FAR INFRARED HEATING OVEN

Narasimha Murthy. H.R [1]
Department of Energy Engineering,
Dr. M.G.R. Educational and Research Institute University, Chennai
Mail id:hrnmurthy@rediffmail.com

Mr. P. Ravichandra Ganesh [2]
Assistant Professor, Department of Energy Engineering,
Dr. M.G.R. Educational and Research Institute University,Chennai

Abstract: This project is aimed at fabricating an oven for a specialized drying application using infrared heating principle. The project involves construction of a miniature oven using long wave infrared heaters. The application is typically aimed at drying the coating on a sand mold used in foundries or for moisture removal of a refractory material / block. The oven has a steel fabricated casing lined with insulation materials, with inner layer fitted with high emissivity reflectors. Long wave (far) infrared heaters are mounted on two inner side walls, power supply to which is controlled by PID temperature controller which gets the signal from thermo couple. As the infrared energy heaters only the objects it strikes and not the air in its path, it is highly energy efficient. Energy Saved is Energy generated and infrared heating system stands out as an "Energy Saving Technology" compared to the conventional heating systems.

Keywords- Infrared, Proportional Integral Derivative (PID).

1. Introduction

Heat Transfer Fundamentals

Conduction: Transmission of heat though solid objects by exchange of heat from warmer molecules to colder molecules. Ex, The handle of the pot getting hot even though the bottom of the pot alone is heated.

Convection: Transmission of heat through fluids (gas or liquids) by the movement of the fluid mass. Ex: Air moving across a fin tube heater, coffee heated in a kettle, etc.

Radiation: Transmission of heat through a space by infrared energy rays emitted from a hot surface. Infrared energy heats only the objects the energy strikes and not the air in its path. Hence, Infrared energy transmission happens even in vacuum as no media is required for transmission.

Infrared Radiation

Infrared (IR) is a form of electromagnetic radiation whose wavelength is slightly longer than red color in the visible light spectrum. IR radiation is created when objects are heated at temperatures not high enough to make them glow. Radiant heat doesn't heat air, but the object/ surface under its purview.

2. Literature Survey

Article on Emerging technologies in the field of infrared heaters [1] highlights on the application of space heating in buildings and the energy savings compared to the fossil fuel burnt furnace or boilers. The space heating applications in western and Scandinavian countries have been using unit heaters that are fired by using fossil fuel like natural gas or oil or electric heaters with air blowers for transferring the heat to the room. Lot of heat is wasted as hot air tends to remain at the ceiling level and un utilized by people occupying the room / building. In case of infrared heaters mounted above, spectrum of heat is directed downwards heating the occupants and not the air. Infrared heaters costs about 50% premium when compared to unit heaters, but the energy saving far outweighs this factor. Infrared heaters are silent whereas the unit heaters are noisy due to the air blower. Infrared heating is truly an energy saving technology and the saving is quite significant, as high as 50% compared to the conventional unit heaters burnt by fossil fuels or electric heaters with convective fan.

Infrared heating application for waste plastic gasification [2] gives a new dimension of energy conversion system of waste plastic materials. In this system, waste plastics are converted into gaseous fuel using infrared gasifier system. The work is focused in developing an economical heating solution for plastic waste gasification. In this modern life, plastic has become an integral part of our life and the usage of Plastic has been very significant, especially in packaging. This has resulted in Enormous plastic waste generation. Since plastic is non-biodegradable, its disposal as landfill waste is polluting the soil. Hence, gaseous fuel generation using plastic has dual benefits, one- generation of gaseous fuel by Waste and second - energy efficient heating by infrared system.

Advanced manufacturing technologies using high density infrared heating [3] highlights its application for selective softening of aluminum alloy in automotive structural for controlling deformation of crumple zones in the event of a crash.High Density Infrared Heating can be effectively used in induction hardening of steel members to increase strength locally in steel body panels thereby avoiding rigid apparatus and direct contact for heating. The HDI process utilizes a unique technology to produce extremely high power densities of 3500 watts/ Sq. cm. with a single lamp. Instead of using an electrically heated resistive element to produce radiant energy, controlled and contained plasma is utilized. The high density plasma arc processing is an innovative, economical production technique in automotive line. It is a robust processing tool that can be easily implemented in automotive assembly lines. Due to radiation, no contact is needed with materials and no open flames. Hence no hazards.

Design and evaluation of Selective far infrared heating system [4] is a selective heating system for drying of food powders, such as soy powder and glucose using infrared technology. The system was made of six ceramic lamps, a wave guide and an optical band pass filter. Long Infrared Heating system can be considered as a surface heating process unlike other thermal radiations. It is a possible alternative to microwave heating which has been established as a powerful and rapid heating technique. The infrared radiation can be filtered / controlled within a specific spectral range to pass through using suitable optical band pass filters. Capability to selectively heat higher absorbing components for processing to a greater extent is the essence of this article. Wave guide can be used to direct the infrared radiation waves to focus any desired selective area, so that heat concentration can be focused. Using optical filter, wavelengths can be changed to suit different types of food proteins. $\lambda = 6\text{-}11\mu m$

Heating by catalytic gas infrared rays, [5] thereby producing maximum wavelengths in the range 3.6 to 6.3 micron range are very efficient infrared emitters for the transfer of thermal energy to materials in the long-band spectrum. The larger surface area of the gas catalytic heaters makes them ideally suited for curing large part. This is done by breaking CH_4 molecular bond. Once the bond is broken, the CH_3 and H becomes very radical, looking to bond with O_2 in this case. The catalyst, being a stabilizer then acts to prevent the amount of IR energy to exceed temperatures of 425°C. Flameless infrared catalytic heater provides instant warmth, emission of no hazardous gases such as CO & NOx are emitted and requires no burner or chimney for flue extraction. The significant advantages are; temperatures are much lower than in flame combustion, ecological, with lower emissions and negligible exhaust gases that can be emitted into the working environment.

Design and engineering guide on high & low intensity gas fired infrared heaters [6] by Modine gas infrared heaters for comfort heating applications can be used to provide superior comfort heating solutions. The guide provides basic understanding of the principles of using infrared heating.Infrared heating system, though in a nascent stage in tropical countries, is now slowly gaining popularity in comfort heating applications in buildings in western and Scandinavian countries Significant energy cost reduction is the prime attraction of switching over to this system from the conventional unit heaters. There is no air mover, reducing the energy cost further. Ability to control heating in selective zones of the building is also a prime factor. Basically, there are two types of infrared heaters, High intensity IR heaters,where source temperature is in the range of 1800°F to 2200°F & Low intensity IR heaters, whose source temperature is around 1200°F. The article basically emphasizes on comfort heating applications in buildings, both domestic and large establishments. Infrared heating has significant edge over conventional unit heaters ie forced air heaters in term of the phenomenal energy saving and also the flexibility of selecting the zones. The literature explains the availability of high & Low intensity heaters, their spread width / distribution, mounting methods, angle of mounting etc.

Temperature uniformity in water films and wet paper through spectrally selective infrared heating [8] Experimentally derived radiant emissions from a near grey body source as well as a source with a narrow band emission centered at 5 microns(both gas radiant burners) were used to calculate temperature distribution along the depth of the water and wet paper (fiber-water suspensions) films. Temperature uniformity in narrow band emission was very good and the grey emitter resulted in wide temperature gradient. An appealing feature of IR heating is the penetration of thermal energy into the paper. This decreases the temperature gradient through the paper thickness, which is one of the problems of conventional steam box heating. In pre-press section, it is desirable to raise the temperature of the fiber / water suspension, which lowers the viscosity of the water making, making water extractionin the first pressing step more efficient.

Temperature uniformity all along the thickness of the paper section yields better water removal in the pressing operation and pressing would be less efficient if the temperature gradient is high. The use of spectrally emitting burner with a high intensity emission band at approximately 1.5 µm resulted in an improvement in temperature uniformity in water film, however at the expense of the overall energy absorption.

3. Infrared Radiation

Infrared heating is the most basic form of heating known to mankind. For example, mountaineers climbing snowy altitudes do not freeze themselves as they are bathed by the rays from the sun which include infrared waves. When infrared waves touch a surface, heat energy is released regardless of the surrounding air temperature.

Infrared Radiation has got three types;

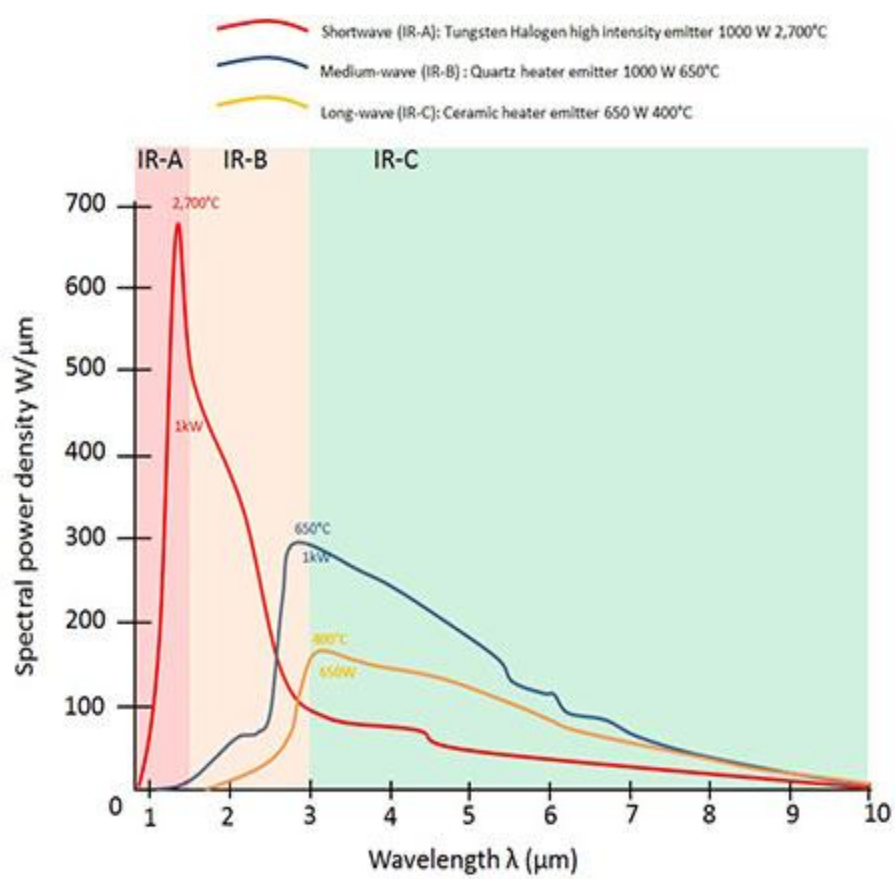

Fig. 1 Types of Infrared Radiation

I) Short Wave Radiation: (IR-A)

They are near infrared or Bright infrared radiation. These radiations glow and emit temperatures of 1300deg.C or even more. They produce bright red visible light. The emitters are typically, quartz with a reflector to concentrate the heat in a particular direction. The wavelength of short infrared waves lies in the range of 0.75 to 1.4 microns. Application: High intensity heat applications like cooking and welding/ thermoforming of plastics.

II) Medium Wave Radiation (IR -B)

Radiations classified in the range, 1.4 to 3 microns are called as medium wave radiations. These radiations emit temperatures between 500 – 800°C and produce a deep red light (like bar fires). Generally, quartz emitters are used for this type of heaters. Application: Used in manufacturing processes like curing of glues and coatings, print toner curing, adding PVC backing to materials, industrial drying etc.

III) Long Wave Radiation (IR-C)

They are called “Far infrared radiators” or “dark radiators”. These radiations are invisible to human eyes. Operates in the wave lengths above 3 microns. Far infrared elements emit much lower temperatures typically around 100°C – 200°Cand there will be no visible light. Ceramic emitters are used for this application. Application: Drying, space heating, curing, etc.

4. Comparison of Infrared v/s Conventional heating

In the Infrared heating principle, the heat transfer is solely by means of radiation even at lower temperatures. Infrared emitters are used and they heat the object directly and not the air. Hence, this can work even in vacuum, where there is no convective media. Most of the conventional heating systems work through convection mode of heat transfer, whereby the surrounding air is first heated and this heat in turn is transferred to the job / object to be heated. The rate of heat transfer is very slow in this case and the losses are also high as the entire volume of the oven and also the inner surface is heated. Whereas, infrared heaters emit a precise beam of heat that heats directly the object by throwing out a steady stream of heat particles on the object to be heated. Infrared heating system is very highly efficient compared to the conventional electric or fossil fuel heating system.

5. Proposed Far Infrared Oven

5.1 Design of Working Model

The objective of the project is to utilize infrared heating for drying / curing coating on sand molds used in foundries or for any thermal curing applications. The heating is done through ceramic far infrared heaters of wavelength λ in the range of 5 -6 microns. This has the following advantages over conventional heating;

- 90% heat energy is transmitted as infrared radiation
- Instant radiant heat

- Ease of installation
- Safe, clean heat source without fumes
- Durable life time of heaters
- Highly energy efficient, low energy costs

The project involves construction of a miniature oven using long wave infrared heaters.. The oven has a metal casing exterior lined with fiber formed insulation materials, with inner layer fitted with high emissivity reflectors. Long wave infrared heaters are mounted on two inner side walls.

Electric power is supplied to the infrared heaters through power relays. Far infrared ceramic IR heaters will produce heat. Temperature is measured by a thermocouple connected to a microprocessor based digital PID temperature controller. The thermocouple senses the temperature inside the oven and the signal is fed to the microprocessor based digital temperature controller. This in turn regulates the temperature by switching the heater relays to the required temperature set point. The power relay controls the input to the infrared heaters. Once the set temperature is reached, power input to the IR heaters is cut off. It will switch ON once the temperature in the oven falls below the set point in the temperature controller.

5.2 Specifications

5.2.1 Oven specification

- Overall size :400 mm W x 400 mm L x300 mm H
- Power capacity: 1300 Watts.
- Max. temperature :200°C
- Oven shell: mild steel sheet construction
- Insulation: Ceramic fiber formed board, mil board
- Useful volume:350 mm W x 350 mm L x300 mm H

5.2.2 Infrared Heater Specification

- No. of heaters: 2 nos.
- Heating type: radiation heating with $\lambda = 4 - 6\ \mu$
- Input power:650 watts, 230 V each
- Temperature:350 °C

5.2.3 Controls

- Thermocouple: N type, simplex, mineral insulated
- Temperature controller: Digital, microprocessor PID controller
- Relays: electromagnetic

5.2.4 Major Components used

- Infrared heaters

- Oven cubicle
- Insulating materials
- Reflectors
- Switchgears
- Thermocouple
- PID Temperature controller

1) Infrared Heaters

In this project, ceramic infrared heaters with wave length, λ in the range 4-6 μ is used.

Two such heaters, each of 650 watts at 230 V AC is used.

2) Oven Cubicle.

5.3 Fabrication of Working Model

The cubicle of the oven is constructed out of 14 / 16 SWGmild sheet steel dulyCRCA sheet dulu formed and welded. It is adequately strong to support the insulation, infrared heaters and accessories required for the oven. The exterior is coated with heat resistant alumina paint. The oven is insulated with ceramic fiber formed boards / MIL boards. Two Ceramic infrared heaters are mounted on opposite walls with reflector sheet backing. The heaters are clamped to the wall with brackets and clip arrangement and of easily removable type.

The heaters are wired to the power supply system through switchgears and relays. Thermocouple is connected to the digital temperature controller and output relay of the digital temperature controller is used for switching ON or OFF the power to the infrared heaters through contactor / relays etc. Protective devices like miniature circuit breaker are used for short circuit or overload tripping.

5.4 Heat Transfer Mechanism

The mode of heat transfer in this oven is predominantly by radiation which is governed by Stefan-Boltzmann law, Wien's law and Planks distribution law. The energy from the source (infrared heaters) is transferred to the job by electromagnetic waves which requires no intermediary medium for heat propagation.

Heat transfer by Stefan-Boltzmann law is given by the equation,

$Q = \varepsilon\sigma\ AT^4$

Where, ε is the emissivity of the of the surface,

σ - Stefan -Boltzmann constant (W/m^2K^4)

6. Results and Discussions

The objective of the performance test is to find out the efficiency of the oven & thereby prove that it is an energy saving model. The object to be heated is placed inside the oven. The required temperature for drying / curing is set in the digital temperature controller. The thermocouple is adjusted such that it is touching the object to be heated. Power supply is switched ON. The current drawn, Voltage input and the time taken for heating and soaking are noted. The typical readings are tabulated and the energy consumption is calculated using the data.

Ambient temperature: 30°C

Measuring instrument used: Digital multi meter cum clamp meter.

Power, W = V x I   Watts

Energy consumed, E = W x TWsec. -------- (A)

Table-1 Experimental data, energy and efficiency calculations:

Trial no.	Temperature °C	Voltage, V volts	Current, I amps	Time, T in secs	Power input, W watts	Energy consumed, Wsec. (A)	Efficiency **η %**
1	180	230	5.6	565	1288	727720	90.67
2	180	230	5.7	556	1311	728916	90.52
3	180	228	5.4	596	1231	733795	89.92

Oven Efficiency testing:

The energy required to raise the temperature of an object is the product of the mas, the mean specific heat and the change in temperature, given by the equation,

$Q = m \times C_p x \, (T_2 - T_1)$

Where,

Q = Quantity of heat in KJoules,

m = mass of the material in Kg.

C_p= Specific heat (mean) in J/Kg.°C

Data:

Mass of the sand mold = 5.3 Kg.

Temperature targeted, T2 = 180 °C

Ambient temperature, T1 = 30 °C

Specific heat of sand mold: 830 J/Kg.°C

Heat energy in the targeted object, $Q = m \times C_p x (T_2 - T_1)$
Therefore, heat energy, $Q = 5.3 \times 830 \times (180 - 30)$
= 659850 J ------ (B)
Energy consumed by the oven is arrived by running the oven, recording the parameters as in the table above and computing the energy consumed.

- **Oven efficiency, η= Heat energy in the object (B) / Energy consumed by the oven (A) x 100**

Efficiency = (659850/727720) x 100 **= 90.67 %**

Advantages:

- Rapid heating
- Selective heating possible.
- Heat to job only.
- Negligible losses.
- Highly energy efficient>90%)

Disadvantages:

- Slow heating is difficult
- Temperature gradient between the surface & core will be more.
- Cannot find application in very slow and uniform job heating.

7. Conclusion

The infrared oven was designed and fabricated using far infrared / long wave heaters. The heating was very effective and quicker. With this method, a highly energy efficient method of heating was demonstrated and proved. Since the heating is rapid, productivity of the system for the intended application is much faster.

Infrared heating stands tall as an "Energy Conservation Technology".

References

[1] Kurt Roth andJames Brodrick "Emerging Technologies – Infrared Radiant Heaters", 2007.
[2] Zuhair E.M. Haruon "Design and development of infrared heater for waste plastic gasification. 2014

[3] J.D.K. Rivard, C.A. Blue, R.D. Ott, A. Sabau, M. Santella, T-Y. pan & Joaquin. Advanced manufacturing technologies utilizing high density infrared radiant heating, 2013.
[4] Soojin Jun & Joseph Irudayaraj “Selective far infrared heating system – design & evaluation. 2006
[5] Mohammed Awwad Al-Dabbas, Mutah University, Karak, Jordan “Heating by catalytic gas infrared rays. 2011.
[6] Modine “ Design & engineering guide- high & low intensity gas -fired infrared heaters. 2016
[7] Information from Herschel website
[8] Hyukjae Lee, Robert F. Speyer and Timothy Patterson “Temperature uniformity in water filmsand wet paper through spectrally selective infrared heating” 2003.