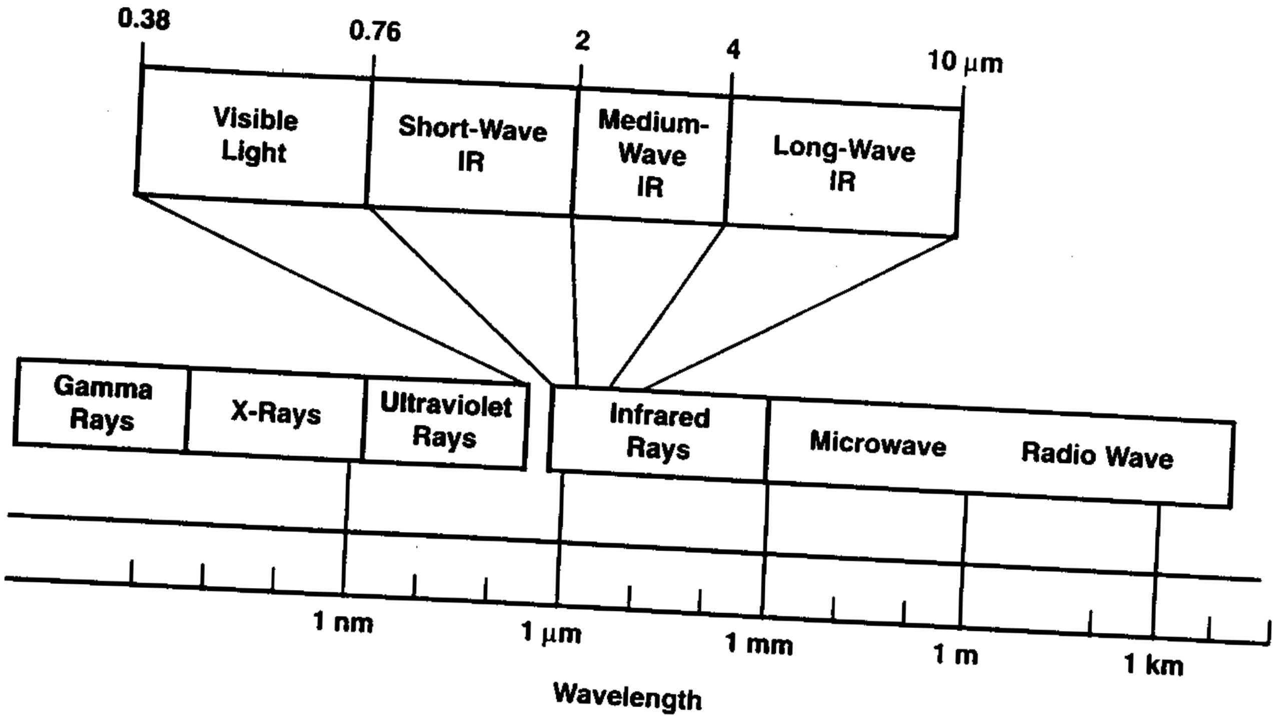
19116

INTRODUCTION TO

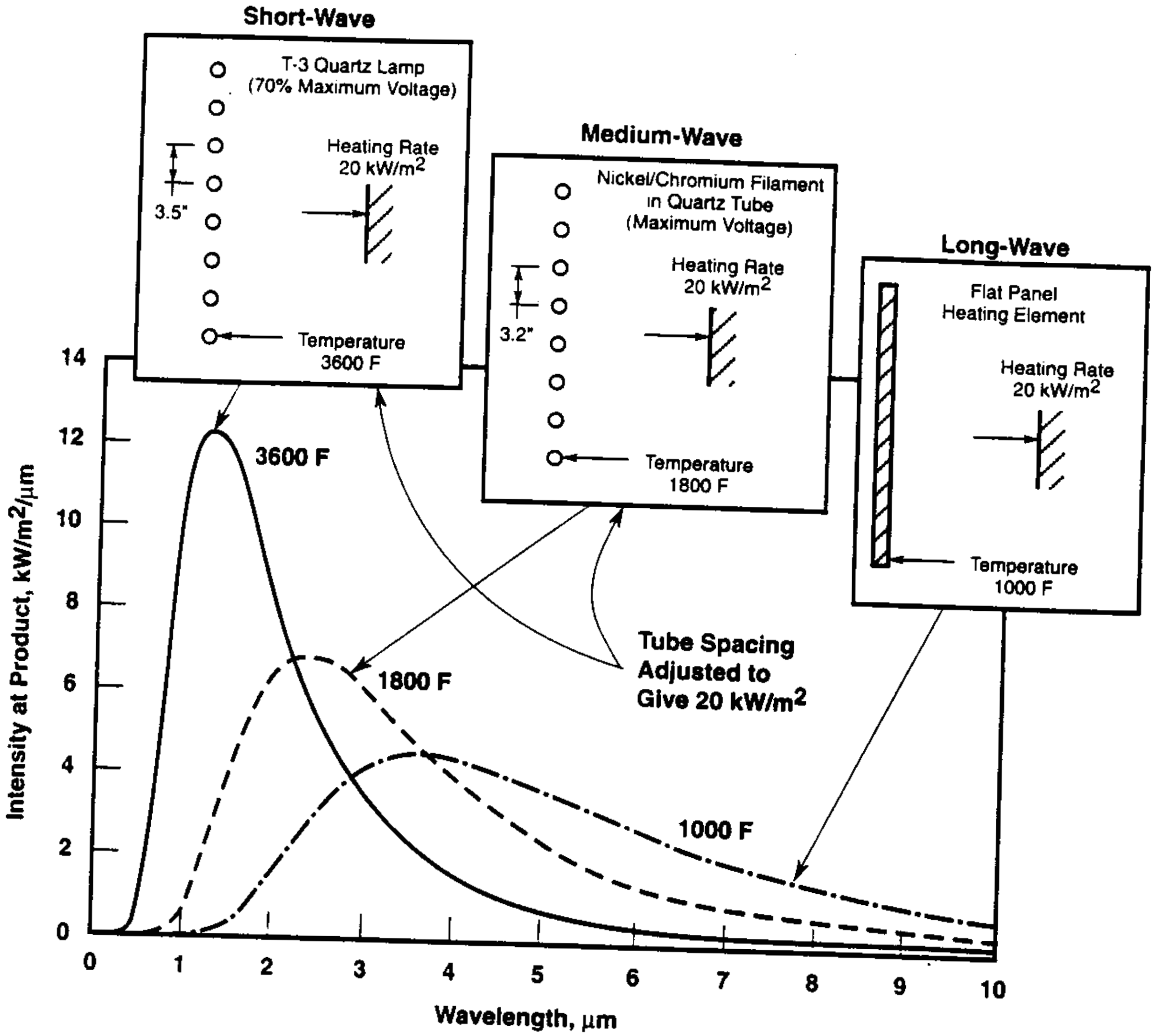
CURING

USING INFRARED

AND CONVECTION OVENS



Electromagnetic Spectrum



Short-Wave
T-3 Quartz Lamp
(70% Maximum Voltage)
Heating Rate
20 kW/m2
3.5"
Temperature
3600 F
Medium-Wave
Nickel/Chromium Filament
in Quartz Tube
(Maximum Voltage)
Heating Rate
20 kW/m2
3.2"
Temperature
1800 F
Long-Wave
Flat Panel
Heating Element
Heating Rate
20 kW/m2
Temperature
1000 F
3600 F
1800 F
1000 F
Tube Spacing
Adjusted to
Give 20 kW/m2
Intensity at Product, kW/m2/μm
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
9
10
Wavelength, μm

Characteristics of IR Radiant Heating

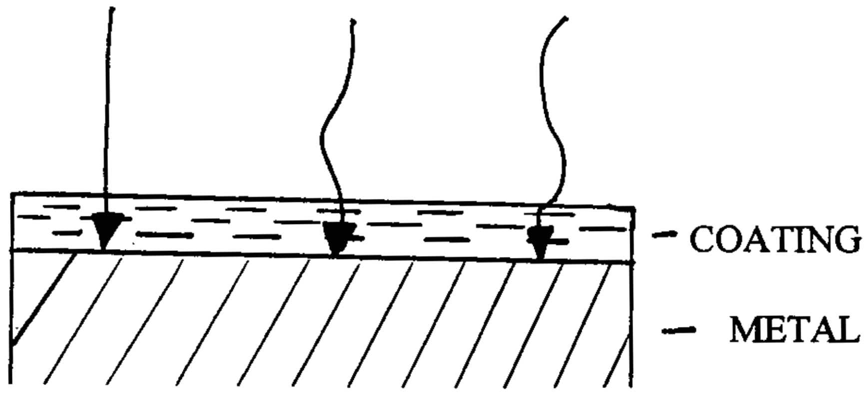
	Short-Wave, High-Intensity	Medium-Wave, Medium-Intensity	Long-Wave, Low-Intensity
Radiant Source Temperature	4000 - 2900 F 2200 - 1600 C	1800 - 1300 F 1000 - 700 C	1300 - 572 F 700 - 300 C
Peak Wavelength Range, µm	1.2 - 1.6	2.3 - 3.0	3.0 - 5.0
Wavelength Band[a], µm	0.76 - 2.8	1.4 - 5.4	1.8 - 9.2
Percent of Radiation Below 2 µm	43 - 63	6 - 17	0 - 6
Percent of Radiation Below 4 µm	84 - 91	47 - 65	13 - 47
Heating Rate Range, kW/m^2	Typical - 40 Max - 150	20 50	10 20
Direct Radiation as Percent of Input Energy[b]	75 - 86	50 - 60	40 - 50

[a]This wavelength range includes that portion of the spectrum where the black body intensity is greater than ½ the peak intensity for the radiant source temperature range given above.

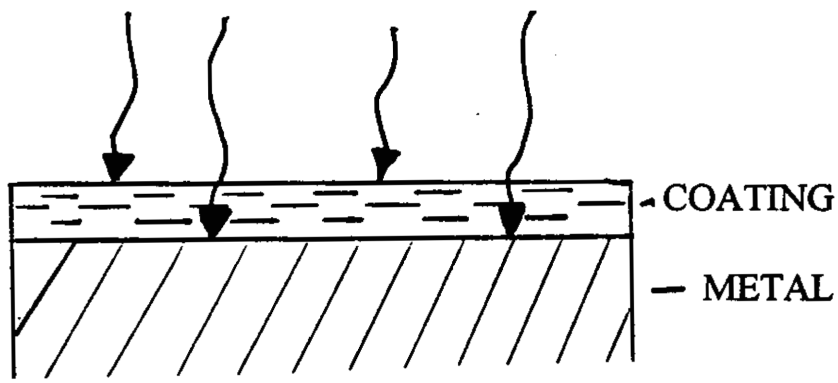
[b]Balance of energy input goes to convection or is reradiated as secondary radiation at a longer wavelength.

INFRARED WAVE BEHAVIOR

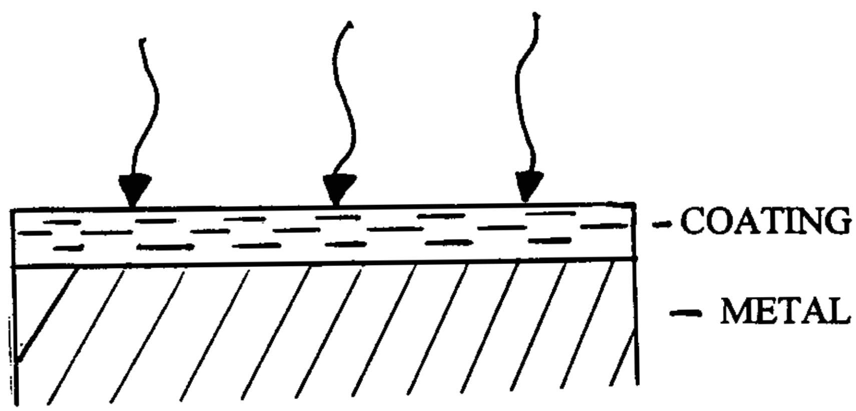
SHORT WAVE



MEDIUM WAVE

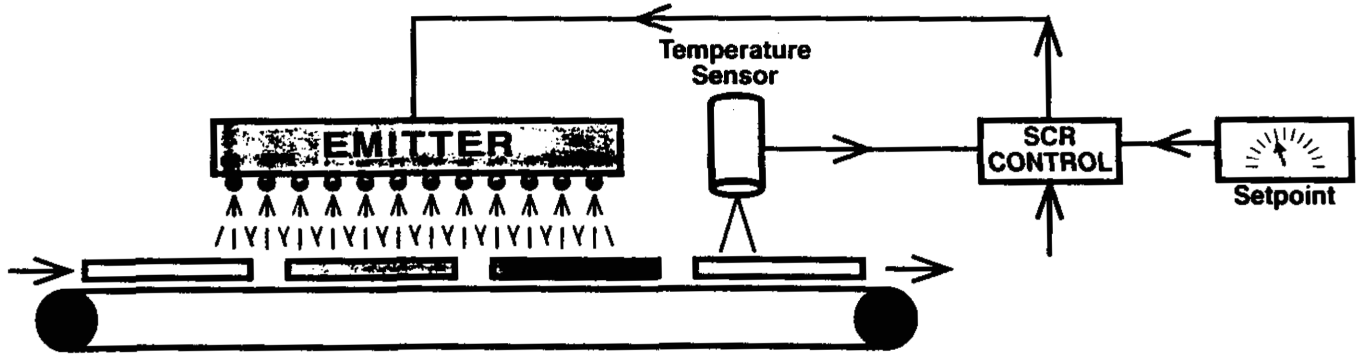


LONG WAVE



Emitters and Applications of IR Radiant Heating

	Short-Wave, High-Intensity	Medium-Wave, Medium-Intensity	Long-Wave, Low-Intensity
Type of Emitters	Tungsten Filament Lamps Type T-3 Quartz Lamps	Coil or Wire in Unsealed Quartz or Silicon Tubes or Panels Metal Radiant Tubes Metal Ribbon Emitters Ceramic Emitters	Glass Panels Vitrified Ceramic Panels
Typical Applications	Curing painted surfaces Curing powder coatings Polymerization of organic coatings on cooking utensils Gelling PVC coatings on fabric Drying iron oxide on recording tapes Production of TV tubes Drying porcelain and ceramics Drying and production of glass-plastic composites (safety glass)	Curing painted surfaces Curing powder coatings Preheating plastic Drying/heat setting fabrics after dyeing or printing Supplemental heater for paper drying Drying of inks in printing and silkscreening Preheating wooden panels prior to coating Curing coatings on wooden panels Curing the varnishes or paints on backs of mirrors	Preheating plastic Drying silk screen inks Activating adhesives Drying textiles Preheating embossing rollers Drying paints and lacquers Printed circuit board processing Animal care in agriculture



Schematic of Automatic Control IR System

High Speed and High Efficiency

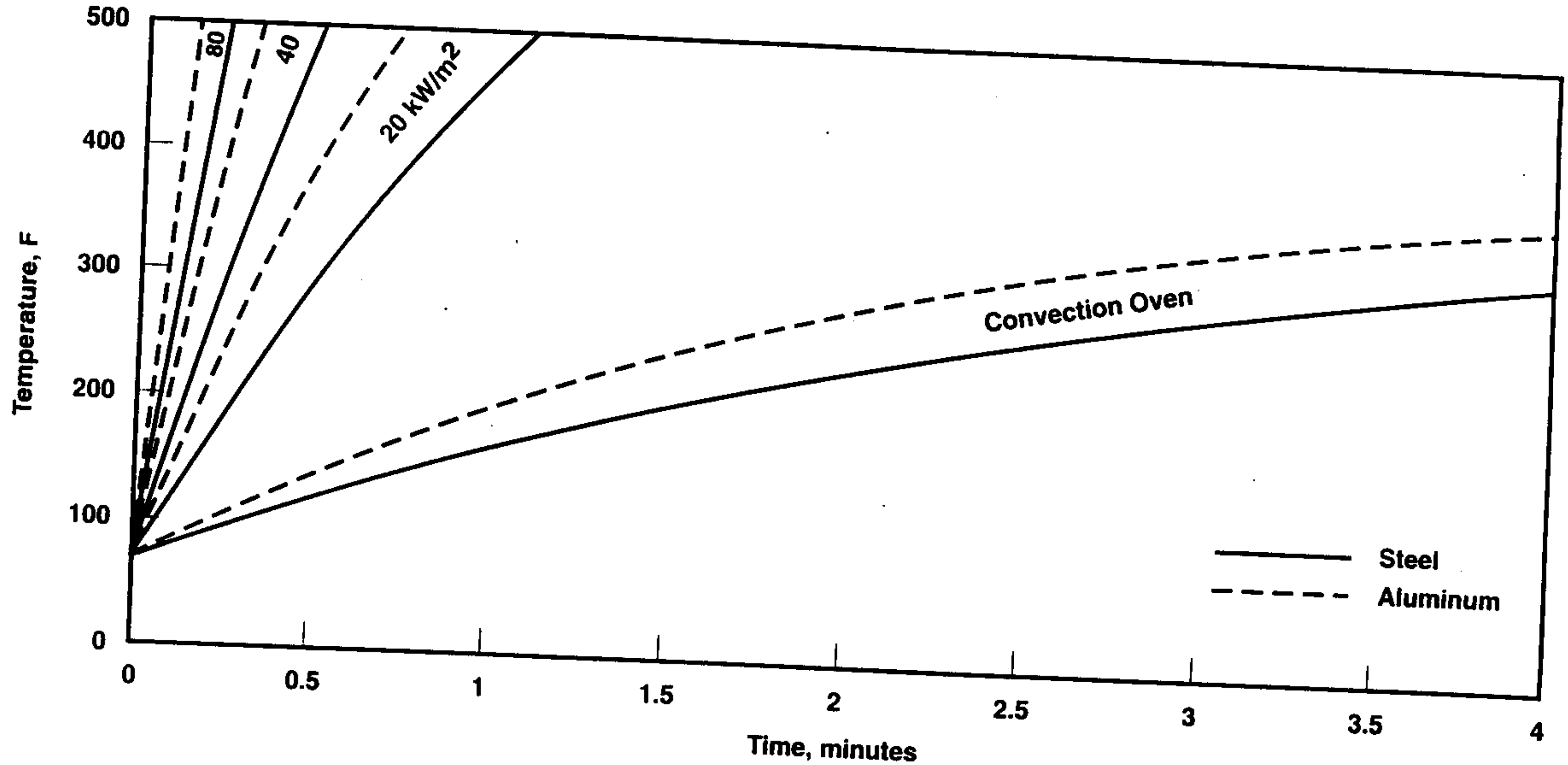
As a result of the greater heating rates and the high degree of control available with electric IR, parts can be heated much more rapidly than in a convection oven. Thus, the decreased residual time in the heating unit increases the throughput of parts to be cured. Higher power densities can also be used to reduce heating cycles to as much as two thirds of what is shown on Table below.

Oven Type	Steel, 0.05" thick	Aluminum, 0.05" thick	Plastic, 0.25" thick	Wood, 0.25" thick
Electric IR[1]	30 seconds	20 seconds	14 seconds	8 seconds
Convection 425°F	3 minutes, 20 seconds	2 minutes, 18 seconds	7 minutes, 40 seconds	6 minutes, 5 seconds
1. Electric IR power density of 20 kW/m^2.				

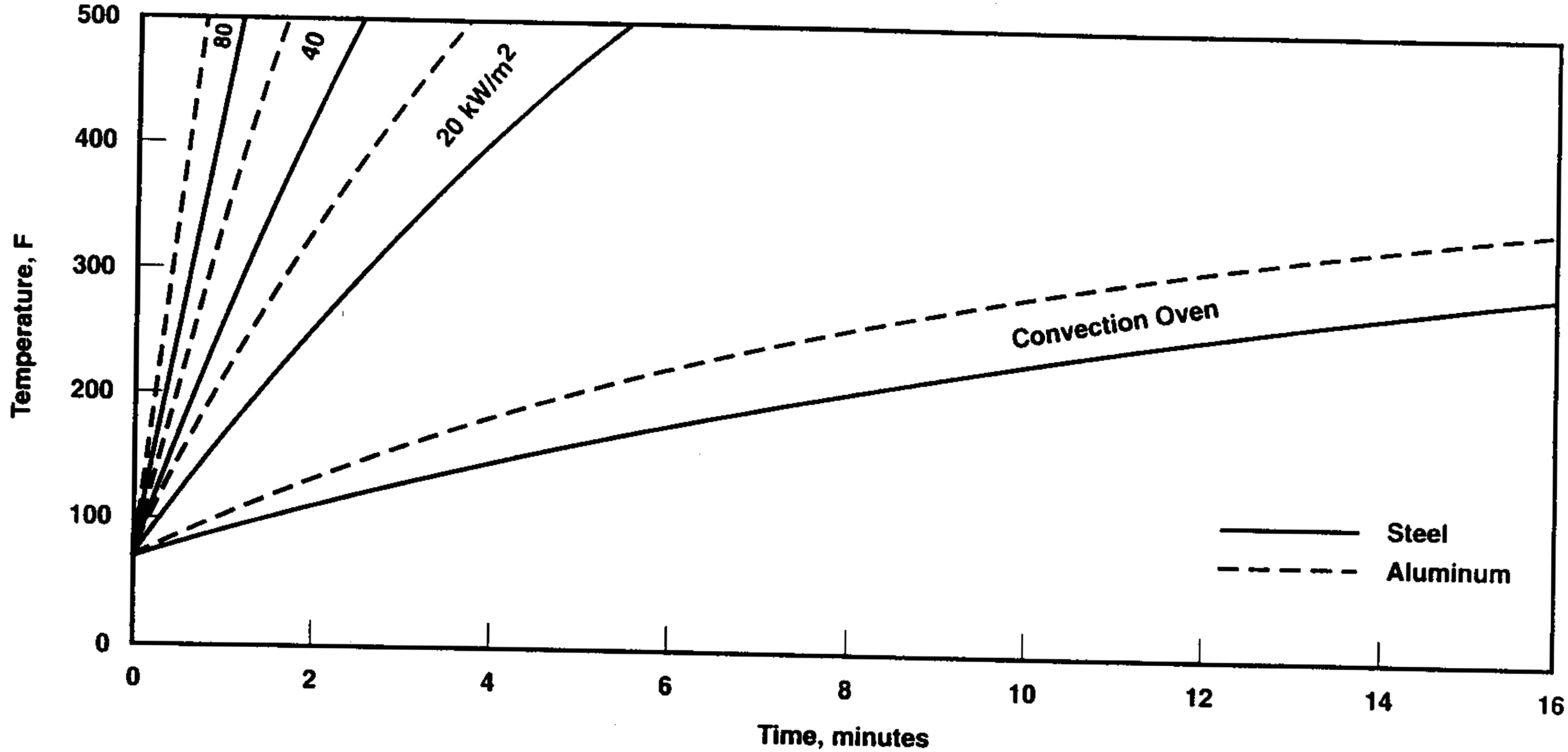
Time to 300° F Surface Temperature

For heating plastic parts, infrared allows the end user to heat the part faster and with less penetration into the part. This can reduce the risk of deformation of the plastic substrate.

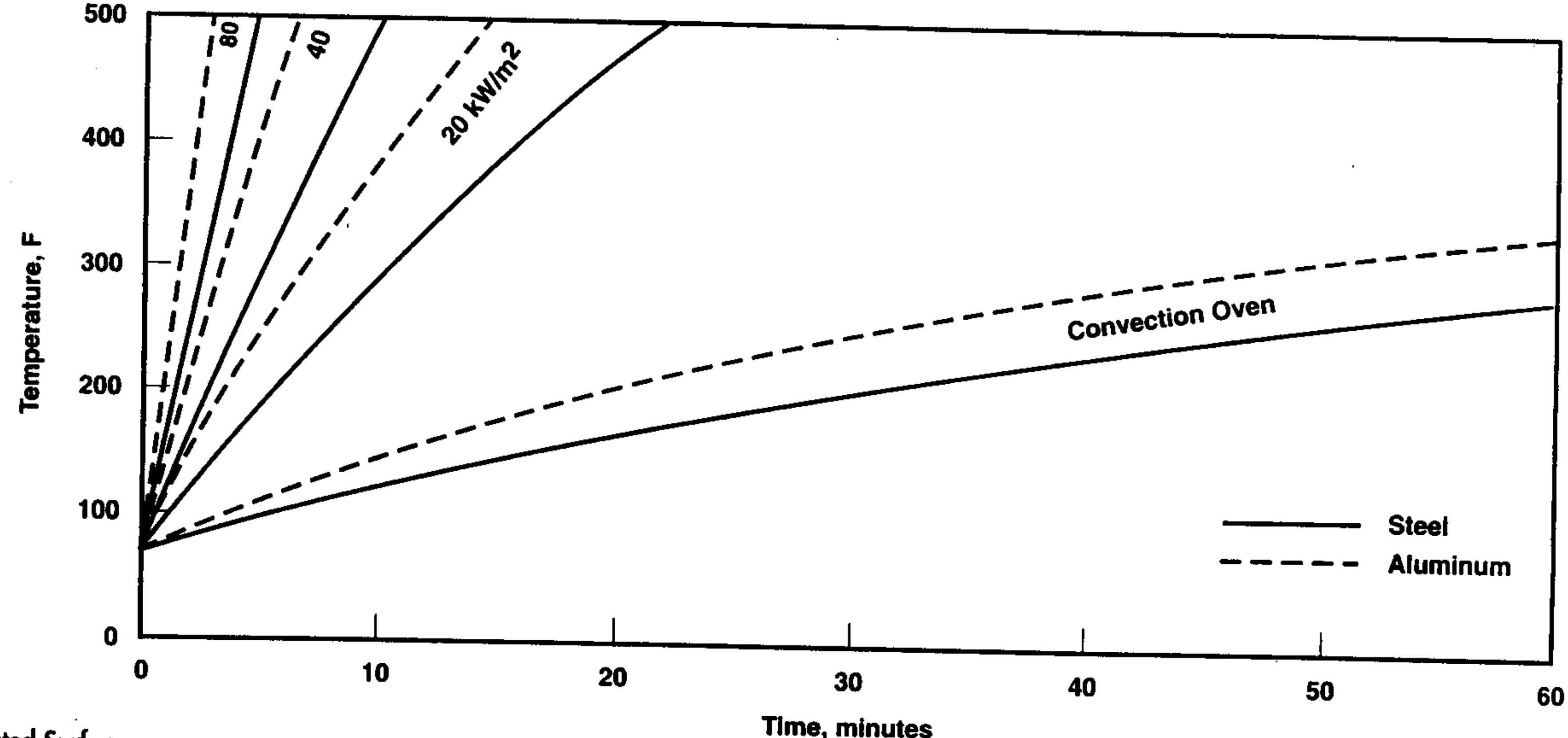
Due to the high efficiency of the IR heating, the purchasing cost can be comparable to, or lower than gas convection. Additionally, the savings of minimal warm-up time and lower energy costs when no product is in the oven can make the selection of IR an effective choice to cure powder coated parts. However, this efficiency can vary greatly by product loading due to the cost of the energy source.



Heated Surface
Temperatures of
Steel and
Aluminum
0.05 Inch Thick



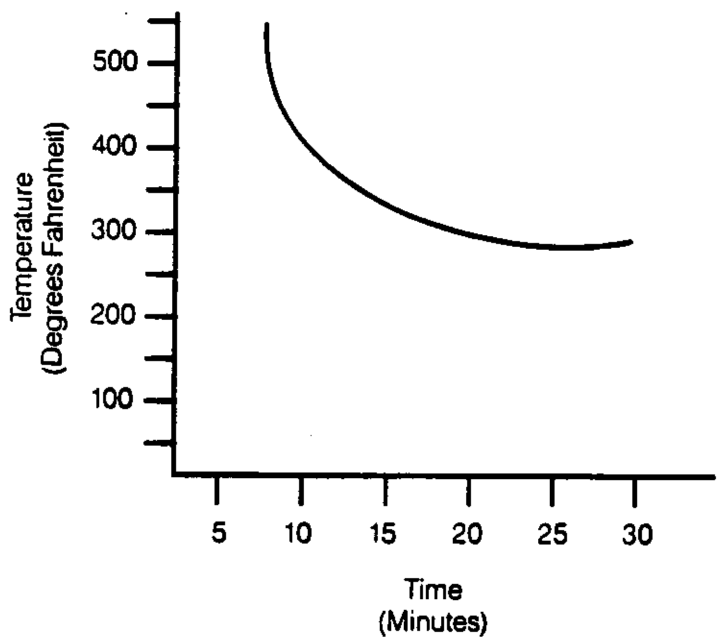
Heated Surface Temperatures of Steel and Aluminum 0.25 Inch Thick



Heated Surface Temperatures of Steel and Aluminum 1 Inch Thick

FIGURE 1

An example of a time-temperature cure index



TIGER **Drylac**®
Powder Coatings

DATA SHEET

As a vital part of Tiger Drylac U.S.A., Inc. customer service program our product Data Sheets are periodically updated. If the version date on this literature is in excess of 12 months old please contact your nearest Tiger Drylac U.S.A., Inc. location to receive current information on this product.
This standard form substitutes all and any previous standard forms and notes for customers published on Drylac Series 39 products.

TIGER Drylac Series 39
lead and cadmium free

Product description: Weather resistant Powder Coating based on Polyester TGIC.

Features:
— Good Weather Resistance
— High Mechanical Properties
— Smooth Flow
— Good Coverage
— Good Storage Stability

Typical applications:
— Residential Windows and Doors
— Patio Furniture
— Lawnmowers and Garden Equipment
— Automotive Accessories
— Bicycles and Motorcycles
— Aircraft Components
— Agricultural Machinery.

Surfaces:
Smooth flow — glossy surface **approx. 70—80***
In 13 colors; any other color can be special ordered.
Smooth flow — mat and semi gloss surface **approx. 10—65***
In 4 colors; any other color can be special ordered.
Silver
Limited weather resistance.

Standard packaging: 55 lbs/25 kg carton

Specific gravity: 1.5—1.7 g/cm^3 depends on pigmentation.

Theoretical Coverage: Depending on pigmentation and processing conditions.
1 lb coats approx. 50 sq.ft. at 3 mils avg.
1 kg coats approx. 10 sq.m. at 75 microns avg.
Product is normally applied at 2.5—3.5 mils/60—90 microns.

Dry storage stability: 6 months at not more than 77° F/25° C.

*Numbers in bold print refer to gloss levels.

TIGER DRYLAC® U.S.A., INC.
West Coast: 1251 E. Belmont Street • Ontario, CA 91761 • Tel. (909) 930-9100 • Telefax (909) 930-9111
Northwest: 18808 142nd Ave. N.E., Ste. 5 B, Woodinville, WA 98072 • Tel. (206) 481-3160 • Telefax (206) 481-1136
Midwest: 1151 Atlantic Drive, Unit # 2 • West Chicago, IL 60185 • Tel. (708) 231-1420 • Telefax (708) 231-1578
East Coast: 1100 Commons Blvd. • Reading, PA 19605 • Tel. (610) 926-8148 • Telefax (610) 926-8149
Southeast: 1730 Cumberland Point Dr., Ste. 10 • Marietta, GA 30067 • Tel. (404) 984-1317 • Telefax (404) 984-1513
South: 349 Exchange Drive • Arlington, TX 76011 • Tel. (817) 277-7995 • Telefax (817) 277-1931

Drylac Series 39

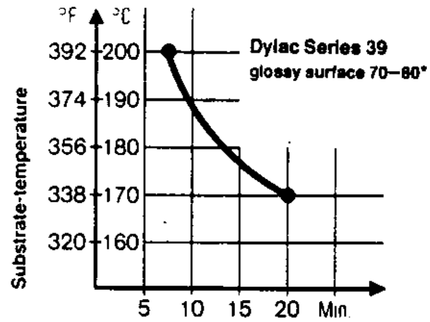
Substrates and pretreatment:

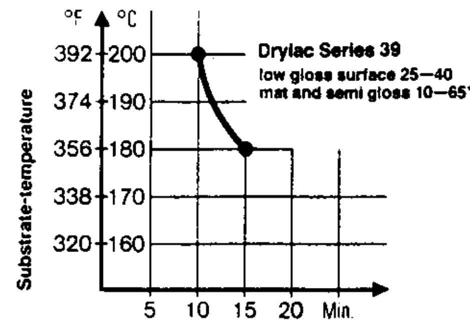
Aluminum:	Yellow or Green Chromate.
Galvanized steel:	Transparent Chromate.
Steel:	Zinc or Iron Phosphate.

For more information see DATA SHEET No. 2051/1-4 – latest edition.

Processing: Electrostatic spraying, manual or automatic.

Cure parameters:



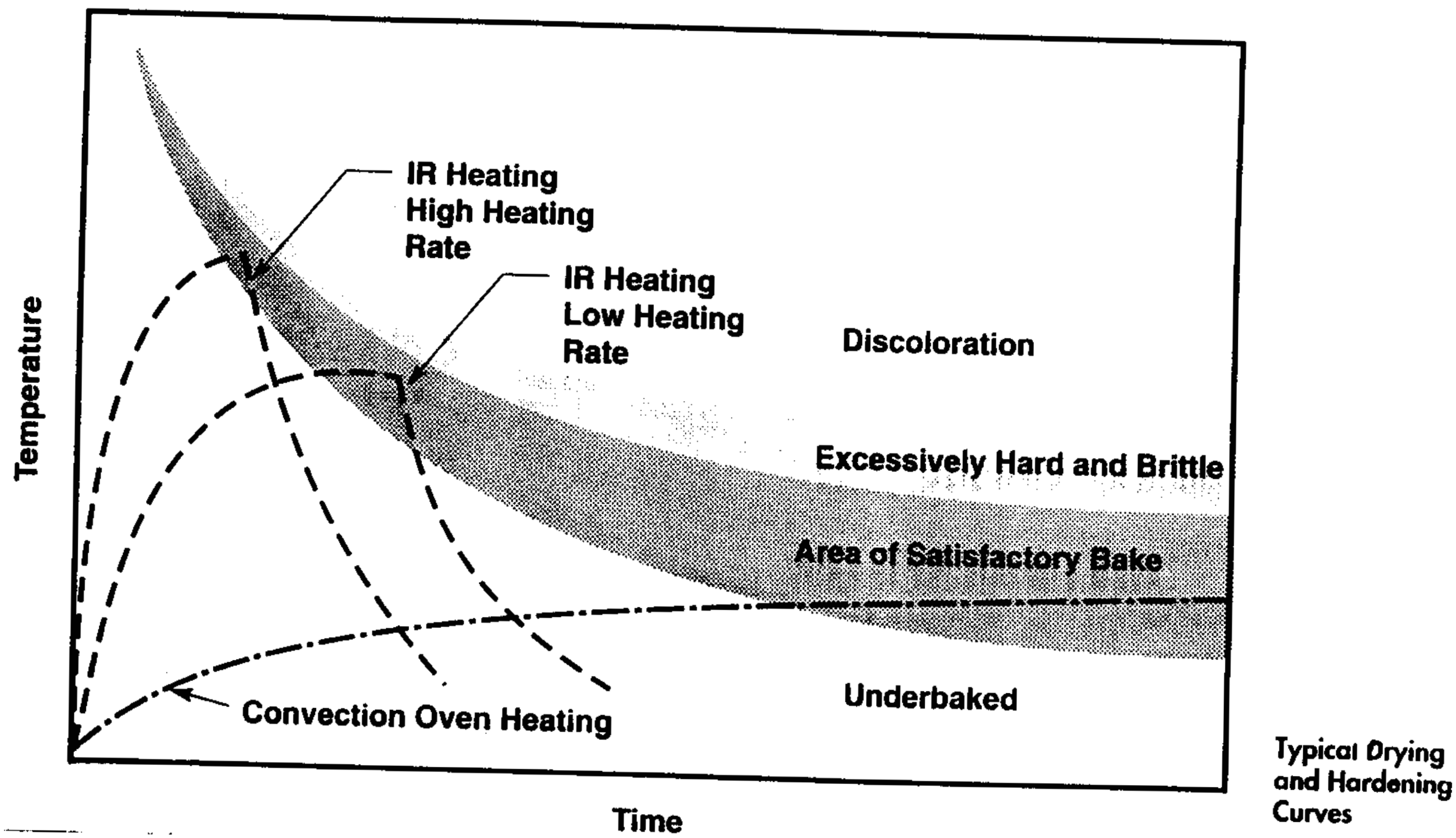


Test results: TIGER-DRYLAC Series 39, smooth, flow, checked on a chromated aluminum test panel which is 1/32 in/0.7 mm thick. Cure conditions according to the cure curves.

	SERIES 39 glossy surface	SERIES 39 low gloss surface
Thickness	2.5–3.5 mils/ 60–90 microns	2.5–3.5 mils/ 60–90 microns
Gloss according to Gardner 60° ASTM D 523	70–80	25–40
Cross hatch adhesion ASTM D 3359 method B	pass 100 %	pass 100 %
Mandrel bending test ASTM D 522	1/8 in/3 mm	3/16 in/5 mm
Impression hardness according to Buchholz ISO 2815	95	95
Impact test ASTM D 2794-90 1/10 in Distortion	up to 160 in/lbs	up to 160 in/lbs
Pencil hardness ASTM D 3363	2 H (min.)	2 H (min.)
Drill mill test	ok	ok
Saltspray resistance test ASTM B 117-90	1000 h test, max. undercutting 1/16 in/1 mm	1000 h test, max. undercutting 1/16 in/1 mm
Humidity resistance ASTM D 2247-87	1000 h test, max. blisters 1/16 in/1 mm	1000 h test, max. blisters 1/16 in/1 mm

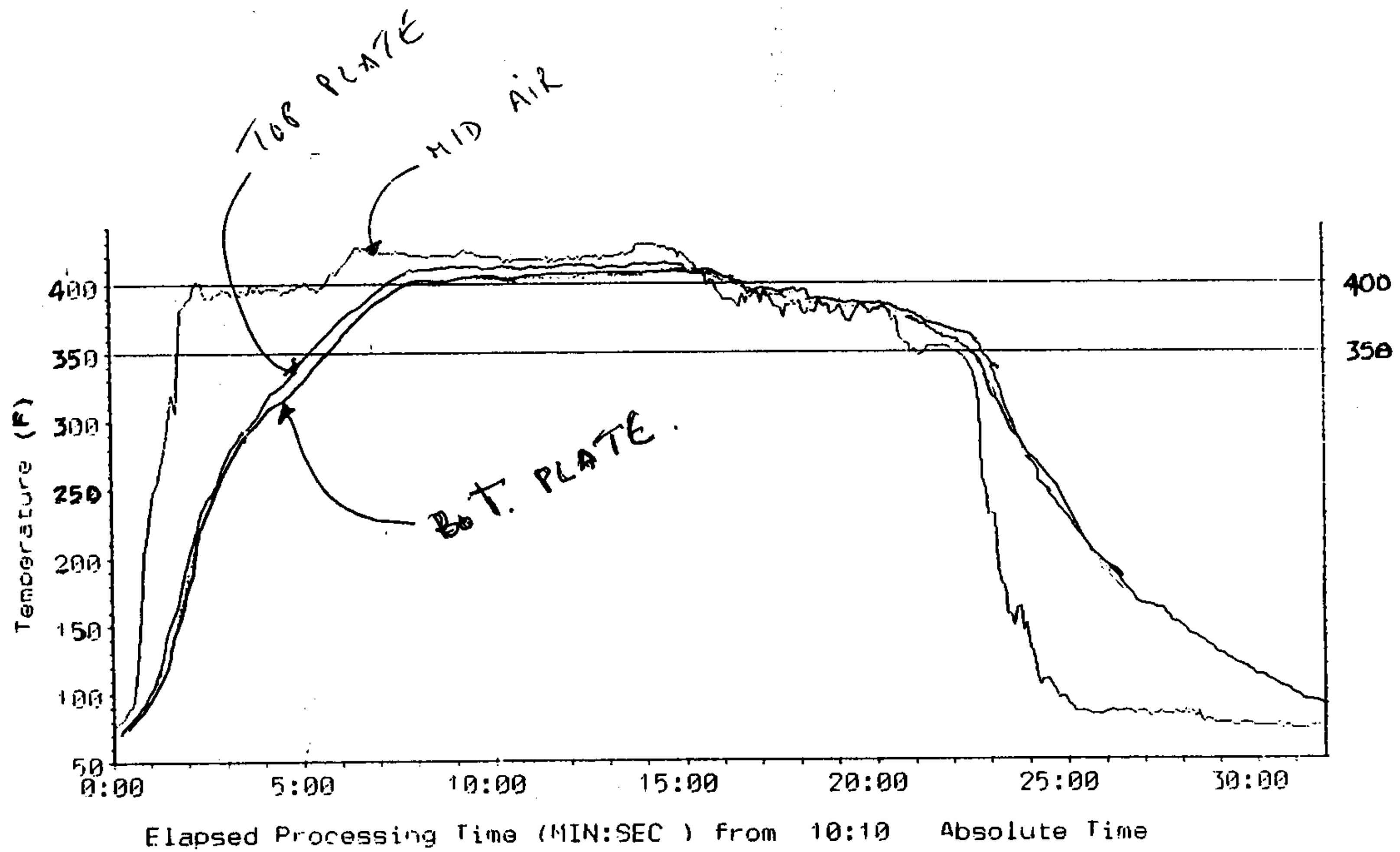
Our verbal and written recommendations for the use of our products are based upon experience and in accordance with present technological standards. These are given in order to support the buyer or user. They are non-committal and do not create any additional commitments to the purchase agreement. They do not release the buyer from verifying the suitability of our products for the intended application.

TIGER DRYLAC® U.S.A., INC.
West Coast: 1251 E. Belmont Street • Ontario, CA 91761 • Tel. (909) 930-9100 • Telefax (909) 930-9111
Northwest: 18808 142nd Ave. N.E., Ste. 5 B, Woodinville, WA 98072 • Tel. (206) 481-3180 • Telefax (206) 481-1136
Midwest: 1151 Atlantic Drive, Unit # 2 • West Chicago, IL 60185 • Tel. (708) 231-1420 • Telefax (708) 231-1578
East Coast: 1100 Commons Blvd. • Reading, PA 19605 • Tel. (610) 926-8148 • Telefax (610) 926-8149
Southeast: 1730 Cumberland Point Dr., Ste. 10 • Marietta, GA 30067 • Tel. (404) 984-1317 • Telefax (404) 984-1513
South: 349 Exchange Drive • Arlington, TX 76011 • Tel. (817) 277-7995 • Telefax (817) 277-1931



Oven Cycle Time (minutes) = Part Bring Up Time (minutes) + Dwell Time (minutes)

Oven Cycle Time



TOP PLATE
MID AIR
BOT. PLATE
400
350
Temperature (F)
400
350
300
250
200
150
100
50
0:00
5:00
10:00
15:00
20:00
25:00
30:00
Elapsed Processing Time (MIN:SEC) from 10:10 Absolute Time

FIGURE 3

In a nozzle-mix burner, a combustion blower supplies air to the burner nozzle where it is mixed with fuel.

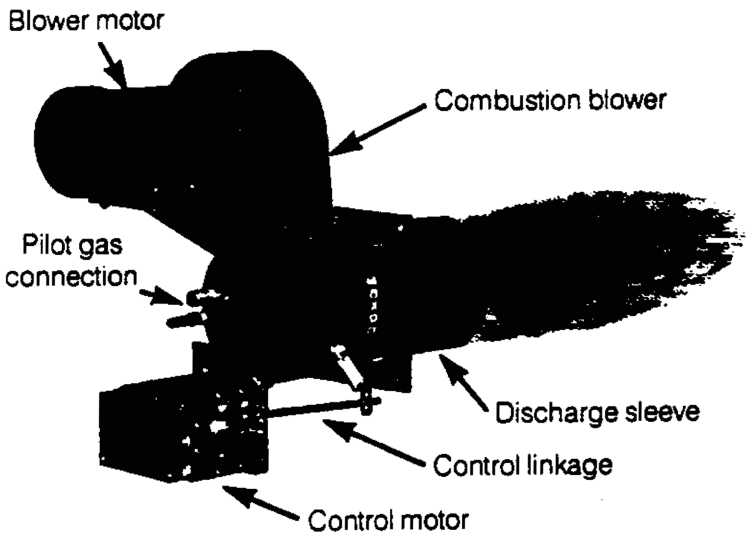


FIGURE 2

The burner box is a gas burner with a blower to distribute heat into the oven.

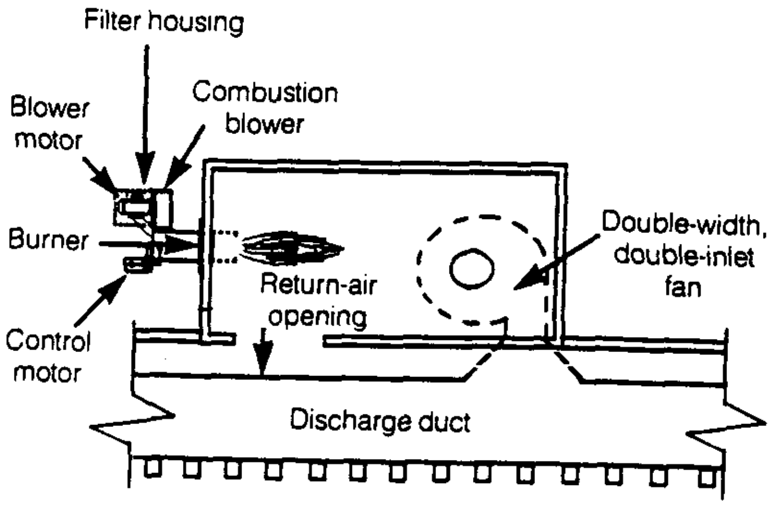


FIGURE 5

An indirect-fired gas convection oven uses an air-to-air heat exchanger to circulate air into the oven.

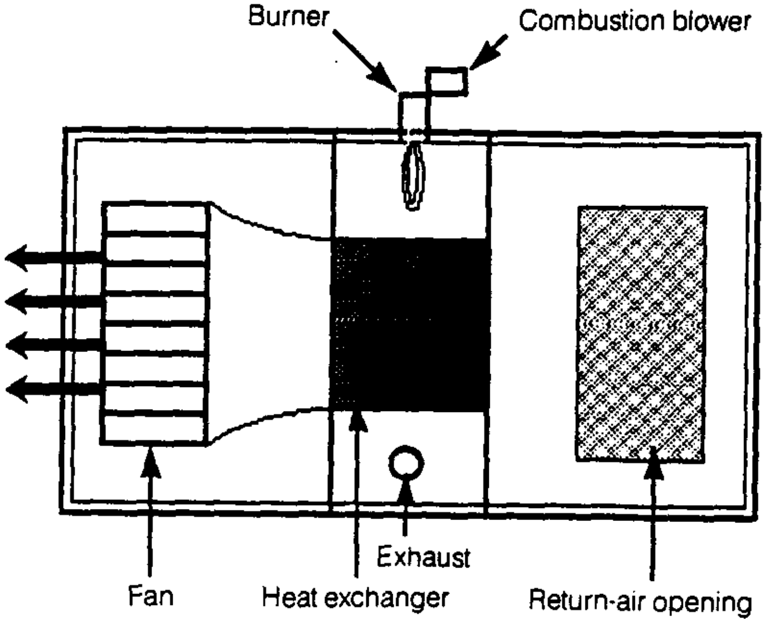


FIGURE 6

Various oven duct arrangements

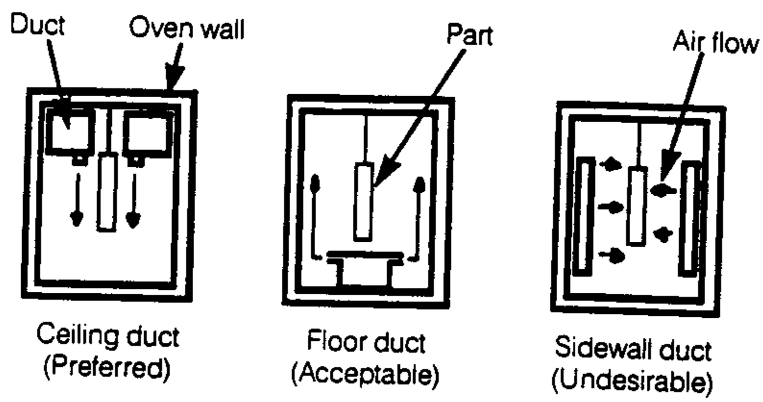


FIGURE 7

A powered air curtain

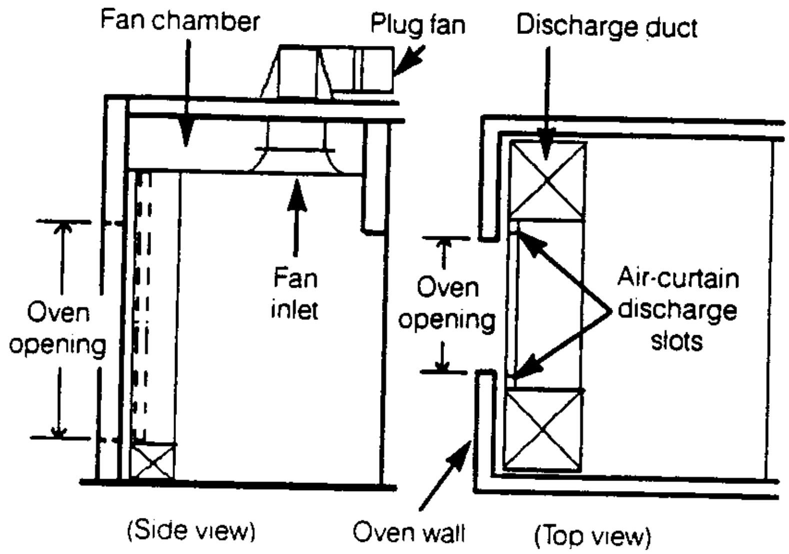


FIGURE 8

A heat-relief hood

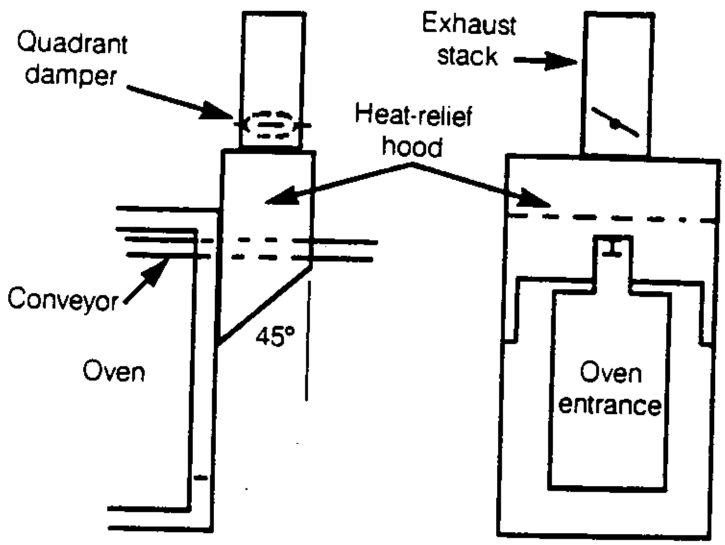


FIGURE 9

Return-air filtration

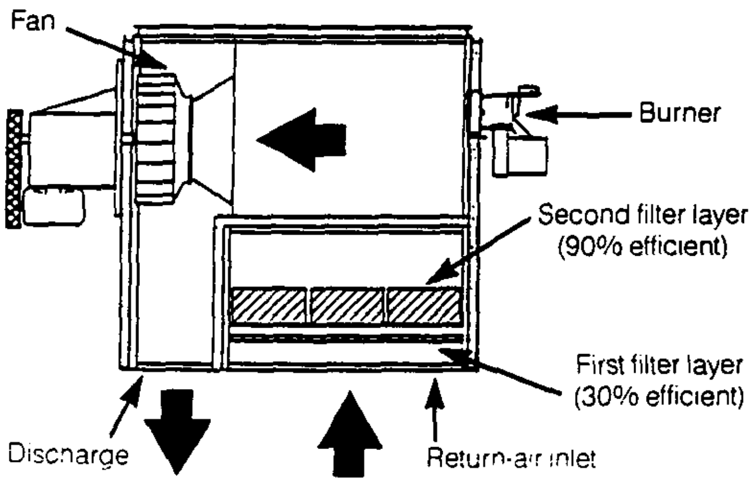


TABLE 1

Specific heat of various metals

Metal	Specific heat (Btu/lb °F)
Aluminum	0.226
Brass	0.092
Copper	0.0928
Gold	0.0312
Iron (99.97%)	0.1075
Lead	0.297
Magnesium	0.249
Manganese	0.1211
Steel	0.12
Titanium	0.1125
Zinc	0.0931

Source: *Eclipse Combustion Engineering Guide*, 2nd ed. (Rockford: Eclipse Inc., 1986)

TABLE 2

Oven-panel heat loss for various panel thicknesses

Panel thickness (Inches)	Loss factor (These insulation factors assume that the insulating material is rated as 4-pound density)
3	0.40
4	0.35
5	0.30
6	0.25
8	0.20

Source: Rodger Talbert, *Systems Design* (Cincinnati: Chemical Coaters Association International, 1994).

Economic Aspects. To evaluate the economic feasibility of electric IR, a number of issues need to be considered. The following issues must be addressed to determine the cost of doing business with and without electric IR:

1. Remaining life of the current heating equipment
2. Current heating capacity
3. Energy source for the current heating method
4. Annual energy costs of the current heating method
5. Current energy charge
6. Percentage of material wasted by the current heating method
7. Scrap value of the material
8. Embedded cost in the scrapped part/material
9. Annual labor costs associated with the heating operation
10. Annual production throughput
11. Space requirements for the current heating equipment
12. Annual cost of floor space
13. Installed replacement cost for the current heating process
14. Payback period required to justify the installation of a new electric IR system
15. Expected capacity of the plant in five years.

These economic issues can be condensed into five basic costs associated with electric IR heating:

- Equipment
- Labor
- Energy
- Scrap
- Floor space.

Trade-Offs Between Electric IR and Gas Convection. Table shows some of the typical trade-offs between electric IR and gas convection. Typically, an electric IR oven has reduced floor space, warm-up time, cure time, and efficiency, combined with an ability to reach higher product temperatures. Gas convection heats more slowly and can heat certain unusually shaped objects with shaded regions more uniformly.

	Electric IR	Gas Convection
Floor Space (Conveyor Length Needed)	25 to 30 ft	300 to 350 ft
Warm-up time	1 to 90 sec	30 min
Cure Time	1 sec to 10 min	20 to 35 min
Efficiency	45 to 60 percent	15 to 25 percent
Product Temperature Range	0 to 1000 F	0 to 450 F
Operational Advantages	Can be turned OFF or reduced to 5 to 10 percent power with no parts in oven	Runs all the time
Ease of Installation	Preassembled; move into position	Erect on-site

Source: Some information supplied by BGK Finishing Systems, Inc., Plymouth, Minnesota

	Short Wave	Gas Convection
Floor Space (required conveyor length)	25 to 30 feet	300 to 350 feet
Warm-up Time	1 to 90 seconds	10 to 30 minutes
Cure Time	1 second to 10 minutes	10 to 35 minutes
Product Temperature Range	0 to 1000°F	0 to 450°F
Operational Advantages	Can be turned OFF or reduced to 5-10% power with no parts in oven	Runs all the time
Number of Parts in Oven	13 to 15	175 to 225
Ease of Installation	Preassembled: move into position	Erected on site.

Typical Oven Comparison

Gas Fired Convection Ovens

Used for Drying and Curing

- TYPES
  - Direct Fired
  - Indirect Fired

- HEAT LOSS SOURCES
  - Product Loading
    Hangers, Parts , Conveyor Elements
  - Oven Panel Radiation Losses
  - Exhaust Loss
    Flue Gases and VOC Removal
  - Other
    Air Curtains, Heat Exchanger, Idle Time

- PROCESS EFFICIENCIES

PRODUCT LOADING

ENERGY NEEDED FOR CONVECTION OVEN -

Energy Spent to heat Parts, Racks, Conveyor Chain and Trolleys

Wt. of Parts + racks + conveyor chain and trolleys x conveyor speed :
= 8,688 lb of steel per hour (for this example)

Oven set point temperature : 350 F
Ambient temperature : 70 F
350 F - 70F = 280 F temp rise

8,688 x 0.12 x 280 = 291,917 Btu/hr

ENERGY NEEDED FOR IR OVEN -

Wt. of Parts x 0.12 x 280 x t (time to heat parts to target temperature and cure coating):

IR Total Cure Time is 1/5 that required for Gas Convection Oven (Rough Rule of Thumb)

OVEN - PANEL RADIATION LOSS

PANEL LOSS FACTOR - Function of oven wall thickness
- holds for sides, ceiling and floor

EXAMPLE -

Oven set pt. Temperature : 350 F
Ambient Temperature : 70 F
350 F - 70 F = 280 F temp rise

Panel Thickness : 4 in. (0.35 panel loss factor)
Oven size : 20 ft wide, 50 ft long, 10ft high

Ceiling & floor : 50 x 20 x 2 = 2,000
Sides : 50 x 10 x 2 = 1,000
Ends : 20 x 10 x 2 = 400

Total panel area: 3,400 sq ft

Energy loss = 3,400 x 0.35 x 280 = 333,200 Btu/hr

EXHAUST VOLUME LOSS

Energy loss through the air and flue gases going up the exhaust stack. Required to remove Powder coating volatiles and fossil fuel combustion gases -

EXAMPLE -

Oven set pt. temperature : 400 F
Ambient temperature : 70 F
Temperature rise : 330 F
Exhaust volume : 984 cfm

$$984 \times 60 \times 0.075 \times 0.24 \times 330 = 350{,}698 \text{ Btu/hr}$$

Exhaust loss for IR is only related to powder gun consumption.

TOTAL ENERGY USAGE OF GAS FIRED CONVECTION OVEN

Product Load	= 291,917 Btu/hr
Oven Panel Loss	= 333,200 Btu/hr
Exhaust Loss	= 350,698 Btu/hr
TOTAL ENERGY	= 975,815 Btu/hr

Indirect Fired Oven add another 20 to 25 % loss due to heat exchanger

Convection oven efficiency runs between 20 to 40 %.

IR ADVANTAGES

1. Potentially 5 times the weight of parts can be heated by the IR oven compared to one hour of operating a gas convection oven. Takes 1/ 5 the time to heatup to temperature (as rule of thumb) because of direct transfer of heat to part.

   IR requires less energy since it only would heat the parts and not conveyor components.

2. IR oven can be shut down during idle times while convection oven must operate at or near the set temperature.

3. Takes time (½ hour or more) to heat convection oven up to set temperature. IR heats up in seconds or minutes.

4. Even if gas prices are 3 times cheaper than the electric rate the cost per pound to cure a product is generally much less using IR.

5. Space and maintenance requirements are much less for IR Ovens.