BASIC INDUSTRIAL DRYING

FUNDAMENTALS AND METHODS

TAPPI

Building and Industrial Mat
2011 Spring Meeting
MAY 18 – 20

Radiant ENERGY SYSTEMS, INC.

Excellence in Process Heating™

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SESSION AGENDA

1. *DEFINING THE PROCESS REQUIREMENTS*
2. *“CONVENTIONAL” DRYING METHODS*
3. *UNDERSTANDING THE DRYING/HEATING PROCESS*
4. *UNDERSTANDING CONVECTION DRYING*
5. *UNDERSTANDING INFRARED DRYING*
6. *EQUIPMENT SELECTION: PROS AND CONS*

DEFINING THE PROCESS REQUIREMENTS

- Drying; Solvent vaporization/evaporation
- Curing; A final web/coating temperature requirement (normally following a drying requirement)
- Heating; Raising the temperature of a product: Substrate Heat set? Curing? Before lamination?; film, foils, etc.

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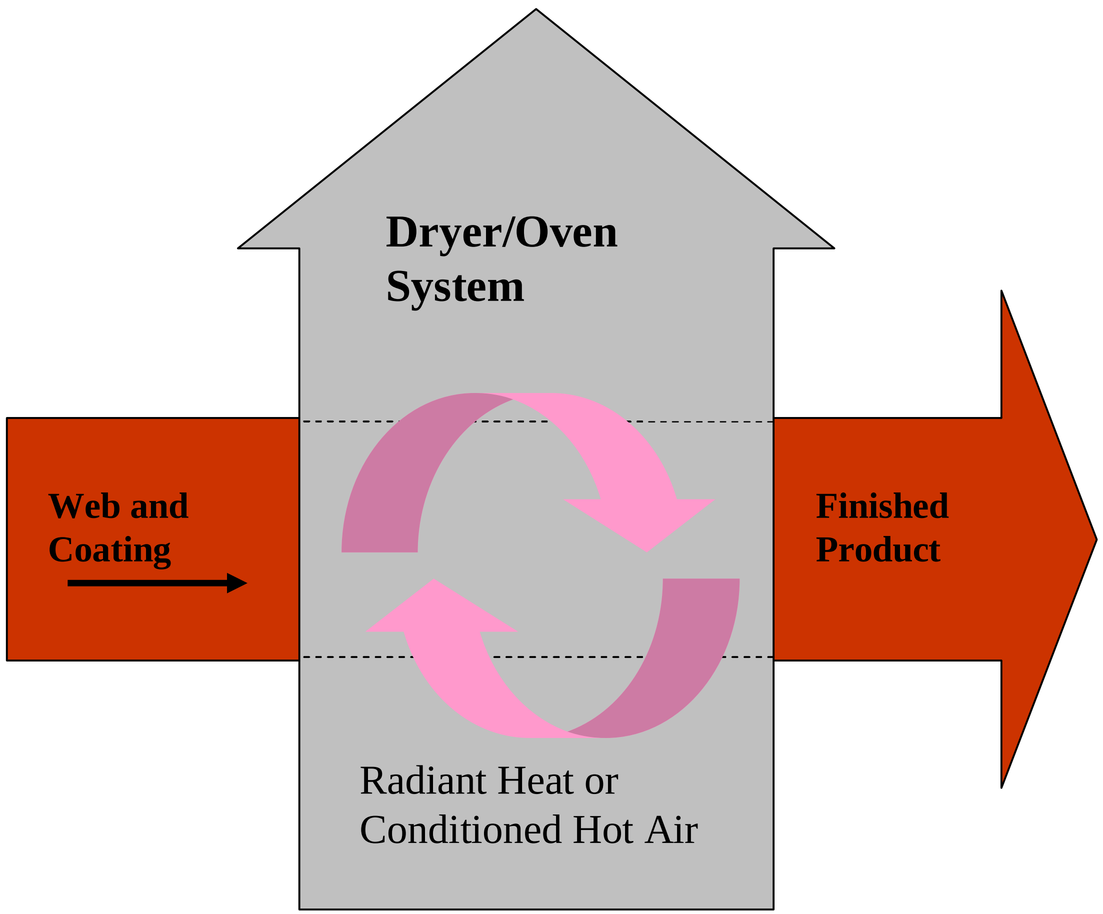
CONVENTIONAL TECHNOLOGIES USED FOR DRYING, CURING AND HEATING A WEB

- **CONVECTION SYSTEMS**
  - *IMPINGEMENT DRYING*
  - *FLOATATION DRYING*
  - *THROUGH AIR DRYING*
  - *BATCH DRYERS/OVENS*

- **RADIANT HEATING/DRYING SYSTEMS**
  - *ELECTRIC INFRARED*
  - *GAS FIRED INFRARED*

A DRYER IS A *“HEAT EXCHANGER”*



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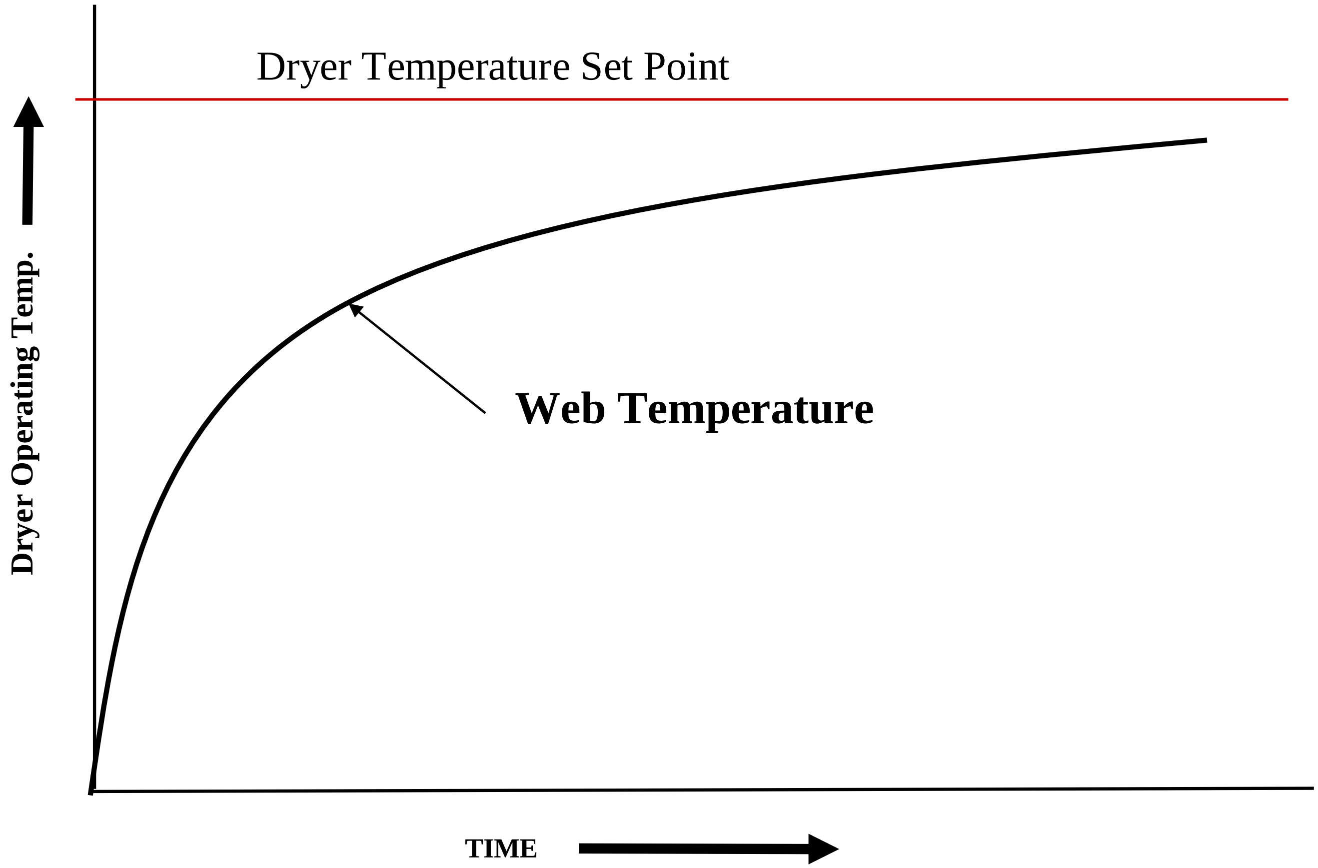
Heating a Web



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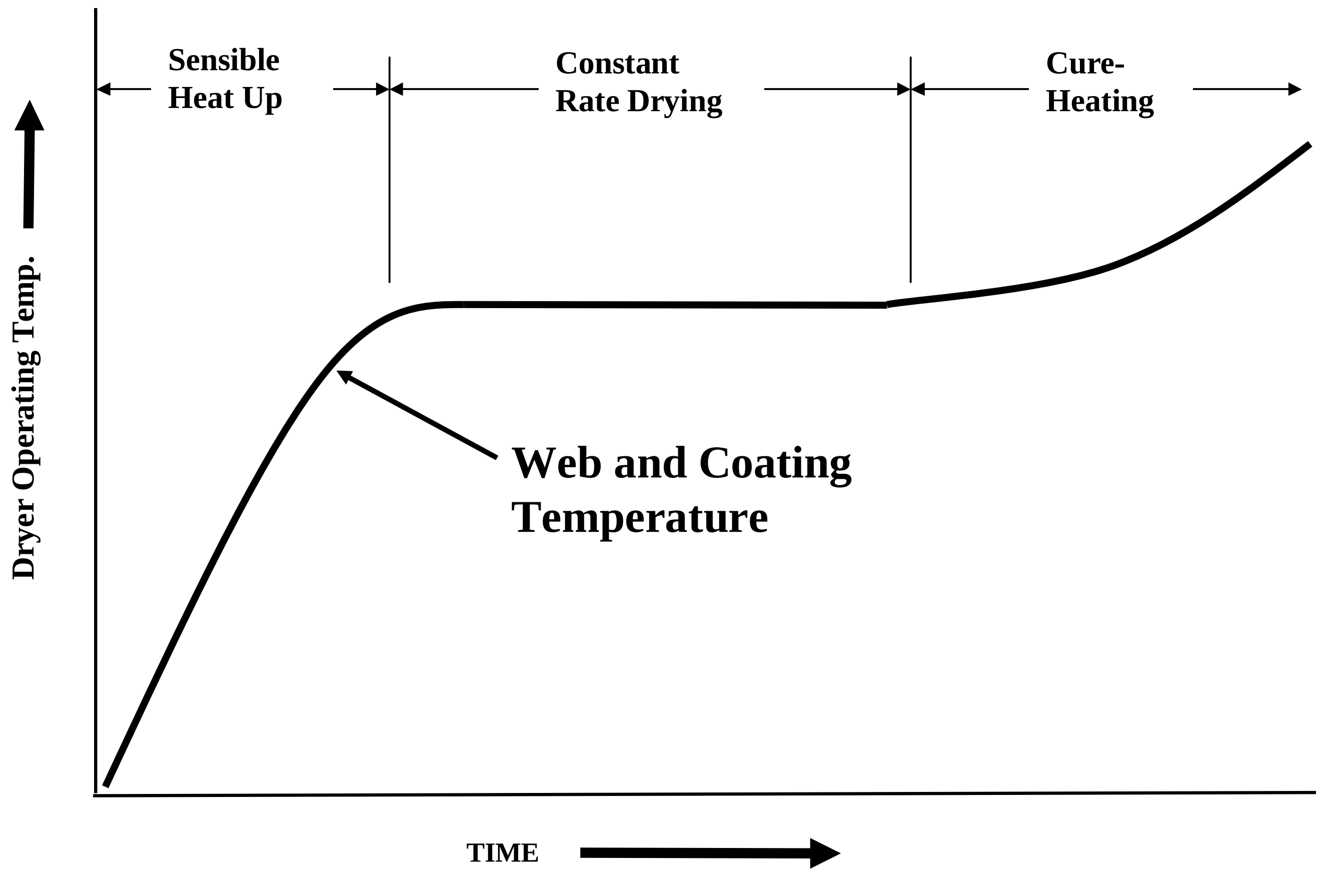
Drying and Heating Stages of a Coated Web



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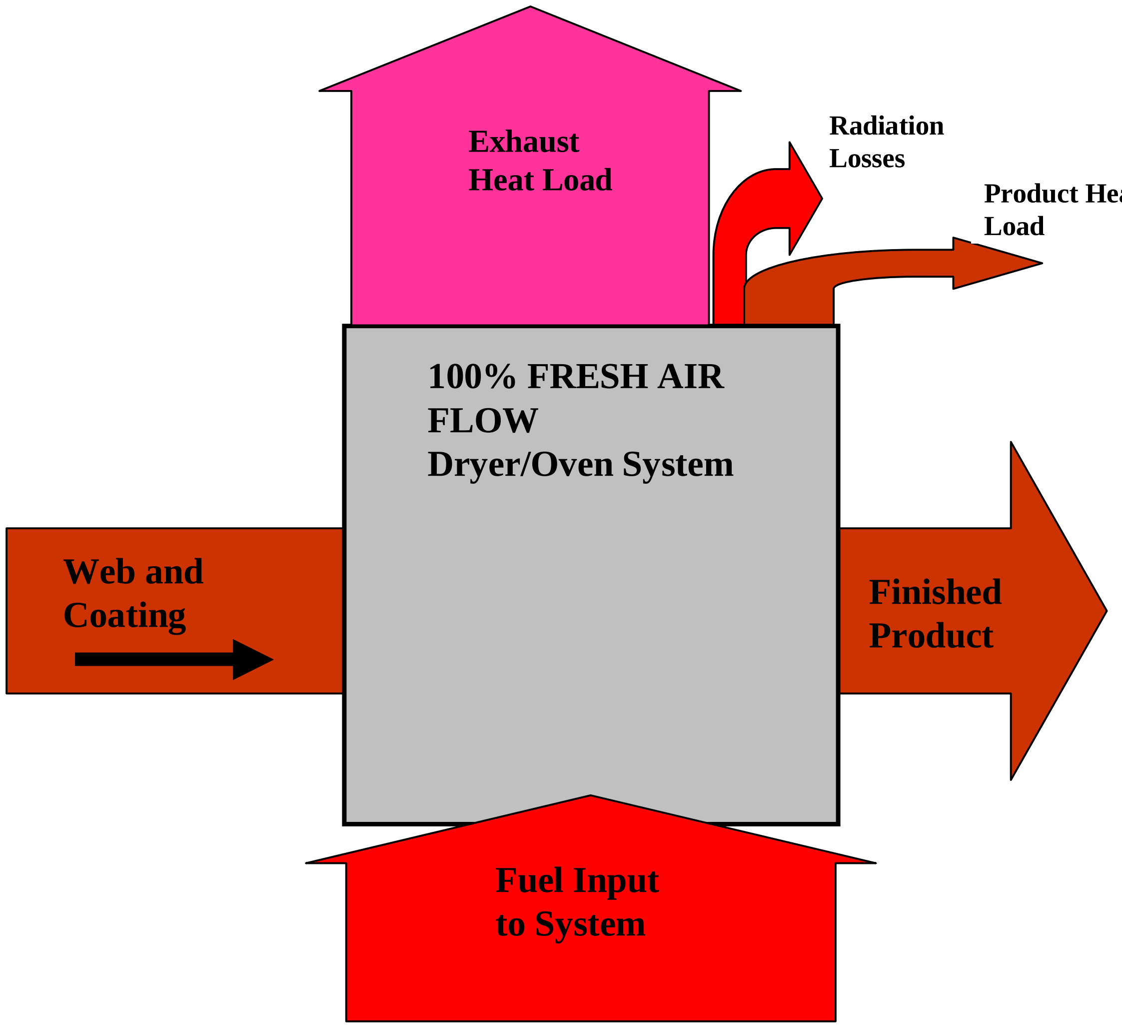
DEFINING CONVECTION:

- **"The transfer of heat by circulation of a gas or a liquid in contact with the object to be heated."**
- **Convection dryers use 'conditioned' (Temperature and humidity controlled) hot air for heat transfer.**
- **Liquid Vaporization and Evaporation by both heat conduction and turbulent air flow.**
- **Convection dryers use a Nozzle array or ducted distribution of the air to uniformly heat the product as it passes through the confined Dryer atmosphere**

CONVECTION DRYER HEAT LOADS – 100% FRESH AIR DESIGN



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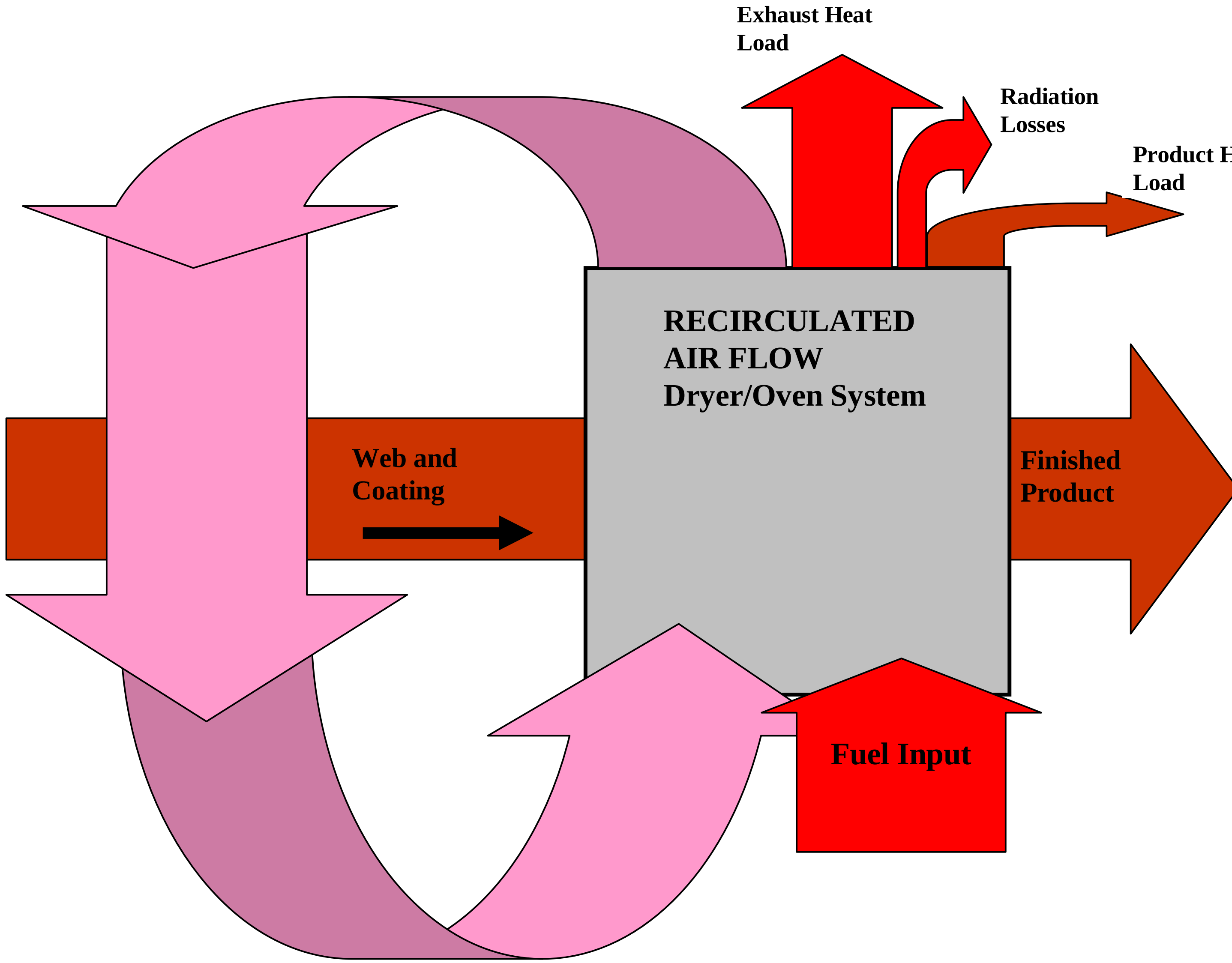
CONVECTION DRYER HEAT LOADS – Using 50% TO 90% RECIRCULATION



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IMPINGEMENT DRYERS

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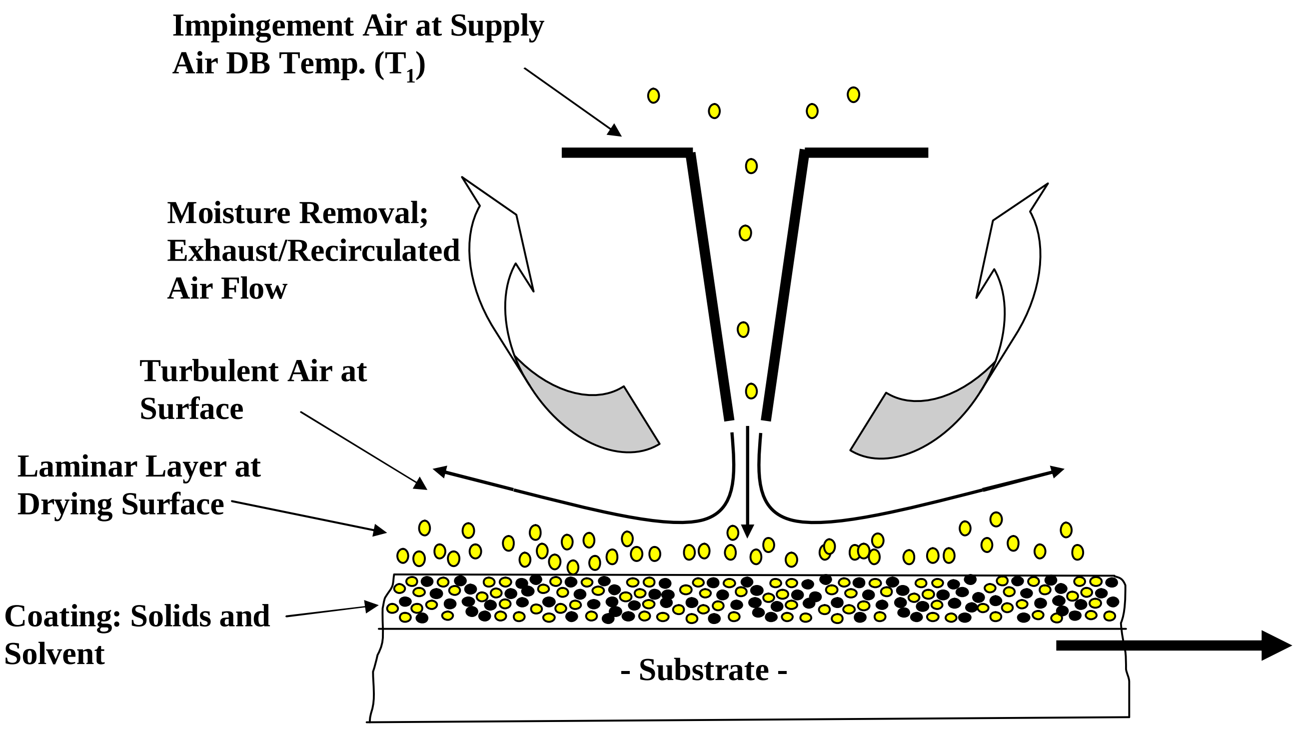
Convection Air Drying Mechanics



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Factors that impact Heat Transfer by Impingement:

- **Velocity effect** on Heat transfer is approximately proportional to the 0.6 power of the change. $(V^1/V^2)^{0.6}$
- **Drying air temperature** increase or decrease will yield an approximate linear change in heat transfer.
- **Humidity of the Supply air** (Low Exhaust/High Recirculation) will reduce the heat transfer. This is due to a lowering of the dT used when a higher wet bulb temperature (higher moisture content in the Exhaust/Return air) vs. the dryer supply temperature is present.
- **Nozzle Distance from the web** impacts the 'Effective' heat transfer (seen on the web surface) by approximately 10% per inch of distance; ***i.e.:*** A 1 inch nozzle to web distance will achieve 20% more theoretical heat transfer than a nozzle 3 inches away.

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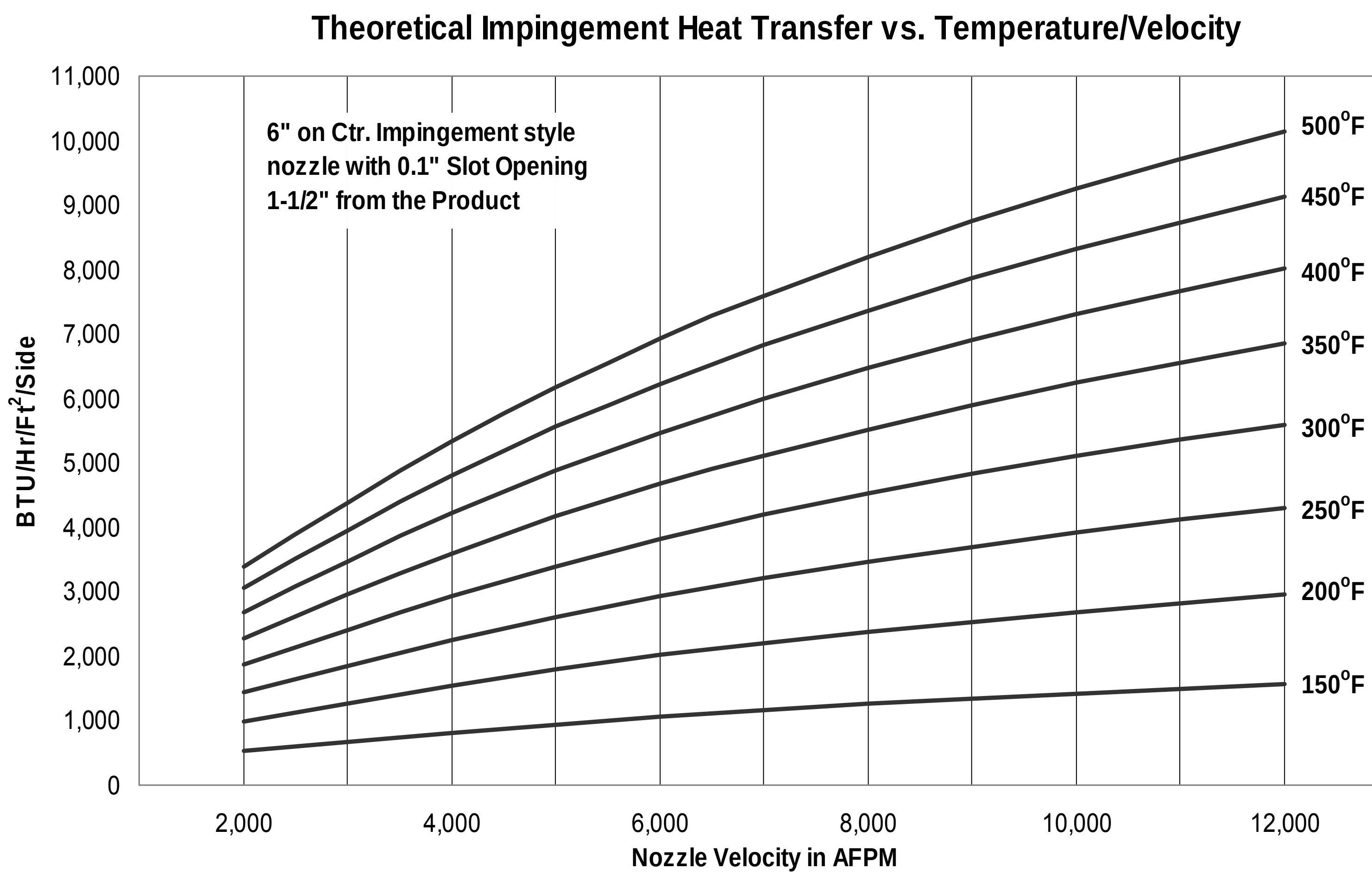

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IMPINGEMENT DRYER ADVANTAGES

- ✓ Heat transfer input (Velocity/Temperature) is somewhat independent of web handling issues.
- ✓ Can be easily arranged for multiple heat transfer zones, and also easily changed for different products requirements
- ✓ Accurate and uniform control of the dryer temperature for heating products irregardless of shape, size or color.
- ✓ Multiple Nozzle configurations and web pass configurations can be used with heat transfer to the top and/or bottom side of the web as required.
- ✓ Cost effective and can be adapted to multiple products with simple velocity and temperature adjustments.

IMPINGEMENT NEGATIVES

- ✓ Roll or conveyor support needed along with the associated initial costs, maintenance issues, and web tension requirements for longer dryers.
- ✓ Possibility of Web Scratching or marking from contact with web support idlers.
- ✓ Lower rates of heat transfer and heating by conduction from the surface being impinged on (Thicker products will take longer to heat).
- ✓ Limitation of heat transfer velocities which may disturb or contaminate the coating.
- ✓ Generally slow to heat up to operating levels and slow to cool down which results in the limitation of maximum operating temperatures that may be dictated by the web properties.

FLOATATION DRYERS

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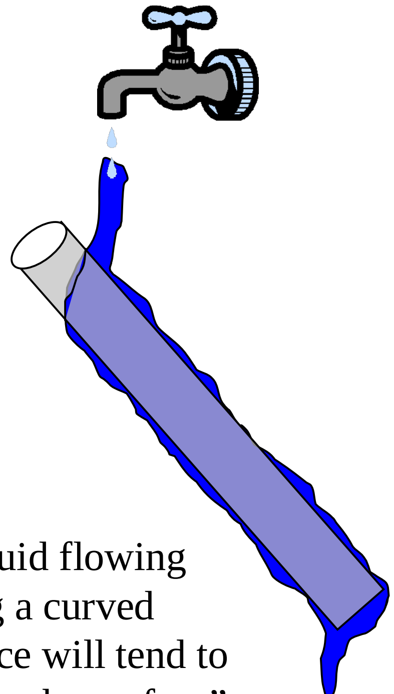
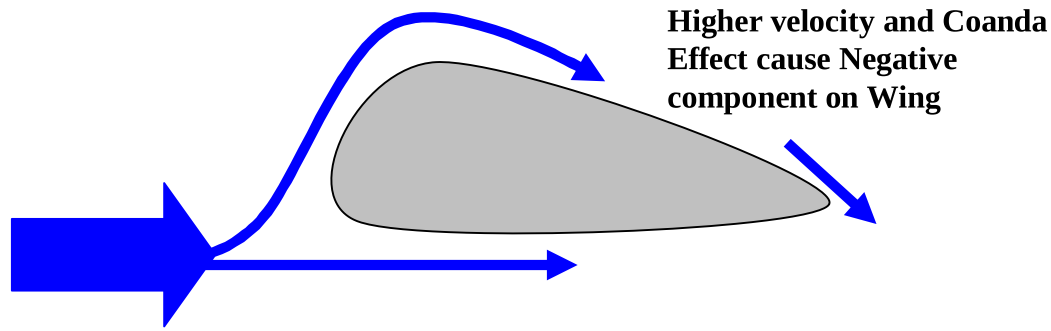
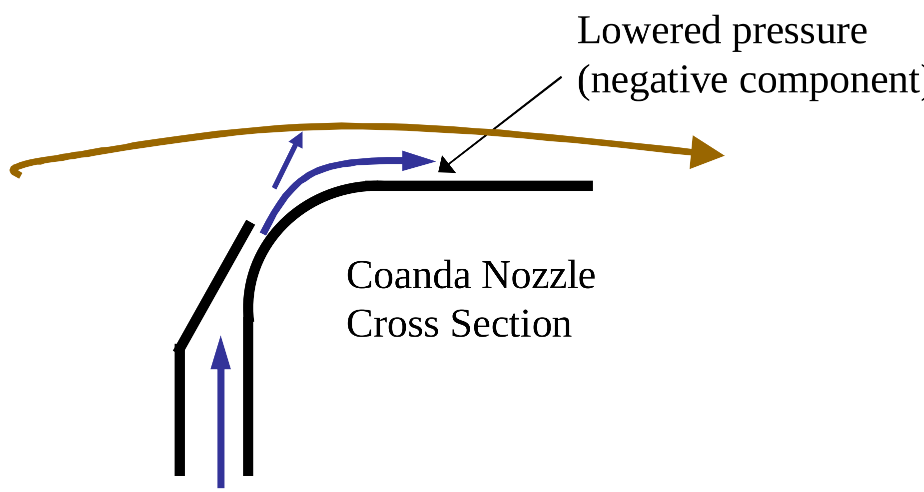
COANDA EFFECT



"A fluid flowing
along a curved
surface will tend to
follow the surface"

COANDA EFFECT ON AN AIRFOIL





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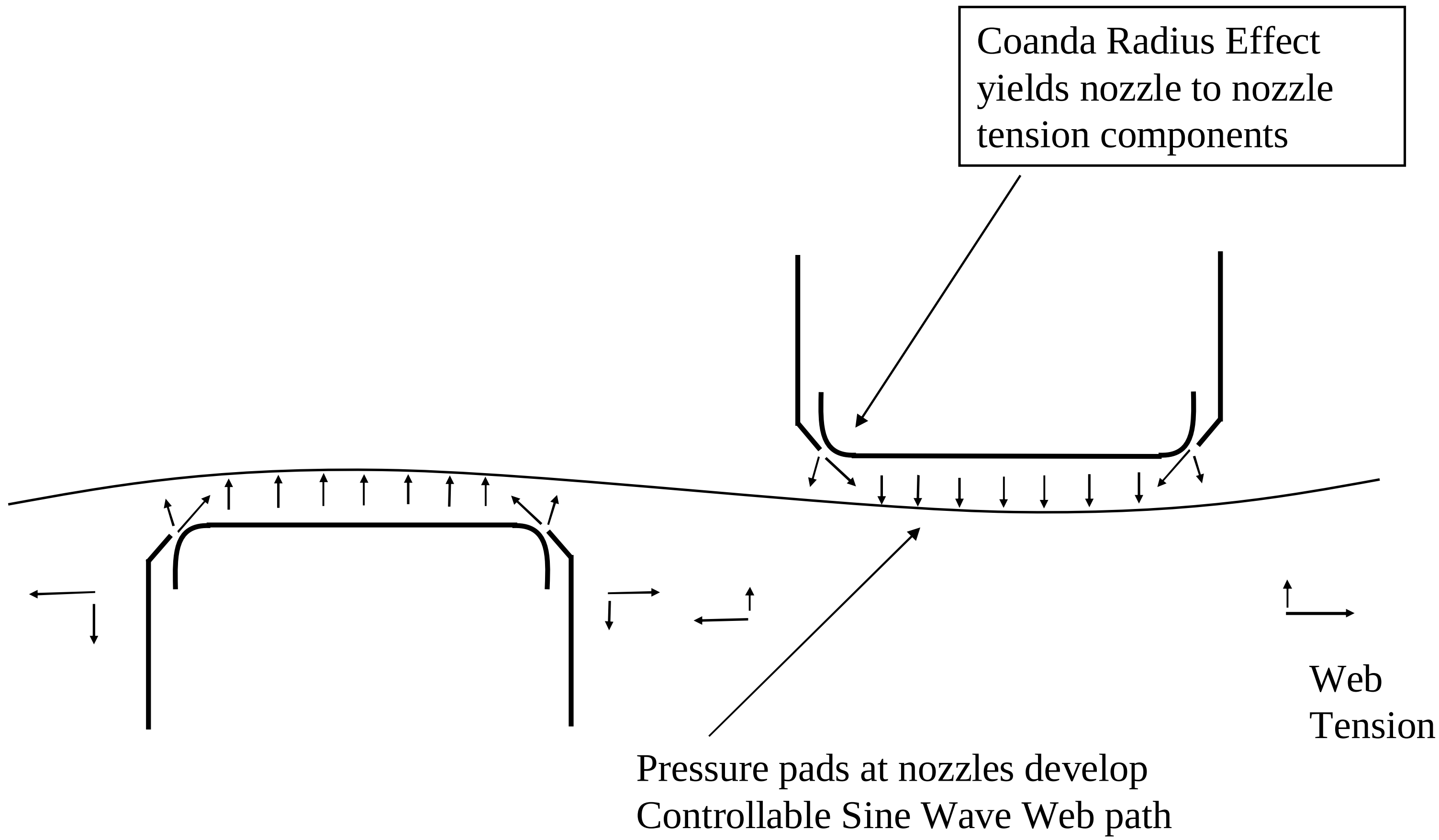
FLOATATION MECHANICS



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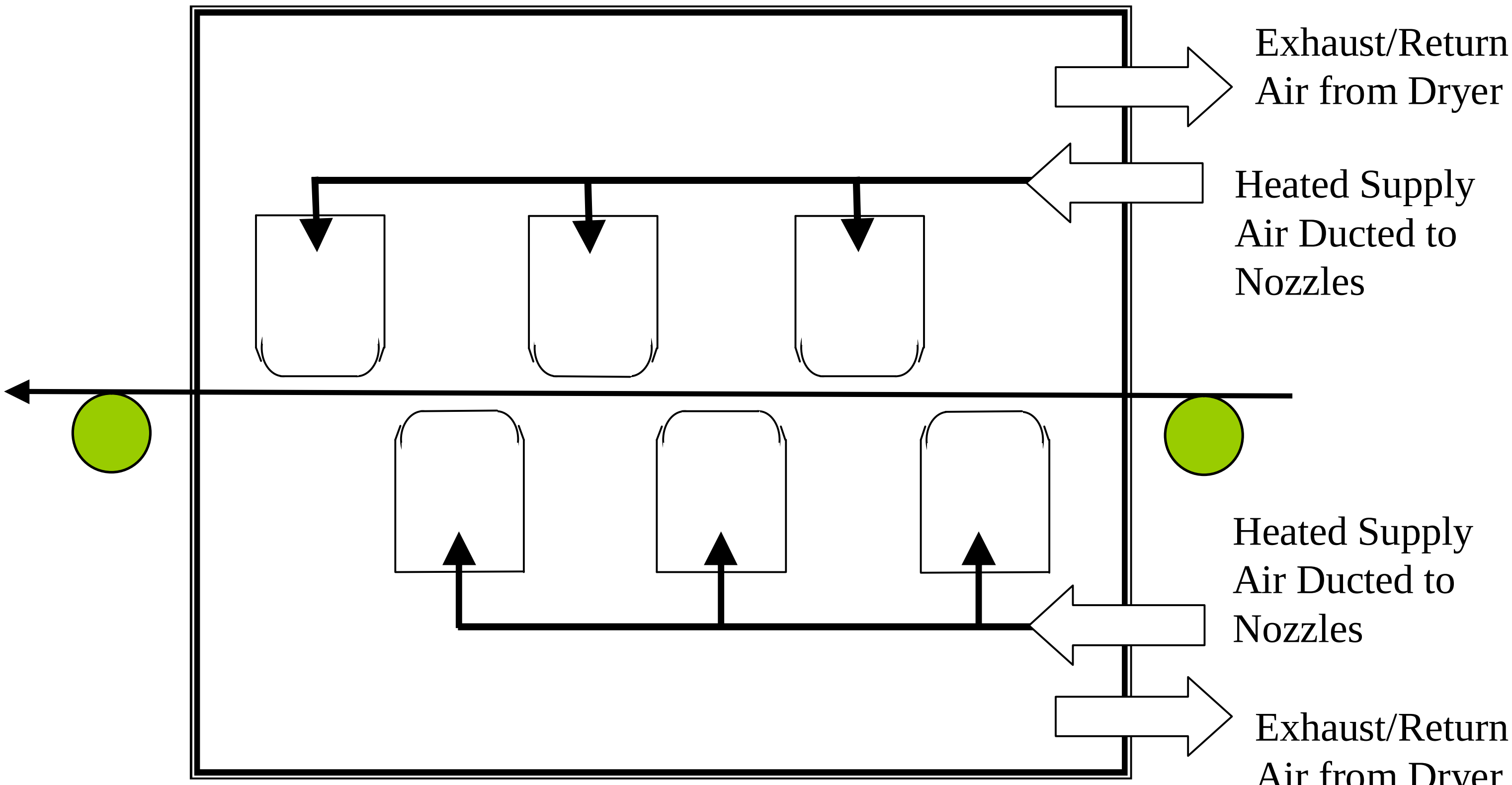
FLOATATION NOZZLE ARRAY



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FLOATATION DRYER ADVANTAGES

- ✓ Non-contact web support eliminating issues with marking or scratching.
- ✓ Eliminates the need for support rolls or conveyor with obvious benefits for running a saturated or 2-side coated web.
- ✓ Sine wave float eliminates edge curl.
- ✓ Positive web tracking through the dryer (‘self centering’) with minimum tension requirements.
- ✓ Accurate and uniform control of the dryer temperatures.
- ✓ Nozzle input from both sides of a coated web increases heat transfer capability and shortens the dryer length needed in most cases as compared to one side impingement.

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FLOATATION NEGATIVES

- ✓ Lower rates of heat transfer and heating by conduction from the surface being impinged on (Thicker products will take longer to heat).
- ✓ Boundary layer breakup is better with impingement, but, the Coanda creates parallel flow averaging of heat transfer.
- ✓ Limitation of heat transfer velocities which may disturb or contaminate the coating.
- ✓ Velocity and flow balance needed to float against line tension may limit heat transfer.
- ✓ Generally slow to heat up to operating levels and slow to cool down which results in the limitation of maximum operating temperatures.

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THROUGH AIR DRYING SYSTEMS

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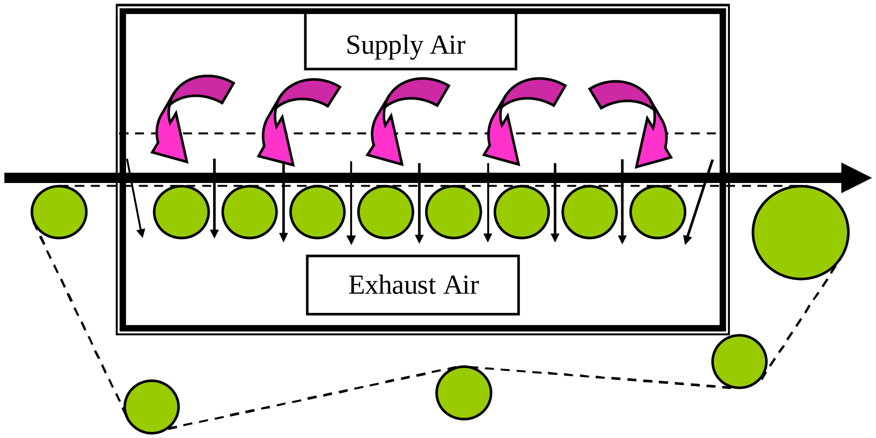
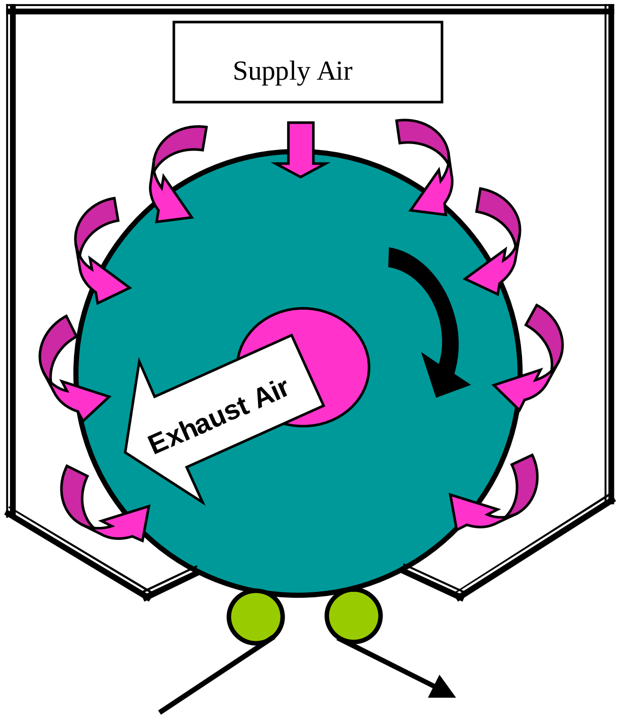
THROUGH AIR DRYERS



FLAT BED THRU AIR DRYER

HIGH TO MEDIUM PERMEABILITY
(dP UP TO 6” W.C.)



ROTARY THRU AIR DRYER

MEDIUM TO LOW PERMEABILITY
(dP CAN BE OVER 20” W.C.)

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THROUGH AIR ADVANTAGES

- ✓ 2 to 3 times higher Air flow (Heat Transfer) than conventional convection.
- ✓ Intimate contact with product interior heats uniformly and rapidly.
- ✓ High thermal efficiency for Heating, cooling or Drying applications.
- ✓ Accurate and uniform temperature control to heat “through” the product.
- ✓ Extremely high evaporation rates from a combination of mechanical and thermal drying.
- ✓ Enhances the ‘Hand’ of Non woven materials.
- ✓ Self tracking suction beds and Simple operation.

THROUGH AIR NEGATIVES

- ✓ Dependent on Permeability of the web.
- ✓ Wet to dry permeability changes in the web properties require multiple zones for Fan selection and efficient operation.
- ✓ Higher Blower Pressure drop needed for the higher air flow rates and to overcome product pressure drops; requires higher HP than convection in most cases.
- ✓ Mechanical losses of fiber and coating are carried in the through air stream.
- ✓ Most Products require a support conveyor or screen to maintain the 'Flat' bed with associated maintenance costs.

RADIANT HEATING

"The transfer of heat via electromagnetic waves between the heat source and the object to be heated."

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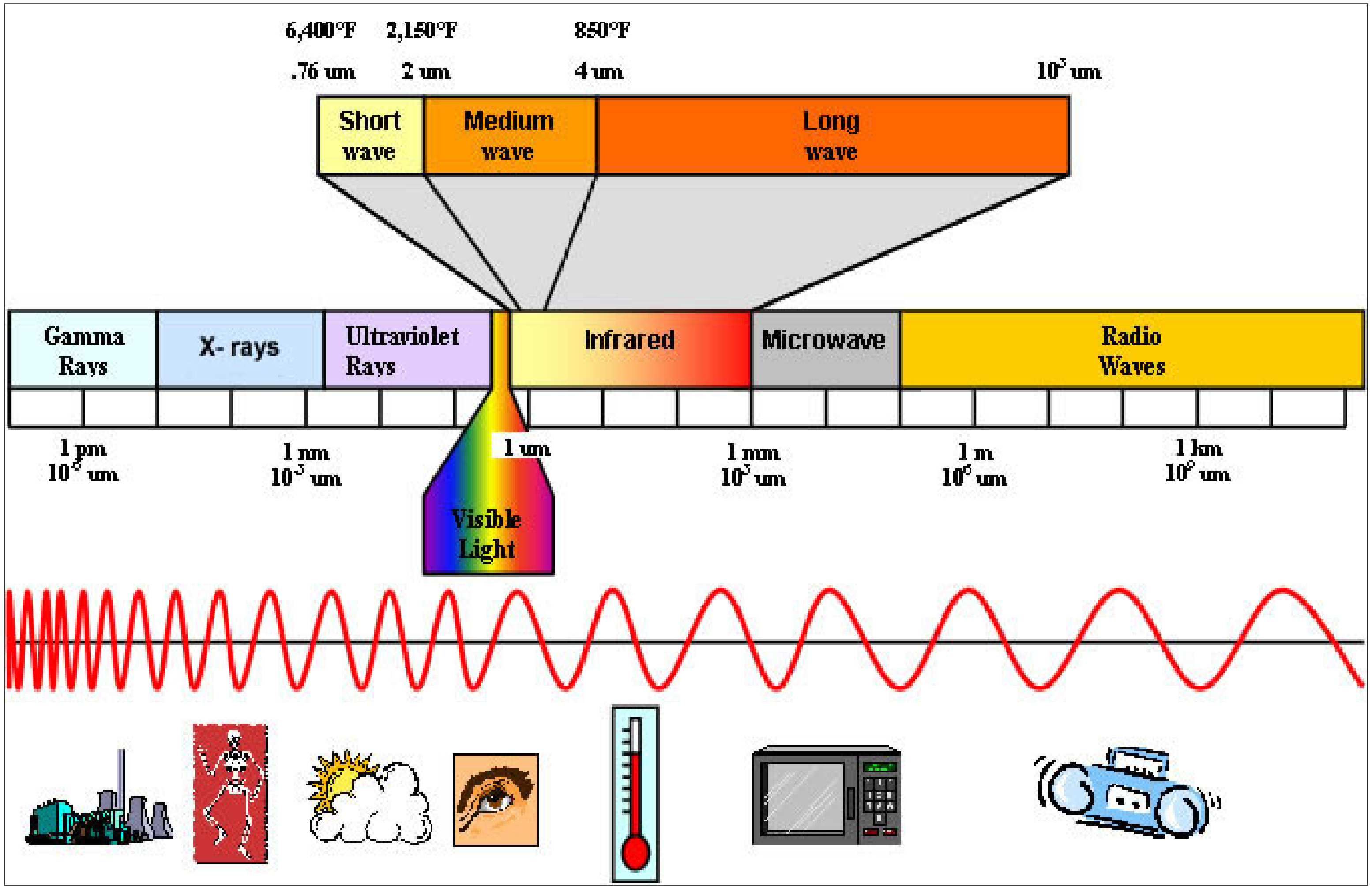
Electromagnetic Energy Spectrum



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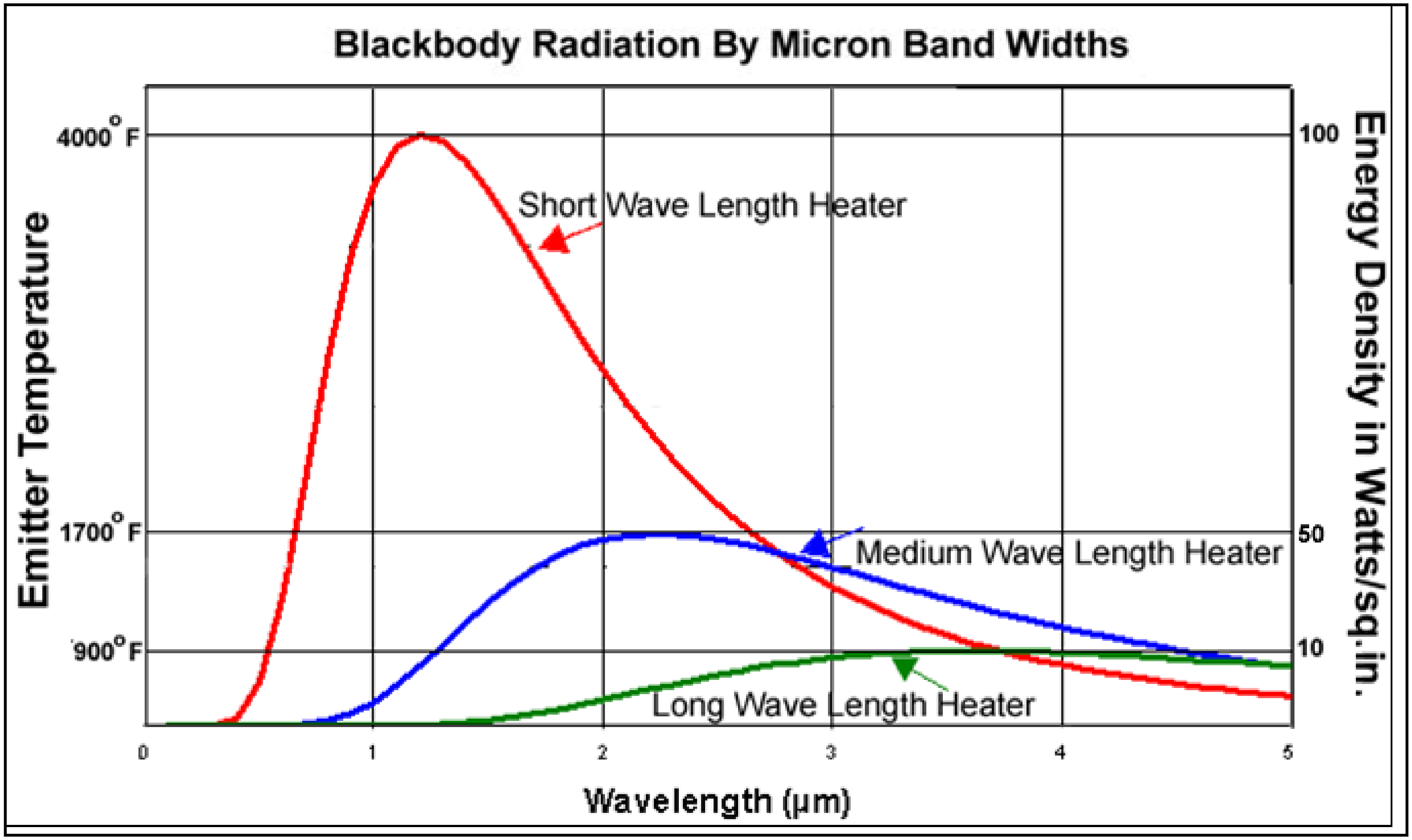
INDUSTRIAL PROCESS INFRARED

- **Wavelengths used for Industrial Infrared heating applications range from 1.17 micron (4000º F) to 5.4 micron (500º F).**
  - ***Short Wave Emitters – 2150º F to 4000º F***
  - ***Medium Wave Emitters – 900º F to 2150º F***
  - ***Long Wave Emitters – 500º F to 900º F***

- **Wavelength is inversely proportional to the temperature of the emitter. (i.e.: As temperature increases; the wavelength decreases)**

Infrared Spectrum



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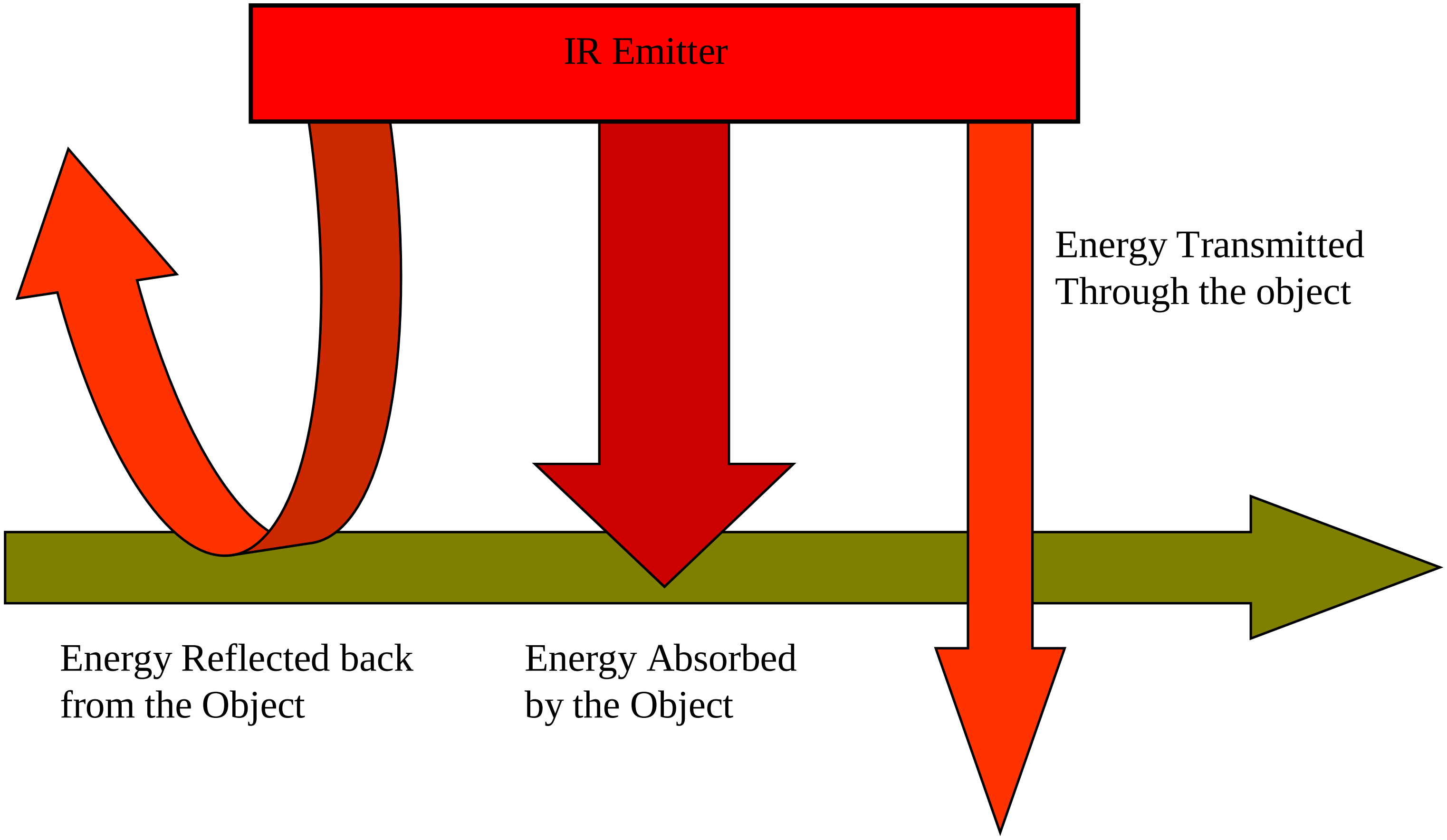
Efficiency of Industrial Infrared Emissions



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Stefan Boltzman Law to Determine Infrared Power

The total energy radiated is equal to the *black body temperature* to the 4th power

$$Q = kT^4$$

Q = Emitted Energy

k = Constant (0.172×10^{-8})

T = Source temperature (°K)

For example: If the temperature of the emitter is increased by 50%, the energy emitted is increased by 500%

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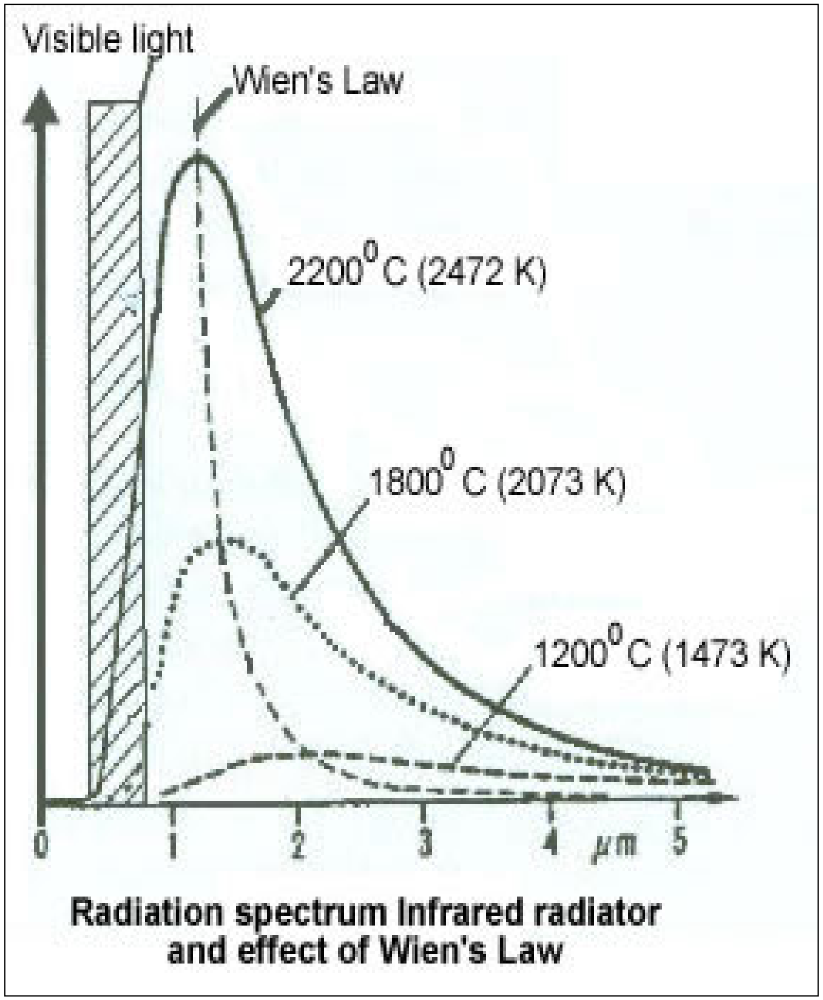
Determining Wavelength



Wien’s Law

The peak wave length of emission of an infrared heater can be calculated by Wien’s Law

λ = C/T

λ – wavelength in microns

C - Constant (2898)

T - Source temperature (ºK)

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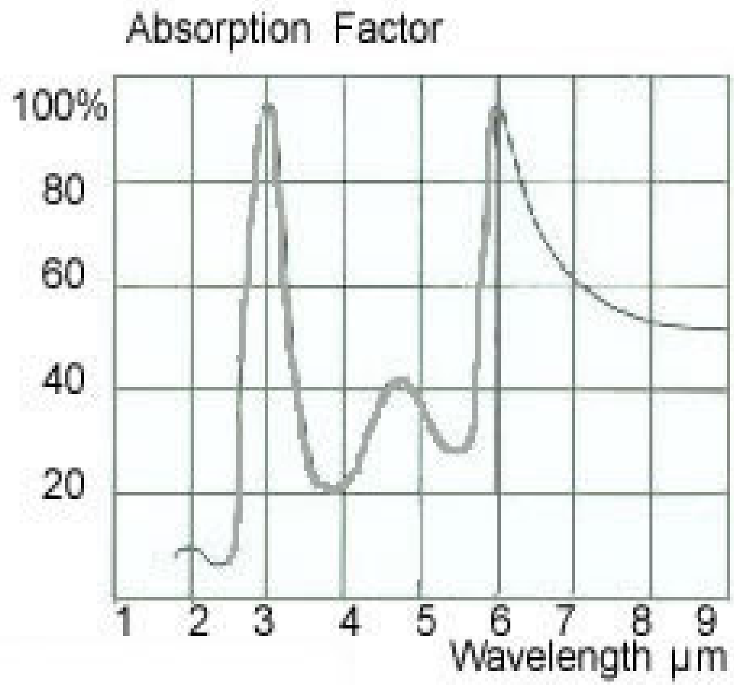
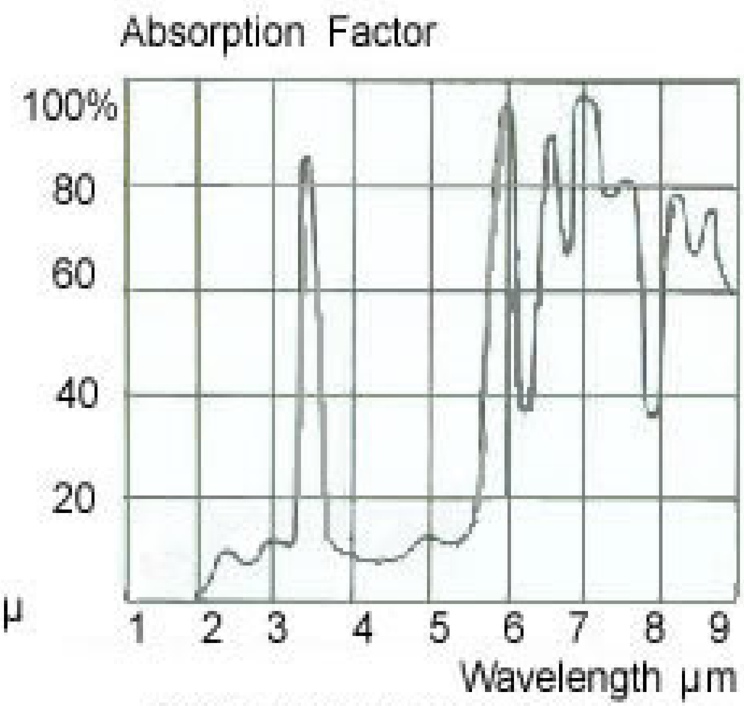
Typical IR Absorption Curves



Water fim thickness at 10 µm

µ



PVC sheet thickness at 1 mm

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Infrared Advantages

- ✓ Higher rate of heat transfer/Square Ft. compared to Convection
- ✓ Floor space savings due to higher density Heat output
- ✓ Easy to zone for uniform heating of the product and range of widths being processed.
- ✓ Fast response to changing process conditions
- ✓ Quick start up and shut down in most styles of heaters
- ✓ ‘Infinite’ temperature control and ‘tune-ability’ with Electric IR Source.
- ✓ Lower initial capital and installation cost
- ✓ Easily added to existing conventional dryers to increase line speed
- ✓ Infrared/Air dryers suitable for solvent based coatings

Infrared Negatives

- ✓ Some coatings may not be able to take advantage of higher rates of heat transfer and may skin and blister
- ✓ Difficult to work with temperature sensitive substrates
- ✓ Electric Source Infrared Kw costs are generally higher than equivalent gas costs – (direct energy cost comparisons)
- ✓ Gas Fired IR has limited turn down and control. Sizing is job specific.
- ✓ Since IR is basically a surface conduction phenomenon, harder to dry heavier coatings rapidly without overheating the surface
- ✓ Almost essential to run trials in lab or on a pilot line to confirm dryer sizing and desired finish product.

To Sum it All up ....

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Which Drying Method is the Best for the Application ??

- ❑ Convection ?
- ❑ Infrared ?
- ❑ Other ?

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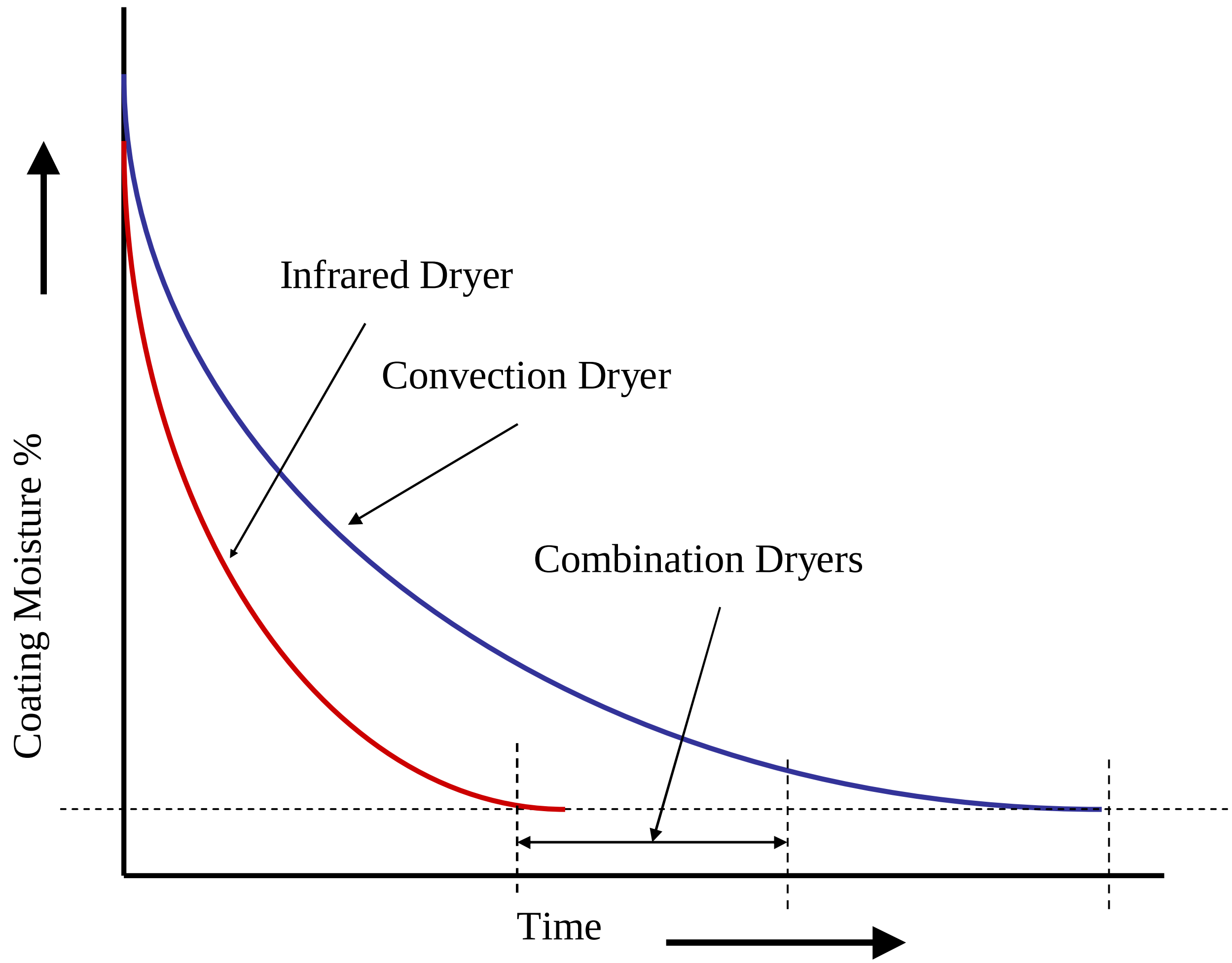
ANSWER:

NO SINGLE METHOD

- ***Product and Web handling issues should always be considered a part of the decision.***
- ***Best Design and Efficiency will normally be a combination of the available technologies.***
- ***Use and consider the advantages (and Negatives) of each.***
- ***Input the features needed to handle special product requirements, cleaning, maintenance, and ease of operation.***

COMPARISON OF DRYING TECHNOLOGIES



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