Energy Efficiency and Conservation Authority
Te Tari Tiaki Pūngao

Technical Information Document

Electric Infra-Red process heating.

Technical Information Document 2019

New Zealand Government

Introduction

Infra-red provides a flexible and efficient form of process heating that can be adapted to fit existing or new production lines. Infra-red equipment is generally low cost. In many cases, installation can be a simple connection to an existing electrical circuit. It is safe, clean and can be used as an efficient way to heat many materials and products. Infra-red is also commonly used to provide heating for humans, plants and animals.

Infra-red is a direct form of heating; unlike convection heating, it does not transfer energy by warming the air in order to heat a target material. Infra-red energy is absorbed directly by the surface of the target material and converted into heat. Infra-red heaters produce heat energy in the far red range of the electromagnetic spectrum. To maximise efficiency and effectiveness, the frequency of the infra-red wavelength can be 'tuned' to the absorption characteristics of the target material. This tuning is achieved by selecting either short, medium or longwave infra-red emitters.

The key difference between infra-red heating and heating using dielectric (microwave or radio frequency energy) is that dielectric heating methods penetrate the core of a product while infra-red energy heats the surface, typically penetrating between 0 to 5 mm into it.

Most materials are good absorbers of infra-red wavelengths, one exception is highly polished metals, which are used as reflectors to increase the efficiency of the infra-red heaters.

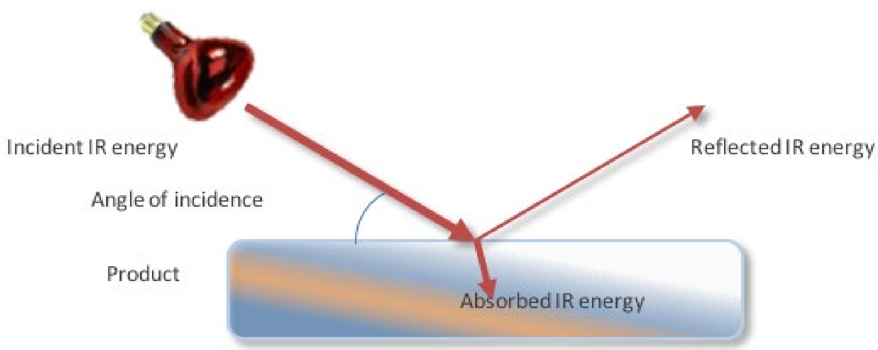

Figure 1. Infra-red absorption into and reflected from a target material

Strata ENERGY CONSULTING

Efficient Energy International
Markets • Policies • Results

EECA commissioned Strata Energy Consulting and Efficient Energy International to produce this document which is one of a series on electrical heating.

The amount of energy absorbed by the target depends on three things:

1. the absolute temperature of the infra-red emitter (this determines the wavelength of the infra-red that it emits)
2. the target product's ability to absorb rather than reflect infra-red energy (emissivity)
3. the geometric features of the emitter and target material (the angle of incidence) see Figure 1.

Infra-red heating is well-suited to non-contact heating applications with variable heating demand. Short and mediumwave infra-red heating can be removed almost instantly by simply switching the emitter off. Similarly, the heat can be almost instantly applied. Infra-red heaters are very efficient; up to 95% of the electrical input energy can be transferred to the target material.

To achieve high efficiency, the infra-red emitter should be located as close as possible to the target material and to the 90 degree angle of incidence (i.e. facing the product).

Maintaining high efficiency performance requires infra-red emitters to be clean and dry. In damp, dusty environments regular maintenance will be required to maintain high efficiency performance.

Infra-red can be a good option where product temperatures are required to reach up to 1100°C. Examples include; drying and curing of paints, moisture removal and mass heating applications such as annealing and heat treatment. Infra-red can also be used in food product manufacturing.

Unlike most other forms of heating, infra-red does not require air circulation to transfer heat to the target material. This feature means that infra-red reduces the potential for contamination of the target material through airborne particles. A good example can be found in paint drying, infra-red heating will significantly reduce the risk of surface contamination as the paint is dried or cured. Reducing product loss due to contamination can be a primary benefit of converting to infra-red heating and drying.

Technical Features

Fundamental features of Infra-red heating

Infra-red is a form of electromagnetic radiation, situated between the visible light and microwave ranges on the spectrum. Infra-red wavelengths are generally considered to be between 0.76 and 1000 μm (micrometres, or microns). Within this range, infra-red is divided into short, medium and long wavelength classifications.

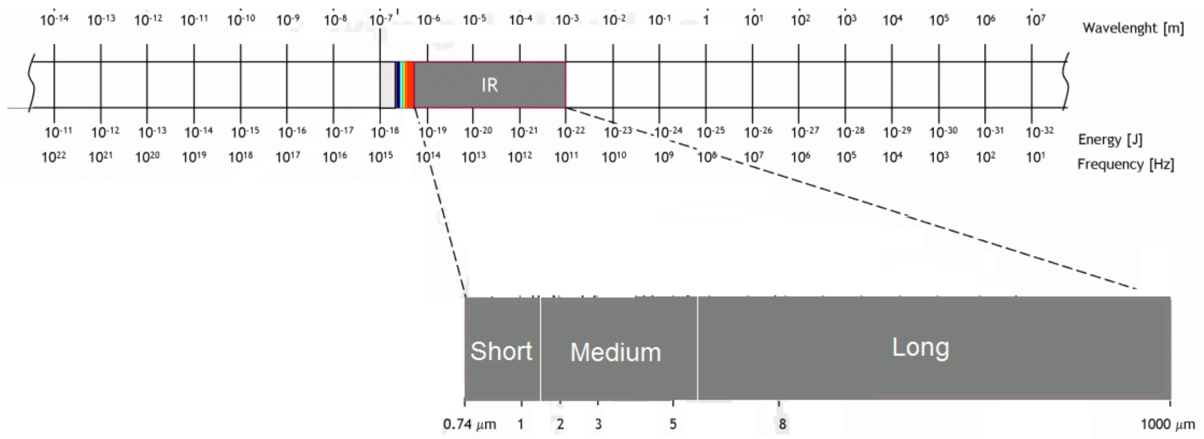

Figure 2. Infra-red frequencies and wavelengths

Infra-red heaters and efficient radiation.

Infra-red energy is absorbed, transmitted or reflected by any object that it strikes. The key factor in determining the efficiency of an infra-red heater is the emissivity of the target product and the heater itself. High emissivity surfaces emit and absorb most of the infra-red energy for the selected wavelength they create or receive. Low emissivity surfaces reflect and don't absorb most of the infra-red energy for a selected wavelength; because of this low emissivity materials such as polished metals are used as reflectors in infra-red heaters.

External reflectors, such as parabolic and elliptical reflectors are commonly used to increase the efficiency of infra-red emitters. The reflectors can also be shaped to concentrate heating on specific areas of the target material. Generally, reflectors increase efficiency by 30%. Parabolic reflectors can create a focused beam of infra-red energy, while flat emitters spread heat more widely.

An additional factor that is critical to the amount of energy radiated or absorbed is the difference in absolute temperature between the infra-red emitter and the target. The range of energy intensities (see figure 3) and temperatures available from different infra-red heaters enables matching of emitter types to the absorption characteristics of target materials.

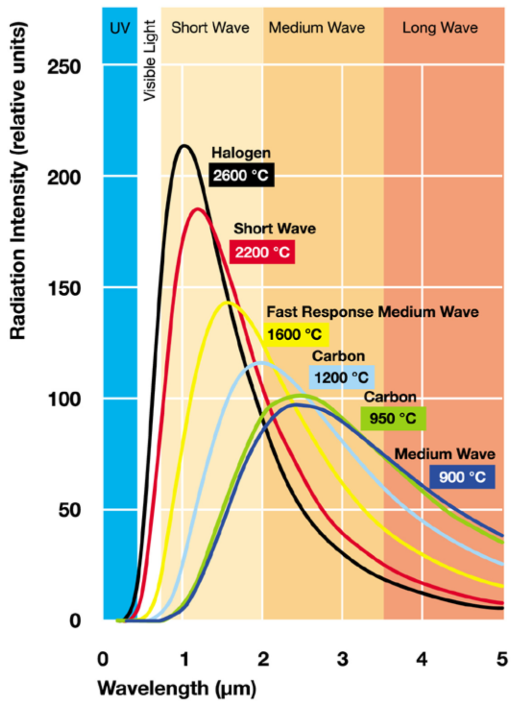

Figure 3. Radiation intensity characteristics of infra-red wavelengths

Source: http://www.infralight.com.au/files/images/infralight/Infrared_Spectrum.jpg

***Short wavelength lamps and quartz* tubes** need very good reflectors to direct the radiant energy from the linear radiant elements to the target. To achieve this, quartz tubes often have reflective gold coatings. Quartz and glass elements are relatively robust and are commonly used in industrial and commercial applications. With relatively low mass and high emissivity, quartz infra-red heaters provide virtually instant heat.

Figure 4. Short wavelength infra-red lamp

Source: http://www.infralight.com.au/infrared-heating-technology

Medium wavelength heaters are generally quartz and silica or ceramic tubes, and metal or ceramic elements that glow a dull red colour. Depending on the choice of element, mediumwave heating can be very responsive but not as instant as shortwave infra-red.

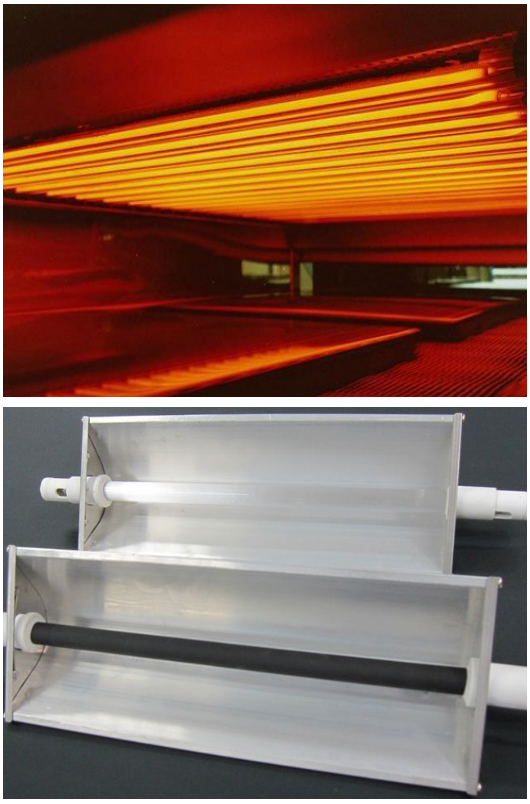

Figure 5. Medium wavelength infra-red quartz, silica and ceramic tube elements

Source: http://www.infralight.com.au/infrared-heating-technology
http://www.hqheating.com.my/heater.html

Figure 6. Ceramic long wave infra-red heater and projector

Source: http://www.elstein.com and https://www.ceramicx.com

Responsiveness and control

Short wave emitters require around one second to reach optimum operating level. Medium wave emitters require up to one minute, and long wave emitters may need up to 10 minutes. Similar time frames are needed to return the emitters to their resting states.

Electronics controllers allow infra-red heaters to be responsive by switching from full output to low levels of heat emission at high speeds. The benefits of electronic control include obtaining higher efficiencies, higher product quality, lower production losses, reduced overheating risks and lower running costs.

Table 1 provides information on a range, of infra-red emitters. This table should be used only as an initial guide to emitters for specific process heating requirements. Due to the broad range of emitter types, further information and advice should be sought before purchasing a heating system.

Radiation range	Emitter Types	Radiant efficiency	Operating Temperature °C	Max product temperature	Heating & cooling response	Max power density (kW/m²)	Service life (hours)
Short Wavelength	Lamps (halogen)	86 – 95%	2,000 Warm White	300	Very fast	10	3,000 Fragile lamps
	Quartz tubes	61 – 95%	2,200 Warm white	600 – 800	Fast	300 (50-70 W/cm tube length)	5,000 – 100,000 Low strength tubes
Medium Wavelength	Quartz tubes	61%	1,050 Yellow	500	Fast	50 – 70	5,000 – 10,000
	Silica or ceramic tubes or panels		650	450	Slow	25	Several years
	Metallic radiating panels, sheathed elements	56 – 88%	750	400	Slow	40	Several years
Long Wavelength	Pyrex radiating panels		350	250	Slow	15	Several years
	Ceramic elements	96%	300 to 700	500	Slow	40	Several years

Sources: https://www.nphprocessheaters.com/_assets/uploads/pdfs/Ceramic%20Infrared%20Heaters/ceramic_infrared_heaters-Technical%20Manual.pdf

Selecting Equipment

Infra-red suppliers generally provide advice on the choice of heating for specific applications. A good starting point is to identify suppliers with experience in applications similar to the one intended. Whilst basic options assessment can be achieved through sample testing, it is advisable to seek expert advice on tailoring a solution to meet the particular heating application. Local infra-red suppliers and installers often have access to international suppliers' experience and design capability.

Benefits

Reduced operating costs

Operating costs can be lower due to the high efficiency of infra-red relative to other forms of heating; this is because the air around the product does not need to be heated. Reflectors can also significantly reduce radiant losses by focusing infra-red energy on the target.

Improved product quality

Contamination of product surfaces and the associated production losses can be avoided because infra-red does not require air circulation or conduction to heat the product's surface.

Highly Responsive

Improved product quality can be achieved due to the responsive control of infra-red emitters. Rapid start-up and shut-down times allow the heaters to respond quickly to the needs of the production process enabling accurate and consistent product temperature control.

High durability, low maintenance costs

Having few components, maintenance costs can be limited to periodic reflector cleaning and replacement of heating elements.

Safety

Through the removal of flammable materials and elimination of hot air, infra-red heating can be a safer option than fossil fuel powered heating solutions. The responsiveness of infra-red can also deliver safety benefits.

Low initial cost

Initial investment costs of infra-red are typically lower than other heating options. Infra-red heaters generally require less space and can be assembled from pre-made modular units, which can reduce design and installation costs.

Challenges

Energy Unit Costs

The main cost of infra-red heating is in the variable energy price of electricity; the per unit charges for electricity can be higher than for other fuels.

Electricity Supply Installation

High capacity infra-red applications may require investment in additional electricity supply capacity. While each unit operates at low voltages (230V), combining several units may require increased electrical installation capacity.

Network Dependency

High capacity infra-red installations may require investment to increase electricity supply capacity from the electricity distribution company. This may impact on peak demand charges.

Safety

Emitters are hot and precautions should be taken. Energy from infra-red heaters can also interact with solvents and explosive chemicals. Potential risk of glass or quartz tubes shattering requires protection if heating food products. Eye protection, such as coloured, reflective glass lenses should be worn when working with high intensity short wavelength infra-red sources.

Manufacturers, suppliers and installers of infra-red process heating systems

Infra-red heaters are well established in New Zealand. In 2018 the following suppliers were identified.

New Zealand Suppliers

Infratech
http://infratech.co.nz/

Infrared Panels
http://infraredpanels.co.nz/

Herschel Infrared
http://www.herschel-infrared.co.nz/

Heating Elements
http://heatingelements.co.nz

CD Automation
https://www.cdautomation.com/products/ir-lamp-short-wawe-control

Tansun
https://www.tansun.co.nz/

Argus Heating
http://www.argusheating.co.nz/infra-red-ir-heating-elements

EEPL
http://www.eepl.co.nz/radiant-heaters-energy-efficient-products-ltd-energotech.html

Ceramic high temperature heaters

Elstein
http://www.elstein.com/en/elstein-products/panel-heaters/hts-series/description/

Ace Heat Tech
http://www.aceheattech.com/super-high-temperature-black-infrared-heaters.html

Glenro
http://www.glenro.com/radplane-rapidresp.html

Kerone
http://www.kerone.net/super-high-temperture-heaters.html

Heating Elements
http://heatingelements.co.nz/elstein-ceramic-infrared-heaters/

International Suppliers and installers

Infralight
http://www.infralight.com.au/infrared-heating-technology

Heraeus
https://www.heraeus.com/en/hng/industries_and_applications/applications_overview.aspx

Fit Infrarred
http://www.fitinfrared.com

Ceramicx
https://www.ceramicx.com

Elstein
http://www.elstein.com/en

Sources of further information

For a detailed outline of the physics of infra-red heating refer to:

NPH Process Heaters
https://www.nph-processheaters.com/_assets/uploads/pdfs/Ceramic Infrared Heaters/ceramic_infrared_heaters-Technical Manual.pdf

Ceramicx
https://www.ceramicx.com/panel-heaters/

Application Note

Infra-red process heating is used across a broad range of applications including:

paints and varnishes on metal, wood, glass and paper; coatings on leather and hides; dyes and primers on fabric; latex coverings on carpets; PVC coatings on fabric; coatings and layers on paper; printing inks; Teflon coatings on cooking utensils; manufacture of electronic components; dehydration and partial drying (papers, ceramics, inks and paints, plants, pharmaceuticals; heat treating; welding and brazing; cooking or grilling; pasteurisation and sterilisation; heating workstations and communal areas.

Applications best suited for infra-red process heating are:

- products requiring high surface heating intensity such as ovens, drying booths, paints and film curing
- products and processes that are sensitive to air circulation and airborne contamination
- intermittent processes - the rapid start-up heat of short wavelength infra-red heaters can be quickly shut off or restarted
- products with a high surface to volume ratio
- sites where heat loads are not coincident with electrical capacity and demand costs
- sites where electric heat loads match existing electrical supply capacity
- distributed smaller heat loads where a number of smaller infra-red heaters avoid central heat distribution system losses.

Application Examples:

Manufacturing Industries

Whenever heating is required in a production line process, infra-red should be considered. Application examples include, heating products of relatively regular or repetitive shape, providing supplementary heating or moisture profiling, shrink wrapping and product surface treatment drying and curing.

Plastics industry

Mould forming, embossing, laminating; welding, pipeline processing, deburring plastics. Preheating panels prior to coating and then drying the coatings is one example of how infra-red heating can be applied in the wood industry.

Curing powder coatings

Infra-red heating is ideal for curing powder coatings. Many coatings have been developed for use with infra-red curing ovens. Using infra-red is highly efficient as the powder coatings are tuned to absorb the maximum possible infra-red energy with no requirement to heat the air surrounding them. A further benefit of infra-red heating for powder coatings is the absence of convection air currents that could disturb or contaminate the painted surface. Because of this, high quality finishes are achievable.

Food Product heating

Infra-red heaters are often used to keep food warm for service in restaurants. The common 250W infra-red lamp produces medium wavelength heat up to 175°C, well above minimum food storage temperatures of 60°C. Similarly, larger food production lines can use the flexibility and responsiveness of infra-red heating to heat food to required temperatures or to provide heating for specific processing requirements such as the rapid heating of food coatings.

Roasting hazelnuts

Treatment lasts approximately half an hour, where the nuts are heated to 320°C. A compact 180 kW unit enables production of up to six tons of hazelnuts per day. Quick response times make the process highly efficient and controllable while the lack of fossil fuel burners reduces contamination.

Pasteurisation and sterilisation of liquids

Infra-red radiation can be used to sterilise liquid foodstuffs such as milk, beer, wine, fruit juices and in some cases, water. The specific energy consumption varies according to treatment, for example a 145 kW installation can produce 4,000 litres per hour of UHT pasteurised milk.

A simplified diagram of infra-red sterilisation is shown below, more complex systems would utilise spiral or cylindrical emitters.

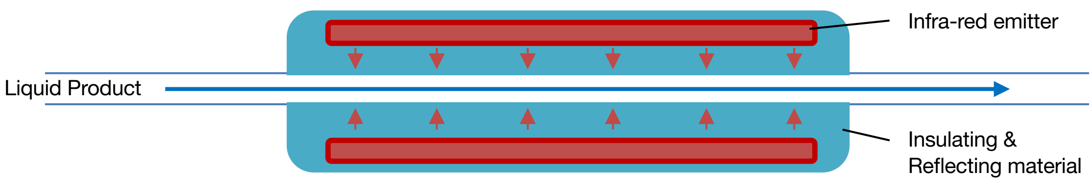

Figure 7. infra-red sterilisation

Incubators

Long wave infra-red heaters provide low intensity radiant heat for raising poultry and young farm animals, and are used in terrariums for ectothermic animals whose regulation of body temperature depends on external heat sources, like sunlight or heated rocks.

Indicative capital and operating costs of infra-red process heating

Due to its relatively simple construction, the capital cost of electric infra-red heating is highly competitive with alternatives. Because installation costs will vary depending on complexity, accessibility of production line equipment and the available capacity of electricity supply, it is only possible to provide a guide of between $200 and $500 per kW, for installed electric infra-red.

Generally, a gas fuelled convection oven for the same purpose would cost around twice as much as an equivalent electric infra-red system.

Operating costs for electric infra-red will also be much lower than gas due to its high efficiency and controllability. For initial feasibility comparisons, electric infra-red can be assumed to use 30% less energy (kWh) than a gas alternative. The higher kWh energy costs of electricity will, to some extent, close the gap between the operating cost advantage of electric infra-red and gas options.

The operating cost for an infra-red system will include the cost of electricity and the cost of maintenance. Maintenance is generally very low and limited to replacement of the emitter element at the end of its useful life or if it is damaged.

For an approximate estimate of running costs and comparison with a gas convection oven you will need to decide values for the following assumptions:

1. Capacity of electric IR installed (electric IR kW)
2. Capacity of gas equivalent (including for heat losses and lower efficiency). If you don't know the gas equivalent you can use, gas kW = electric IR kW x 1.3
3. Annual operating hours for electric IR (electric IR hours)
4. Annual operating hours for gas, including for warm-up/cool-down and reduced responsiveness (gas hours). If you don't know the gas operating hours you can use, gas hours = electric IR kW x 1.2
5. Average unit cost of electricity and gas ($/kWh).

Annual cost of electricity consumed = electric IR kW x electric IR hours x electricity $/kwh

Annual cost of equivalent gas consumed = gas kW x gas hours x gas $/kWh

Impact on CO_2 GHG emissions

Electric infra-red will not directly produce any greenhouse gas (GHG) gas emissions, but the electricity used to produce infra-red heat may have been generated from non-renewable sources that do produce GHG gases. In New Zealand, the proportion of non-renewable generation is low, therefore any GHG gas impact of electric infra-red will be much lower than for gas or other fossil fuel ovens.

Climate change gas rule of thumb comparison:

Electricity

CO_2 = kWh consumed x 0.10 kg/kWh

For every 100 kWh of electricity used 10 kg of CO_2 is emitted

Natural gas

CO_2 = kWh consumed x 0.216 kg/kWh

For every 100 kWh of gas used 21 kg of CO_2 is emitted

In summary, electric Infra-red will generally use 30% less energy than an equivalent gas oven and, because electricity emits approximately half the CO_2, electricity will reduce CO_2 emissions by around 67%.

Each potential infra-red application will have specific operating conditions, operational efficiency opportunities and duty cycles. Because of this, capital and operating costs, and the potential benefits will vary considerably.

Design of infra-red process heating systems

The inherent flexibility and range of infra-red heating equipment means that systems can be:

- Off-the-shelf units
- Incorporated in production and processing equipment
- Customised oven units made to fit specifics and situations

Designs for infra-red systems can be as simple as positioning a heater unit over a production bench, and as complex as designing and construction a major continuous process system.

Designing an infra-red oven from basic thermodynamic principles is unreliable as a range of varying parameters have to be considered. These include the:

- Power density
- Optimum wavelength absorption characteristics of the material to be heated
- Residence time in the oven of the material to be heated
- Distance between the emitter and the material to be heated
- Required heating profile (e.g. heating and holding)

Step 1

Establish the variable parameters through pilot scale tests using different wavelengths and emitters. Portable infra-red test units may be available from suppliers for onsite testing.

Step 2

Once a pilot scale test has determined the optimum wavelength and other parameters, the infra-red oven is relatively simple to design and construct. In most cases, modular infra-red panels can be used which reduces capital cost substantially.

Step 3

Compare electric infra-red to other options. The options can include dielectric heating, convection heating and, for drying, dehumidification.

Gas infra-red systems are available and can be considered. However, equipment tends to be bulky and the ovens require pre-heating. Generally, gas infra-red will have higher capital and operating costs than electric infra-red. Gas convection ovens are likely to have higher capital costs and require flues.

Case studies

Case study: Infra-red plastics thermoforming production line.

An international food service packaging producer required a complete upgrade on one of its main plastics thermoforming lines, replacing an existing electric element oven with an efficient ceramic-based top and bottom infra-red panel heater oven.

The infra-red oven reduced the overall plastics thermoforming oven length by half - resulting in immediate energy savings. Heating cycle times were reduced by 50% making the upgraded line the fastest machine within this international organisation.

Quality infra-red-based heaters combined with best-in-class heat control systems have all but nearly eliminated maintenance at the plant - with only four component replacements in some 26 months of new operation to date. In addition, downtime, scrap and heat-up times at the factory have all significantly decreased resulting in a very quick return on investment.

The motion control package included the first ever Ethernet communication. In terms of operations, the machine operator had complete machine visibility through two 15” touch screen monitors.

Source: https://www.ceramicx.com/case-study-int-food-service-packaging-producer/

Case study: Infra-red thermoplastic heat shrinking at Mecalbi Actividades de Engenharia, Portugal.

The Mecalbi STCS (Shrinking Tube Control Systems) is a range of high quality products for heat shrinking thermoplastics typically used in automotive manufacturing.

Two new quartz-based infra-red heaters were developed for the STCSCS 19 and STCS-RT heat-shrinking machines to provide more robust heating. The STCS product range itself divides into 2 subsections: machines based on hot air blowers and machines based on infra-red heaters. The infra-red range has the advantage of being more energy efficient and delivering higher temperatures but with a higher pre-heating time. The previous equipment set-up had been easily damaged by the cable’s terminals.

https://www.ceramicx.com/case-study-mecalbi-actividades-de-engenharia/

Case study: Infra-red paint drying, Cummins Engines.

Cummins Engines Ltd, an engine painting business, identified a bottle neck to increasing its worldwide sales. A single oven supporting three spray-booths caused delays in the paint application process. High energy cost and CO_2 were identified as the problems. A paint drying improvement project led to more than a 100% increase in capacity. Energy costs and CO_2 per engine were reduced by 50%.

The project is a good example of the design considerations for an infra-red dryer.

An on-site curing trial identified a cure time of 20 minutes and a requirement for three ovens (one per spray- booth) for smooth process from paint to cure, without delays within the coating process. An oven was designed to ensure that all varying engine sizes could be accommodated, and heat susceptible parts were identified to ensure that no damage would be caused during the curing cycle.

An infra-red oven specialist, FIT Infrared Ltd. manufactured the ovens to the agreed design and installed them based on a project timing plan. The ovens were commissioned and various engine sizes cured to provide the ideal curing cycle. Training was given to maintenance staff and operators. All running data is continually collated within the PLC to provide a continuous history of performance; this data is analysed routinely to identify trends and scope for process improvements.

The infra-red ovens achieved a 98% reduction in CO_2, a 74% energy cost saving per engine, and a 340% increase in capacity.

Source: http://www.fitinfrared.com/case-studies/cummins

Case Study: Infra-red drying and coating curing

Drying and curing of coatings such as paints, adhesives, claddings, enamels and inks.

Infra-red dryers deliver heat quickly and accurately to the product. Infra-red dryers are much smaller than normal convection ovens or dryers. An infra-red dryer can be less than a tenth of the size and cost of a convection dryer.

Convection heating is extremely inefficient for fast process line/web applications.

Case Study Glass industry; glass processing, forming, annealing

Infra-red heating is also used to fire paints and varnishes on mirrors, dry enamel, fire coatings and in the production and drying of glass-plastic composites (such as safety glass). Increasingly, glass products, including windows, are required to be annealed or toughened.

Case study: Heraeus Infra-red glass tempering oven.

Glass, when cut or cooled, develops internal stresses that make it less tough under use. These residual manufacturing stresses are relieved by annealing or tempering, a process with a controlled heating and cool-down cycle. Heraeus developed a quartz lined infra-red annealing furnace that heats glass products to 600°C at a 50°C / second heating rate and then cools within a 5-minute cycle. The 15 kW infra-red oven uses 90 percent of the energy but achieves five times the throughput of a conventional electric annealing oven.

The maximum emitter temperature for an oven with a heated length of 700 mm and a chamber cross section of 150x150 mm is achieved in less than one minute. Because of the exceptional energy efficiency, a holding power of around 3.0 kW is all that is required to maintain a 900°C holding temperature during in-line continuous operation. The highly efficient infra-red oven has other applications such as; burning decorative paints onto glass or ceramics, shaping and forming sheet metal, shaping and forming plastic tubes, heating highly reactive metals, re-crystallisation and annealing of metal wires and enamelling.

Source: https://www.heraeus.com/media/media/hng/doc_hng/products_and_solutions_1/infrared_emitters_and_systems/infrared_oven_max.pdf

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