UNIVERSITY OF PITESTI SCIENTIFIC BULLETIN
FACULTY OF MECHANICS AND TECHNOLOGY AUTOMOTIVE series, year XX, no.24(1)

STUDIES ON INFRARED RADIATION HEATING FOR INCREASING THERMAL COMFORT

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Article history:
Received: 10.06.2013; Accepted: 20.09.2013.

Abstract: *Infrared radiation as a heat source which is used in many fields and the positive effect of on living organisms has been observed. This study of the infrared radiation started from an analysis regarding heating of from passenger compartment for electric cars which is insufficient on the cold periods. So, IR heating could be a solution in this case, and an alternatively or additionally system for cars with internal combustion engines. In addition, the heat generated by infrared heating surfaces is distributed without any need for drafts of air and is completely silent. Also each passenger can be provided with his own individual heating system, it is also possible to selectively heat only those seats that are occupied and thus reduce energy consumption. This paper presents technical information about infrared radiation, different characteristics of infrared heat sources used, as well advantages and disadvantages of this solution.*

Keywords: Infrared radiation, thermal comfort, infrared source

INTRODUCTION

Everyone knows infrared energy is heat that can be applied to many things for manufacturing, finishing, drying and heat processing. But, do we really know and understand the characteristics of infrared energy or do we use it simply as another source of heat? To find out what infrared really does, what it can do, and where it can and cannot be used to its full advantage. Infrared radiant heating can have beneficial effects on the human body: stimulates blood circulation - hypotensive, no movement, so no movement of dust, odors, does not dry the air: asthma or severe rheumatic.
Essentially, infrared is an electromagnetic phenomenon, which is measured in wavelengths (microns). Electromagnetic energy particles attack the surface of materials to be processed after which conduction takes over. Materials can act as a good heat conductor. In many cases, however, the conductivity is less than desired resulting in absorbing and retarding the penetration of heat. Some of the materials may work as an insulator. In this case, the infrared energy must be applied from two sides
Until this moment doesn't exist any studies in automotive field who uses infrared radiation heating.
Only, BMW announced developing infrared heating system installed in car doors for EVs, last year (http://green.autoblog.com/2012/09/19/bmw-developing-infrared-heating-system-for-evs).
Conventional heaters and air conditioners today heat the air inside the vehicle, which then transfers its heat to the driver and passengers. In contrast, in systems employing infrared heating surfaces, energy is converted into infrared radiation, which then warms the occupants' bodies directly.

TECHNICAL INFORMATION

Infrared (IR) light is electromagnetic radiation with longer wavelengths than those of visible light, extending from the nominal red edge of the visible spectrum at 700 nanometers (nm) to 1 mm. This

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range of wavelengths corresponds to a frequency range of approximately 430 THz down to 300 GHz.[1] Most of the thermal radiation emitted by objects near room temperature is infrared.
Infrared radiation was discovered in 1800 by astronomer William Herschel, who discovered a type of invisible radiation in the light spectrum beyond red light, by means of its effect upon a thermometer. [2].

THERMAL AND INFRARED RADIATION

The term thermal radiation describes that part of the spectrum of electromagnetic radiation which every object radiates in relation to its temperature when this temperature differs from absolute zero on the Kelvin temperature scale (0 K). As a form of heat transfer, it isn't dependent on mass, and in contrast with heat conduction and convection, it also appears in a vacuum. The best known form of thermal radiation is solar radiation, which can be divided into the areas of UV radiation, visible light and infrared radiation (Figure 1).

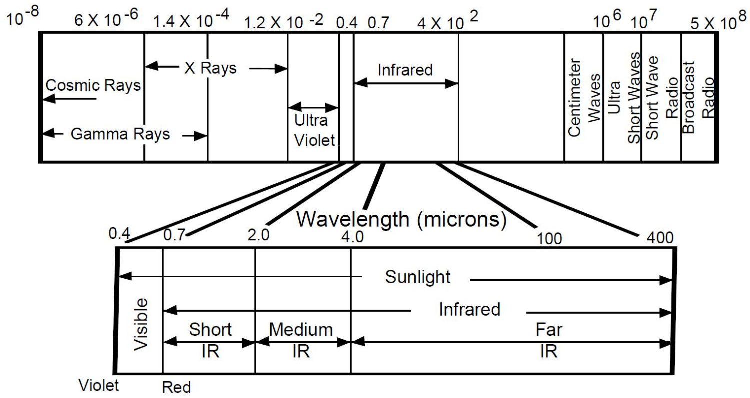

Figure 1. Electromagnetic Spectrum.

Radiation exchange takes place continuously amongst all objects and it theoretically ends only when all the surfaces of the objects have the same temperature. In the reality of a heated residential space, all heating elements, walls, ceilings, windows, doors, furniture, people, animals etc. function as surfaces which emit radiation. As the heating elements or heating surfaces have the highest temperature and continuously supply this energy, the temperature of all the remaining surfaces would ideally increase until all the surfaces in the room obtain the temperature of the heating surfaces. From the whole spectrum of thermal radiation only infrared radiation plays a certain role in heating technology. It is often called thermal radiation in short, even though infrared radiation is actually only one part of thermal radiation. Infrared heating is divided into bands according to the wavelengths IR-A (0.78 µm to 1.4 µm), IR-B (1.4 µm to 3.0 µm) and IR-C (3.0 µm to 100 µm). Another classification is into near, mid and far infrared radiation (fig.1). Far infrared radiation and IR-C radiation are identical.[3,4].

EMISSIVITY AND ABSORPTIVITY

Not all the radiant energy that reaches the product is absorbed. Some may be reflected and some transmitted right through. Only absorbed energy will serve to heat the product.
Total Incident Energy = Absorbed + Reflected + Transmitted. It is the physical nature of the product that determines how well the product absorbs the radiant energy that strikes it. This same physical property determines how well a surface emits radiant energy. At the same temperature and wavelength, absorptivity and emissivity are equal. From here on, the term "emissivity" will be used for the numerical value that describes either the ability to absorb or emit radiant energy. Figure 2 lists the emissivity of some common materials and surfaces [4].
The most common filament material used for electrical infrared heaters is tungsten wire, which is coiled to provide more surface area. Low temperature alternatives for tungsten are carbon, or alloys of iron, chromium and aluminum (trademark and brand name Kanthal). While carbon filaments are more

fickle to produce, they heat up much more quickly than a comparable medium-wave heater based on a FeCrAl filament [5].

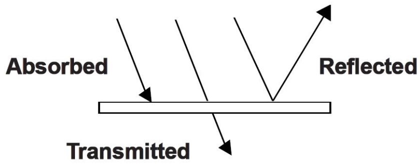

Figure 2. Total Incident Energy

Industrial infrared heaters sometimes use a gold coating on the quartz tube that reflects the infrared radiation and directs it towards the product to be heated. Consequently the infrared radiation impinging on the product is virtually doubled. Gold is used because of its oxidation resistance and very high IR reflectivity of approximately 95% [5].
To achieve successful process heating, it is important that the infrared emitter is carefully matched to the properties of the product to be heated in terms of its wavelength, its shape and its power output. Radiation which precisely matches the absorption characteristics of the product is quickly converted into heat in the product, without unnecessary heat being transferred to the surroundings. It also saves time and money if products can be transferred quickly for further processing after the heating stage. The correct wavelength depending on the temperature of the heating element, an infrared emitter delivers distinctly different radiation at various wavelengths. It is important to select the correct emitter for the product, as the wavelength has a significant influence on the heating process [6].

Metals	Polished	Rough	Oxidized
Aluminum	0.04	0.055	0.11-0.19
Brass	0.03	0.06-0.2	0.60
Copper	0.018-0.02	—	0.57
Gold	0.018-0.035	—	—
Steel	0.12-0.40	0.75	0.80-0.95
Stainless	0.11	0.57	0.80-0.95
Lead	0.057-0.075	0.28	0.63
Nickel	0.45-0.087	—	0.37-0.48
Silver	0.02-0.035	—	—
Tin	0.04-0.065	—	—
Zinc	0.045-0.053	—	0.11
Galv. Iron	0.228	—	0.276
Miscellaneous Materials			
Asbestos			0.93-0.96
Brick			0.75-0.93
Carbon			0.927-0.967
Glass, Smooth			0.937
Oak, Planed			0.895
Paper			0.924-0.944
Plastics			0.86-0.95
Porcelain, Glazed			0.924
Quartz, Rough, Fused			0.932
Refractory Materials			0.65-0.91
Rubber			0.86-0.95
Water			0.95-0.963
Paints, Lacquers, Varnishes			
Black/White Lacquer			0.8-0.95
Enamel (any color)			0.85-0.91
Oil Paints (any color)			0.92-.096
Aluminum Paint			0.27-0.67

Figure 3. Approximate Emissivities.

Infrared heaters are usually classified by the wavelength they emit. Near infrared (NIR) or short-wave infrared heaters operate at high filament temperatures above 1,800 °C and when arranged in a field reach high power densities of some hundreds of kW/m^2. Their peak wavelength is well below the absorption spectrum for water, making them unsuitable for many drying applications. They are well suited for heating of silica where a deep penetration is needed.
Medium-wave and carbon (CIR) infrared heaters operate at filament temperatures of around 1,000 °C. They reach maximum power densities of up to 60 kW/m^2 (medium-wave) and 150 kW/m^2 (CIR).
Far infrared emitters (FIR) are typically used in the so-called low-temperature far infrared saunas. These constitute only the higher and more expensive range of the market of infrared sauna. Instead of using carbon, quartz or high watt ceramic emitters, which emit near and medium infrared radiation,

heat and light, far infrared emitters use low watt ceramic plates that remain cold, while still emitting far infrared radiation. Characteristics of commercially used infrared heat source are presented in Figure 4.

	Tungsten Filament		Nickel Chrome Resistance Wire			Wide Area Panels	
Infrared Source	Glass Bulb	T3 Quartz Lamp	Quartz Tube	Metal Sheath	Ceramic	Ceramic Coated	Quartz Face
Source Temperature (°F)	3000 - 4000°F	3000 - 4000°F	Up to 1600°F	Up to 1500°F	Up to 1600°F	200 - 1600°F	Up to 1700°F
Brightness	Intense white	Intense White	Bright Red to Dull Orange	Dull to Bright Red	Dark to Dull Red	Dark to Cherry Red	Dark to Cherry Red
Typical Configuration	G-30 Lamp	3/8" Dia. Tube	3/8 or 1/2" Tube	3/8 or 1/2" Tube	Various Shapes	Flat Panels	Flat Panels
Type of Source	Point	Line	Line	Line	Small Area	Wide Area	Wide Area
Peak Wavelength (microns)	1.16	1.16	2.55	2.68	3 - 4	2.25 - 7.9	2.5 - 6
Maximum Power Density	1 kW/ft²	3.9 kW/ft²	1.3 - 1.75 kW/ft²	3.66 kW/ft²	Up to 3.6 kW/ft²	3.6 kW/ft²	5.76 kW/ft²
Watts per Linear Inch	N/A	100	34 - 45	45 - 55	N/A	N/A	N/A
Conversion Efficiency Infrared Energy	86%	86%	40 - 62%	45 - 56%	45 - 50%	45 - 55%	45 - 55%
Response Time Heat/Cool	Seconds	Seconds	1 - 2 Minutes	2 - 4 Minutes	5 - 7 Minutes	5 - 8 Minutes	6 - 10 Minutes
Color Sensitivity	High	High	Medium	Medium	Medium	Low to Medium	Low to Medium
Thermal Shock Resistance	Poor	Excellent	Excellent	Excellent	Good	Good	Good
Mechanical Ruggedness	Poor	Fair	Good	Excellent	Good	Good	Fair

Figure 4. Characteristics of commercially used infrared heat source.

Apart from the energy transfer between objects as a result of radiation exchange, energy transfer from an object into a liquid which surrounds it also exists, via the absorption of emitted radiation energy in the liquid. In heating technology, the absorption of infrared heating into the air exists, but it usually has a significantly lower share in the energy transfer than convection. The degree of absorption in dependence on the wavelength is shown in Figure 5.

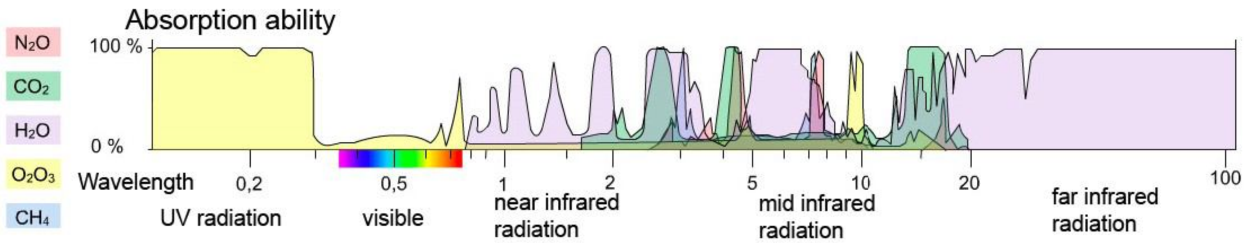

Figure 5. Absorption spectrums of various substances in the air.

It can be seen easily that a large amount of infrared radiation can be absorbed as a result of high air humidity. Apart from that, a permeability "window" in the band of approx. 7 m to 13 m can be seen in which infrared radiation can spread through the air almost without any restrictions. The absorption zones for ozone, hydrocarbons and nitrogen oxides which are marked here do not play any role in a residential area. The maximum of the used IR-C radiation can be found in this permeability "window" in an ideal situation [7-17].

THE ADVANTAGES OF RADIANT HEAT

Electric radiant heat has many benefits over the alternative heating:

Non-Contact Heating : Radiant heaters have the ability to heat a product without physically contacting it. This can be advantageous when the product must be heated while in motion or when physical contact would contaminate or mar the product's surface finish.

Fast Response : Low thermal inertia of an infrared radiation heating system eliminates the need for long pre-heat cycles. Since radiant heaters generally require only a few minutes to reach operating temperature, energy savings can also result from turning off the oven during gaps in production. Radiant heating times are typically less than one-third that of a conventional convection oven. Since radiant energy heats the product directly, without an intervening heat transfer medium such as air, radiant heating can be much faster than convection heating. Convection heating must conduct the heat energy through the boundary film of air that clings to the product's surface. Radiant energy is absorbed at and below the surface of the product and then transferred by conduction throughout the material's thickness.

High Efficiency : Radiant heaters generate electromagnetic waves that, when intercepted and absorbed by the product, are converted directly to heat. Since they do not necessarily heat the air or surroundings, radiant ovens can be designed to achieve a high level of efficiency. The energy radiated may also be concentrated, focused, directed, and reflected in the same manner as light, which greatly increases its flexibility and adaptability and reduces energy losses.
Control Accuracy : Electric radiant heaters can be easily and precisely controlled. They can be zoned to provide uniform heating or a custom distribution of power density. Infrared sensors can sense the actual product temperature and be used to control the heater temperature or line speed.
Low First-Time Costs : The simplicity of electric infrared systems, the lightness of the structures, and the elimination of massive furnace foundations reduce initial system and installation costs.
Floor Space Savings : High heat source concentrations quickly increase product temperature allowing for shorter conveyor lengths. Radiant heaters can heat products equally, whether they are moving vertically or horizontally. Compact radiant systems can also be suspended from the ceiling. The value of these floor space saving options will often exceed the first cost of the system.
Clean Heat : Unlike gas-fired ovens, electric radiant heaters do not produce combustion by-products, so, the product is not contaminated. Low air velocities reduce the possibility of surface contamination by airborne dirt [4].

Medical aspects:

Individuals with allergies / asthma : Mainly individuals who are allergic to dust in the household suffer due to the heating technology used there. Allergy to dust in the home means oversensitivity and allergic reactions to the excreta of mites in dust in the household, which can cause a runny nose, itching and allergic asthma. This reaction of the immune system isn't caused by the household dust itself but by the excrement of mites which live in the dust. This excreta sticks to the dust and is “stirred up” by every form of flow. The lower the amount of flow, the better for an allergic person. Due to its functional principle, infrared heating has the lowest ratio of flow (convection).
Medical treatment with heat: Medical treatment with infrared radiation belongs to the field of physical treatment or physiotherapy. Here, we deal with medical forms of treatment which are based on physical principles such as heat, electric current, infrared radiation and UV radiation, the use of water and mechanical treatments such as massage. In particular, the use of IR-C radiation, which is used in infrared saunas, has been well-researched in the areas of treating pain, overstrain of the locomotor apparatus and the treatment of vascular problems. Infrared heating has a positive medical and therapeutic effect. Apart from that, it is a component of radiation which surrounds us in our everyday lives constantly because it is radiated, to a higher or lower level, by all objects anyway [18 - 20].

EFFICIENCY OF RADIATION

The efficiency of radiation described in the DIN EN 416-2 and DIN EN 419-2 standards, as well as in directive (90/396/EHS), is valid for infrared heating powered by gas. Both are decisive for the rational use of energy and for economy, while the aim is to achieve an efficiency of radiation (corresponding to the proportion of infrared radiation) which exceeds the value of 50% by as much as possible.
For electrically powered infrared heating, it is necessary to analogically use the efficiency of radiation as a ratio between the output of the infrared heating and the supplied electric wattage, though of course no standard exists for this yet [21].

COMPARISON OF ENERGY FLOWS NATURAL GAS AND INFRARED HEATING SYSTEM.

Gas heating system: During burning natural gas in the burner, it transforms into approx. 10 kWh of thermal energy for every cubic meter of gas. Part of it enters the circulation of heating water via the heat exchanger, while the rest is lost from the burner via the cellar space or chimney in an outward direction.

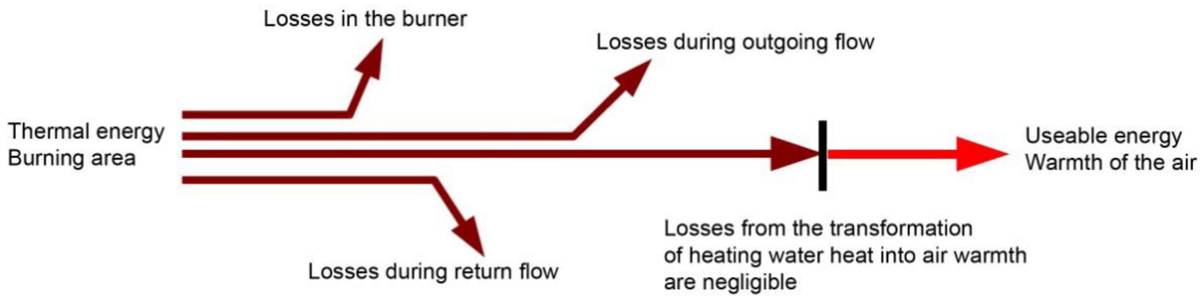

Figure 6. The flow of energy in the gas heating system

The pipes in the heating water circuit leading from the burner to the radiator and back are laid in the walls and ceilings and are more or less insulated, and they heat the surrounding material from the inside. A small portion of thermal energy thus enters the room directly via the walls, ceilings and floors. A substantially larger part, however, gets lost through the outside walls because the temperature difference towards the outside is the greatest in the winter. Apart from that, so called heat leaks cause cooling in the outward direction in old residential buildings. Heat loss occurs in the heating water circuit both during the flow outwards and back. The remaining thermal energy is transferred into the air in the room as useable energy via the radiators. The radiation heat, which is simultaneously given off from the radiators (infrared radiation), can be ignored because it makes up only a few per cent of the total thermal energy transferred and it also heats the air in the room. The objects in the room and the surfaces which delimit the room (walls, ceilings and floors) warm up via the convection (flow) of air in the room. Therefore, the temperature of the air in the room is usually higher than the surface temperature. In old residential buildings, particularly where the burners are old, losses can occur due to bad insulation to the extent that less than half of the energy remains in the air of the room as useable energy.

Infrared heating system: Electrical energy and thermal energy are obtained from fossil and nuclear energy carriers, though the thermal energy is usually given off into the surroundings unused as waste heat. On average, 10% of created electrical energy is lost during transfer between the power plant and the main box of the house. In a house, the incoming electrical energy is transformed into heat radiation energy (infrared radiation) in infrared heaters as useable energy and it is radiated directly into the inhabited spaces. Direct heating of air, as is the case with radiators, can be ignored. Relatively little convection is created. Infrared radiation warms up mainly the wall surfaces, ceilings and floors and objects in the room. A small part of infrared radiation is absorbed by the air and heats it directly. Otherwise, the air is heated indirectly with the help of the surfaces onto which the radiation falls, via large-surface, exceptionally weak convection. Therefore, the surfaces in the room are usually warmer than the air [21 - 23].

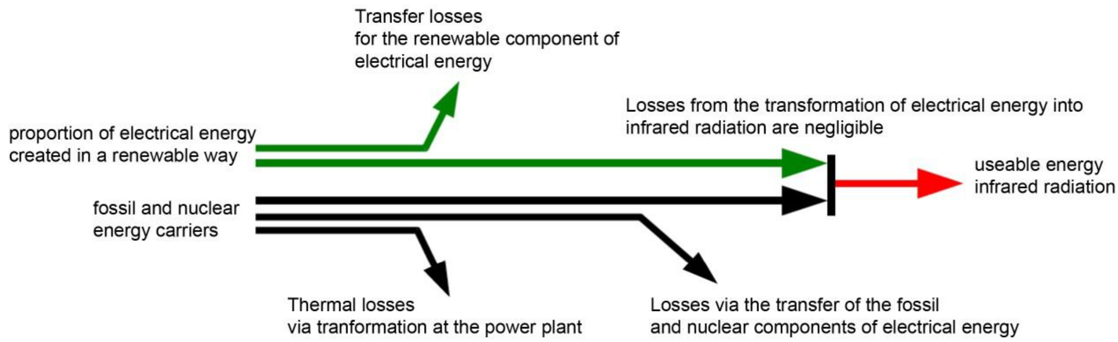

Figure 7. The flow of energy in the infrared heating system

CONCLUSIONS

In the field of vehicle heating systems, modern infrared heating surfaces are a new solution that not only promotes low power consumption but also provides a noticeable improvement in the passengers' level of comfort. Particularly when used in battery electric vehicles, future infrared heating surfaces will yield gains in efficiency, since the electrical energy will be used to directly warm the occupants. Apart from rapidly warming the passengers, infrared heating surfaces can be used as an additional feature to create an agreeable, cosy climate within the vehicle.

As presented in this paper, radiant infrared heating is safe both in terms of security and health and safety of people and stability in operation. So, do not work with liquids or steam under pressure and does not pollute. Are environmentally friendly: does not emit smoke, pollutants, CO etc..

One disadvantage which may disturb in some cases, is that infrared radiation does not heat the air, but only persons and bodies in the area, that only surfaces on which "sees" the radiant panel.

So for passenger compartment heating which used infrared heat source must done a detailed analysis so as to obtain a optimal thermal comfort.

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