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A simulation supported chimney design application for greener buildings

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Abstract

Exhaust gases emitted by heat sources must be discharged into the atmosphere in the most dependable manner possible without endangering human health. This is possible because the chimneys are connected to the heat source. There are some guidelines for locating chimneys in relation to existing structures, determining the minimum height, and calculating the chimney section. The performance of the heat source is also directly affected by the correct sizing of the chimneys.

The large diameter of the chimney at a fixed height causes hot air inside the heat source to be thrown into the atmosphere more than necessary, resulting in incomplete combustion formation and additional cost. A small chimney diameter affects the device's combustion performance and causes efficiency loss. The ideal chimney diameter should be chosen with the existing conditions in mind. There are numerous calculation programs available for checking chimney diameter on a computer.

In this study, the performances of chimney building materials and chimney type alternatives that can be used for the most environmental chimney design in a planned building in Malatya province of Turkey were investigated. Boilers for the building are designed as solid fuel (coal). The calculations have been expanded so that the boiler capacities are between 100.000 kcal/h and 250.000 kcal/h, taking into account the variability of the usable energy amounts in the planned building. The analysis was carried out for comparison using the Kesa-aladin calculation program, which was accepted by Europe.

1. Introduction

Chimneys are systems built in the building, either in the open air or adjacent to the building, to ensure that exhaust gases are discharged to the atmosphere as safely as possible while meeting the requirements of the construction technique. Because of the chimney, the heat source must meet the standards for a safe and continuous operation. The heat source and chimney must work in tandem and be made of durable materials. As a result, chimney systems must be carefully calculated and installed by qualified individuals [1]. Exhaust gases from these heat sources must be transported to the atmosphere when a new combustion device system is installed [2]. A proper chimney system must be designed in order to carry out this process safely. Flues are critical components of any boiler installation, with condensation caldrons and biomass caldrons posing special challenges. High-performance boilers place additional strain on flue mechanisms. This is owing to the lesser natural lifting force of chimney gaseous as they exit the appliance's exit. Because of the high tool efficiency, the moisture within the flue gases can become so cold that it condenses. If the flue mechanism is properly planned, this can be a preferred aspect of reclaim additional concealed energy; however, condensing can be rather harmful owing to the corrosion risk if not properly anticipated during the planning step. On cold days, there is a danger of ice development at the flue station too [3]. The difference in density between the exhaust gas inside the chimney and the outdoor air causes the draught at the chimney inlet. The density of the exhaust gas should always be less than that of the external ambient density. When there is a temperature difference, this condition occurs. As a result, chimney draft is heavily influenced by chimney height, heat losses, waste gas temperature, and external ambient temperature.

The chimney also begins to draw as the high-temperature exhaust gas enters the chimney and rises due to the density difference with the surrounding environment. This draught also ensures the entry of combustion air into the device, the passage through the device, and the process until it flows through the connecting pipe and enters the chimney, depending on the type of device. The chimney can be built at positive pressure by using forced draft and an air exhauster as needed [4-6]. The most important criteria to be checked during the chimney calculation are the pressure

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and temperature conditions. The pressure condition necessitates that the pressure in the flue be high enough to export the gaseous waste. Temperature is another criterion that should be checked over time to protect chimneys from condensation damage and to avoid freezing in the flue mouth depending on temperature [7].

Low-temperature chimney gases, in general, require fan help to generate enough constructive pressure to move the gaseous waste by the chimney connector and apparatus into the perpendicular flue. All the same, flues have been historically run under a natural design, thus at a moderate negatory pressure, with many apparatuses, particularly with certain fuels like biomass. It is critical to decide whether a positive-pressure flue should be used from the start [8]. The laws of fluid dynamics have a complex influence on the relationship between temperature, pressure, and mass flow rate. Basic codes or approved documents are frequently used to simplify compliance with building and emission regulations. These differ between devolved regions, but they are all underpinned by sets of European norms that aid to categorize elements and ensure planning computations that allow for coherent research along [9].

Approved Document J, one guide to the most recent England and Wales Construction Rules for combustibility apparatuses, was released in October 2010. This included information on how to calculate chimneys and flues, as well as a reference to the approved computation procedure in BS-EN13384. This methodology is recommended by the guide as a good starting point for determining whether a flue planning will ensure enough design (ADJ pg. 30). The BS EN1443 norm [Chimneys - general requirements] allows for deviation from the thumb's typical rules as long as a computation is performed. A minimal property for combusting wood, for example, could be 'T400-N2-D-3-Gxx,' where each of series figures defines a significant parameter. It is frequently adequate to comply the legislation general rules for smaller sub-50kW mechanisms, but for systems producing more than 50 kW or with multi-apparatuses, a computation becomes the preferred choice for accuracy. It is necessary to use the calculation methods that allow for chimney section calculations for this purpose. The EN 13384 standard describes these methods in detail. The European chimney calculation norm EN 13384 defines the calculation method for single and multi-device chimneys. As a result, installers and engineering consultants are increasingly turning to computer software to test various chimney options and demonstrate that a chimney system will work in accordance with BS EN 13384 [10]. BS-EN13384, which is divided into two parts, is the European standard used for performance calculations. Section-1 is for sole apparatuses, while Section-2 is for multi-appliances, with the inclusion of flue connector pipe cascading. Using European standards such as these is becoming a more and more significant part of the planning operation for combustion-sourced plant rooms. Multiple-caldron mechanisms should be thought where possible for more preferable prospect and minimal-load matching. If a flue and chimney connecting pipe can be shared between multi-combustion apparatuses, significant savings on chimney costs can be realized. All the same, this isn't always prospective as technical and may disagree with local codes, despite the fact that European standards generally support this as long as the chimneys run at similar pressures. Because of the current availability of the Renewable Thermal Incentives, biomass boilers have recently received special attention. This pays the owner of a commercial appliance on a regular basis for burning bio-mass, normally pellets or wood chips. According to technology anticipates, the renewable energy incentive will have to be increased to meet 0.25 of the trading attempts' paying business ratios heat requisition on premises ranging from low-scale holdings and retail shops to hospitals and schools by 2030 [11]. End users receive not only the potency gains from utilizing a less expensive energy resource, but also routine renewable heat incentive costs based on a metered supply for 20 years. It isn't uncommon to anticipate a yearly benefit combined of around £40000 for a 200 kW chip caldron that replaces oil. This would importantly offset capital and operating costs over a 20-year period [12].

The standard includes several complicated computations with multi-variables. This isn't surprising given that flue draughts vary due to a variety of elements. Temperature is one of these elements, so whether the flue is outside or inside the building, as well as flue insulating degrees, must be considered. Chimney gas velocity, height, diameter, and number of bends overall play a role [13]. Juggling complex hydraulic equations is required to produce accurate calculations. All of these are connected to each other, as when a variant, like moisture or neighboring construction heights, alters, overall others are affected. This is a reiterative operation that is extremely trouble to optimize manually, and such computations are typically performed with specialized computer software. The thermal losses caused by exhaust gases being discarded into the atmosphere range from 10 to 35%. The hot exhaust gas from the boilers is cooled by a heat exchanger added to the system, such as an economizer or a recuperator, and the heat generated from the boiler combustion air or water, etc. fluids can also be heated. The temperature of the exhaust gas will then be lower than the catalogs of the heat source. The temperature at the flue mouth must be taken into account when calculating the diameter of the chimney [14, 15]. Everyone prefers package computer programs that are highly useful for easy control of the chimney norm proper. Chimney calculations can be made by comparing the diameters of various options. These program modules can be chosen for common stack types. As stated in the EN 13384 standard, it is preferable to use computer programs because chimney calculations are difficult to perform manually.

However, chimney calculation programs must also follow the standard rules [1]. This enabled a calculation to EN 13384-1 to be performed using Kesa-aladin software [13].

With the renewable heat incentive, more premises than ever before are occurring as commercial applicable for bio-mass. This occurs at a time when raising emission requirements necessitate optimizing flue efficiency. Diverse caldrons have diverse design needs, and weighing the available alternatives is a time-consuming work. Simulation is quickly occurring a necessary planning equipment, utilized to apply efficient flue efficiency computations and design orders in three-dimension. The Kesa-aladin flue computation simulation was utilized to demonstrate that the flue efficiency would meet BS-EN13384-2 standards.

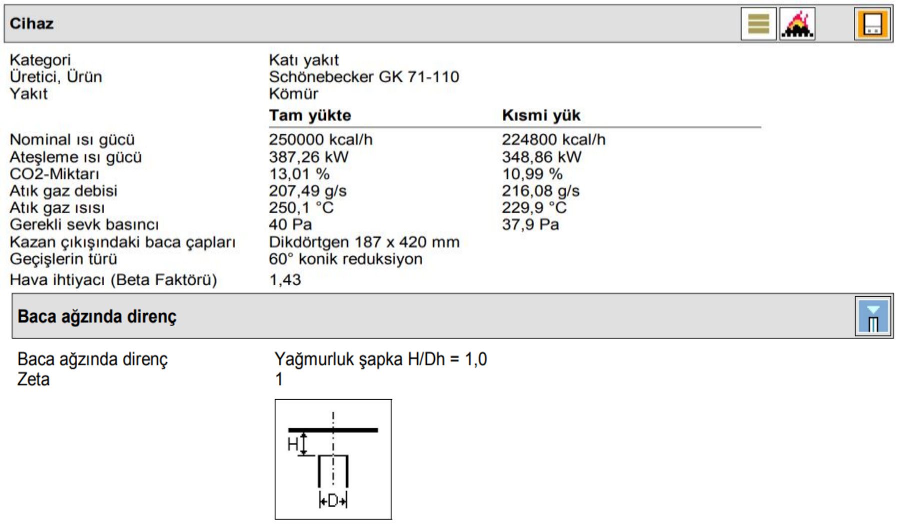
In this paper, the performance of chimney building materials and chimney type alternatives that can be used for the most environmentally friendly chimney design in a planned building in Turkey's Malatya province was investigated. Building boilers are designed to run on solid fuel (coal). The analysis was carried out using the Kesa-aladin calculation program.

2. Methodology

The Kesa-aladin professional package is a software for calculating chimneys in accordance with European standards (BS EN13384). Using Kesa-aladin, it is possible to compute a three-layer house flue for an oil-fired caldron as easily and protective as a complicated caldron system that is, for instance, occurrence of 5 condensation boilers and free from room-air in sole cascade mechanism. Expert simulation, like Kesa-aladin, allows engineering consultants and installers to test various flue options and demonstrate that a flue mechanism meets BS-EN13384. This process is aided by the availability of manufacturer information in a digital database alongside the calculation. It is possible to check compliance with the following standards using Kesa-aladin: Temperature conditions ensure that the flue is long-time protected from condensing damage and that the exit does not freeze if the external temperature is too less. Pressure requirements ensure that the pressure in the flue is adequate to safely send the exhaust-gases to the external. There are 4 programme alternatives to comply with overall requirements. Kesa-aladin sole tool (Flue mechanisms with one sole tool), Kesa-aladin light (5 fire-places in cascade or with one widespread collection chimney pipe, flue mechanisms with upwards 5 tools, flue mechanisms with a sole tool), Kesa-aladin norm (Combustion air computation, 9 fireplaces in cascade or with one widespread collection chimney pipe, flue mechanisms with upwards 10 tools, flue mechanisms with a single tool.) Kesa-aladin professional (Combustion air computation, 9 fire-places in cascade or with one widespread collection chimney pipe, flue mechanisms with upwards 20 tools, flue mechanisms with one sole tool) [13].

Diverse outputs such as exhaust gas velocity are checked instantly on the detailed results screen of Kesa-aladin computation simulation, and the exhaust gas velocity can only be controlled within the Excel calculation program. Furthermore, the Kesa-aladin computation simulation option allows one to instantly view the results in different diameter ranges on a separate screen. Moreover, Kesa-aladin supplies the computations stated at the output rated; Minimum draught (Pa), mass flow stated of manufacturer at output rated (g/s), CO2 percent, flue condensation risk (Co), flue temperature, flue speed at output rated (m/s) [15].

In this study, an output section of the analysis made by the Kesa-aladin simulation is presented below.



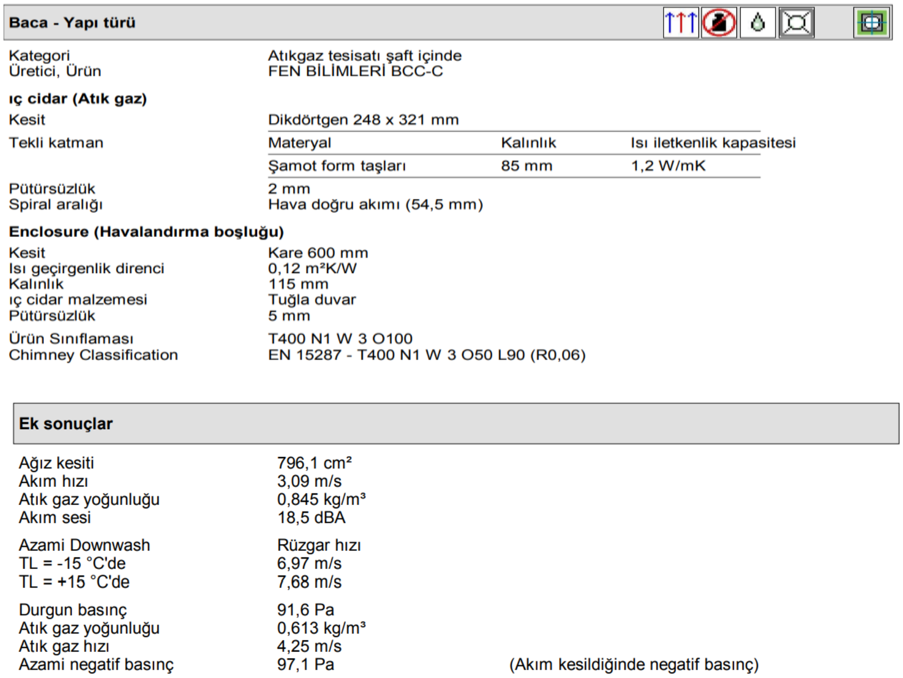
Cihaz

Kategori	Katı yakıt
Üretici, Ürün	Schönebecker GK 71-110
Yakıt	Kömür

	Tam yükte	Kısmi yük
Nominal ısı gücü	250000 kcal/h	224800 kcal/h
Ateşleme ısı gücü	387,26 kW	348,86 kW
CO2-Miktarı	13,01 %	10,99 %
Atık gaz debisi	207,49 g/s	216,08 g/s
Atık gaz ısısı	250,1 °C	229,9 °C
Gerekli sevk basıncı	40 Pa	37,9 Pa
Kazan çıkışındaki baca çapları	Dikdörtgen 187 x 420 mm	
Geçişlerin türü	60° konik reduksiyon	
Hava ihtiyacı (Beta Faktörü)	1,43	

Baca ağzında direnç

Baca ağzında direnç	Yağmurluk şapka H/Dh = 1,0
Zeta	1



Baca - Yapı türü

Kategori	Atıkgaz tesisatı şaft içinde		
Üretici, Ürün	FEN BİLİMLERİ BCC-C		
ıç cidar (Atık gaz)			
Kesit	Dikdörtgen 248 x 321 mm		
Tekli katman	Materyal	Kalınlık	Isı iletkenlik kapasitesi
	Şamot form taşları	85 mm	1,2 W/mK
Pütürsüzlük	2 mm		
Spiral aralığı	Hava doğru akımı (54,5 mm)		
Enclosure (Havalandırma boşluğu)			
Kesit	Kare 600 mm		
Isı geçirgenlik direnci	0,12 m²K/W		
Kalınlık	115 mm		
ıç cidar malzemesi	Tuğla duvar		
Pütürsüzlük	5 mm		
Ürün Sınıflaması	T400 N1 W 3 O100		
Chimney Classification	EN 15287 - T400 N1 W 3 O50 L90 (R0,06)		

Ek sonuçlar

Ağız kesiti	796,1 cm²	
Akım hızı	3,09 m/s	
Atık gaz yoğunluğu	0,845 kg/m³	
Akım sesi	18,5 dBA	
Azami Downwash	Rüzgar hızı	
TL = -15 °C'de	6,97 m/s	
TL = +15 °C'de	7,68 m/s	
Durgun basınç	91,6 Pa	
Atık gaz yoğunluğu	0,613 kg/m³	
Atık gaz hızı	4,25 m/s	
Azami negatif basınç	97,1 Pa	(Akım kesildiğinde negatif basınç)

Fig. 1. A sample analysis by Kesa-aladin simulation

2.1. Simulation parameters

Coal is divided into classes according to its metamorphosis state. Moisture, C, ash and sulfur ratios in coal are taken into account in class. Grades containing 86-98% C, 2-14% volatile elements are considered “anthracite”. Primarily anthracite is meta-anthracite and semi-anthracite. Class status “bituminous” materials in which the carbon content varies between 75-69% and the evaporative components between 14-31%. They are known as low level, medium level, and high volatility bituminous coals. Its calorific values vary between 11500 - 14000 Btu/lb. The amounts of carbon and volatile elements vary in sub-bituminous and linguistic purity. The calorie values are between 9500-11500 Btu/lb for the first group scheme and 8300-6300 Btu/lb for the second group scheme [16].

The flue gas temperature (T) is the desired value for the flue gases coming out of the boiler to be at the lowest temperature that can be reached, depending on the fuel type and the S ratio in it. Unusual fuel flow, poor quality boiler heating surface, and excessive pollution in the smoke pipes cause high flue gas temperature. The important point to be considered in this is that the boiler test is carried out with a fuel flow rate that is prone to the boiler rated power in terms of flue gas analysis. Because with small boiler capacities, the flue gas temperature is also expected to be low. High flue gas temperature causes loss of efficiency. The minimum values that can be deducted in the flue gas temperature are related to the dew temperature of the flue gases. The dew temperature depends on the amount of SO_2 in the flue gas and therefore the sulfur (S) in the fuel. Flue gas temperature values of 150°C in the use of natural gas and 175°C in the use of solid-liquid fuels can be accepted as appropriate. In case of high flue gas temperatures, the burners and boilers should be intervened in absolute value, the flue gas temperature should be reduced by partially reducing the capacity value or adding turbulators to the boiler fire pipes. A flue gas temperature drops at 20 °C causes a 1% increase in efficiency.

The chimney draft value effect increases in proportion to the flue height value and the difference between the boiler temperature value and the outdoor temperature value [17, 18].

$$\Delta P = H \text{ x } g \text{ x } (\gamma 2 - \gamma 1) \text{ (Pa) [18]}$$

$$\Delta P = H \text{ x } (\gamma 2 - \gamma 1) \text{ (mmSS) [19]}$$

H = Chimney height (m)

$\gamma 1$ = Density of air at boiler temperature (kg/m^3)

$\gamma 2$ = Density of air at outdoor temperature (kg/m^3)

The hot air velocity in the chimney increases in direct proportion to the chimney draft value.

$$W = \sqrt{}\, 2.\ g.\ \Delta P / \gamma 1 \text{ [m/s]}$$

While the chimney cross-section value increases in direct proportion to the boiler capacity value (Qk) and a flue coefficient (n), which depends on the fuel, it decreases inversely with the square root of the chimney height value (H).

$$F = n \times \frac{Q\,k}{\sqrt{H}} \ (\mathrm{cm}^2)$$

n = A coefficient depending on the fuel type
(Natural gas.......n = 0.010 – 0.012) [20]
(Fuel-Oil.........n = 0.020) [21]
(Solid Fuel......n = 0.030) [21]

The flow of hot air formed in the chimney increases in direct proportion to the chimney cross section value and air velocity.

$V = F \times W \times 3600 \ (\mathrm{m}^3/\mathrm{h})$

The amount of heating value carried by hot air in the chimney increases in direct proportion to the difference between the air gain flow rate, the temperature of the boiler and the outside air [22]. In order to determine the effect of internal cooling value losses in boilers on annual periodic efficiency, some assumptions must be made in parameters such as the operating time of the burners, the annual accumulated operating time, the boiler temperature value, the outside temperature value change and the boiler sealing value. In this respect, the internal value cooling losses as a ratio to the type of boiler and fuel, instead of giving regular values at this stage, the expressions of the general results that do not change are evaluated based on the specified theoretical values.

$Q = V \times \gamma\ 1 \times (T_1-T_2) \times Cp \ (\mathrm{kcal/h})$
T_1 = Boiler temperature (°C)
T_2 = Outside temperature (°C)
C_p = Specific heat of air (kcal/kg K)

Despite the environmental sensitivity of fuel devices in terms of causing the necessary pollution in the atmosphere layer, the changes made are insufficient to take the necessary precautions. The atmosphere is a self-cleaning system, but these processes take hours and sometimes days. High population density, high traffic and large industrial facilities cause the atmosphere to be polluted more rapidly. Air polluting gases (NO2, SO2 etc.), suspended particles, special grains (organic substances dissolved in benzene, benzoprene, ammonium salts, nitrates, sulfates) are counted. Carbon monoxide and nitrogen oxides formed by internal combustion engines, sulfur dioxide formed by S fuels, hydrocarbons formed from vehicle exhausts and industrial plants are the main sources of air pollution products. Measures are taken to minimize air pollution. In power units up to 1200 ft. chimney applications, SO_2 is distributed. Gaseous wastes are reduced by the required initial cleaning of the fuel. It is converted into combustible and harmless waste values by chemical reaction and is retained as absorption. Dusty waste gases are passed through the required dust traps. There are basic specifications that must be complied with for solid, liquid and gaseous wastes. These specifications are also applied in the modern technological world order.

3. Results and Discussion

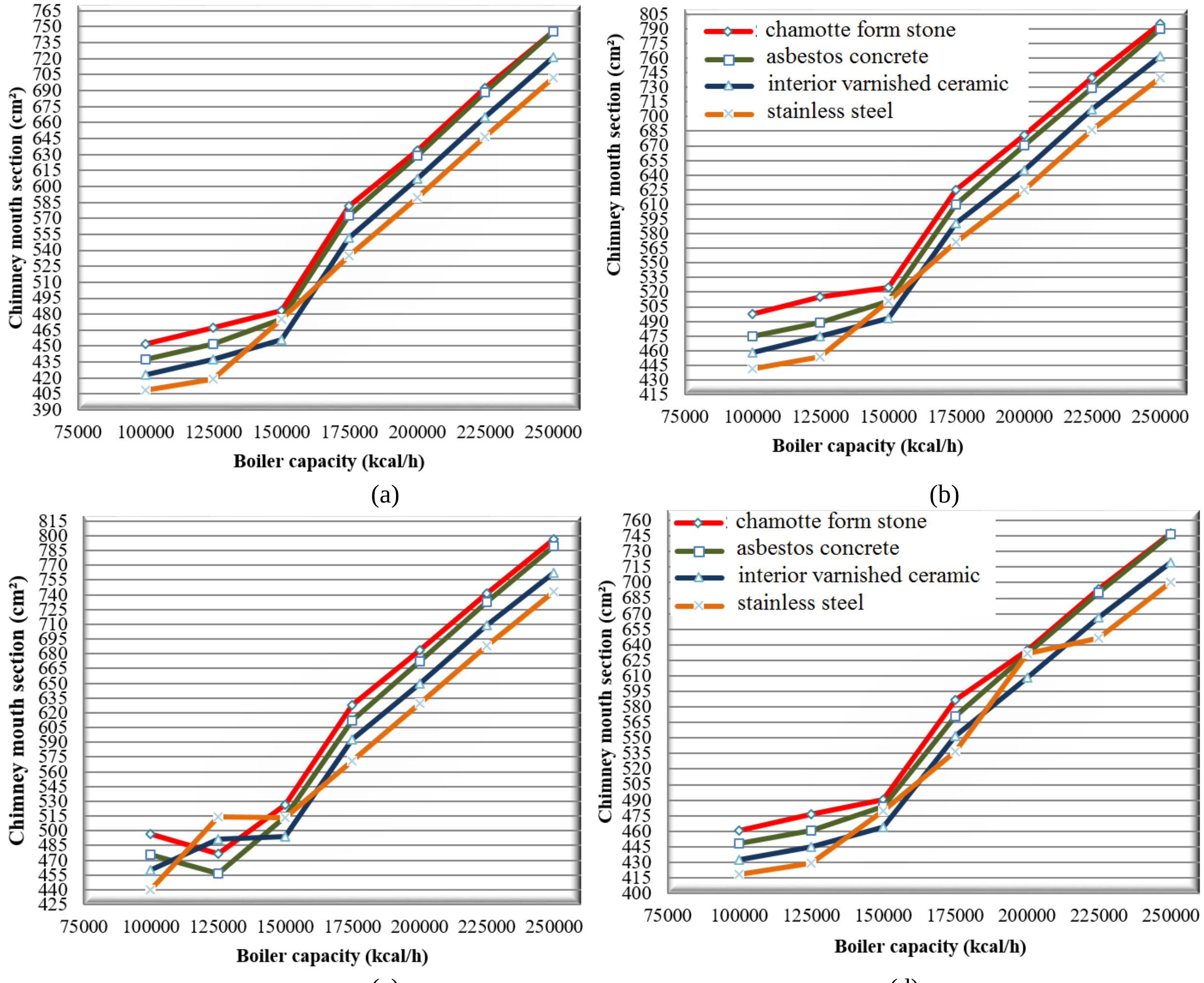
It must be assured that the exhaust-gaseous are transferred in a protective way to the exterior when a new flue system is built or an existing one is modified. Typically, a flue computation is performed for this aim. The EU flue computation standard EN 13384 depicts the computing methodology for flues with multi and single apparatuses. At minimum 2 circumstances are always controlled during the chimney calculation.

The pressure need is met to ensure that the pressure in the flue is adequate to protective transfer of the exhaust-gaseous to the exterior. Furthermore, compliance with the temperature need provides that the flue is protected in the long-term from condensing damage or that the exit does not freeze if the exterior temperatures are so less.

Because of the large selection of the chimney diameter at a constant height, the hot air inside the combustion device is overcast, resulting in incomplete combustion and excessive cost. The small diameter of the chimney affects the device’s combustion performance and results in a loss of efficiency. This necessitates determining the ideal chimney diameter while taking current conditions into account.

In this study, the most environmentally friendly chimney alternatives suitable for a solid fuel boiler designed for a planned building in Malatya province of Turkey were investigated. The important performance criteria of these chimneys were analyzed and evaluated.

In Malatya province, the chimney section areas, flow rates, waste gas densities, maximum negative pressures, inner wall temperatures of designed chimneys of different capacities designed with different forms and different chimney materials are given in Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, respectively.

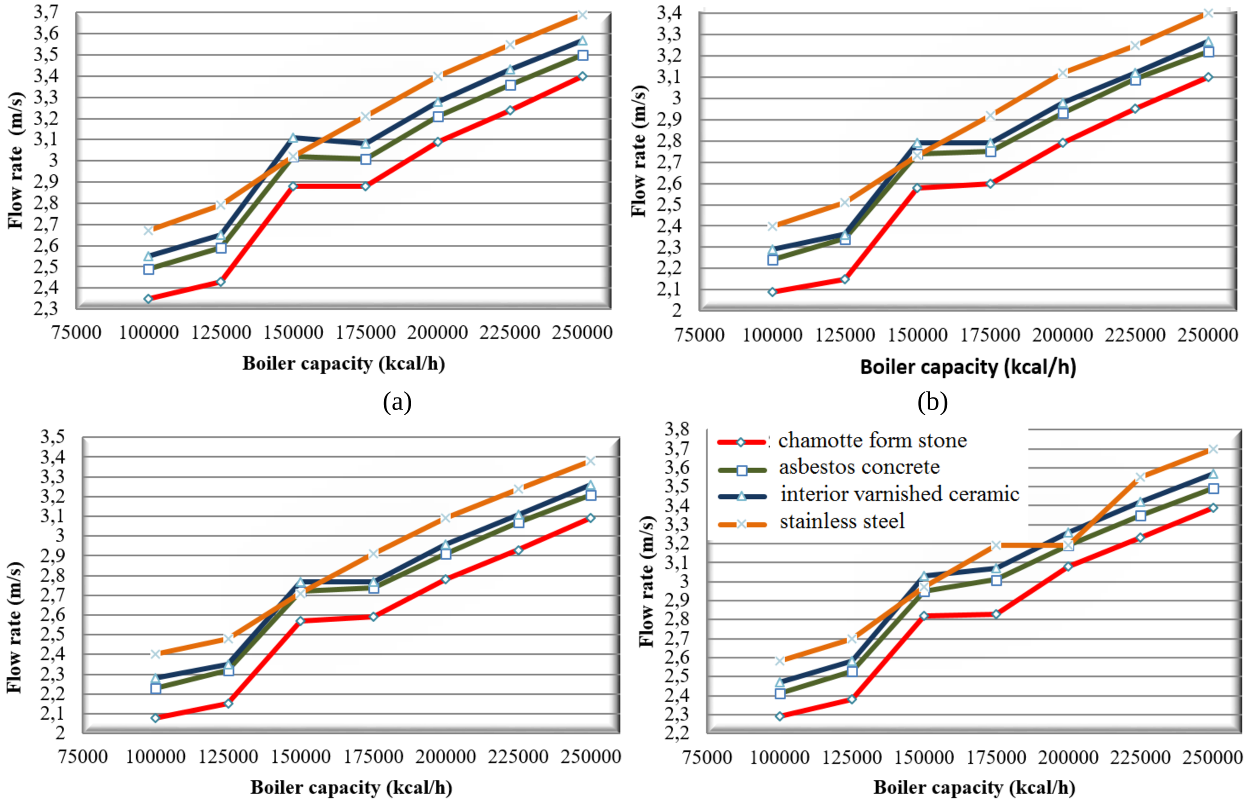


(a) (b)

(c) (d)

Fig. 2. The chimney section area of designed chimneys of different capacities designed with different forms and different chimney materials. a) circular form b) square form c) rectangular form d) oval form

As seen in Figure 2, the highest chimney section area values were obtained from square and rectangular chimneys. The lowest chimney section area values were obtained from circular and oval form chimneys. In oval form chimneys, the lowest chimney mouth cross section values were found [For the 100000, 125000, 150000, 175000, 200000, 225000 and 250000 kcal/h boiler capacities, the chimney mouth cross section values are obtained as 418.1, 429.3, 480.1, 536.7, 631.2, 646.5, and 700.7 cm^2, respectively] when “stainless steel” was used as the chimney material. In rectangular form chimneys, the highest chimney mouth cross section values were obtained [For the 100000, 125000, 150000, 175000, 200000, 225000 and 250000 kcal/h boiler capacities, the chimney mouth cross section values are obtained 497, 476.7, 526.3, 627.6, 683.8, 741.6, and 796.1 cm^2, respectively] when “chamotte form stone” was used as the chimney material.

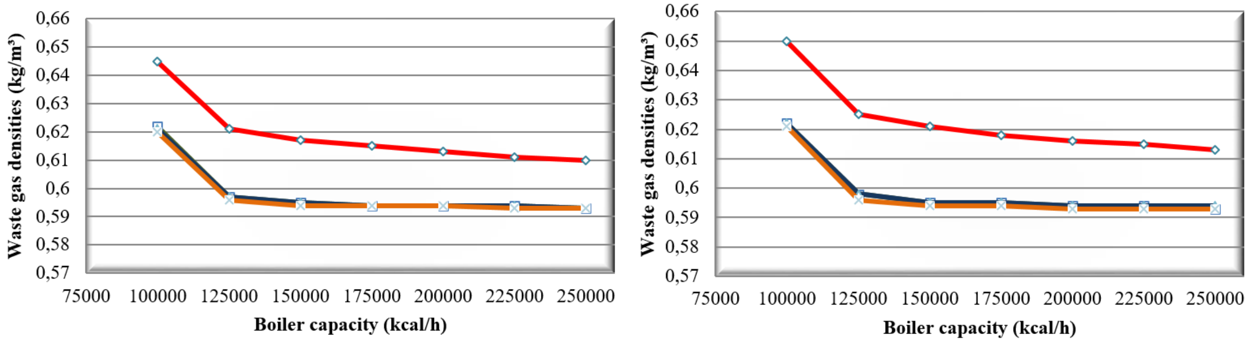


(a) (b)

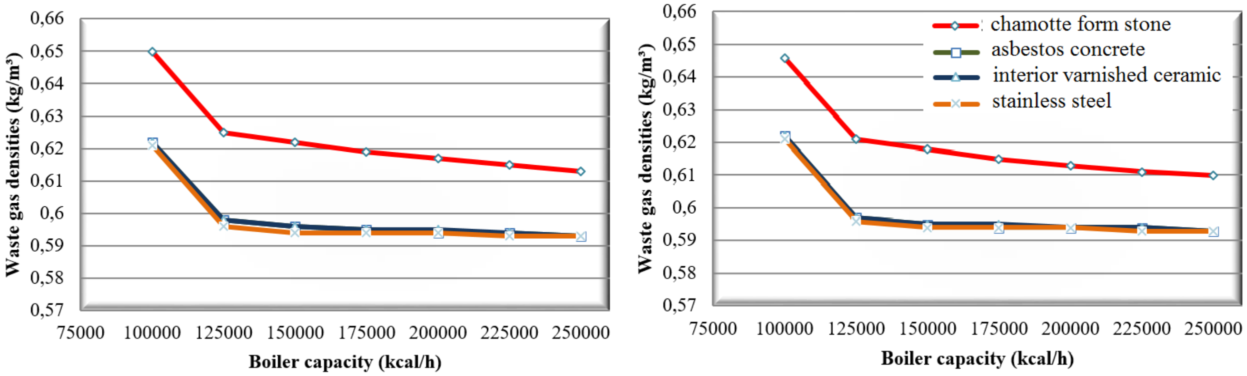
(c) (d)

Fig. 3. The flow rates of designed chimneys of different capacities designed with different forms and different chimney materials. a) circular form b) square form c) rectangular form d) oval form

As seen in Figure 3, the lowest flow rate values were obtained from rectangular form chimneys. By chamotte form stone, these values are 2.08, 2.15, 2.57, 2.59, 2.78, 2.93, and 3.09 m/s for the 100000, 125000, 150000, 175000, 200000, 225000 and 250000 kcal/h boiler capacities, respectively. The highest flow rate values were found from oval form chimneys. By stainless steel, these values are 2.58, 2.7, 2.97, 3.19, 3.19, 3.55, and 3.7 m/s for the 100000, 125000, 150000, 175000, 200000, 225000 and 250000 kcal/h boiler capacities, respectively. The highest flow rate values were obtained when "stainless steel" was used as the flue material, and the lowest flow rate values were found when "chamotte form stone" was used as the flue material.



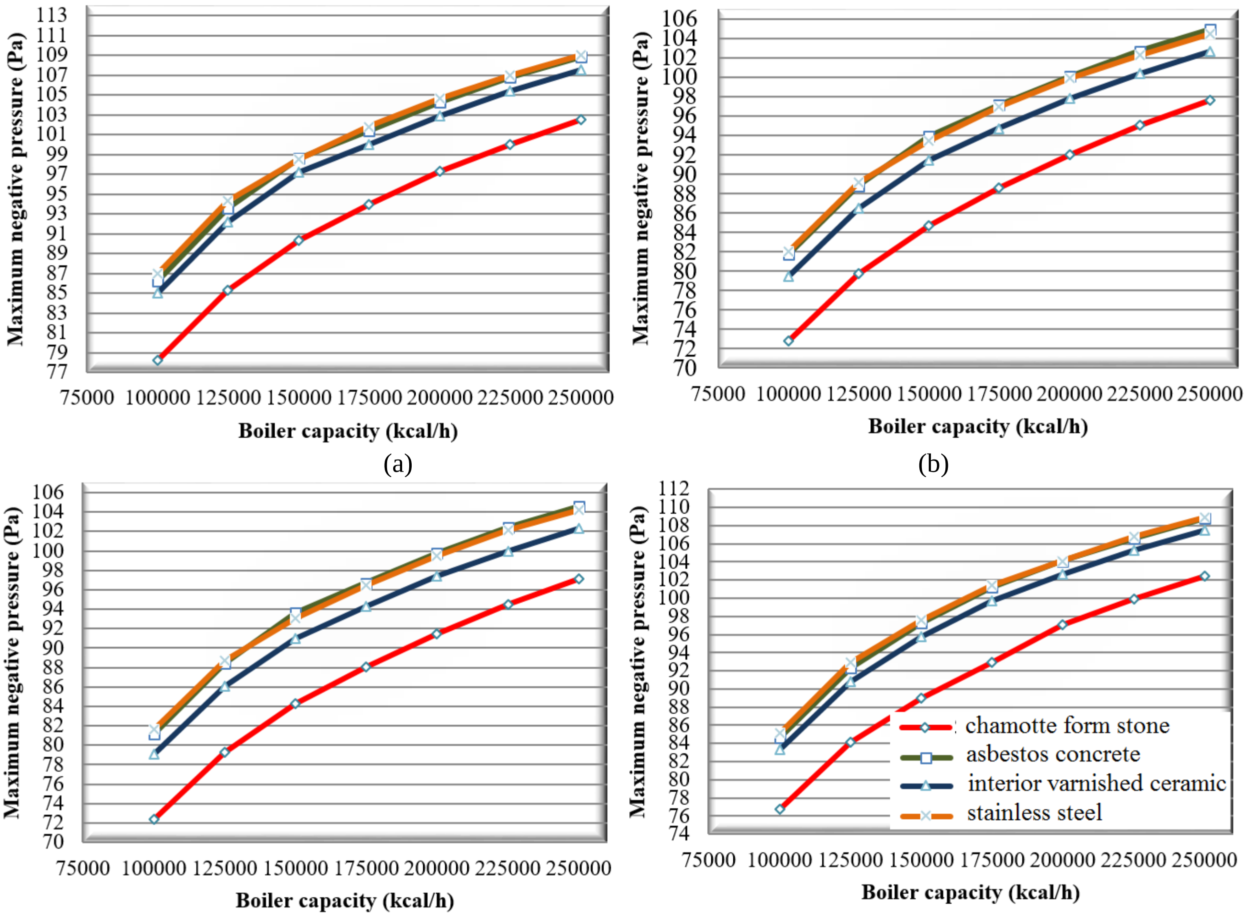
(a) (b)



(c) (d)

Fig. 4. The waste gas densities of designed chimneys of different capacities designed with different forms and different chimney materials. a) circular form b) square form c) rectangular form d) oval form

In Figure 4, the lowest waste gas density values were obtained by circular and oval form chimneys. The highest waste gas densities values were obtained from square and rectangular chimneys. The highest waste gas density values were obtained between 0.610 kg/m^3 and 0.650 kg/m^3 when “chamotte form stone” was used as the flue material, and the lowest waste gas density values were obtained between 0.593 kg/m^3 and 0.610 kg/m^3 when “stainless steel” was used as the flue material. In minimum chimney section area values, the maximum waste gas density values are analyzed.

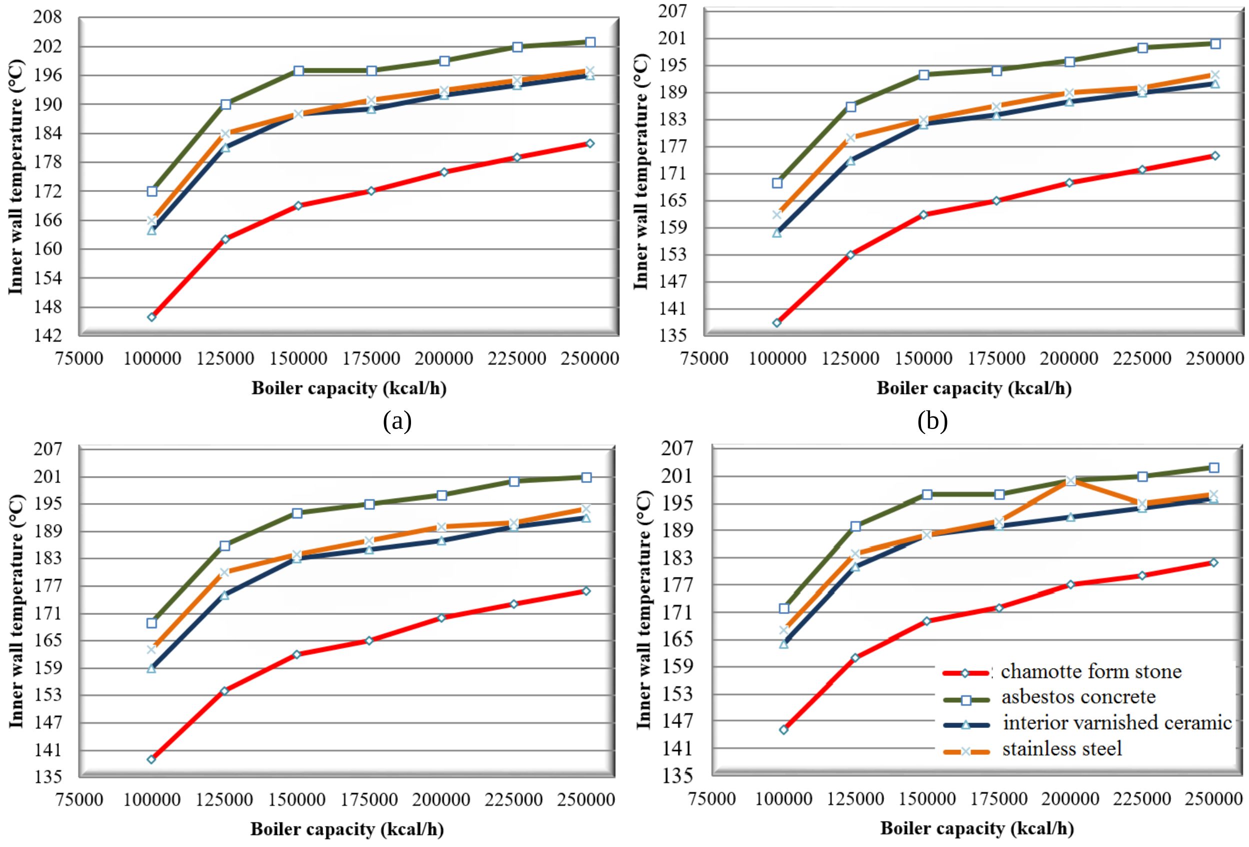


(a) (b)

(c) (d)

Fig. 5. The maximum negative pressures of designed chimneys of different capacities designed with different forms and different chimney materials. a) circular form b) square form c) rectangular form d) oval form

As seen in Figure 5, the lowest maximum negative pressure values were found by rectangular chimneys. The highest maximum negative pressure values were found from oval chimneys. The highest maximum negative pressures values were found [These values are found to be 85.1, 92.9, 97.6, 101.4, 104.1, 106.8 and 108.9 Pa for the 100000, 125000, 150000, 175000, 200000, 225000 and 250000 kcal/h boiler capacities, respectively.] when “stainless steel” was used as the chimney material. The lowest maximum negative pressures values were obtained [These values are analyzed as 72.4, 79.3, 84.3, 88.1, 91.5, 94.5 and 97.1 Pa for the 100000, 125000, 150000, 175000, 200000, 225000 and 250000 kcal/h boiler capacities, respectively] when “chamotte form stone” was used as the chimney material. “stainless steel rectangular chimneys.



(a) (b)

(c) (d)

Fig. 6. The inner wall temperatures of designed chimneys of different capacities designed with different forms and different chimney materials in Malatya province. a) circular form b) square form c) rectangular form d) oval form

In Figure 6, the lowest inner wall temperature values were obtained by square and rectangular form chimneys. The highest inner wall temperature values were obtained from circular and oval form chimneys. The highest inner wall temperature values were obtained when “asbestos concrete” was used as the chimney material, and the lowest inner wall temperature values were obtained when “chamotte form stone” was used as the chimney material. The minimum inner wall temperature value is found as 138 ^{0}C with chamotte form stone for 100000 kcal/h boiler capacity by square form chimney. The maximum inner wall temperature value is found as 203 ^{0}C with asbestos concrete for 250000 kcal/h boiler capacity by circular and oval form chimneys.

When all the figures are evaluated together, the chimney section area, waste gas density, maximum negative pressure, and inner wall temperature values increased as the boiler capacity increased. However, the flow rate value has decreased.

4. Conclusions

A good chimney is required for good, clean combustion. Chimney design must be optimized to reduce air contamination and fulfill the more clean air agenda of the government. The EN13384 standard provides a stronger defense against negligence claims. In the long run, using software to compute to this norm reduces danger and saves time. Engineering and installers advisors progressively choose the independence to apply their own computations among diverse flue trademarks, with the added benefit of having the manufacturer's information in an advanced numerical program beside the computation. Flue computation simulation converts the primarily troublesome EN 13384 computations into a more visible methodology, allowing clients to better understand the operation.

The chosen applications were from 100000 to 250000 kcal/h boilers operated by coal. This study presents the planning of critical chimney designs with a simulation supported analysis using Kesa-aladin software. The most efficient chimney types and chimney materials were evaluated comparatively.

For greener environment with greener buildings, the minimum waste gas density is needed. In this way, the lowest waste gas density value is obtained between 0.593 and 0.62 kg/m^3. In optimal chimney design, the stainless steel is generally used as the chimney material. For the 100000, 125000, 150000, 175000, 200000, and 225000 kcal/h boiler capacities, the chimney mouth cross section values are obtained as 408.35 cm^2 (for waste gas density 0.62 kg/m^3), 419.15 cm^2 (for waste gas density 0.596 kg/m^3), 475.35 cm^2 (for waste gas density 0.594 kg/m^3), 589.6 cm^2 (for waste gas density 0.594 kg/m^3), and 646.5 cm^2 (for waste gas density 0.593 kg/m^3) designed by stainless steel at circular form, respectively. For 250000 kcal/h boiler capacity, the chimney mouth cross section value is analyzed as 700.7 cm^2 (for waste gas density 0.593 kg/m^3) by stainless steel at oval form.

Acknowledgement

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