fixed at 50 % of the maximum load per EN 15544.

$$m_{B\min} = (0.5)(m_B) \quad (1)$$

where:

m_B = maximum load (kg), and
$m_{B\min}$ = minimum load (kg).

4.3 *Design of the Essential Dimensions:*

4.3.1 *Combustion Chamber Dimensions*—The design of the dimensions of the combustion chamber is necessary because, on one hand, enough room to place the fuel in it is needed and, on the other hand, the requirements for a clean combustion have to be fulfilled.

4.3.1.1 *Combustion Chamber Surface:*

(1) The dimension of the combustion chamber surface has to be calculated per EN 15544.

(2) For the calculation of the combustion chamber surface all its walls, the ceiling, and the base, including the area of the combustion chamber opening and the combustion chamber exit for the flue gas, have to be regarded equally.

4.3.1.2 *Combustion Chamber Base:*

(1) The combustion chamber base can be varied between a minimum and a maximum value.

(2) The minimum value results from the requirement that, at maximum load, a height of the fuel of 33 cm shall not be exceeded. Therefore, a base of 100 cm^2 per kg fuel is needed per EN 15544.

(3) The maximum area of the base of the combustion chamber is defined per EN 15544.

(4) When the base is rectangular, the proportion of length to width can be varied from 1 to 2, but a minimum width of 23 cm is required per EN 15544.

4.3.1.3 *Combustion Chamber Height:*

(1) The minimum combustion chamber height is defined per EN 15544.

(2) On the basis of the specifications of the combustion chamber base and the combustion chamber surface, the combustion chamber height shall be calculated per EN 15544.

4.3.2 *Minimum Flue Pipe Length:*

4.3.2.1 *Construction without Air Gap*—The minimum flue pipe length shall be calculated per EN 15544.

4.3.2.2 *Construction with Air Gap*—The minimum flue pipe length shall be calculated per EN 15544.

4.3.3 *Gas Groove Profile*—The gas groove profile shall be calculated per EN 15544.

4.4 *Calculation of the Burning Rate*—The burn rate shall be calculated per EN 15544.

4.5 *Fixing of the Air Ratio*—Combustion in a masonry heater is a process, which is variable, it is not steady state. The mean air ratio is fixed per EN 15544.

4.6 *Combustion Air, Flue Gas:*

4.6.1 *Combustion Air Flow Rate*—The mean combustion air flow rate shall be calculated per EN 15544.

4.6.1.1 *Temperature Correction*—The temperature correction factor shall be calculated per EN 15544.

4.6.1.2 *Altitude Correction*—The altitude correction factor shall be calculated per EN 15544.

4.6.2 *Flue Gas Flow Rate:*

4.6.2.1 The knowledge of the flue gas flow rate is important for the calculation of the flue pipe diameter. It is calculated per EN 15544.

4.6.2.2 The value, f_t, shall be calculated using the flue gas temperature of the flue pipe section. This means that along the flue pipe the decreasing temperature leads to a lower flue gas flow rate.

4.6.3 *Flue Gas Mass Flow Rate*—The flue gas mass flow rate shall be calculated per EN 15544.

4.7 *Calculations of the Density:*

4.7.1 *Combustion Air Density*—The density of the combustion air at standard conditions shall be per EN 15544.

4.7.2 *Flue Gas Density*—The density of the flue gas at standard conditions is 1.282 kg/m^3. It shall be calculated per EN 15544.

4.8 *Calculation of the Flue Gas Temperature:*

4.8.1 *Mean Combustion Chamber Temperature*—The combustion chamber temperature is necessary to calculate the standing pressure in the combustion chamber. Because of the calculation of the combustion chamber surface, the calculation temperature of all combustion chambers is similar. The temperature shall be fixed per EN 15544.

4.8.2 *Flue Gas Temperature in the Flue Pipe:*

4.8.2.1 The decrease of the temperature along the flue pipe shall be calculated per EN 15544.

4.8.2.2 This development of the temperature is valid from the combustion chamber exit to the connecting pipe.

4.8.3 *Flue Gas Temperature in the Connecting Pipe*—The flue gas temperature in the connecting pipe shall be calculated based on EN 13384-1.

4.8.4 *Flue Gas Temperature at Chimney Entrance, Mean Flue Gas Temperature of the Chimney, and Temperature of the Chimney Wall at the Top of the Chimney*—The flue gas temperature at chimney entrance, the mean flue gas temperature of the chimney, and the temperature of the chimney wall at the top of the chimney are calculated based on EN 13384-1. The outside temperature for the calculation shall be fixed with 0°C.

4.9 *Calculation of Flow Mechanics:*

4.9.1 *Calculation of the Standing Pressure:*

4.9.1.1 The standing pressure results in the difference between the densities of the flue gas and the air.

4.9.1.2 The standing pressure shall be calculated per EN 15544.

4.9.1.3 The effective height is the vertical difference between the flue gas exit and the flue gas entrance of a flue pipe section, the connecting pipe, or the chimney. For the combustion, the combustion chamber height, H_{BR}, shall be used. The air density shall be calculated per EN 15544, and the flue gas density shall be calculated per EN 15544. For the combustion chamber, the combustion chamber temperature, *t*BR, shall be used.

4.9.2 *Calculation of the Flow Velocity:*

4.9.2.1 The velocity shall be calculated by dividing the air or flue gas flow rates by the profile per EN 15544.

4.9.2.2 The flow velocity in the flue pipe, the connecting pipe, and the chimney shall be between 1.2 and 6 m/s per EN 15544.

4.9.3 *Calculation of the Static Friction*—The static friction in the flue pipe, the connecting pipe, and the chimney shall be calculated with EN 13384–1 as follows:

$$p_R = (\lambda_f)(p_d)(L)/(D_h) \quad (2)$$

where:

p_R = static friction (Pa);
p_d = dynamic pressure (Pa);
λ_f = friction coefficient;
L = length of flue pipe section, connecting pipe, or chimney (m); and
D_h = hydraulic diameter (m).

4.9.3.1 *Dynamic Pressure*—The dynamic pressure shall be calculated per EN 15544.

4.9.3.2 *Friction Coefficient:*

(1) The friction coefficient shall be calculated according to an approximation per EN 15544.

4.9.3.3 *Hydraulic Diameter*—The hydraulic diameter shall be calculated per EN 15544.

4.9.4 *Calculation of the Resistance as a Result of Direction Change:*

4.9.4.1 The resistance as a result of direction change shall be calculated by multiplication of the dynamic pressure with the resistance coefficient per EN 15544.

4.9.4.2 Interim values shall be interpolated linearly.

4.9.4.3 If a flue pipe section is shorter than its hydraulic diameter (short flue pipe section: $L < D_h$), the resistances of the direction changes before and after the section are not fully effective. Therefore, the calculation of the resistance coefficient shall be done per EN 15544.

4.10 *Operation Control:*

4.10.1 *Pressure Condition:*

4.10.1.1 At nominal heat output, the sum of all buoyancies (p_h) shall be compared with the sum of all resistances (p_r, p_u) per EN 15544.

4.10.1.2 The calculation shall be done section by section starting with the air inlet and ending with the exit of the chimney. For the calculation, the conditions (temperature, velocity) in the middle of each section shall be taken per EN 15544.

4.10.1.3 The following term shall be fulfilled per EN 15544:

$$(\Sigma\, p_r + \Sigma\, p_u) \leq \Sigma p_h \leq (1.05)(\Sigma\, p_r + \Sigma\, p_u) \quad (3)$$

where:

Σp_r = sum of all static frictions (Pa),
Σp_u = sum of all resistances as a result of direction change (Pa), and
Σp_h = sum of all buoyancies (Pa).

4.10.2 *Dew Point Condition:*

4.10.2.1 At the lowest load, the temperature of the chimney wall at its top is compared with the dew point temperature of the flue gas.

4.10.2.2 The following term shall be fulfilled per EN 15544:

$$t_{i,2} \geq 45 \quad (4)$$

where:

$t_{i,2}$ = chimney wall temperature at its top (°C).

4.10.2.3 For this calculation, a dew point temperature of 45°C is used. The chimney wall temperature at its top shall be calculated based on EN 13384-1.

4.10.3 *Efficiency of the Combustion,* η—The efficiency of the combustion, η, shall be calculated per EN 15544.

4.10.4 *Flue Gas Triple of Variates*—The flue gas temperature is the outlet temperature of the flue pipe calculated according to 4.8.2 with the total flue pipe length. The flue gas mass flow rate shall be calculated according to 4.6.3. The required delivery pressure shall be calculated per EN 15544.

5. Calculations

5.1 If the calculations of this specification are observed, the minimum energy efficiency of 78 % (fuel low-heat value) and the emission values of carbon monoxide 1500 mg/m_n^3 (1000 mg/MJ), nitrogen dioxide 225 mg/m_n^3 (150 mg/MJ), organically bound carbon 120 mg/m_n^3 (80 mg/MJ), and dust 90 mg/m_n^3 (60 mg/MJ) will be observed too.

5.2 This calculation method for the dimensioning of tiled/mortared stoves shall be based on appropriate literature as well as EN 13384-1, in which, besides physical and chemical formulas, empirically determined correlations are also used.

NOTE 1—In case of a calculation method for different interior materials than fireclay, the proof of the compliance of the emission values has to be delivered separately. Furthermore, the empiric data of the combustion chamber dimensions, the minimum flue pipe length, the burning rate, as well as the combustion chamber temperature and the decrease of the temperature along the flue pipe have to be determined.

6. Keywords

6.1 dimensioning; emissions; masonry heater; tiled/mortared stove