TECHCOMMENTARY

INFRARED PROCESSING OF COATINGS

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IR Brings New Light to Manufacturing

Consumers of coated metal, wood, paper, glass, plastic and textile products are demanding attractive, long-lasting, wear-resistant surfaces. At the same time, stricter safety and environmental standards are forcing manufacturers to look at new types of finishes, e.g., water-borne and powder coatings, and at different technologies to process them. Among the technologies well suited to both drying and curing the newer finishes is electric infrared (IR) process heating.

Electric infrared has actually been used by industry since the mid 1930's, when the Ford Motor Company developed and adopted it for curing paint on auto bodies. However, early users often became disillusioned with electric IR because the technology was oversold. But emitter design and process control have been improved to such an extent that there is now essentially a "new IR" technology. And, unlike many traditional coatings, the new coating systems being developed are extremely tolerant of high levels of IR energy. Innovative manufacturers are capitalizing on these developments to obtain higher quality products for a lower unit cost.

This TechCommentary discusses current and potential applications of electric IR, as well as the technical and economic factors to consider in selecting a processing unit.

Advantages/Drawbacks

Companies in the automotive, plastic, metal finishing, paper converting, graphics, packaging, home appliance, textile and wood products industries find numerous advantages in using electric IR to process coatings. Many of these advantages translate into better product quality, increased productivity and lower costs.

Electric IR processing offers:

Energy efficiency—In a properly designed system, radiant heat acts directly on the coating, resulting in faster product curing or drying and lower energy costs.

Space savings—Faster heating means shorter ovens, so equipment occupies less floor space. IR ovens can be added to an existing production line without difficulty, and, since units are modular, ovens can be easily enlarged or reconfigured.

Clean products—Since IR heats the coating directly, there is no need to blow hot air, and dust, through the treatment area.

Precise control—Electric IR emitters respond quickly, can be controlled by microprocessors and can follow process changes with little lag.

Flexibility—Emitters can be zoned and adjusted to suit product width and processing requirements.

Low maintenance—Electric IR emitters have a very long life and require little routine maintenance.

Adaptability—Any heat-curable coating can be processed with IR.

IR does have some drawbacks. On poorly conducting substrates such as fiberboard or plastic, there must be a direct line of sight between the radiation source and the surface to be cured or dried. This largely restricts its use to flat products like

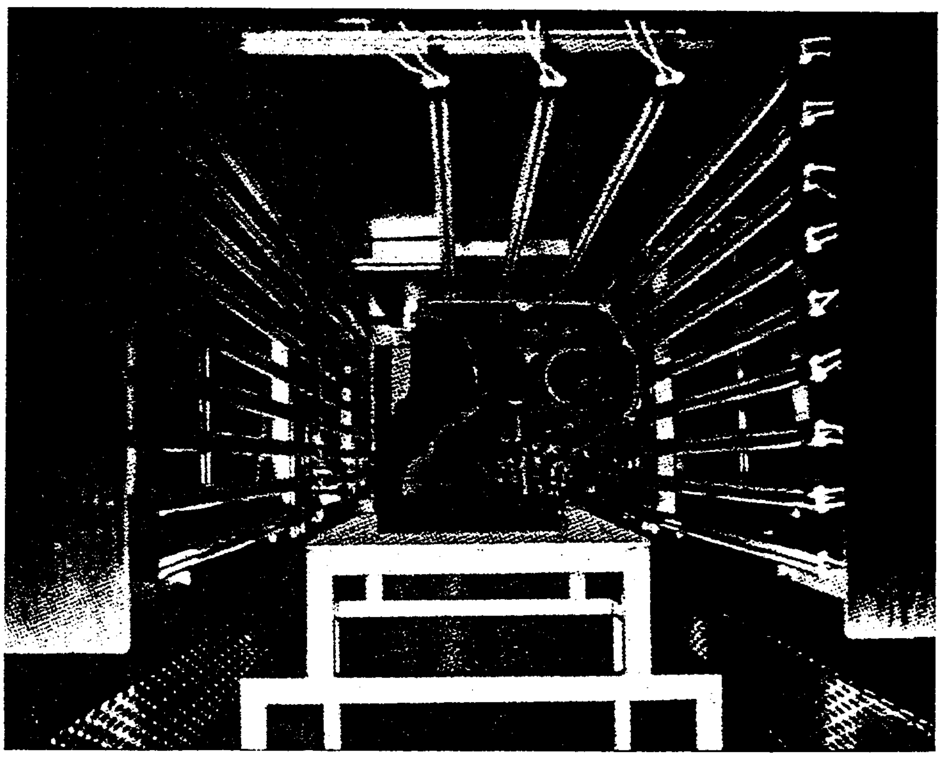


Figure 1. **IR curing of powder coating on an engine block.**

wood panels. With metal parts, which conduct heat well, enough energy is absorbed by the metal substrate that areas not directly in the IR radiation are heated by conduction. Therefore, even complex parts like engine blocks can be properly cured.

Applications

A major use of IR processing is curing both water- and solvent-borne paints and inks. In a conventional oven, paints must be cured slowly to prevent the formation of a surface skin. If a skin forms before the underlying paint has cured, the remaining carrying agent will produce surface blisters as it evaporates, resulting in a less attractive and less durable finish. IR radiation passes through the outer surface and dries and cures the paint from the inside out, so skinning is not a problem. The result is a better-looking, more durable surface, produced in less time.

IR is also an ideal method for curing powder coatings, which are being used increasingly for consumer products such as venetian blinds and appliances, and for automotive parts like oil filters. Electrostatically-charged powder is sprayed over the workpiece and heated until it melts. It flows over the surface and is cured in an even layer. A major problem in convection ovens is that moving air can blow the powder around before it melts, leading to uneven coating. With IR curing there is no need for air flow so this problem does not arise.

Another growing use of electric IR is for booster ovens in front of existing convection ovens. For example, on auto body production lines an IR oven at the start of the line rapidly heats the paint and sets the body finish. The car then moves into a forced air convection oven where the underparts, on which surface finish is less critical, are dried more slowly. Initial rapid setting of the topcoat eliminates concerns about dust damage in the convection oven. With a booster oven, conveyor speed is increased significantly without much increase in oven length.

IR processing has been used successfully in many applications including drying and/or curing:

- Paint on car bodies and home appliances
- Paint and powder coatings on light fixtures
- Paints and varnishes on sheets of hardboard, particleboard and chipboard
- Coatings on steel and aluminum coil
- Epoxy powder coatings on oil filters and irrigation pipes
- Polyvinyl chloride waterproofing on automobile rocker panels
- Printing ink on paper.

Success Stories

A company that manufactures coated steel strap replaced 180 feet of gas-fired convection ovens with 17 feet of IR heating units. They increased their line speed from 800 to 1000 feet/min and decreased their energy costs from $9.92 to $6.92 per hour.

Adding a 7-foot IR booster oven to a convection oven enabled a light fixture manufacturer to double line speed, double production, reduce energy cost per part by 25% and improve product quality. Payback time was six months.

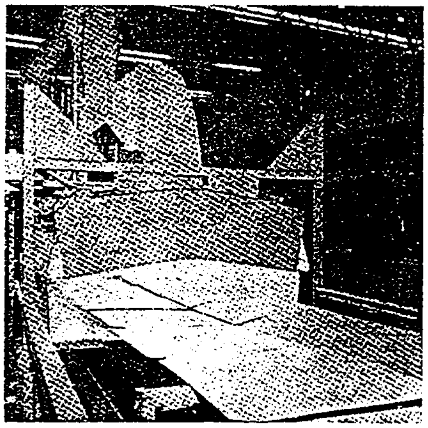


Figure 2. **An IR booster oven curing a water-based coating on light fixtures.**

Alternate Technologies

Electric IR competes with traditional methods, such as air or gas-oven drying, and with gas IR. Other types of radiation, such as electron beam (EB) and ultraviolet (UV), are used to cure specially-formulated coatings that cannot be treated with IR.

Air-drying is slow and the coated surface is exposed to dust, insects and other airborne contaminants. Gas-fired convection ovens are costly, slow, cumbersome and energy inefficient. A large volume of air is heated and the heat is then transferred to the coating. This process is slow and difficult to control since oven heating and cooling takes a long time. Therefore, if a conveyor stops, the product can be ruined by overheating.

Heating a ceramic surface with a gas flame also produces IR radiation. However, heat transfer is mainly by convection.

Technical Considerations

A number of factors have to be considered when tailoring IR to a specific situation. They include:

Emitters — Electric IR sources produce primarily either short or medium wavelength IR. Short wave IR is intense and easy to focus, and penetrates coatings well. It is used where intense, directed heat is required, such as in curing thick coatings, or in high speed conveyor lines for curing coatings on steel

Glossary

Curing involves heating or irradiating a polymeric material so that it forms a new, three-dimensional network structure with improved physical and chemical properties. As a result of the structural changes, the coating usually bonds better to the substrate and is more durable.

Drying involves removing the carrying agent, either an organic solvent or water, from a liquid-coating mixture.

Heat treating involves heating a workpiece for any of a variety of reasons including drying, curing, hardening, tempering, etc.

Powder coating involves spraying an electrostatically-charged powdered polymer onto an oppositely-charged substrate. There is no solvent — the spray is 100% coating. The coating is heated until it melts and flows over the substrate and is cured in an even layer.

Substrate is the material to which the coating is applied.

straps and wood products.

Medium wave radiation is less intense, so heating with medium wave emitters takes longer. This can be an advantage for treating materials not tolerant to high heat levels. Medium wave IR is usually used where a lower temperature, more diffuse source of heat is required, such as in drying water from metal or plastic surfaces or curing inks on paper or screen-printed fabrics.

The number of emitters required will depend on product size, line speed and exposure time. Since emitters usually come in modular units, it is not difficult to add or remove them as necessary.

Reflectors — Emitters radiate in all directions, so reflectors are placed behind them to redirect as much of the radiation as possible onto the product. Appropriately placed reflectors can radiate the whole product uniformly, or focus radiation on a section that needs extra heating.

Reflector materials include ceramics, polished aluminum or stainless steel, and gold-plated aluminum or steel. Gold is the most efficient reflector material. It reflects approximately 98% of the IR energy, whereas polished metals reflect only 70-75%. These values apply only to clean reflectors. Dirt severely degrades their performance, so reflectors should be cleaned regularly.

Reflectors come in different forms. Often, they are separate panels mounted behind the emitters. However, one emitter design uses a twin bore tube with the filament in one bore and a thin layer of gold plated on the inside of the second bore. Thus, the reflector is an integral part of the emitter.

It may be necessary to cool reflectors to protect them and the lamps and wiring they shield. Usually, air is blown over them (from behind to eliminate blowing dust). The hot air can be recycled to heat other parts of the work area, or to augment a convection oven if the IR unit is being used as a booster oven.

Process Description

Infrared (IR) is the name given to the part of the electromagnetic spectrum between visible light and radio waves. IR wavelengths range from 0.8 and 1000 microns, but we will consider only the 0.8 to 3.3 micron band since these wavelengths work best for treating coatings.

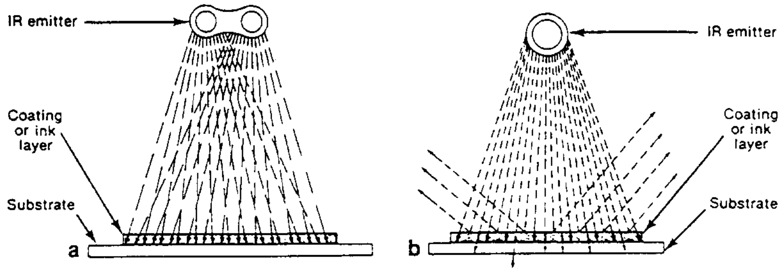
When a material absorbs infrared radiation, the motion of its molecules increases and it gets hotter — this is the basis of infrared process heating.

Electric IR is used for both drying and curing surface coatings. Drying is used by metals fabricators to remove the carrying agent, be it water or an organic solvent, from wet coatings on armature windings, inexpensive metal furniture or other products. These articles do not need a high-performance, long-lasting finish, but must be "dry to the touch" before subsequent handling. However, many products require a higher quality, more durable finish, so the coatings on them must be polymerized, or thermally cured, as well as dried.

IR radiation is produced by heating the filament of a source, or emitter. All emitters produce radiation over a range of wavelengths, with the peak of the output spectrum determined by the maximum temperature to which the filament is heated.

Commonly used IR emitters fall into two major categories. One type consists of a non-oxidizing wire coil in an open-ended glass or quartz tube. Such emitters can be heated up to about 1800 F, and they emit predominantly medium wave IR (2.3-3.3 microns). Medium wavelengths are absorbed very efficiently by most organic materials. The second type is a tungsten filament in a sealed quartz tube, which is either evacuated or filled with an inert gas. When tungsten filament emitters are heated to their maximum temperature, 3000-4000 F, they emit primarily short wavelength IR (0.8-2.2 microns). Short wave IR tends to penetrate deeper and to heat faster than medium wave. If the applied voltage is reduced, the filament does not get as hot and tungsten filament emitters become primarily medium wave IR sources.

Processing is usually done in an IR oven, consisting of a bank of IR emitters and a conveyor belt or web that carries the product through the oven. Oven design is best left to a manufacturer who should carefully study your application and provide you with the optimal design.



Schematic representations of (a) medium and (b) short wave IR radiation

Coating material — The color, thickness, reflectivity, and absorption chemistry of the coating being treated all affect the amount of heat required. For example, it may take longer to cure an automobile panel if the finish is a highly reflective metallic silver than if it is matte black.

Carrying agents — Some organic solvent vapors become explosive at certain concentrations. Thus, with solvents like toluene, hexane, or methanol it is essential that there be adequate air flow in the oven to prevent vapor accumulation. (This applies to any type of oven in which organics are treated, not just IR ovens.) The contaminated air must then be properly treated. With water-borne coatings, the accumulated water vapor must be removed.

Substrates — IR can treat coatings on a wide variety of substrates including metals, wood products, most plastics, fabrics, ceramics, glass and paper.

If you think that IR may be appropriate for treating coatings you use, talk to manufacturers about doing pilot tests. This service, which is often free, helps you determine the size and type of equipment you need. It also gives you an opportunity to evaluate both a company and its equipment before making any commitments.

Economic Considerations

When deciding on the economic feasibility of IR heating, the following items should be considered.

Capital costs — IR ovens are custom-designed, so it is difficult to give exact costs. However, an oven with a heating area about 10 feet long and 4 feet wide would likely cost between $50,000 and $100,000. About half the cost is for the oven and reflectors and the other half is for the rather sophisticated control equipment. Although the control system is complex, it is designed to be easy to use, so highly skilled operators are not necessary.

Operating costs — This category includes costs for energy, maintenance, and replacement emitters.

Short wave emitters require more electric power (the filaments are heated to a higher temperature) but conversion to radiant energy is more efficient—85-90% compared with 60-65% for medium wave lamps. Generally, 50-70% of the radiant energy is actually absorbed by the product. In gas IR ovens only about 25% of the input energy reaches the product, and in gas convection ovens it is only 15%. Thus, electric IR is significantly more efficient.

Maintenance is limited to cleaning the reflectors regularly and replacing burned out emitters. Emitter life is long. Short wave emitters should last 5,000 hours, or about two years with one shift a day, when operated at full power. Decreasing the power input to 80-90% of maximum extends emitter life to more than 30,000 hours. Medium wave emitters last even longer. Replacement emitters cost between $15 and $300, depending on size and whether or not they have an integral reflector.

Payback — Electric IR ovens are about four times as efficient as convection ovens. Therefore, if electricity costs less than four times as much as gas, electric IR may be justified in terms of energy costs alone. However, with electric IR ovens there is also faster product throughput, a higher quality finish, and less wastage than with convection ovens. IR ovens also save space, which can be a major advantage. With all these savings, the payback period for electric IR equipment is often less than a year.

In Summary

Electric infrared heating is an excellent method for treating many kinds of coatings, both new and traditional, on a wide variety of substrates. The process is easy to implement and control and is much more efficient than gas convection ovens and gas IR.

European manufacturers have been aware of the benefits of electric IR process heating for many years and the technology is well established there. The number of IR processing systems in the US is likely to grow substantially in the coming years as manufacturers here, too, begin to recognize the advantages this technology offers for producing long-lasting, durable and high-quality finishes on a variety of products.

The information in this issue of TechCommentary is intended only to introduce you to the many applications of IR heat treating. More information is available from the Center for Materials Fabrication and from the many suppliers of IR equipment.

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The Center's mission is to assist industry in implementing cost- and energy-efficient, electric-based technologies in metals fabrication and related fields. TechCommentary is one communication vehicle that the Center uses to transfer technology to industry. The Center also conducts research in metal heating, metal removal and finishing, and fabrication.

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