Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X
Volume 3, Issue 3, 2025

ENHANCING THERMAL AND COMBUSTION PERFORMANCE OF GAS WATER TANK GEYSER THROUGH BAFFLE INTEGRATION

Faiq Said*[1], Afzal Khan[2], Zeeshan Khan[1]

[1]*Department of Mechanical Engineering, University of Engineering & Technology, Mardan 23200, Pakistan*

[2]*Department of Mechanical Engineering, University of Engineering & Technology, Peshawar 25120, Pakistan*

*[1]engr.faiq.said@uetmardan.edu.pk

DOI: https://doi.org/10.5281/zenodo.15037922

Keywords
Water tank Geyser; thermal efficiency; combustion efficiency; baffles; burner

Article History
Received on 07 February 2025
Accepted on 07 March 2025
Published on 17 March 2025

Corresponding Author: *

Abstract

Enhancing the thermal and combustion performance of gas water tank geysers is crucial for improving energy efficiency and minimizing fuel consumption. This study systematically investigates the impact of seven distinct baffle configurations baseline (no baffle), strip, cylindrical, conical, finned conical, frustum, and bladed frustum on the thermal and combustion performance of a gas water tank geyser. Experimental findings demonstrate that structured baffle designs significantly enhance heat transfer, optimize fuel-air mixing, and reduce fuel consumption. Among the tested configurations, the bladed frustum baffle exhibited the highest thermal efficiency (69.03%), surpassing the conical baffle (61.24%) by 7.79% while achieving an 8.4% reduction in gas consumption. The frustum baffle demonstrated a 5.83% increase in thermal efficiency (67.07%) and a 6.49% reduction in gas consumption compared to the conical baffle, underscoring its superior heat retention and transfer capabilities. In terms of combustion performance, the frustum baffle achieved a 3.99% higher combustion efficiency (69%) than the conical baffle (65.01%), ensuring more complete fuel utilization. However, the bladed frustum baffle showed a 0.61% decline in combustion efficiency (64.4%), attributed to increased stack temperature and altered combustion dynamics. Overall, the frustum baffle emerges as the optimal configuration, offering the best balance between improved thermal efficiency (67.07%), stable combustion (69%), and reduced fuel consumption. These findings provide a robust framework for enhancing the energy efficiency of gas-fired heating systems in residential applications.

1. Introduction

The economy of Pakistan is mostly dependent on oil, coal, gas, and electricity, etc. According to a report 2023 by Pakistan Energy year book, Pakistan is one of the most focused countries in the world, with domestic gas usage of around 30 percent of its primary energy supply. The country has a vast network of gas pipelines serving over 10.7 million users [1]. Natural gas provides 50% of Pakistan's energy demands, despite the country's energy challenges. Gas water heaters are responsible for 33% of household use, which makes up 24%. The use of wood and fossil fuels for traditional heating exacerbates energy problems [2]. The increasing global energy demand, driven by population growth, technological advancements, and industrial expansion, remains heavily dependent on nonrenewable sources, with oil, coal, and natural gas accounting for approximately 40%, 35%, and 20% of consumption, respectively. Despite their role in economic and technological progress, the combustion of fossil fuels generates substantial environmental pollutants, necessitating sustainable energy alternatives [3]. Despite the projected annual growth of renewable and nuclear energy by 2.6% and 2.3%, respectively, fossil fuels are expected to remain the primary energy source, meeting 78% of global demand by 2040. Within this sector, natural gas consumption is anticipated to grow at 1.9% per year, while liquid fuels and coal are expected to increase by 1.1% and 0.6% annually, respectively [4]. Tank-storage water heaters, commonly known as geysers, are the most widely used water heating systems in Pakistan, available in both electric and gas models. These heaters contain an internal heating element that maintains water at the thermostat-set temperature throughout the day, regardless of usage. When hot water is drawn, the tank simultaneously refills with cold water, reducing the overall water temperature and requiring continuous heating to sustain the desired level [5].

Srinivasarao, M., et al., analyzed three burner configurations: 2-stage, 3-stage, and 4-stage. The 4-stage burner showed the best performance, with the lowest NOx emissions (0.8 PPM/kW) and no ammonia slip at 40 kW. The 2-stage burner performed well at 10 kW but had higher emissions at higher power. Improved mixing, oxygen control, and preheating led to better efficiency in the 4-stage setup [6]. Sekar et al. used ANSYS Fluent in this study and found that increasing hydrogen (25%, 50%, 75%) in methane-air mixtures improved combustion, raised temperature (H75 highest), enhanced turbulence, and reduced CO_2 emissions, while incomplete methane combustion increased CO formation [7].

Ali, I., et al., study recovered 1901.71–2074.9 W of heat from wastewater (30–40°C), reducing gas consumption with a 1.86–3.42% energy difference. A heat exchanger preheated inlet water (5–15°C), and a servo motor-based gas flowmeter maintained a stable output temperature, improving efficiency and cost savings [8]. Shervani Tabar, M.T., et al., in this research, focus on optimizing gas consumption and increasing thermal efficiency in a household gas water heater. By designing and configuring baffles inside the middle tube, the retention time of exhaust gases is increased, enhancing thermal energy retention. Numerical simulations using Ansys Fluent were conducted to analyze the combustion process, heat transfer, and gas velocity distribution. Results show that methane gas is fully consumed, and the simulation results align with experimental findings, confirming improved efficiency [9].

Gopal et al. developed a low-cost gas geyser designed to mitigate CO and CO_2 emissions through sensor-based combustion control and filtration. A CO sensor in the heat exchanger detects incomplete combustion, triggering gas flow modulation to optimize oxygen supply. An activated charcoal filter in the exhaust duct adsorbs residual emissions, while a secondary CO sensor ensures safety by initiating an automatic shutdown if high CO levels persist. This experimental approach integrates real-time monitoring, emission control, and automated safety mechanisms, demonstrating a significant reduction in harmful emissions compared to conventional gas geysers [10].

Hosseini, H., et al in this paper aims to boost efficiency in a household water heater by replacing the traditional shell and tube heat exchanger with a finned flat plate. The proposed flat plate exchanger has the potential to increase efficiency by 20% to 50% compared to conventional configuration [11]. Veetil, J.E., et al., in this study, cleared how flames behave on perforated plate burners. They found that when the holes are arranged in a staggered way, the flames are taller and farther from the burner compared to when the holes are arranged in a straight line. Also, increasing the space between the holes made the flames more stable [12]. Samkaria, R., et al., study discussed a smart geyser that can automatically adjust its heating using a special Atmega16 microcontroller. This helps save electricity and makes the geyser more efficient. Users can also set their preferred temperature for added convenience [13]. Singh, E.G. and B. Singh investigated improving gas geyser efficiency through an economizer in the heat exchanger. Findings revealed a 25% heat flow increase, offering insights for enhancing energy-efficient water heating systems [14].

Despite extensive studies on baffles in industrial heat exchangers and boilers, their application in domestic gas water tank geysers remains underexplored. Existing research primarily focuses on conventional heating methods, with limited analysis of different baffle geometries on thermal and combustion efficiency. Previous studies lack a comprehensive comparison of various designs in terms of fuel consumption and emissions, relying mostly on computational simulations without real-world validation. This study systematically investigates multiple baffle designs integrated with circular burners, experimentally analyzing their effects on thermal efficiency, combustion performance, fuel savings, and emissions. By bridging the gap between theoretical and practical applications, it provides new insights into optimizing domestic water heating systems for improved energy efficiency and environmental sustainability.

2. Methodology

2.1 Methodological Workflow

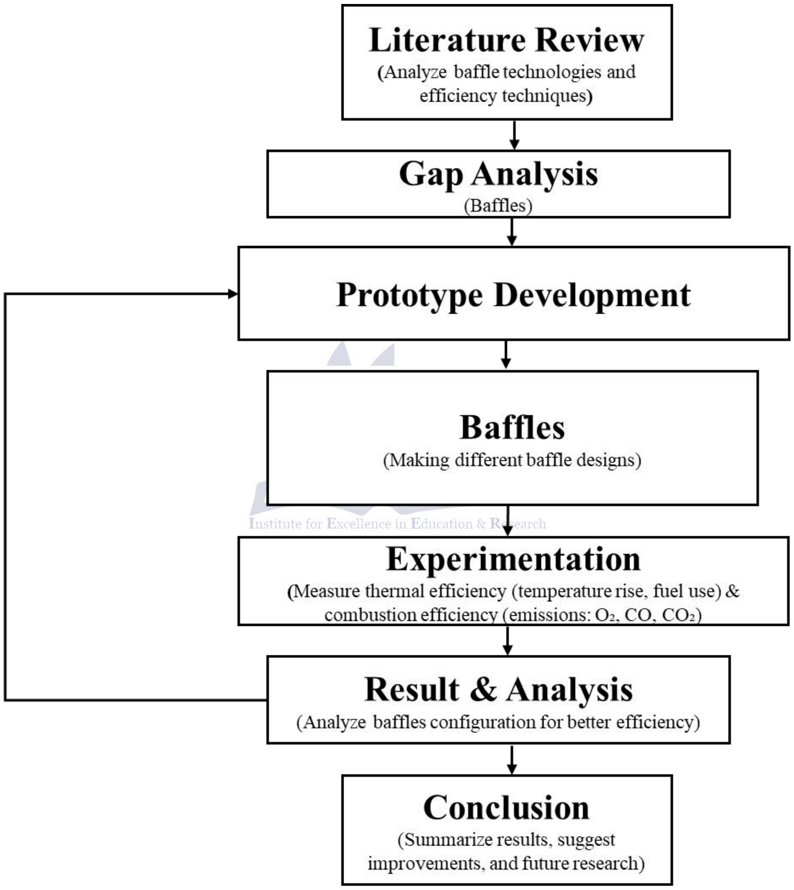


Figure 1. Flow chart of Methodology

2.2 Thermal Efficiency

It is the ratio of heat generated by natural gas to heat absorbed by water, showing how well the energy in the fuel is used for heating. It is a crucial factor in evaluating the performance of a geyser and is computed using the formula [15].

$$\text{Thermal efficiency} = \frac{mwCp\Delta T}{\Delta VHv} \times 100 \tag{1}$$

mw: Mass of water = 113.562 kg (30 gallons), Cp: Specific heat of water at constant pressure = 4184 J/kg·K, ΔT: Change in temperature, ΔV: Amount of gas consumed, Hv: Heating value of natural gas = 38.7×10^6 J/m³

2.3 Natural Gas Saved

Enhancing thermal and combustion efficiency can lower gas usage. A baffle in the geyser improves thermal efficiency, which reduces the need for natural gas.

$$\text{Gas saved} = \left(\frac{\left(\frac{\Delta V}{\Delta T}\right) - \left(\frac{\Delta V}{\Delta T}\right)b}{\left(\frac{\Delta V}{\Delta T}\right)} \right) \times 100 \qquad (2)$$

Where $(\Delta V/\Delta T)b$: Natural gas (m^3) required to raise water temperature by 1°C with a baffle, $(\Delta V/\Delta T)$: Natural gas (m^3) required to raise water temperature by 1°C without a baffle.

2.4 Thermal Efficiency Improved

By taking the geyser's efficiency without a baffle as a reference and comparing it with efficiencies from various baffle and burner combinations, thermal efficiency improvement is computed.

$$T_{EI} = T_{EWB} - T_{EWOB} \qquad (3)$$

Where TEI: Thermal Efficiency Improved, TEWB: Thermal Efficiency with Baffle, TEWOB: Thermal Efficiency without Baffle

2.5 Combustion Efficiency

Combustion efficiency determines how effectively heat is extracted from fuel. It is calculated by subtracting dry flue gas loss from the total energy. Various methods exist for its calculation, with the Siegert formula being the most widely used in Europe. These calculations will follow the Siegert formula [15].

$$q_A = (Ts - Ta) \times \left(\frac{A2}{(21 - O2)} + B\right) \qquad (4)$$

$$\text{Efficiency} = 100 - q_A \qquad (5)$$

Where qA: Flue loss, Ts: Stack Flue temperature, Ta: Supply air temperature, O2: Measured volumetric oxygen concentration (%), A2, B: Fuel-dependent constants

The constant values of A2 and B are derived from the fuel compositions. The constants are given in Table 1.

Table 1. Constants values of A2 and B [16]

Fuel type	A2	B
Natural Gas	0.66	0.009
Fuel Oil	0.68	0.007
Town Gas	0.63	0.011
Cooking oven gas	0.60	0.011
LPG	0.63	0.008

When carbon doesn't completely oxidize such as CO appears in the products because of insufficient fuel supply, often refer as lean combustion.

$$\rho CH_4 + \zeta(O2 + 3.76N_2) \rightarrow O_2 + CO_2 + NO + NO_2 + HC + CO + \Gamma H_2O + \Phi N_2 \qquad (6)$$

$$FAR = \frac{mf}{ma} = \frac{12+4}{2[32+3.76(28)]} = 0.0583 \qquad (7)$$

2.6 Experimental setup

The experimental investigation was conducted using a 30-gallon gas water tank geyser, modified to incorporate a circular burner and various baffle configurations as depicted in figure 2. The setup was equipped with precise instrumentation for measuring temperature, gas flow rate, and combustion emissions to assess the impact on thermal, combustion efficiency, and heat transfer performance.

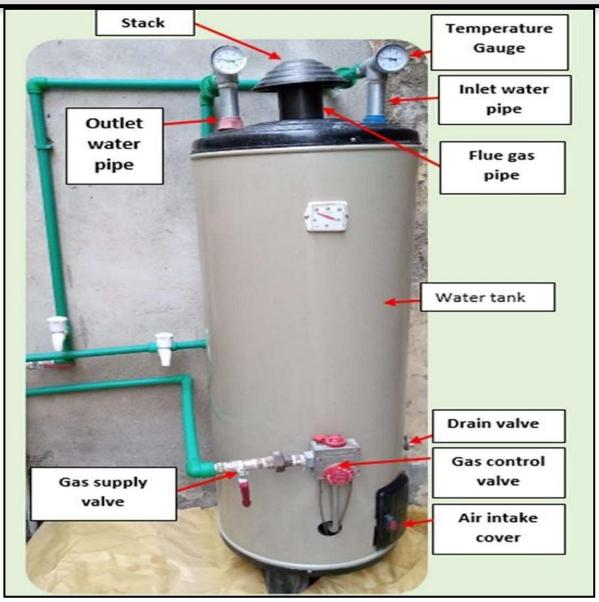


Figure 2. Experimental Arrangement

2.7 List of Equipment Used:

The setup includes a 30-gallon gas water tank geyser, a circular burner, a Testo350 flue gas analyzer as displayed in figure 3, an SNGPL gas meter, and various baffles (strip, cylindrical, conical, finned conical, frustum, bladed frustum).

Figure 3. Flue gas analyzer

2.8 CAD Modeling & Fabrication

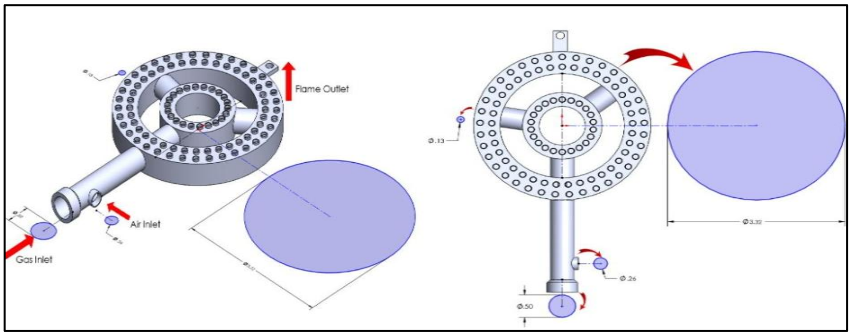


Figure 4. CAD Model of Circular Burner

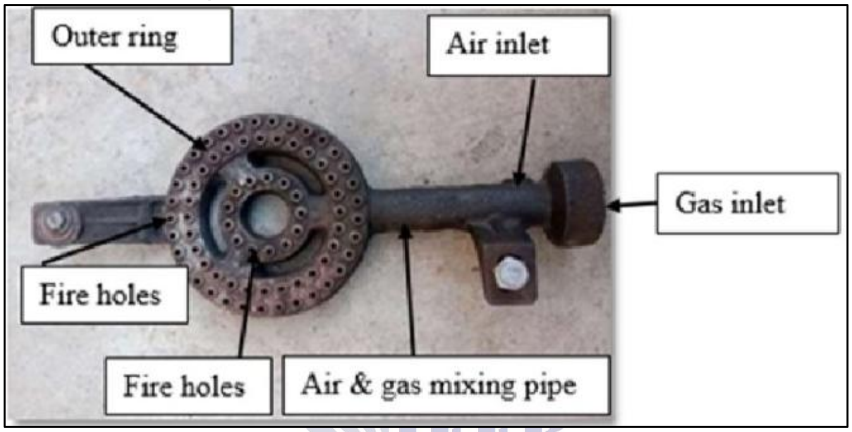
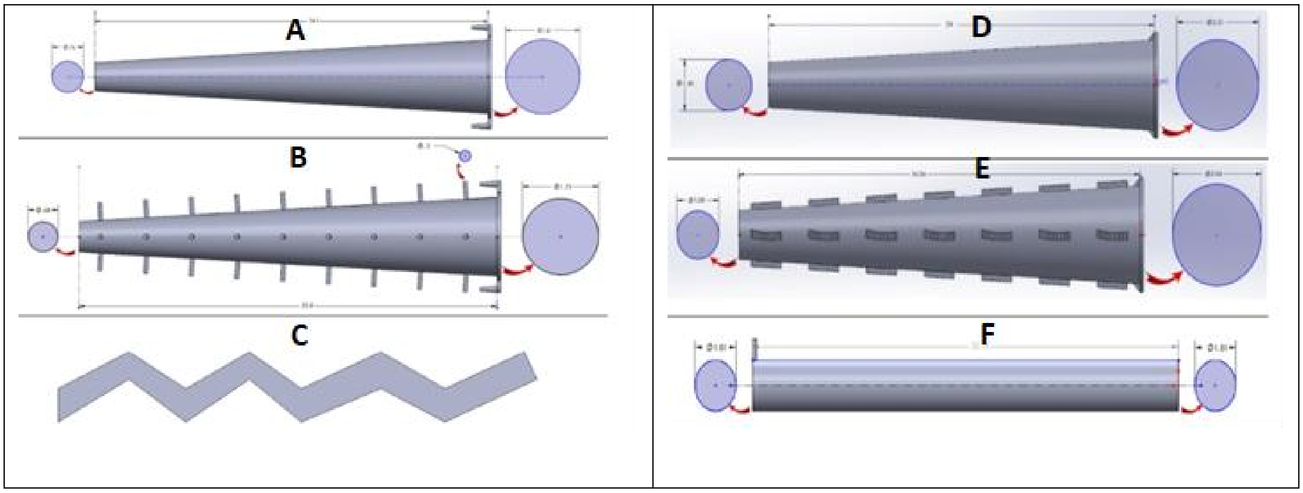


Figure 5. Fabricated Circular Burner

The CAD and fabricated Model of circular burner are shown in figure 4 and 5 respectively.

Figure 6. CAD Modeling of various Baffles



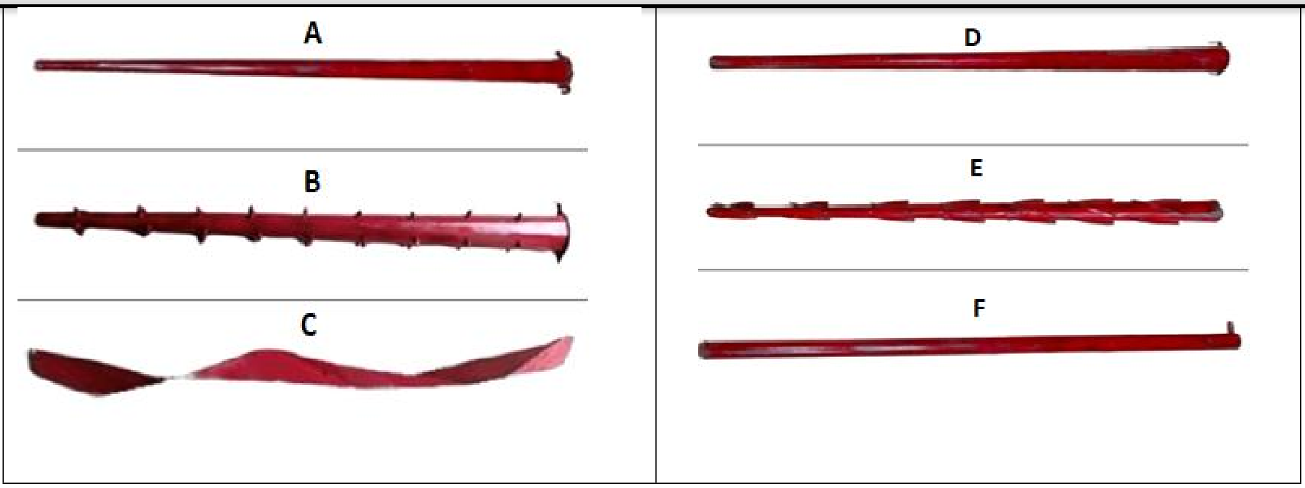


Figure 7. Different Baffle Fabricated Model

Figures 6 and 7 show different CAD and manufactured baffle models that are intended to improve combustion and thermal efficiency. These are designed to maximize fluid dynamics and heat transfer, and they include (A) Conical (B) Finned conical (C) Strip (D) Frustum (E) Bladed frustum, and (F) Cylindrical shapes.

3. Experimental Analysis

3.1 Readings using Circular Burner

3.1.1 Without Baffle

None of the baffles is inserted inside the flue pipe of the gas water tank geyser and hence experiment is performed using a circular burner. So, the data obtained for given test is tabulated below.

Table 2. Data for Thermal Efficiency without Baffle using the circular burner

Data	
Initial temperature	23°C
Final temperature	60.4°C
Initial volume	1158.73m^3
Final volume	1159.711m^3
Time	76minutes

The calculation for ΔT /ΔV, t/ΔT, ΔV/ΔT and thermal efficiency is made in the same manner as in the plate type burner and using the same equations.

Calculations	
Temperature difference	37.4°C
Gas consumed	0.981 m^3
ΔT/ΔV	38.1°C/m^3
t/ΔT	2min/$^{\circ}$C
ΔV/ΔT	0.0262m^3/$^{\circ}$C
Thermal efficiency	46.81% (using Eq. 1)

Table 3. Data for Combustion Efficiency without Baffle using circular burner

O_2	12.7%	Γ	10.042
CO	0.005%	ζ	22.735
NO	0.0029%	$\emptyset$	85.482
NO_2	0.00051%	M_f	80.37
CO_2	5.01%	M_a	3121.061
HC	0.0081%	FAR	0.02575 (Using Eq. 7)
T_s	510.8	q_A	43% (Using Eq. 4)
T_a	25 °C	Efficiency	57 % (Using Eq. 5)
ρ	5.0231		

3.1.2 Strip Baffle

Similarly, the data as well as the calculations for the given data for strip baffle with circular burner are given in the following tables.

Table 4. Data for Thermal Efficiency with strip Baffle using circular burner

Data	
Initial temperature	22°C
Final temperature	70.4°C
Initial volume	1161.32m^3
Final volume	1162.443m^3
Time	59 minutes
Calculations	
Temperature difference	48.4°C
Gas consumed	1.123 m^3
ΔT/ΔV	43.1°C/m^3
t/ΔT	1.2min/°C
ΔV/ΔT	0.0232m^3/°C
Thermal efficiency	52.92% (using Eq. 1)
Gas saved	11.45% (using Eq. 2)
Thermal Efficiency Improved	6.11% (using Eq. 3)

Table 5. Data for Combustion Efficiency with strip baffle using circular burner

O_2	12%	Γ	12.574
CO	0.031%	ζ	24.535
NO	0.0041%	$\emptyset$	92.249
NO_2	0.00034%	M_f	100.731
CO_2	6.23%	M_a	3368.165
HC	0.0347%	FAR	0.02991 (Using Eq. 7)
T_s	496.6	q_A	38.95% (Using Eq. 4)
T_a	23.5°C	Efficiency	61.05% (Using Eq. 5)
ρ	6.2957	Efficiency Improved	4.05 %

3.1.3 Cylindrical Baffle

Table 6. Data for Thermal Efficiency with Cylindrical Baffle using circular burner

Data	
Initial temperature	20°C
Final temperature	57.1°C
Initial volume	1167.91m^3
Final volume	1168.72m^3
Time	65minutes
Calculations	
Temperature difference	37.1°C
Gas consumed	0.81m^3
$\Delta T/\Delta V$	45.8°C/m^3
$t/\Delta T$	1.8min/°C
$\Delta V/\Delta T$	0.0218m^3/°C
Thermal efficiency	56.23% (using equation 1)
Gas saved	16.79% (using equation 2)
Thermal Efficiency Improved	9.42% (using equation 3)

Table 7. Data for Combustion Efficiency with Cylindrical Baffle using circular burner

O_2	9.21%	Γ	15.169
CO	0.24%	ζ	24.258
NO	0.0031%	ϕ	91.208
NO_2	0.00156%	M_f	121.379
CO_2	7.34%	M_a	3330.138
HC	0.0062%	FAR	0.03645 (Using Eq. 7)
T_s	562.8	q_A	34.99 (Using Eq. 4)
T_a	24.3°C	Efficiency	65.01% (Using Eq. 5)
ρ	7.5862	Efficiency Improved	8.01 %

3.1.4 Conical baffle

Table 8. Data for Thermal Efficiency with Conical Baffle using circular burner

Data	
Initial temperature	23°C
Final temperature	63.9°C
Initial volume	1169.802m^3
Final volume	1170.622m^3
Time	53minutes
Calculations	
Temperature difference	40.9°C
Gas consumed	0.82m^3
$\Delta T/\Delta V$	49.9°C/m^3
$t/\Delta T$	1.3min/°C
$\Delta V/\Delta T$	0.02m^3/°C
Thermal efficiency	61.24% (usingequation1)
Gas saved	23.66% (using equation 2)
Thermal Efficiency Improved	14.43% (using equation 3)

Table 9. Data for Combustion Efficiency with Conical Baffle using circular burner

O_2	9.43%	Γ	14.834
CO	0.19%	ζ	24.146
NO	0.0029%	⦰	90.786
NO_2	0.0021 %	M_f	118.816
CO_2	7.2 %	M_a	3314.763
HC	0.036%	FAR	0.03584 (Using Eq. 7)
T_s	585.2	q_A	37% (Using Eq. 4)
T_a	25°C	Efficiency	63% (Using Eq. 5)
ρ	7.426	Efficiency Improved	6%

3.1.5 Finned conical Baffle

Table 10. Data for Thermal Efficiency with Finned conical Baffle using circular burner

Data	
Initial temperature	26°C
Final temperature	57.2°C
Initial volume	1174.4m^3
Final volume	1174.989m^3
Time	56minutes
Calculations	
Temperature difference	31.2°C
Gas consumed	0.589m^3
ΔT/ΔV	53°C/m^3
t/ΔT	1.8min/°C
ΔV/ΔT	0.0189m^3/°C
Thermal efficiency	65.04% (using equation 1)
Gas saved	27.86% (using equation 2)
Thermal Efficiency Improved	18.23% (using equation 3)

Table 11. Data for Combustion Efficiency with Finned Conical Baffle using circular burner

O_2	8.1%	Γ	17.185
CO	0.17%	ζ	25.18
NO	0.0021%	⦰	94.675
NO_2	0.0019%	M_f	137.602
CO_2	8.4 %	M_a	3456.71
HC	0.0301%	FAR	0.03981 (Using Eq. 7)
T_s	559.1	q_A	32.1 (Using Eq. 4)
T_a	25.5°C	Efficiency	67.9% (Using Eq. 5)
ρ	8.6001	Efficiency Improved	10.9%

3.1.6 Frustum Baffle

Table 12. Data for Thermal Efficiency with Frustum Baffle using circular burner

Data	
Initial temperature	24.5°C
Final temperature	65.8°C
Initial volume	1176.251m^3
Final volume	1177.007m^3
Time	49minutes
Calculations	
Temperature difference	41.3°C
Gas consumed	0.756m^3
$\Delta T/\Delta V$	54.6°C/m^3
$t/\Delta T$	1.2min/°C
$\Delta V/\Delta T$	0.0183m^3/°C
Thermal efficiency	67.07% (using equation 1)
Gas saved	30.15% (using equation 2)
Thermal Efficiency Improved	20.26% (using equation 3)

Table 13. Data for Combustion Efficiency with Frustum Baffle using circular burner

O_2	8.10%	Γ	16.411
CO	0.091%	ζ	24.455
NO	0.0029%	ø	91.948
NO_2	0.00210%	M_f	131.36
CO_2	8.10 %	M_a	3357.182
HC	0.0190%	FAR	0.03913 (Using Eq. 7)
T_s	541.3	q_A	31 (Using Eq. 4)
T_a	26°C	Efficiency	69 % (Using Eq. 5)
ρ	8.21	Efficiency Improved	12%

3.1.7 Bladed Frustum Baffle

Table 14. Data for Thermal Efficiency with Bladed Frustum Baffle using circular burner

Data	
Initial temperature	23°C
Final temperature	51°C
Initial volume	1180.781m^3
Final volume	1181.279m^3
Time	57minutes
Calculations	
Temperature difference	28°C
Gas consumed	0.498m^3
$\Delta T/\Delta V$	56.2°C/m^3
$t/\Delta T$	2 min/°C
$\Delta V/\Delta T$	0.0178m^3/°C
Thermal efficiency	69.03% (using equation 1)
Gas saved	32.06% (using equation 2)
Thermal Efficiency Improved	22.22% (using equation 3)

Table 15. Data for Combustion Efficiency with Bladed Frustum Baffle using circular burner

O_2	8.34%	Γ	4.792
CO	0.23%	ζ	13.002
NO	0.0005%	$\varnothing$	48.887
NO_2	0.00048%	M_f	38.416
CO_2	2.15%	M_a	1784.915
HC	0.021%	FAR	0.02152 (Using Eq. 7)
T_s	606.8	q_A	35.6 (Using Eq. 4)
T_a	24.5°C	Efficiency	64.4% (Using Eq. 5)
ρ	2.401	Efficiency Improved	7.4%

4. Results and Discussion

4.1 Thermal Efficiency Findings

Table 16. Thermal Efficiency for different baffle configurations using circular burner

S.NO	Baffles	ΔT/ΔV(°C/m^3)	t/ΔT(min/°C)	ΔV/ΔT(m^3/°C)	Thermal Efficiency (%)	Gas Saved (%)	Thermal Efficiency Improved (%)
1	Without Baffle	38.1	2	0.0262	46.81	-	-
2	Strip	43.1	1.2	0.0232	52.92	11.45	6.11
3	Cylindrical	45.8	1.8	0.0218	56.23	16.79	9.42
4	Conical	49.9	1.3	0.02	61.24	23.66	14.43
5	Finned Conical	53	1.8	0.0189	65.04	27.86	18.23
6	Frustum	54.6	1.2	0.0183	67.07	30.15	20.26
7	Bladed Frustum	56.2	2	0.0178	69.03	32.06	22.22

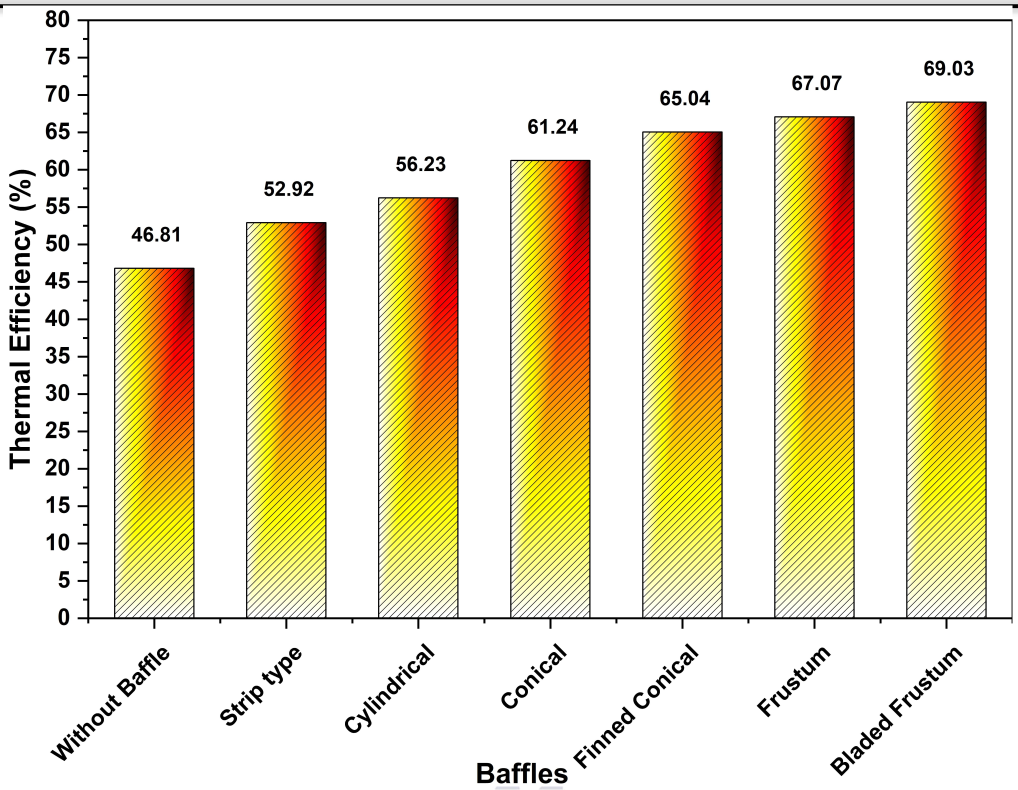


Figure 8. Thermal Efficiency for Different Baffle Combinations

When baffles are added to a circular burner, the results in Table 16 and Figure 8 show a significant increase in thermal efficiency. The system with no baffle had the lowest efficiency (46.81%) because it used more fuel and absorbed heat inefficiently. By improving heat retention and flow management, the addition of a strip baffle raised efficiency to 52.92%. Conical (61.24%) and cylindrical (56.23%) baffles showed further advancements, thanks to enhanced convective heat transmission and flame stability. The bladed frustum baffle had the maximum efficiency (69.03%) with a 32.06% decrease in gas consumption, while the finned conical (65.04%) and frustum (67.07%) baffles significantly enhanced performance. Its improved heat transfer surface and capacity to create regulated turbulence, which guarantees improved combustion uniformity, are responsible for this greater performance. All things considered, these findings demonstrate how well baffle designs may increase thermal and combustion efficiency, with the bladed frustum baffle showing up as the best arrangement for maximum fuel savings and thermal efficiency.

4.2 Combustion Efficiency Findings

Table 17. Combustion Efficiency for different baffle configurations using circular burner

S.No	Baffles	Combustion Efficiency (%)	Stack temp (°C)	CO (%)	O2 (%)	CO2 (%)	Fuel: Air
1	Without Baffle	57	510.8	0.005	12.7	5.01	0.02575
2	Strip type	61.05	496.6	0.031	12	6.23	0.02991
3	Conical	65.01	562.8	0.24	9.21	7.34	0.03584

4	Cylindrical	63	585.2	0.19	9.43	7.2	0.03645
5	Finned Conical	67.9	559.1	0.17	8.1	8.4	0.03981
6	Frustum	69	541.3	0.091	8.1	8.1	0.03913
7	Bladed Frustum	64.4	606.8	0.23	8.34	2.15	0.02152

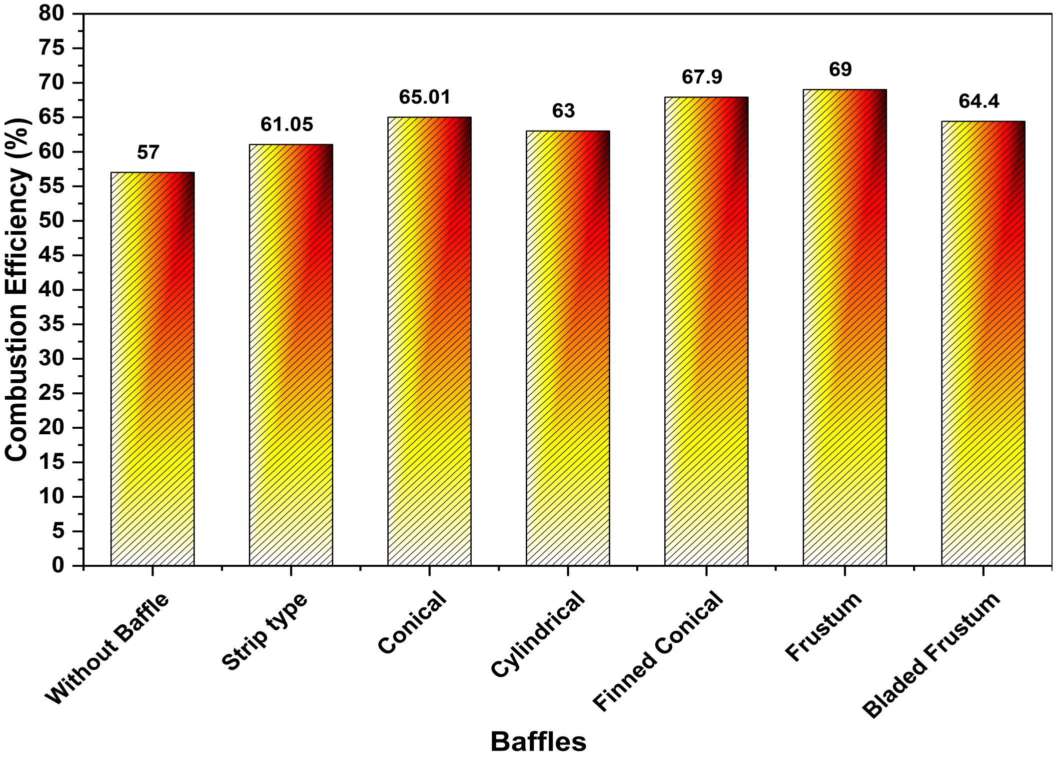


Figure 9. Combustion Efficiency for different baffles combination

Table 17 and Figure 9 results show how baffle designs affect combustion efficiency and how airflow control plays a part in optimizing fuel use. The unbaffled baseline configuration had the highest stack temperature (510.8°C) and the lowest efficiency (57%) suggesting incomplete combustion. Efficiency increased to 61.05% with the inclusion of a strip baffle, and performance was further improved to 65.01% and 63% with conical and cylindrical baffles, respectively. Fuel-air mixing was adjusted in the finned conical (67.9%) and frustum (69%) baffles, which showed the greatest efficiency. Despite its excellent thermal efficiency, the bladed frustum baffle's combustion efficiency was somewhat lower (64.4%) because of its higher stack temperature (606.8°C) and CO emissions. These results highlight how crucial baffle design is to attain the best possible combustion efficiency while preserving thermal performance and emission control.

5. Conclusion

This study systematically evaluated the impact of various baffle configurations on the thermal and combustion efficiency of a circular burner. The findings demonstrate that structured baffle designs significantly enhance heat transfer, optimize fuel-air mixing, and reduce fuel consumption.

- The bladed frustum baffle exhibited the highest thermal efficiency, achieving a 7.79% improvement over the conical baffle and resulting in an 8.4% reduction in gas consumption.

- The **frustum baffle** demonstrated a **5.83% increase in thermal efficiency and a 6.49% reduction in gas consumption as** compared to the conical baffle, highlighting its effectiveness in heat retention and transfer.
- In terms of combustion performance, the **frustum baffle achieved a 3.99% higher combustion efficiency** than the conical baffle, ensuring more complete fuel utilization.
- However, the **bladed frustum baffle showed a 0.61% decline in combustion efficiency** compared to the conical baffle, likely due to increased stack temperature and associated combustion dynamics.

Based on these findings, the **frustum baffle is identified as the optimal configuration**, offering the best balance between enhanced thermal efficiency (67.07%), improved combustion stability (69%), and reduced fuel consumption. Its adoption in burner systems presents a viable strategy for increasing energy efficiency while minimizing fuel wastage in domestic and industrial heating applications.

References

1.*Chapter 14 ENERGY - Ministry of Finance* [*https://www.finance.gov.pk/survey/chapters_23/14_Energy.pdf*](https://www.finance.gov.pk/survey/chapters_23/14_Energy.pdf) *[Online] Accessed August 15, 2024.*

2.Barik, D., M.A. Saeed, and T. Ramachandran, *Experimental and computational analysis of aluminum-coated dimple and plain tubes in solar water heater system.* Energies, 2022. **16**(1): p. 295.

3.Alnasif, A., et al., *Evolution of ammonia reaction mechanisms and modeling parameters: A review.* Applications in Energy and Combustion Science, 2023. **15**: p. 100175.

4.Coskun, G., et al., *Methane-fueled porous burner combustion in a domestic boiler: Experimental and numerical study.* Fuel, 2025. **381**: p. 133391.

5.Shami, I., et al., *Comparitive Study of Energy and Water Conservation in Domestic Gas Geysers.* Nurture, 2011. **5**(1): p. 45-54.

6.Srinivasarao, M., et al., *Experimental and numerical analysis on influence of air staging in a tangential flow burner for pure ammonia combustion.* Applied Thermal Engineering, 2025: p. 125580.

7.Sekar, M., T.A. Alahmadi, and S. Nithya, *Numerical simulation of industrial gas burners fueled with hydrogen-methane mixtures for enhanced combustion efficiency and reduced greenhouse gas emissions.* Fuel, 2024. **370**: p. 131807.

8.Ali, I., et al., *Design of an economically sustainable energy recovery system for domestic instant geyser.* Journal of Thermal Analysis and Calorimetry, 2024. **149**(5): p. 2293-2302.

9.Shervani Tabar, M.T., et al., *Numerical Study on the Enhancement of the Thermal Efficiency of a Household Gas Water Heater and Verification with Experimental Results.* Amirkabir Journal of Mechanical Engineering, 2022. **54**(5): p. 1199-1220.

10.Gopal, N.V. and K.S. Kumar. *Design of a Low-Cost Gas Geyser to Reduce CO and CO 2 Emissions.* in *2021 IEEE Pune Section International Conference (PuneCon)*. 2021. IEEE.

11.Hosseini, H., et al., *Development in household water heaters by replacing the shell and tube heat exchangers by inclined flat ones having rectangular fins.* Case Studies in Thermal Engineering, 2021. **28**: p. 101490.

12.Veetil, J.E., et al., *Effect of hole pattern on the structure of small scale perorated plate burner flames.* Fuel, 2018. **216**: p. 722-733.

13. Samkaria, R., et al. *Smart geyser with usage profiling to reduce electricity consumption.* in *Proceeding of International Conference on Intelligent Communication, Control and Devices: ICICCD 2016*. 2017. Springer.

14.Singh, E.G. and B. Singh, *An Experimental investigation of Gas Geyser's Heat Exchanger with addition of Economizer.*

15.Tajwar, S., et al., *Improving thermal and combustion efficiency of gas water heater.* Applied Thermal Engineering, 2011. **31**(6-7): p. 1305-1312.

16.Shalaeva, D., et al. *Analysis of the development of global energy production and consumption by fuel type in various regions of the world.* in *IOP*

Conference Series: Materials Science and Engineering. 2020. IOP Publishing.