Which one is better between Gas Stove and Infrared Cooker?

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Contents

Abstract

Gas Stoves take the majority in number when it comes to the average household. But being on the situation of inadequate gas supply, my family were compelled to buy an *Electric Infrared Cooker*. And from that the simple question follows, "which one is more reliable in terms of Energy Consumption and Efficiency?". As the notion of using more and more Electric appliance in increasing, how can the well regarded use of Infrared cooker can effect our daily lives economically? The following tries to find answer to such a question with an experiment of calculating the Efficiency.

1 Introduction

2 Background

2.1 Gas Stove

The idea of a Gas Stove is easily comprehended, the inlet is the source to gas for the stove. When a flame is let, then the spontaneous *Exothermic* reaction yields Heat from breaking the molecular bonds of the specific gas, along side with some chemical residue. For Bangladesh, the typical usage of Methane is made. The reaction is followed,

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \Delta H \tag{1}$$

Here, ΔH is the heat released, which is about $890\,kJ$ per every mole of Methane which is CH_4. One side of the reaction is the Carbon Dioxide residue.

2.2 Infrared Cooker

Infrared Cookers have a halogen top that is composed of 4 light tubes. When switched on, the halogen tubes excite the states of gas inside and because of the spontaneous change of excitation levels of atoms, a radiation of photon is observed. These photon constitute the light that has a wavelength of the infrared range. Classically, the radiation power per unit surface area is described by the Poynting Vector, microscopically,

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B} \tag{2}$$

The infrared Radiation is radiated exactly upward to the pot and that's why the convective heat loss from surrounding is lesser, radically more efficient in delivering heat than the usual stove cooking methods, thermodynamically.

1. Circular metal container tray.
2. Microporous insulating material (typically Microtherm).
3. Right supporting flange.
4. Left supporting flange.
5. Right flange end.
6. Left flange end.
7. Tungsten halogen infrared filament lamp (four in total).
8. Ceramic fiber packing.
9. Molded ceramic end cap.
10. Lamp holder tab.
11. Metal thermostat ("thermal limiter") expands and contracts as it heats and cools, pressing against microswitch.

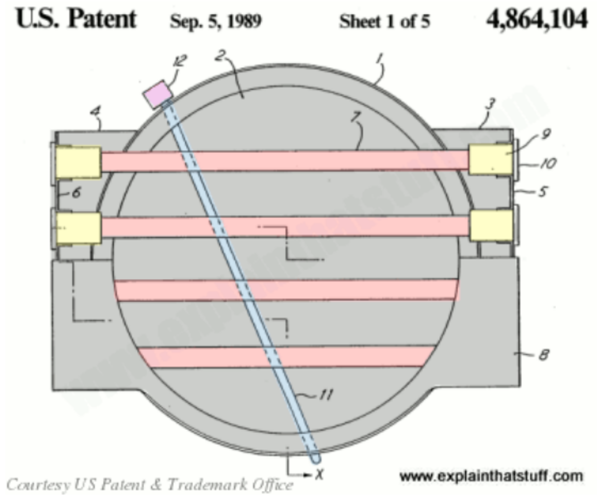

Figure 1: Diagram of a Halogen Tube Ring of Infrared Cooker

12. Microswitch, controlled by the thermostat, turns halogen lamps on and off, keeping the cooktop at a steady temperature.

That's basically how the system is constructed.

3 Experiment

The whole procedure summarizes that we find the *Effective Power Output* of the cookers by evaporating a known mass of water. Because, during the *Phase Transition* process, the total heat required to carry out the process remains directly proportional to the mass of water. Later we find out the *Efficiency* to make a final decision what works better.

3.1 Method

Analysis will be made between two kinds of cookers, the gas stove and infrared cooker.

Water of known mass will be taken in a conducting pot and heated to 100° at first using the two cookers. Then, the phase transformation would technically begin and we can start to record the time interval until all the water is evaporated to gaseous phase and gone to atmosphere. We can know the total heat required in the process, thus taking the heat dissipated per unit time, the power output of the cookers can be known.

This power output to power input ratio can be used to determine how much wastage of energy is made by the following cookers. Using this, we can finally conclude which is effectively more efficient.

3.2 Theoretical Background of Experiment

3.2.1 Phase Diagram

The *Phase Diagram* of water can be easily shown by the Clausius Clapeyron Equation, which follows,

$$\frac{dp}{dT} = \frac{\lambda}{T(V_2 - V_1)} \tag{3}$$

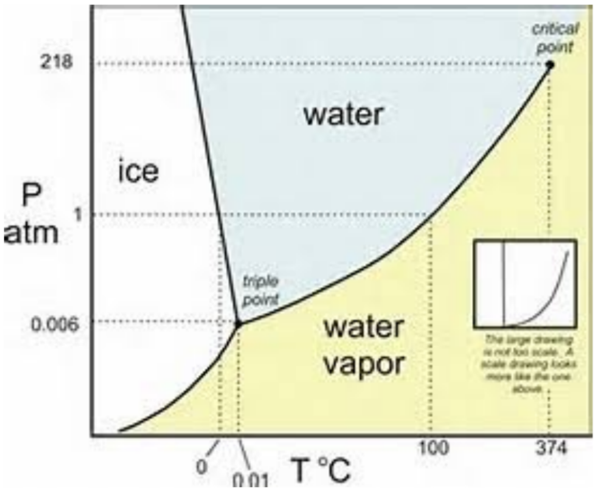

Figure 2: Phase Diagram

Where p and T are Pressure and Temperature of surrounding, λ is the Latent Heat, which is also the difference in Enthalpy per unit material for a process, and V is the Volume of matter in Phase Transition. This case the matter is Water. The Phase Diagram tells that at usual atmospheric pressure of $1\,atm$, the temperature required for water to turn vapour is $100°$.

In the $p - T$ plane of Phase Diagram, the curve that separates between *Liquid* phase and *Gaseous* phase is seen. We find the curve shown in Diagram from above equation.

3.2.2 First Law of Thermodynamics

From the *First Law of Thermodynamics*, the overall change in internal energy is defined by,

$$\Delta U = \Delta Q + \Delta W \tag{4}$$

Where U is the Internal Energy, Q is the Heat transfer, W is the work performed by the matter. Here in this case of boiling water, W will effectively be very small, as the volume of water doesn't change too much before turning to Gas phase (vapour).

Now, for case of water, at $100°$ temperature, the Heat applied doesn't go to increase the Temperature of the Water, rather, it is dissipated to break the Inter-molecular Bonds of Water; to turn it into Gaseous Phase. So, the internal energy change is equal to the heat given directly.

Internal Energy change for Phase change of m mass water is given by,

$$\Delta U = m\lambda \tag{5}$$

Where λ is Latent heat constant. The constant value is $\lambda = 2160\,kJ/kg$. Hence, the First Law of Thermodynamics for this case tells us that,

$$\Delta Q = m\lambda \tag{6}$$

Now if the heat given to change phase of m mass water is spontaneous, then ignoring convective heat loss, the power of heating of water is given by the following,

$$P = \frac{\Delta Q}{\Delta t} = \frac{m\lambda}{\Delta t} \tag{7}$$

It is the cooker that is going to supply the power P. The heating effects of the vessel or cooking pots is unnecessary because during the process of boiling of water, the system is stable at a constant temperature of $100°$. Hence, heating of pots is effectively zero.[1]

Hence, the P is logically the output power P_{out}. We can know the input power P_{in} from the cooker model specifications.

$$P = P_{out} = \frac{m\lambda}{\Delta t} \tag{8}$$

3.2.3 Efficiency

Efficiency is defined by the ratio of the output power and input power. That is,

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \tag{9}$$

3.3 Apparatus

Name	Quantity	Specifications
Double Burner Gas Cooker	1	4300W Power Supply
Infrared Cooker	1	2000W Input
Utensil (Conductive with Circular Surface)	2	15 cm diameter
Beaker	1	•
Water (H_2O)	varied	•
Alcohol Thermometer	1	•

3.4 Procedure

1. Utensils are put with known mass of water, one on the infrared cooker and the other on the gas stove. Data from both cooker will be simulataneously be measured for ease.

2. Time was given until water started to boil; which is, start to change phase. No record made till here.

[1] Though this is not the case. The heating of vessel is equal to the heat loss through convection of surrounding air around the vessel, the both effects balance each other achieving a "Dynamic Equilibrium", but the effect is hopefully small enough to be ignored.

3. Two stopwatches were used. Immediately as water started boiling in each pans, stopwatches were switched.
4. Stopwatches ran until all the water evaporated.
5. When water completely vapourized, the corresponding stopwatches were switched off.
6. We conducted the experiment for a couple of times(Experiment was conducted a few more times.)

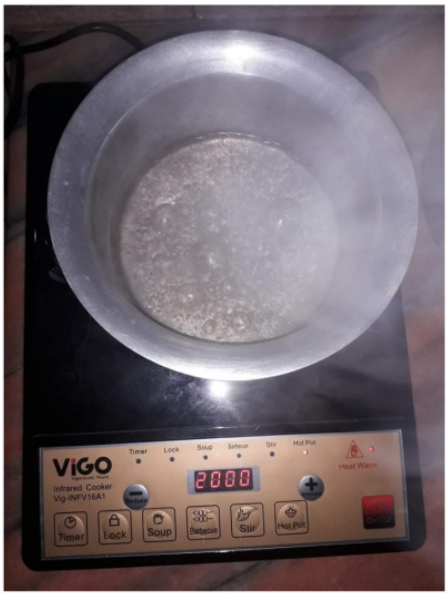

Figure 3: Infrared Cooker)

3.5 Data Analysis

From the Experiments, these were the following measured values.

3.5.1 Infrared Cooker

The output power is calculated by the following,

$$P_{out} = \frac{m\lambda}{\Delta t} \tag{10}$$

$$\lambda = 2160\, kJ/kg$$

Unit conversation was automatically done.

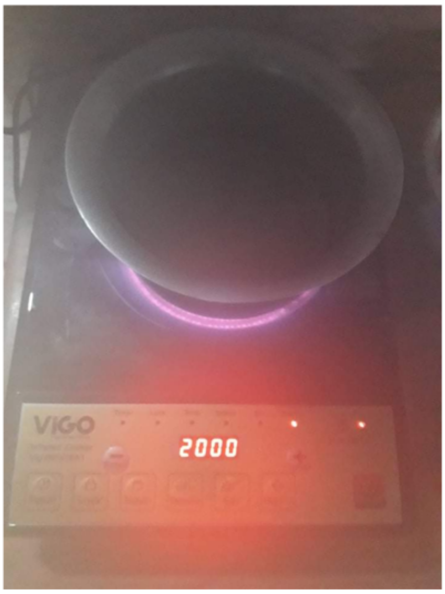

Figure 4: Infrared Cooker with the Halogen Lamp Radiation

Figure 5: Usual Heating

Serial	Time (min)	Mass of Water (kg)	P_{out} (W)
1	26.212	0.5	686.708
2	25.304	0.5	711.349
3	26.013	0.5	691.961
4	12.641	0.25	711.968
5	10.081	0.25	892.768

The efficiency calculated,

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \tag{11}$$

For infrared cooker it is $P_{in} = 2000W$.

Serial	Efficiency η
1	34.335%
2	35.567%
3	34.598%
4	35.598%
5	35.035%

3.5.2 Gas Stove

The output power is calculated by the following,

$$P_{out} = \frac{m\lambda}{\Delta t} \tag{12}$$

$$\lambda = 2160\, kJ/kg$$

Unit conversation was automatically done.

Serial	Time (min)	Mass of Water (kg)	P_{out} (W)
1	23.388	0.5	769.625
2	21.023	0.5	856.123
3	22.949	0.5	784.347
4	15.106	0.25	595.789
5	12.844	0.25	700.716

The efficiency calculated,

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \tag{13}$$

For Gas stove it is $P_{in} = 4300W$.

Serial	Efficiency η
1	17.898%
2	19.909%
3	18.240%
4	13.856%
5	16.279%

4 Final Decision and Conclusion

The Experiment results the **Infrared Cooker is much more efficient that the Gas Stove**. It tends to be more durable, though the time for the Infrared Cooker to start functioning takes a bit more time than the Gas Stove. But it is notable that more efficiency is allowed than the fact of using Natural Gas (Methane).

References

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