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Heat Loss Reduction In Fuel Burner Using Concealed Flame Guard

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Abstract

Heat transfer is omnipresent in our surrounding& that is why it is so much to study the deep of heat transfer processes at actually. Heat energy is vital form of energy which involves in almost every process. Whether it may be any mechanical or chemical or physical process, heat is always transferred during this process. This heat may be loss or gain by the system. Sometimes this may be due to frictional & abrasive forces, and sometimes this may be due to combustion processes. We know that energy neither be created nor be destroyed, but this can be transfer from one system to another system, well known statement from the first law of thermodynamics i.e. law of conservation of mass. And yes all living things are using this form of energy in their everyday life very constantly.

During this type of uses or energy utilization there is always heat loss through the system and continuous degradation of energy is happening in this process. This heat loss may be through condition, convection, radiation. Sometimes this heat loss can be beneficial or useful to us but many of times heat loss is considered as unnecessary part of the system. So we are always trying to minimize these losses. These losses can be also due to friction. To avoid these type losses we consider to use highly finish and low viscosity or coefficient of friction products. Also the heat losses through conduction or convection we can reduce those losses by using the thermo insulations in the system so that heat loss from the system will be minimum.

In this report we are further going to elaborate how to use thermo insulation to reduce the heat losses from system to surrounding.

Keywords:*Concealed flame guard, Heat transfer by convection, Heat transfer by radiation, thermal insulation*

1. INTRODUCTION

Heat transfer is a basic science that deals with the rate of transfer of thermal energy. This introductory text is intended for use in a first course in heat transfer for undergraduate engineering students, and as a reference book for practicing engineers. The objectives of this text are to cover the basic principles of heat transfer, to present a wealth of real-world engineering applications to give students a feel for engineering practice and to develop an intuitive understanding of the subject matter by emphasizing the physics and physical arguments.
Many people are assumed to have completed their basic physics and calculus sequence. The completion of first courses in thermodynamics, fluid mechanics, and differential equations prior to taking heat transfer is desirable. The relevant concepts from these topics are introduced and reviewed as needed. In engineering practice, an understanding of the mechanisms of heat transfer is becoming increasingly important since heat transfer plays a crucial role in the design of vehicles, power plants, refrigerators, electronic devices, buildings, and bridges, among other things. Even a chef needs to have an intuitive understanding of the heat transfer mechanism in order to cook the food "right" by adjusting the rate of heat transfer. We may not be aware of it, but we already use the principles of heat transfer when seeking thermal comfort. We insulate our bodies by putting on heavy coats in winter, and we minimize heat gain by radiation by staying in shady places in summer. We speed up the cooling of hot food by blowing on it and keep warm in cold weather by cuddling up and thus minimizing the exposed surface area. That is, we already use heat transfer whether we realize it or not.

1.1 Thermalradiation:

Although all electromagnetic waves have the same general features, waves of different wavelength differ significantly in their behavior. The electromagnetic radiation encountered in practice covers a wide range of wavelengths, varying from less than 10 -10μm for cosmic rays to more than 1010μm for electrical power waves. The electromagnetic spectrum also includes gamma rays, X-rays, ultraviolet radiation, visible light, infrared radiation, thermal radiation, microwaves, and radio waves. Different types of electromagnetic radiation are produced through various mechanisms. For example, gamma rays are produced by nuclear reactions, X-rays by the bombardment of metals with high-energy electrons, microwaves by special types of electron tubes such as klystrons and magnetrons, and radio waves by the excitation of some crystals or by the flow of alternating current through electric conductors. The short-wavelength gamma rays and X-rays are primarily of concern to nuclear engineers, while the long-wavelength microwaves and radio waves are of concern to electrical engineers. The type of electromagnetic radiation that is pertinent to heat transfer is the thermal radiation emitted as a result of energy transitions of molecules, atoms, and electrons of a substance. Temperature is a measure of the strength of these activities at the microscopic level, and the rate of thermal radiation emission increases with increasing temperature. Thermal radiation is continuously emitted by all matter whose temperature is above absolute zero. That is, everything around us such as walls, furniture, and our friends constantly emits (and absorbs) radiation.

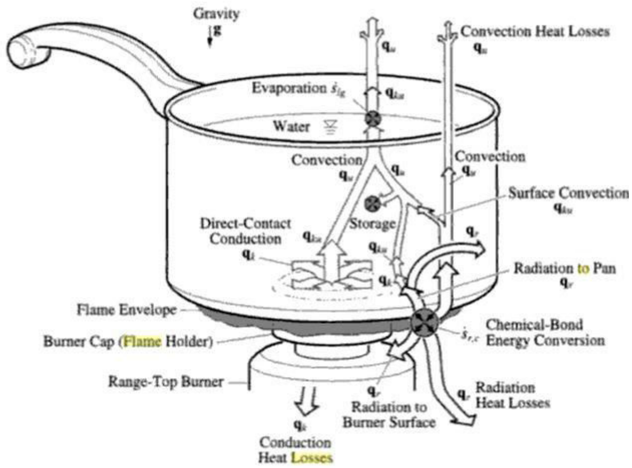
2. LIETRATURE REVIEW

Further we will see some work done by researchers related to subject previously.

Massoud Kavinay in "Principles of Heat Transfer"illustrated the modes of heat transfer in practicality conditions of the kitchen atmosphere. There are many losses also occurring during the heating of the food. Consider below mentioned cook top placed on a burner, this illustration is taken from the mentioned book of the same author in which he had explained type of heat losses occurring during the process of cooking.

Here author had described the way of flame & flue gases of flame are going alongside of the pot region and losses occurring in surrounding. Figure illustrates the path followed by flame by arrow, it going upwards and if there is turbulence in the natural convective air, then the path followed by the flame also gets disturbed.

As we can see, heat is transferred to atmosphere more by convection and radiation. This heat wasted in environment is no where useful to system, to cook the food.



2.2 Heat loss diagram during heating of water in cook top

Before we discuss details of flame temperatures, it is important to distinguish between some of the major flame types. Flames can be divided into 4 categories:

- laminar, premixed
- laminar, diffusion
- turbulent, premixed
- turbulent, diffusion

An example of a laminar premixed flame is a Bunsen burner flame. Laminar means that the flow streamlines are smooth and do not bounce around significantly. Two photos taken a few seconds apart will show nearly identical images. Premixed means that the fuel and the oxidizer are mixed before the combustion zone occurs.

A laminar diffusion flame is a candle. The fuel comes from the wax vapor, while the oxidizer is air; they do not mix before being introduced (by diffusion) into the flame zone. A peak temperature of around 1400°C is found in a candle flame [3].

Most turbulent premixed flames are from engineered combustion systems: boilers, furnaces, etc. In such systems, the air and the fuel are premixed in some burner device. Since the flames are turbulent, two sequential photos would show a greatly different flame shape and location.

Most unwanted fires fall into the category of turbulent diffusion flames. Since no burner or other mechanical device exists for mixing fuel and air, the flames are diffusion type.

Adiabatic flame temperature

When one consults combustion textbooks for the topic of 'flame temperature,' what one normally finds are tabulations of the adiabatic flame temperature. 'Adiabatic' means without losing heat. Thus, these temperatures would be achieved in a (fictional) combustion system where there were no losses. Even though real-world combustion systems are not adiabatic, the reason why such tabulations are convenient is because these temperatures can be computed from fundamental thermo-chemical considerations: a fire experiment is not necessary. For methane burning in air, the adiabatic flame temperature is 1949°C, while for propane it is 1977°C, for example. The value for wood is nearly identical to that for propane. The adiabatic flame temperatures for most common organic substances burned in air are, in fact, nearly indistinguishable. These temperatures are vastly higher than what any thermocouple inserted into a building fire will register.

Flames temperatures of open flames

For convenience, we can subdivide the turbulent diffusion flames from unwanted fires into two types: flames in the open, and room fires. First we will consider open flames.

The starting point for discussing this topic can be the work of the late Dr. McCaffrey, who made extensive measurements [4] of temperatures in turbulent diffusion flames. He used gas burners in a "pool fire" mode (i.e., non-premixed) and studied various characteristics of such fire plumes. He described three different regimes in such a fire plume:

Slightly above the base of the fire begins the continuous flame region. Here the temperatures are constant and are slightly below 900°C.

Above the solid flame region is the intermittent flame region. Here the temperatures are continuously dropping as one move up the plume. The visible flame tips correspond to a temperature of about 320°C.

Finally, beyond the flame tips are the thermal plume region, where no more flames are visible and temperature continually drop with height.

French researchers at the University of Poitiers recently made the same types of measurements and reported numerical values [5] indistinguishable from

McCaffrey's. Cox and Chitty [6] measured similar plumes and obtained very similar results: a temperature of 900°C in the continuous flame region, and a temperature of around 340°C at the flame tips. The latter value does not appear to be a universal constant. Cox and Chitty later measured slightly higher heat release rate fires, and found a flame tip temperature of around 550°C. In a later paper [7], researchers from the same laboratory examined turbulent diffusion flames under slightly different conditions, and found peak values of 1150-1250°C for natural gas flames, which is rather higher than 900°C. The above results were from fires of circular or square fuel shape. Yuan and Cox [8] measured line-source type fires. They found a temperature of 898°C in the continuous flame region, and a flame tip temperature of around 340°C. This suggests that such results are not dependent on the shape of the fuel source.

In studying fires in warehouse storage rack geometry, Ingason [9] found an average solid-flame temperature of 870°C. At the visible flame tips, the average temperature was 450°C, but the range was large, covering 300~600°C. In a related study, Ingason and de Ris [10] found typical flame tip temperatures of 400°C for burner flames of propane, propylene, and carbon monoxide fuels.

Sullivan et al. [14] cite Australian studies on wildfire flames, finding that flame tip temperature correspond to 300°C, while peak values around 927°C can be expected.

Heskestad [11] adopts a criterion of 500°C rise as defining the flame tip temperature, i.e. an actual temperature of about 520°C.

Taking all of the above information in account, it appears that flame tip temperatures for turbulent diffusion flames should be estimated as being around 320~400°C. For small flames (less than about 1 m base diameter), continuous flame region temperatures of around 900°C should be expected. For large pools, the latter value can rise to 1100~1200°C.

Lakshmisha, K. N. | Paul, P. J. | Mukunda, H. S.[15]in the study related to biomass fuel we get to know that,

Biomass is unique as a renewable energy source because it can be used for all three energy sectors electricity, heat and transport. This puts a high demand on the resources available. Solid biomass fuels have the advantage that a wide range ofmaterials can be used. This flexibility also applies to the methods used for biomassutilization which can vary depending on the nature of the output, heat or electricity and on the size of unit required. Domestic appliances up to ~25 kW include openfires, simple stoves, household heating boilers and cookers—including traditionalcook stoves used widely in developing countries. The use of biomass for heating has recently been widely promoted, especially in the EU. Modern biomass furnaces incorporate state-of-the-art design, but there are still problems associated with meeting NOx and particulate emissions limits. Many of the methods used for the larger scale utilization of solid biomass are based on technologies developed for conventional fuels such as coal and lignite.These methods are described in standard textbooks on combustion technology (Speight 2013; Spliethoff 2010). They use technologies such as fixed bed combustors (up to 5 MW), moving or travelling grate combustors (up to 100 MW), fluidized bed (up to 500 MW), suspension firing/pulverized fuel (pf) combustion and co-firing withfossil fuels (up to 900 MW). Many industrial processes such as biomass co-firingfor power generation use only minor modifications to equipment designed for coalfiring. This influences the pollutants formed.Domestic heating is widely used throughout the world especially NorthAmerica, Scandinavia, Europe and most Developing Countries. In Europe Franceis the largest consumer of wood for domestic heating, followed by Sweden, Finland and Germany. In the wintertime around half of all particulate organicmatterin Paris has been attributed to biomass burning. Three methods availableare open fires (up to 5 kW), simple enclosed stoves, Pat sari cook stoves andhousehold heating boilers (3–10 kW). Unlike larger units, these systems do notincorporate any flue gas after-treatment and as such emit significant particulate matter, unburned volatile organic matter and NOx directly into the atmosphere. There is ongoing debate on the nature of these emissions from domestic applications as the rating of many units is based on steady state operation and does not take into account the initial start-up and refueling emissions into account.

This article showed the gasification process of combustion of solid fuel (biomass fuel). Gasification is a process that converts organic or fossil fuel based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called syn-gas (from synthesis gas) or producer gas and is itself a fuel. The power derived from gasification and combustion of the resultant gas is considered to be a source of renewable energy if the gasified compounds were obtained from biomass.

Consider a solid fired fuel burner running on biomass fuel (First Energy Product- Oorja). One cook top placed on burner and water in it placed to heat up. We will consider the heat losses occurring in the process. Basically there will be two types of losses of heat as follows.

3. OBJECTIVES

The main objectives of the project are as follows:

- It's a part of the syllabus of our Final Year in Masters of Mechanical Engineering as per the rules of Pune University.
- To get acquainted with the various heat loss reducing techniques.
- To procure knowledge concerning with various heat transfer processes and losses occurring in surrounding atmosphere.

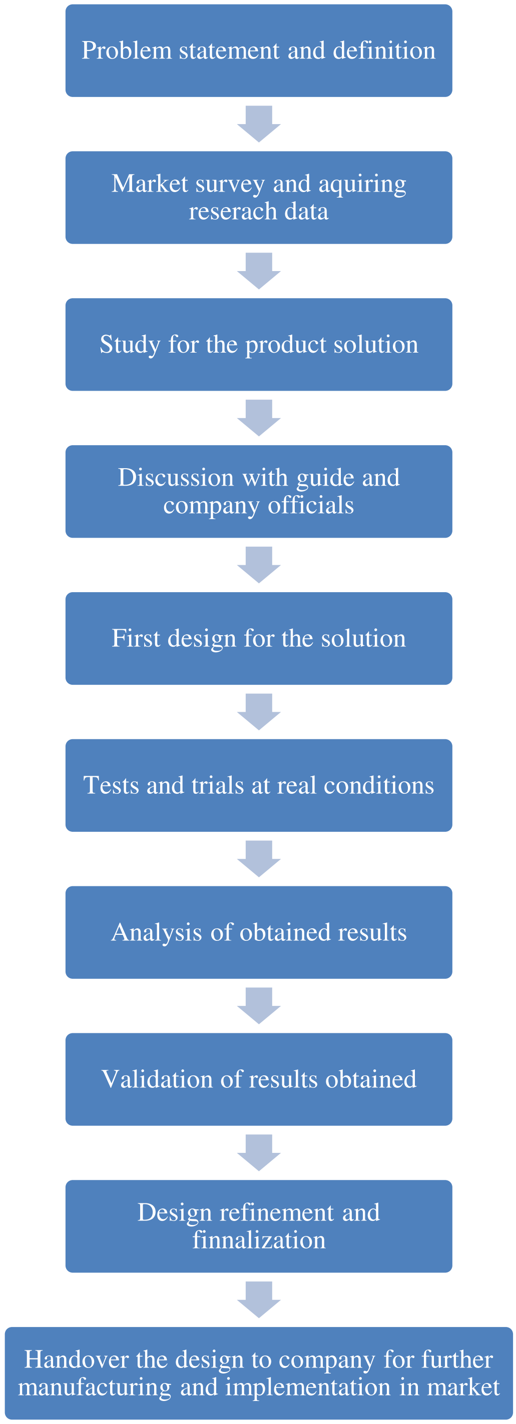
- To reduce manpower, fatigue, losses, etc. for acquiring the productivity as per the requirement of the company.
- To obtain required surface efficient cooking system

4. METHODOLGY

As our scope and main motive of project is concerned to save the heat loss caused by flame with surrounding. We will first go through market to check whether others customers have already have their own solutions on this or not. For this we have to search for the local market and some big kitchens. Simultaneously we will go for the internet database to search for solution or work done by researchers all over the world for the said topic and project. We have to take necessary data from these sources to apply our knowledge and methods to give best possible solution. After this survey, we will have to implement our idea to save the heat losses. We will do one robust design for first experiment and calculations to analyze how our idea is going to affect and then we have to go for in depth analytical solution.

After this all analysis and experiment work we will have to go for the refining work to design a good aesthetic and easy to use product for the solution. In this designing we will have to more concern about two things, one is easy to use application and second is that while designing the product we should not allow going down the performance of the product as compare to our experimental and analytical data.

5. Plan of Work



6. Product brief- Concealed flame guard

This product is to be designed for making cooking efficient by using the heat energy which is going out in radiation & convection. This guard is made up of steel and filled with the rock wool insulation internally.

The guard is used to surround the pot placed on a burner. Oorja stove burner is having quite large burner size i.e. why flame produced in the burner is of larger diameter. Due to this larger dia. Flame, it is more heat wasting to surrounding through radiative and convective heat transfer.

Rockwool insulation helps to prevent heat losses to flame guard & it does not heats up to a larger extent.

Concealed flame guard

7. Design Considerations:-

7.1 Flame Guard dimensions-

As flame guard we are going to design is used in taking consideration of pot dimensions. This pot in food industry, it is used for heating the water, for boiling milk, making rice, etc. So Pot & utensils used are quite larger than the burner size. Still due to large burner size flame always goes outside the range of pot and leads to radiative heat losses.

So Avg. size of pot used in many industries it is observed that of 350-400mm range (Outer dia.of pot). This is used on a burner size of 200mm. And height of the pot varies from 300 mm to 380 mm.

So Dimensions of flame guard will be as per following:

Internal dia. of guard- 480 mm

External dia. of guard- 630 mm (considering insulation thickness of 75mm)

7.2 Insulation-

Insulation selection is important factor in this process as flame temperature is higher at inside the flame guard, so there should be some heat retardant material to keep as much as heat inside the guard to use again to the pot.

Formulae to be used:-

Heat transfer from internal surface to external surface of the guard is by conduction. Thus heat transfer can be calculated as Fourier's law of heat conduction as:

$$\dot{Q}_{\text{cond}} = kA\frac{T_1 - T_2}{\Delta x} = -kA\frac{\Delta T}{\Delta x} \qquad \text{(W)}$$

Here, Q_{cond}/A = Heat conduction rate

= 30 w (as per Oorja burner model)

K = Thermal conductivity of Insulation

= to be calculated

(t_1-t_2) = Temp. Difference bet. Surfaces

= (90-35) = 55°C

35°C is the temperature close to surrounding we are expecting from the outer surface

X= thickness of insulation

= 75 mm (as per space constrained)

7.2.1 Calculations:-

Therefore,

30 = K x (55)/75

K= 0.0409 w/m.k

So, for getting desired heat transfer we need to select the insulation material which has thermal conductivity of 0.0409.

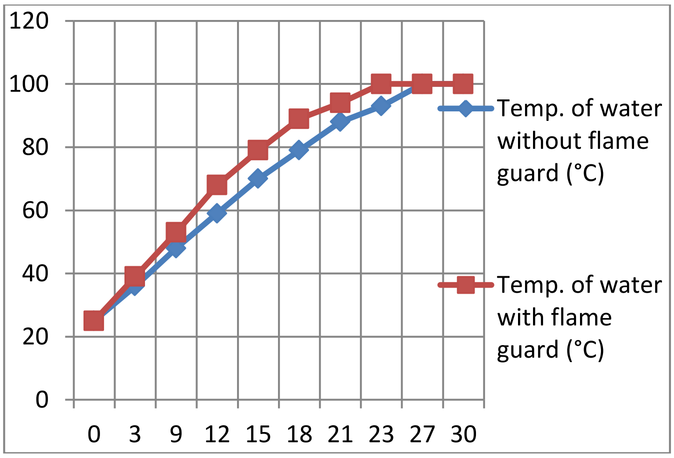
Considering Rockwool insulation which has thermal conductivity of 0.045 w/ m.k

8. Trials & observations:-

We carried out some trials on the product of Oorja burner with flame guard & without flame guard. Below it is shown that a table which illustrates the observations made during heating of water in pot with the flame guard & without flame guard:

Sr. No.	Time (min)	Temp. of water without flame guard (°C)	Temp. of water with flame guard (°C)
1	0	25	25
2	3	36	39
3	9	48	53
4	12	59	68
5	15	70	79
6	18	79	89
7	21	88	94
8	23	93	100
9	27	100	100
10	30	100	100

Graph of Time Vs Temp.



Oorja model used: - K30 burner
Qty. of water: - 30 liters
Time taken to boil water:

1. *Burner without flame guard- 27 min*
2. *Burner with flame guard- 23 min*

Insulation used- Rockwool insulation.
Thickness of rock wool Insulation- 75mm
Thermal conductivity of Insulation- 0.045 w/m.k
Internal Dia. Of flame guard- 480mm (as per dia. of pot)
Height Of flame guard- 390mm (as per height of pot)

Heating of water without flame guard

Heating of water with flame guard

9. CONCLUSION

As per observations made in the trials & experiment, Oorja burner with flame guard gives better efficiency as compared to the one without flame guard. This experiment shows that practically for heating 30 litersof water we are saving approx. 4 min of heating time in the burner with flame guard used.

So as per 30 kW model of Oorja, we are saving 4 kW energy per every liter of water to boil.

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