Euroasia Journal of Mathematics, Engineering, Natural & Medical Sciences
International Indexed & Refereed
ISSN: 2667-6702

COMPARISON OF CALCULATION PROGRAMS IN A STAINLESS-STEEL CHIMNEY APPLICATION

Kürşat TANRIVER

Marmara University, Institute of Science, Istanbul/Turkey

Mustafa AY

Prof. Dr., Marmara University, Faculty of Technology, Istanbul/Turkey

Geliş Tarihi / Received: 07.05.2020
Kabul Tarihi / Accepted: 15.07.2020
Araştırma Makalesi/Research Article
DOI: 10.38065/euroasiaorg.104

ABSTRACT

Exhaust gases produced by heat sources must be discharged into the atmosphere in the most reliable way without harming human health. This is possible with the chimneys attached to the heat source. There are some standards for positioning the chimneys according to the existing structures, determining the minimum height and calculating the chimney section.

The correct sizing of the chimneys also directly affects the performance of the heat source. The large selection of the chimney diameter at a fixed height causes the hot air inside the heat source to be thrown to the atmosphere more than necessary, it means incomplete combustion formation and also excess cost. Small selection of the chimney diameter affects the combustion performance of the device and causes loss of efficiency. For this, the ideal chimney diameter should be chosen considering the existing conditions.

There are many calculation programs where chimney diameter calculation can be checked on computer. Chimney diameter calculation can be checked quickly by entering different diameter range with the user's comments. When it is desired to use air exhauster to provide additional flue draught contribution to the system, it is necessary to select the restricted devices specified in the program. Therefore, calculations cannot be made or the missing diameter is calculated. This creates difficulties for its users, chimney controllers, and is often miscalculated.

In order to overcome the difficulties mentioned in this study, a chimney diameter calculation is designed in which the air exhauster features can be entered manually in Excel format. Without the air exhauster of a project application to be made with both Excel calculation both calculations with Turkey and several European countries used Kesar Aladin chimney calculation program is made. The results were compared, and comments were made on the correctness of the calculation. In addition, stainless steel chimney calculation and application of a natural gas fired lahmacun furnace were made by adding an air exhauster.

Keywords: Stainless steel chimney, chimney calculation, software for the calculation, air exhauster

1. INTRODUCTION AND OBJECTIVE

When a new combustion device system is installed, exhaust gases from these heat sources must be transported to the atmosphere. In order to perform this process safely, a correct chimney system must be designed. For this purpose, it is necessary to apply the calculation methods in which chimney section calculations can be made. These methods are described in detail in EN 13384 standard. EN 13384 is the European chimney calculation norm defining the calculation method for single and multi-device chimneys. The pressure and temperature condition are the most important criteria to be checked during the chimney calculation. The pressure condition requires that the pressure in the chimney is at a sufficient level to safely export the waste gases. Temperature is another criterion that should be checked in the long run for the protection of the chimneys from condensation damages and for the avoidance of freezing in the flue mouth depending on temperature. There are package computer programs that are highly useful for easy control of these methods and are preferred by everyone. Chimney calculations can be made by checking the diameter for different options. The modules of these programs can be selected for common stack types. The chimney design cannot be intervened manually and additional stack fan for design, etc. when necessary, limited quantities of components registered in the calculation program can be placed. This creates a sense of uncertainty among project designers and projects.

For this reason, a chimney diameter calculation program that can be applied to Excel format according to the methods specified in EN 13384 has been designed. Packaging programs are suitable for chimney designs that do not have an air exhauster and are therefore intended for natural draft chimney design and application. The results were compared with the Kesa Aladin calculation program, which was accepted by Europe and our country for the accuracy of this calculation. The calculations were renewed by adding additional chimney air exhauster data to the Excel program. Moreover, chimney with air exhauster was applied according to the calculation result.

2. CHIMNEYS

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 and that meet the conditions for the construction technique. The heat source must comply with the standards for safe, safe and uninterrupted operation due to the chimney. The heat source and chimney must work in harmony and be made of long-lasting material. Therefore, chimney systems must be calculated very well and installed by qualified persons (Kılıç, Alkan, Solmaz and Yılmaz, 2009).

Chimneys are divided into five: Ordinary, Shunt (common), Individual (individual chimneys), Kaskad chimneys and air-waste gas system chimneys.

The individual chimney application used for type B devices shall be identified in this study. Also, the system will be made of stainless-steel chimneys so that it is corrosion resistant due to combustion-induced materials because it is natural-fuel. Figure 1 shows a sample boiler chimney system suitable for the individual type B chimney.

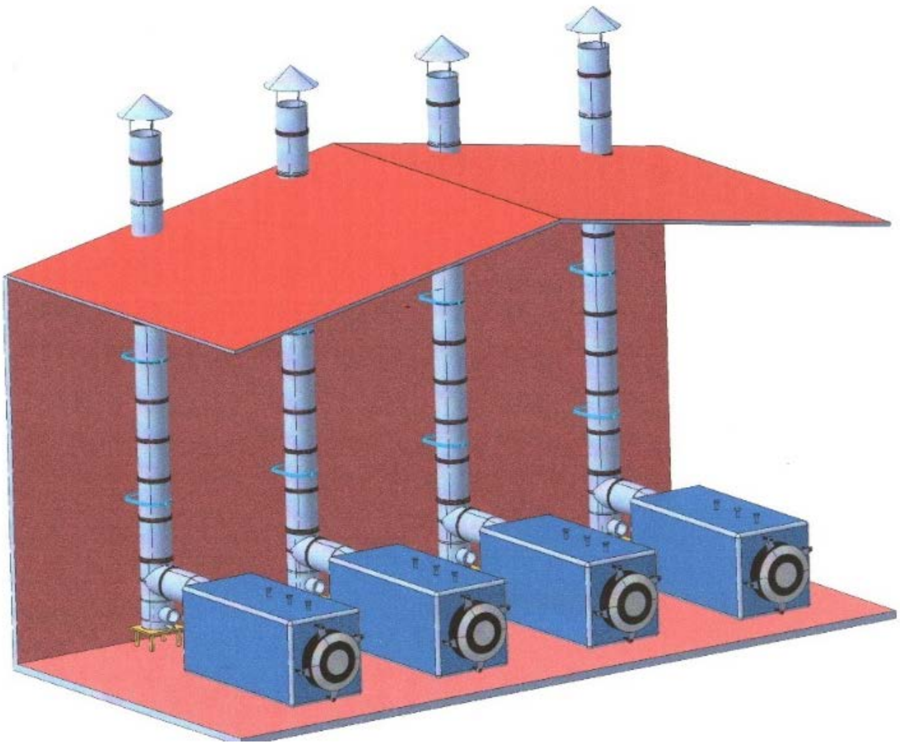

Figure 1. Example of Type B Boiler Chimneys

The stack should be resistant to high heat and fire, chemical effect, corrosion and water vapor of the gases due to combustion. Stainless steel chimneys are more durable than chimneys made of other brick and carbon steel in terms of these characteristics. However, as there are a large number of stainless steel sheets in terms of quality, methods must be well known according to the type of fuel, construction rules and the quality of the sheet must be selected. This study will process stainless chimneys used in gas-fueled systems (MEGEP, 2006).

3. STAINLESS STEEL CHIMNEYS

Natural gas calculations for 47%, electricity for 26%, and motor for 17% of the energy consumption in our country. Natural gas generates electricity in domestic and industrial applications, heating systems, and so on. and a wide range of uses in heat sources. The use of stainless steel chimneys due to the chemical effects in waste gases from natural gas-fueled heat sources is also important when production and field control is required (Aksoy, Solmaz and Y. Aksoy, 2018; İlbaş, Karyrene and Locksmith 2016).

An example of stainless steel chimney is shown in Figure 2. Stainless steel chimneys are required to bear the CE marking in accordance with Construction Products Directive (CPR) and manufacturers are required to perform factory production checks according to the relevant standards. Various standards are available such as EN 1443, EN 1856 and EN 13084. EN 1443 specifies the general specification requirements for chimneys. The rules required for metal chimneys according to EN 1856 are specified and reference is made to some test methods in accordance with EN 1859. Tests are requested to determine the safety of the chimneys in terms of strength, the temperature limit, gas tightness and distance from combustible materials that they can withstand in terms of thermal performance. The EN 13084 standard specifies the requirements for industrial chimneys.

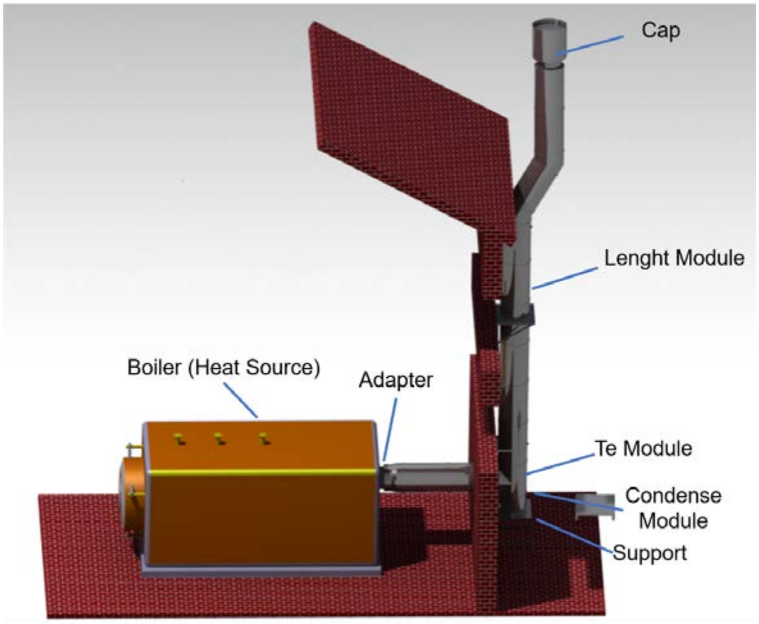

Figure 2. Stainless Steel Chimney Example

Stainless steel chimneys; The adapter, Te module, Condensate Module, lenght module and Cap sections. Chimney is supported to to the existing structure against factors like earthquake, rain, wind load, etc. condensate and cleaning lid must always be available for easy cleaning. If there is no other factor or high structure as specified in the rules, the chimney mouth must be designed to be above the rooftop. Chimney and chimney parts that are manufactured according to the standards for the combustion device or heat source must be selected. Therefore, a product mark must be present on the chimney. Precautions must be taken to ensure the sealing of the smoke ducts and the internal surfaces must be smooth.

According to the static calculations and tests, the use of the products declared by the manufacturer and Chimneys must also be fixed with the support, tension clip and flashing of the chimneys. In addition, different types of chimneys can be used as an option. These sections are shown in Figure 3.

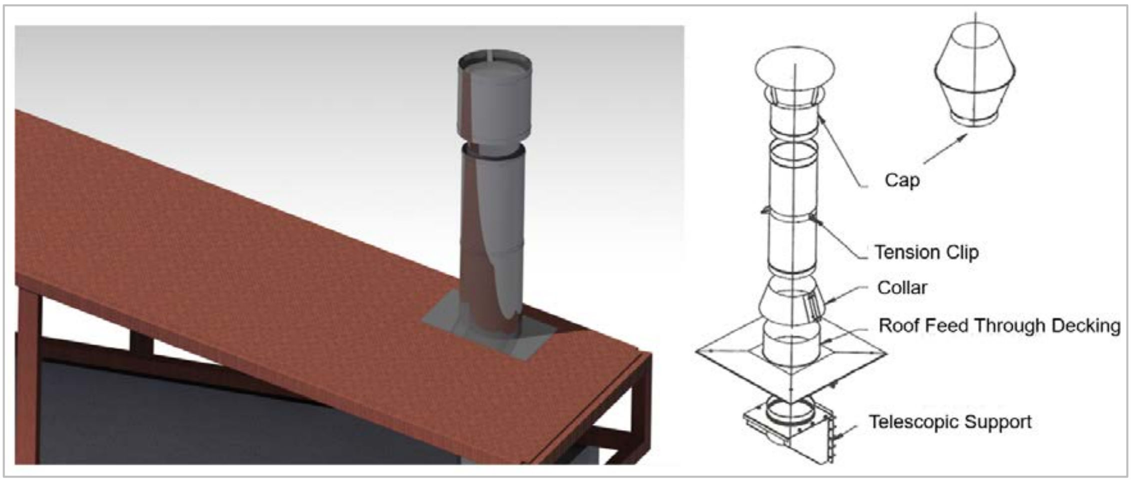

Figure 3. Stainless Steel Chimney Sections

Stainless steel chimneys can be made as single and double walls. Single wall chimneys are used in areas where the chimney is also protected by a shaft, and double wall chimneys are used inside and outside the building. Temperature conditions must be provided for the calculations made for projects designed for both. If a temperature condition is not met even within a stack shaft, double wall must be made. Insulation materials used on double wall chimneys must be fire-proof and fire-resistant. Moreover, condensation can occur at certain external air temperatures, even if the necessary conditions are met. Due to the acidic properties of this condensing water, it is not desirable to accumulate in the chimney. It must be collected at the bottom of the chimney and discharged to the sewer through a drain pipe.

To do this, condensate sewer vessel should be placed under the stack as shown in Figure 4.

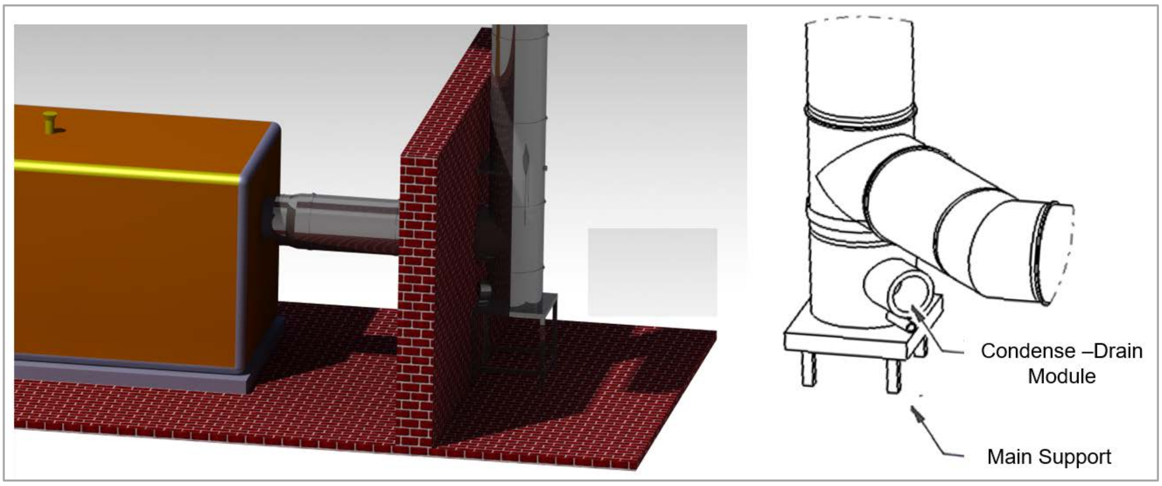

Figure 4. Condensate-Drainage Vessel

Special attention should be paid to condensation formation during the design phase and its operation to protect the building elements exposed to corrosive effects. It is particularly important to keep chimneys clean as they increase chimney durability and significantly reduce corrosion. This is possible through maintenance work. Figure 5 shows an example of a corroded chimney. The chimneys must be repaired, repaired and chimney cleaning at least once a year (Zdzislaw, 2019).

Figure 5. Corrosion formation in the Chimney[Zdzislaw, 2019]

Corrosion on the flue material is related to the condensation of exhaust gases reaching the dew point. Acidic vapors in the concentrated exhaust gas cause corrosion to the surfaces. Studies are available on AISI 304 grade stainless steel to investigate corrosive effects from condensation. According to these studies, condensation caused by 42 % sulfate ions on internal surfaces at low temperatures touched by flue gas is occurring and has a significant corrosive effect on the stacks made of AISI 304 stainless steel quality sheet. Therefore, carbon steel is not recommended for chimneys (Chandra, Kain, Dey, 2011).

In addition, AISI 316 L stainless steel containing molybdenum (Mo) is recommended to be used as an additional measure to the acidic effect in Turkish natural gas-fueled chimneys. Table 1 shows 316 L stainless steel chemical properties. The Mo value is 2,057 here (Sinaga, Simanjuntak, Manurun, 2020).

Table 1. AISI 316 Grade Stainless Sheet Chemical Characteristics [Sinaga vd., 2020]

C	SI	S	P	MN	NI	CR	MO	FE
0,029	0,390	0,035	0,050	1,648	9,930	16,860	2,057	-

Cross-sectional calculations should be done correctly for chimneys and should be high in accordance with the type of boiler. The chimney cap should be such that it prevents rainfall. Exterior air required for combustion must be provided.

In stainless steel chimneys, we often face three major problems. These are condensation, cold draft stress and inadequate draught. Condensation can be corrected by providing a temperature condition and additional thermal insulation as mentioned earlier. Cold draft occurs as the laminar flow deteriorates when cold air outside is descending from the mouth of the chimney in the chimneys where exhaust gas velocity is low. It can be solved by adding a chimney air exhauster or by adjusting the stack sizes. Inadequate draught can be removed by increasing the chimney diameter or height. High pressure can be added to these substances. In some cases, exhaust gas with high-pressure, which occurs instantly inside the chimney, damages the chimney and its connection parts. There are studies that indicate that pressure can be relieved without damaging the chimney by installing an exhaust damper in the system (Tanrıver, Çavuşoğlu, Ay ve Kurt, 2019).

As can be seen, the chimney is correctly calculated with the temperature and pressure conditions of the chimney measurements in order to solve the most important problems that appear. Height of the chimney for calculation, number of equipment to generate pressure losses, flow of exhaust gas from heat source, temperature of exhaust gas, required exhaust gas discharge pressure for the device, ambient air temperature, altitude, etc. information should be known. Most of the information here is either fixed or readily available depending on the location of the heat source, type of heat source, location. Sometimes the chimney height exceeds the structure where the heat source is located, but it is not sufficient alone. For this purpose, the chimney position and height should be determined according to the structures surrounding the chimney and the chimney calculation should be performed accordingly. For this reason, the location rules and cross-sectional calculation were examined as sub-headings.

3.1 Position Rules for Stainless Steel Chimneys

According to the EU Waste Incineration Directive, they must be effectively disposed of before reaching the level ground and life to avoid the harmful effects of exhaust gases. Since incineration and other facilities will cause significant air pollution at ground level, exhaust gases must be discharged in a controlled, appropriately, and in accordance with the relevant standards by means of structures of a certain height to protect human health and the environment. For this reason, a chimney in the appropriate height and location must be designed to achieve this objective (Anzola, 2012).

Chimneys, locations in the settlements, outlets in the building and energy efficiency should be examined, tested and documented for energy-environment-human health. The chimneys must cross the wind accumulation zone on the side of the building where they are connected. This aims to minimize the reverse pressure effects of wind. Roof wind zone are shown in Figure 6. The rules of the chimney crossing the roof were created with this logic according to the ridge and the roofing inclination. In general, the chimney is desired to be at least 1 m above of the ridge.

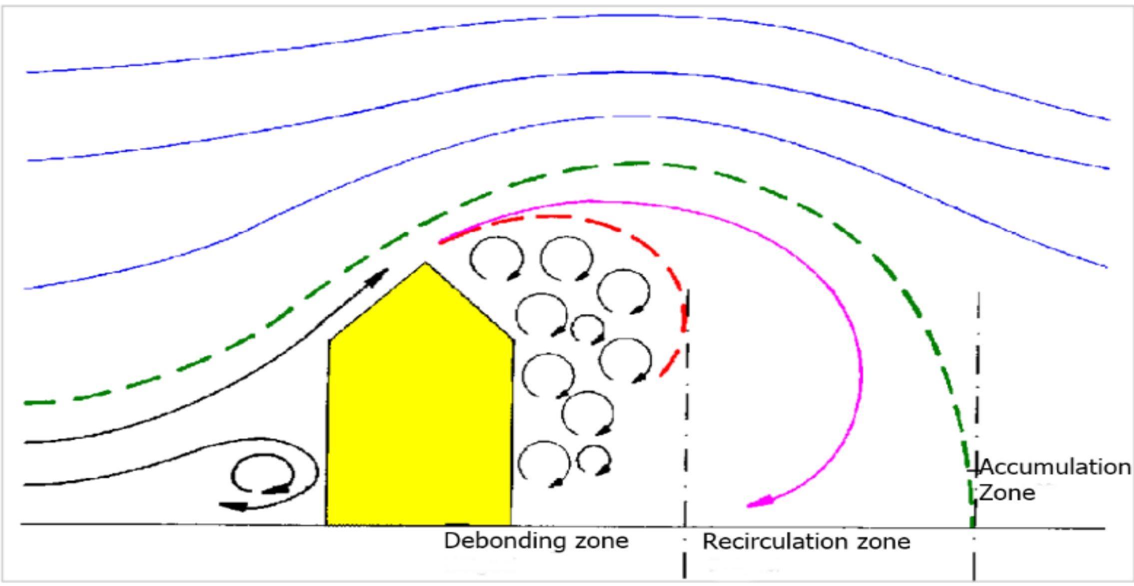

Figure 6. Roof Wind Zones

The condition of the structures around the chimney is also subject to certain rules so as not to build up wind. In accordance with EN 13384-1 standard, when a chimney is less than 15 m between the chimney outlet and the adjacent building (L) and the building is a horizontal angle (α) of more than 30 º with the chimney outlet and the top boundary is a vertical angle (β) of more than 10 º with chimney outlet is accepted to be under the influence to adjacent building. In this case, a negative 25 Pa wind pressure should be added to the chimney cross section calculation. The dimensions are shown in Figure 7.

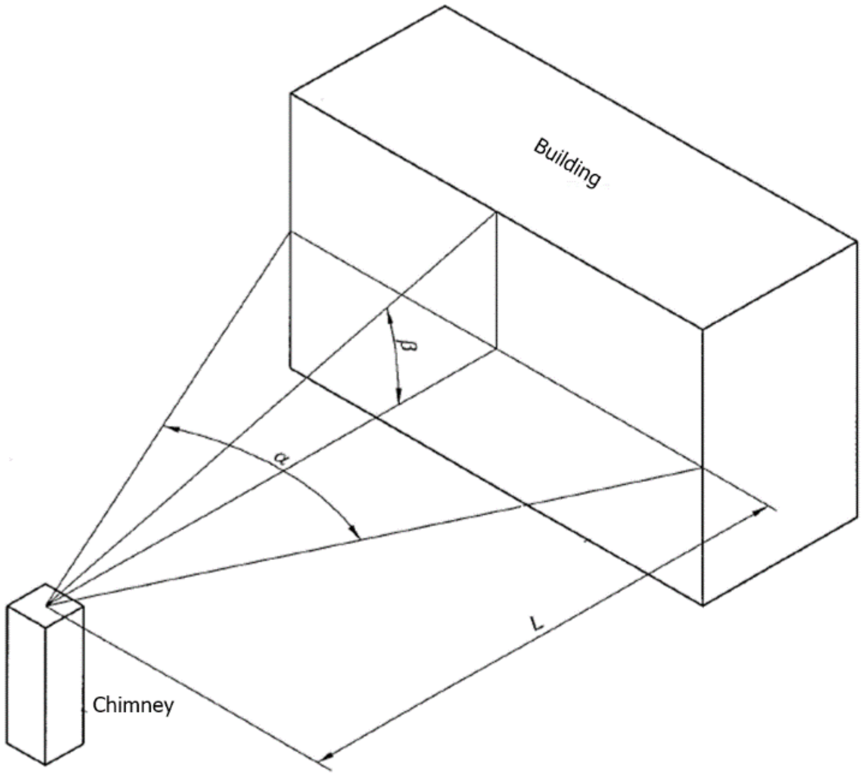

Figure 7. Position of the Chimney Compared to the Surrounding Buildings

According to the Construction Products Directive Regulation, the CE marking must be affixed on the chimneys and the technical files must be prepared by the manufacturers. Furthermore, the outlet of the chimneys must comply with the rules specified in EN 15287.

The necessary precautions should be taken to expand on the high chimneys and carry the chimney itself. Chimney must be resistant to high temperatures that may occur due to any fire. Minimum distance must be specified.

The chimney cross section should be selected according to the combustible device to ensure optimum draught performance. Chimnet cross section should be calculated according to standards by specialists. Chimney cross section should be circular unless required.

3.2 Chimney Cross Section Calculation

The large selection of the chimney diameter at a constant height causes the hot air inside the combustion device to be overcast, which means incomplete combustion and also excessive cost. The small selection of the diameter of the chimney affects the combustion performance of the device and results in loss of efficiency. This requires the selection of the ideal chimney diameter, taking into calculation the current conditions.

The draught the chimney inlet consists of the difference in density between the exhaust gas inside the chimney and the outdoor air. The exhaust gas density should always be lower than the external ambient density. This condition occurs with a temperature difference. The chimney height, heat losses, waste gas temperature and external ambient temperature are therefore very important for chimney draft.

The chimney also starts to draw as the high-temperature exhaust gas enters the chimney and tends to rise due to the difference in density with the external environment. This draught, Depending on the type of device, 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. The chimney can be constructed at positive pressure by providing forced draft with a air exhausteraddition where required.

The thermal losses formed as a result of exhaust gases being discarded to the atmosphere vary between 10-35 %. The hot exhaust gas from the boilers is cooled down by a heat exchanger such as an economizer to be added to the system, a recuperator, and the heat generated from the boiler combustion air or water, etc. fluids can also be heated. The Exhaust gas temperature will then be lower than the catalogs of the heat source. When calculating the diameter of the chimney, the temperature at the flue mouth must be taken (Mineral, 2014; Terhan ve Çomaklı, 2015).

Broad information on chimney calculation is available in EN 13384. As stated in the standard, it is more appropriate to use computer programs as chimney calculations will be difficult to do manually. However, chimney calculation programs must also fulfill the rules set out in the standard. Figure 8 shows the main data required for the chimney’s calculation (Kılıç et al., 2009).

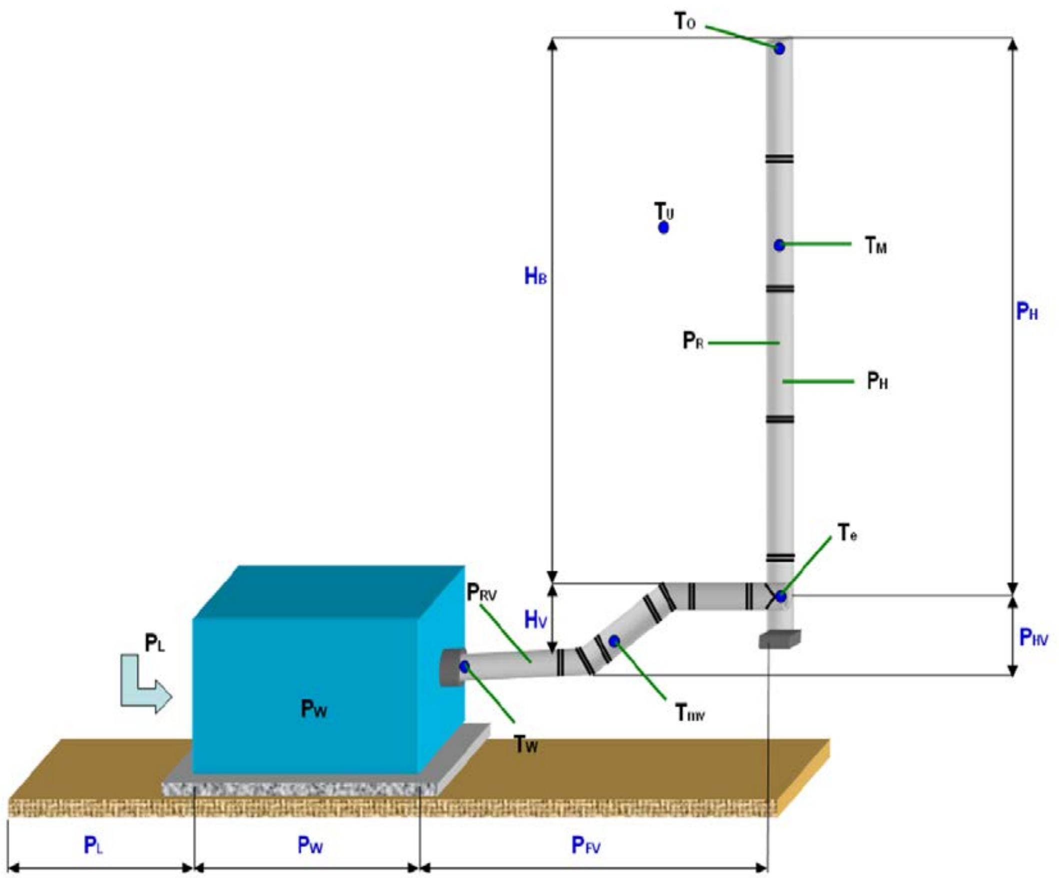

Figure 8. Data Required for Chimney Calculation [Sword, etc., 2009]

Icon List

- PZ: Pressure where exhaust gas enters the chimney (Pa)
- PZE: The required pressure at the point where the exhaust gas enters the chimney (Pa)
- PR: Friction pressure inside the chimney (Pa)
- PD: Static pressure of exhaust gas in the chimney (Theoretical draught) (Pa)
- PW: Required push pressure for device/ Heat source (Pa)
- PFV: The required push-pressure (Pa) for the connecting pipe
- PL: The required pushing pressure for supply air (Pa)
- Tw: Heat source exhaust gas outlet temperature (K)
- TMV: Average temperature of exhaust gas in connecting pipe (K)
- Te: Exhaust gas temperature at the chimney inlet (K)
- Tm: Average temperature of exhaust gas (K)
- Tu: Ambient temperature through the chimney (K)
- To: Temperature of exhaust gas in chimney outlet (K)
- Tp: Raw point temperature (K)
- TL: External Air temperature (K)
- HV: Vertical distance between heat source outlet and exhaust gas chimney inlet (m)
- HB: Effective chimney height (m)

Temperature and pressure conditions are required for draught conformity. If these conditions are met when on-hand data is used, the chimney draught is suitable. The temperature requirement must be as in Equation 1, Equation 2.

$$T_0 \geq T_P \quad (1)$$

$$T_e > T_L \quad (2)$$

Pressure condition must be as in Equation 3,4 and 5.

$$P_Z = P_H - P_R \quad (3)$$

$$P_{ZE} = P_W + P_{FV} + P_L \quad (4)$$

$$P_Z > P_{ZE} \quad (5)$$

The chimney section be calculated according to the temperature and pressure conditions mentioned and lahmacun furnace chimney will be designed.

4. APPLIED COMPARISON OF CHIMNEY CALCULATION PROGRAMS

The chimney diameter calculations of type B devices shall be in accordance with the standard EN 13384-1. Additionally, the Pw = 10 Pa for stone and lahmacun furnace and the exhaust gas temperature Tw =200 °C shall be considered. The design shall be designed without air exhausterand hoods for both programs and the results shall be compared. The without air exhauster chimney design drawing Figure 9 shows the data required for chimney dimension cross section calculations in Table 2.

Table 2. Data Required for Without Air Exhauster Chimney Cross Section Calculation

Explanation	Dimension	Unit
Thermal Capacity	35	Kw
P_w	10	pa
T_w	200	pa
Connecting Part (1)	7	m
Losses (1)	Bend 90=2	Pieces
Chimney (2)	14	m
Losses (2)	Te 90=1, Cap=1	Pieces

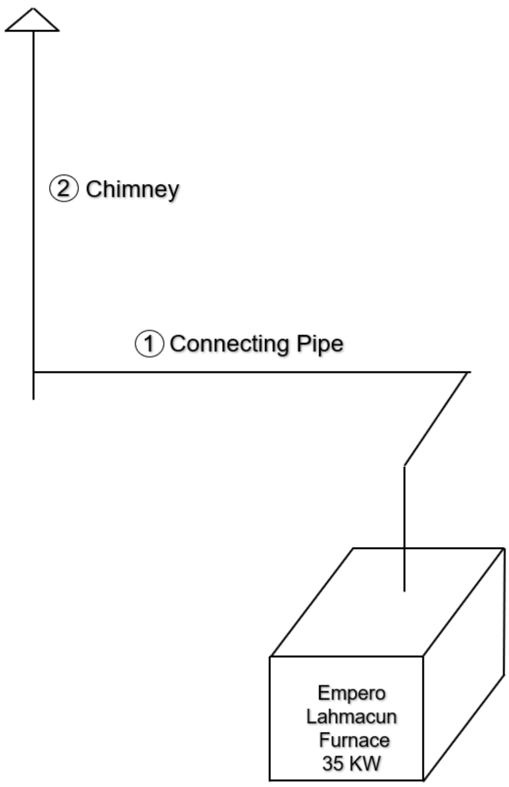

Figure 9. Without Air Exhauster Chimney Design

The appropriate solution range can be found easily as a result can be immediately seen when different diameter ranges are entered in the calculation programs. Therefore, results were observed by entering the diameter range Ø120, Ø140 and Ø160 in the calculation programs. Fig. 10 for Kesa aladin calculation program and the results for Excel calculation are shown in Figure 11. It has been observed in both calculations that the diameter Ø120 does not meet the pressure condition and that the proper draught is provided by establishing the pressure condition in the dimensions Ø140 and Ø160. According to this; Since Kesa aladin is based on the calculation program, the Excel program results from the pressure condition. Considering the diameter Ø160, the Kesa aladin calculation pressure condition was 18.8 Pa while the Excel program was 29.16 Pa. The calculation result in the Excel program was the same as Kesa aladin, but not as accurate as the tolerance. In Kesa aladin program, it is estimated that the calculation is more accurate because of the insulation materials, the clarity of zeta values of the losses in the stack and the diversity of other selection parameters.

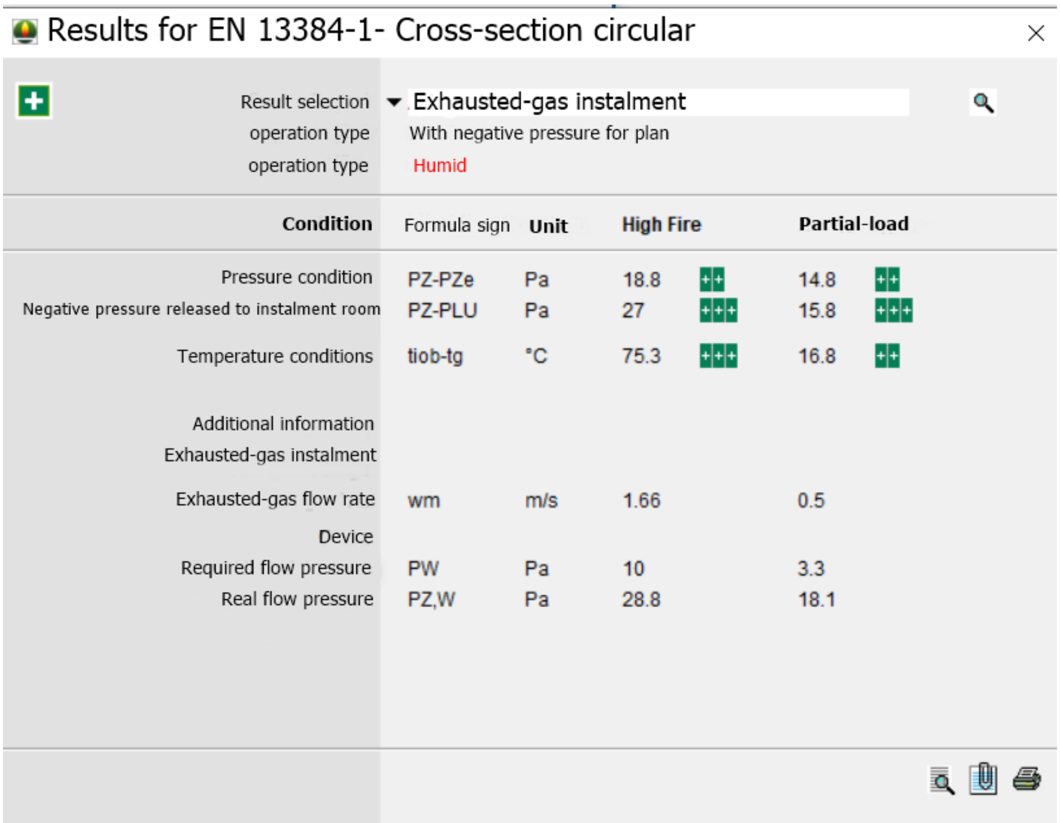

Figure 10. Without Air Exhauster Chimney Kesa Aladin Calculation Result Display

CHIMNEY DIAMETER CALCULATION SECTION								
PH	>=	PW+PL+PA+PBP	CHIMNEY HEIGHT	H=	14.00	Meter	D= 160	mm
37.67769	>=	29.16544	CHIMNEY CROSS- SECTION ARE SUITABLE					

Figure 11. Without Air Exhauster Chimney Excel Calculation Result Display

Temperature condition cannot be considered in Excel calculation. Since the Exhaust gas temperature of 200°C of the lahmacun furnace is above the condensation and freezing temperature, no temperature requirements are required. This shows that the calculation is correct for this project. However, this is a limiting feature since the Excel calculation cannot be used for devices with low exhaus gas temperature such as condensing combi boiler or boilers.

On the detailed results screen of Kesa aladin calculation program, different outputs such as exhaust gas velocity are checked instantly and the exhaust gas velocity can be controlled only within the Excel calculation program. Furthermore, the results in different diameter ranges can be viewed on a separate screen instantly using the Kesa aladin calculation program option. A comparative summary of the result section is shown in Table 3.

Table 1. Comparison of Chimney Programs

Data	Kesa aladin	Excel
Pressure condition	Yes (in result screen)	Yes (in conclusion part)
Temperature condition	Yes (in result screen)	No
Exhaust gas veloicity	Yes (in result screen)	Yes (in calculation)
Instantaneous measure control	Yes (in result screen)	Yes (in conclusion part)
Accuracy of calculation in different diameter	Reference program	Yes
Result Optimizasyon	Yes	No
Precision	Yes	No

A air exhauster and hood were added to the Excel calculation, which was found to provide the pressure condition, and a chimney was designed and applied. Fig. 12, the with air exhauster chimney design drawing shows the data required for chimney cross-section calculations in Table 4.

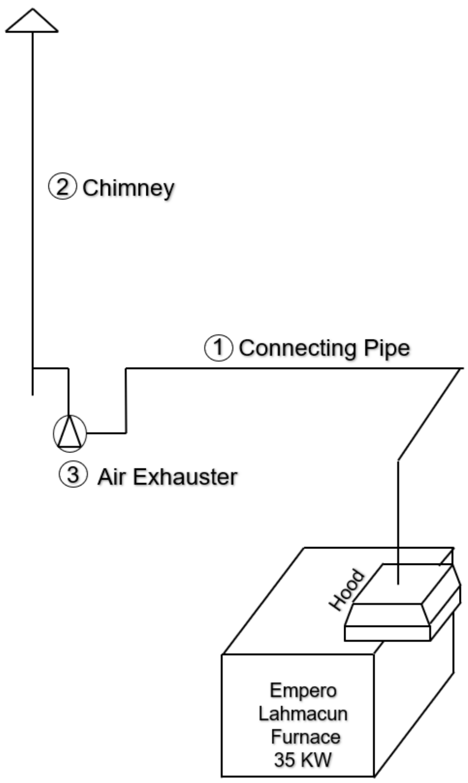

Figure 1. Chimney Design with Air Exhauster

Table 4. Data Required for With Air Exhauster Chimney Cross Section Calculation

Explanation	Dimension	Unit
Thermal Capacity	35	Kw
P_w	10	pa
T_w	200	pa
Connecting Part (1)	7	m
Losses (1)	Bend 90=5	Pieces
Chimney (2)	14	m
Losses (2)	Te 90=1, Cap=1	Pieces
Air Exhauster Air Volum (3)	1.800	m^3/h
Air Exhauster Blow Heigh (3)	450	Pa

The results for the Excel with air exhauster chimney are shown in Figure 13. The air exhauster with 315 m3/h and 135 Pa for the chimney, measuring Ø160, has been found suitable for the draw by establishing the pressure condition.

CHIMNEY DIAMETER CALCULATION SECTION				
PH+PAir Exhauster	>=	PW+PL+PA+PBP	CHIMNEY HEIGHT	H= 14.00 Meter D= 160 mm
172.67769	>=	143.01158	CHIMNEY CROSS- SECTION ARE SUITABLE	

Figure 13. With Air Echauster Chimney Excel Calculation Result Display

Installation of a lahmacun furnace with a 35 Kw thermal capacity, designed with air exhauster and hood, is done as shown in Figure 14.a and Figure 14.b. Furthermore, no problems were observed in draught that was tested by starting the furnace.

(a) (b)

Figure 14. Chimney Application

5. CONCLUSION

In order to eliminate the uncertainties mentioned in this study, a chimney diameter calculation was designed to allow manual entry of air exhauster features in Excel format. A project to be implemented without air exhauster has been calculated using both Excel and Kesa aladin calculation program and the results have been compared.

The appropriate solution range can be found easily as a result can be immediately seen when different diameter ranges are entered in the calculation programs. Therefore, results were observed by entering the diameter range Ø120, Ø140 and Ø160 in the calculation programs. It has been observed in both calculations that the diameter Ø120 does not meet the pressure condition and that the proper draught is provided by establishing the pressure condition in the dimensions Ø140 and Ø160. According to this; Since Kesa aladin is based on the calculation program, the Excel program results from the pressure condition. Considering the diameter Ø160, the Kesa aladin calculation pressure condition was 18.8 Pa, while the Excel program increased 29.16 Pa. The calculation result in the Excel program was the same as Kesa aladin, but not as accurate as the tolerance. In Kesa aladin program, it is estimated that the calculation is more accurate because of the insulation materials, the clarity of zeta values of the losses in the chimney and the diversity of other selection parameters.

On the detailed results screen of Kesa aladin calculation program, different outputs such as exhaust gas veloicity are checked instantly and the exhaust gas veloicity can be controlled only within the Excel calculation program. The results in different diameter ranges can be viewed on a separate screen instantly using the Kesa aladin calculation program option. Furthermore, a stainless steel chimney calculation and installation of a natural gas-fueled lahmacun furnace was made by adding a air exhauster and hood. No problems were observed in the chimney draught that was tested by running the furnace.

Temperature condition cannot be considered in Excel calculation. Since the Exhaust gas temperature of 200°C of the lahmacun furnace is above the condensation and freezing temperature, no temperature requirements are required. This shows that the calculation is correct for this project. However, since the Excel calculation cannot be used for devices with low exhaust gas temperature such as condensing combi boiler or boilers, it is recommended that these devices be not used in excel chimney diameter calculations. Programs can be developed to check temperature condition for future studies.

REFERENCES

1. Aksoy, B.A., Solmaz, Ö ve Aksoy Y. (2018). Baca gazlarının ekserji analizi ve yapay sinir ağları ile modellenmesi. Pamukkale Univ Muh Bilim Derg, 24(4), 610-615, 2018.

doi: 10.5505/pajes.2018.32549

2. Anzola, M. (2012). Sustainable Engineering: Renewable Energy Systems and the Environment. University of strathclyde Department of Mechanical and Aerospace Engineering A thesis of Master of Science, UK.

3. Chandra, K., Kain, V., Dey. G. K. (2011). Accelerated Corrosion of a Boiler Chimney: Causes and Preventive Steps. J Fail. Anal. and Preven. (2011) 11:466–472. DOI 10.1007/s11668-011-9474-8

4. Madan, E. (2014). Seramik Fırınlarında Atık Baca Gazından Enerji Geri Kazanımı ve Bir Uygulama. Bilecik Şeyh Edebali Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Tezi, Bilecik.

5. İlbaş, M., Karyeyen, S ve Çilingir, K. (2016). Ön Karışımsız ve Ön Karışımlı Metan Alevlerinin Baca Yanma Parametrelerinin Deneysel Olarak İncelenmesi. Politeknik Dergisi, 2016; 19.(DOI): 10.2339/2016.19.3 357-365 (3) : 357-365

6. Kılıç, A., Alkan, N., Solmaz, Ö ve Yılmaz, T. (2009) Bacalar. İgdaş Yayınları-22 ISBN: 978-975-7003-22-9, İstanbul

7. MEGEP, (2006). Tesisat Teknolojisi ve İklimlendirme. Bacalar ve Yanma Isısı. T.C. Millî Eğitim Bakanlığı Mesleki Eğitim ve Öğretim Sisteminin Güçlendirilmesi Projesi, Ders Notları.

8. Sinaga, A.J., Simanjuntak, S ve Manurun C. (2020). SJoME Vol. I No. 2, Maret 2020. E-ISSN 2685-8916. DOI: https://doi.org/10.36655/sproket.v1iNo%202.186

9. Tanrıver, K., Çavuşoğlu, İ., Ay, M., Kurt M. (2019). Biyogaz Yakıtlı Gaz Motorlu Kojenerasyon Sistemlerinde Egzoz Boru Tasarım İyileştirilmesi ile Verimlilik Artırımı. İCAR Congress 2020 Uluslararası Akademik Araştırmalar Kongresi, 11-18-19 Şubat 2020 ISBN: 978-605-7736-81-9, Bolu.

10. Terhan, M., Çomaklı, K. (2015). "Baca Gazı Atık Isısı ile Kazan Yakma Havasının Ön Isıtılmasının Fizibilitesi," Mühendis ve Makina, cilt 56, sayı 668, s. 56-63.

11. Zdzislaw, P. (2019). Failure of a steel boiler chimney caused by corrosion of the structural shell plate. ICSF 2019 MATEC Web of Conferences 284,09007. https://doi.org/10.1051/matecconf /201928.