The JF Swinehart Co., Inc.
PO BOX 510 · 1370 NORTH MAIN STREET · FOSTORIA, OHIO 44830 · USA
TELEPHONE 419.435.6013 · FACSIMILE 419.435.0528
www.jfswinehart.com / jfs@jfswinehart.com

JFS FLAT GLASS TEMPERING INFORMATION

GLASS AND GLASS TEMPERING

The main focus of the next few pages is to give some background and definition to the word "Glass". Over the centuries glass has been used in many ways, today it is used for thousands of different products in all sorts of shapes and sizes. For our purposes, we will be discussing what is generally referred to as tempered flat glass, sheet glass or architectural glass. It is all flat regardless of how different producers or end users define it.

There will always be controversy as to whether glass is a liquid or a solid but, it is a known fact that old glass, left in a vertical position in a normal environment will become larger at the bottom and thinner at the top. In other words, without heating a piece of glass over an ambient temperature the glass will flow. As glass is heated to higher temperatures, it will be become very soft and malleable.

Oxides of several metals are used to manufacture raw glass; the main ingredient is sand, which generally is over 70% of the total composition. Other ingredients include soda ash and limestone. Additional materials are added for clearness, color, appearance, hardness and other desirable qualities. The general composition and the amounts and types of materials that are mixed and melted to produce raw glass are just about the same worldwide.

Almost all of the flat glass is produced today is on a "float line". The ingredients are mixed and melted together at approximately 2800°F (1537°C) and deposited on a liner of tin. As the molten glass floats down the float line, the glass thickness is gauged and the glass is slowly cooled to an annealed state. The glass is then cooled and cut for distribution to glass fabricators.

Annealed glass is very weak under tension but strong under compression. When annealed glass is broken, the pieces are usually long with sharp jagged edges which can be very dangerous. To overcome this dangerous situation annealed glass is heat-strengthened or tempered which makes the glass much stronger and safer than annealed glass.

Due to the inherent danger of annealed glass there have been various standards written that require the use of tempered or heat-strengthened in many of the flat glass products we come in contact with every day. Oven doors, architectural windows, display glass, shower doors, RV windows, aircraft windshields, fireplace doors and many other products are required to be tempered or heat-strengthened depending on where they are used and their purpose.

WHAT IS TEMPERED GLASS?

There have literally been volumes of books and papers written on the subject of tempering glass and the effects it produces but, simply put, glass is heated slowly and cooled very quickly and the result is tempered glass. Although this sounds simple and usually is, there are reasons and causes that will give us different results, some good, some bad.

Annealed glass has very low stresses so that when the glass is bent, one side or surface is put into tension and the glass breaks. When we temper glass we put the outside surfaces into compression and the center of the glass into tension. With the outer surface in compression, the glass becomes stronger and the outer surface acts as a hard shield or shell that protects the inner, softer glass from being broken. To break a piece of tempered glass, the bending force must over come the compression strength of the outer surface or, the outer surface has to be pierced, similar to busting a balloon. When tempered glass is broken, it produces small rounded pieces of glass, referred to as cullet. These pieces are generally small, resembling small stones with no sharp or dangerous edges. Depending on how fast we cool the glass after it reaches temperature will determine the size of the cullet and whether the glass is heat-strengthened or tempered.

Generally the difference between heat-strengthened and tempered glass is that heat-strengthened glass has a surface compression of between 4000 psi to 6500 psi and breaks into larger pieces of cutlet. Tempered glass has a surface compression above 10,000 psi and the cutlet is much smaller.

The faster the outer glass surfaces are cooled and the hotter the core temperature remains, the higher the surface compression becomes. Smaller cullet is produced and the glass strength is increased.

PREPARATION

There are several things to consider before we can begin to temper a piece of glass. All of these items are very important to our final glass quality and yields.

<u>The glass must have good edge work.</u>

A. Bad edges or chips can cause breakage when the glass is being cooled. Remember that the surface of tempered glass is in compression. Rough edges or chips act as small fault lines or fractures that break the surface or edge compression and can explode the glass during the cooling or quench cycle.

B. In some cases, if the edge work is not good and the glass did not break in the quench cycle, it could break at a later time after the product is shipped.
C. Edges of drilled holes or other modifications must also be edged or sanded smooth. Drilled holes should never be located any closer than half the hole diameter from the edge of the glass.

The glass must be clean.

A. When the glass is being heated it is conveyed on ceramic rolls. As the glass becomes hotter the surfaces become softer. Foreign particles that are on the glass can become embedded in the glass or on the rolls. Foreign particles can reduce the surface quality of the glass. They can also cause the glass to break in the quench by acting as a small crater that breaks the surface compression during the cooling or quench cycle.
B. The ceramic rolls are very expensive and must be kept clean and free of debris. Introducing dirt or foreign particles into the furnace that can settle or be forced onto the roll surface can deteriorate or damage the rolls. This condition can cause scratches, marks or imperfections in the glass surface which can reduce glass quality or reduce yields.
C. Furnace temperatures can be as high as 1400°F (760°C). At these higher temperatures, many foreign particles can crystallize or become hard and bond to the roll surface. When the roll is cleaned, part of the ceramic is removed when the particle is removed causing a small crater in the roll. These craters can attract other impurities and build small nodules that can mark the glass surface.

Load table and furnace rolls must be kept clean.

A. It is just as important to have clean rolls as it is to have clean glass for the same reasons listed above.
B. The load rolls should always be kept clean and free of any debris.
C. SO/2 and its use will be discussed later, but it can and does build up on the ceramic furnace rolls and in any small craters in the rolls. When this occurs this can also mark the glass. Clean the furnace rolls as required.

HEATING THE GLASS

Before the glass can be quenched, it must be evenly heated to a temperature of approximately 1139°F (615°C) to 1202°F (650°C) actual temperature. Keep in mind, regardless of the manufacturer or type of furnace, all like furnaces will operate differently and annealed glass of the same thickness, supplied by different manufacturers may take slightly different temperature profiles. As the glass enters the furnace, certain events will occur. To understand these events and how they affect the glass we must first understand the reason for the furnace design and three types of heat transfer that are in motion.

The standard JFS Flat Glass tempering System uses medium wave infrared heating elements that are positioned perpendicular to the flow. We generally design for approximately 20 watts in/2 of the total top and bottom furnace area with the top and bottom heat being evenly distributed. One reason for this type of design is that when the rolls reach the operating temperature of the furnace they become a main source for transferring heat into the bottom surface of the glass.

This method of heat transfer is called **conduction** and is the most efficient type of heat transfer. It also causes problems because the bottom of the glass will receive more heat than the top when the glass first enters the furnace. Proper control of the lower elements is important so that the roll temperature remains stable and we don’t overheat the lower portion of the glass.

Medium wave infrared serves several purposes when heating the glass. The elements heat the surrounding area, which is what we describe as a low mass thermal environment. The furnace liner is hard, non-dusting silica or ceramic composite board with a minimum backing of 6 inch (152.4 mm), 1900°F (1038°C) insulation. As the interior walls reach the operating temperature, they absorb the heat and create thermal mass. The interior will reach a certain color temperature, similar to the elements and begin to radiate infrared into the glass. The walls become a secondary infrared emitter. Together with the heating elements they transfer heat by **infrared radiation** into the glass. By using infrared, some of the energy penetrates the surface and heats the glass from the interior or core of the glass to the outside surface. This is one of the major advantages of medium wave infrared. This design helps the colder upper portion of the glass to heat more rapidly so the temperature difference created by the hot rolls is minimized and the glass will lie flat on the rolls more quickly. Due to fast response of elements the JFS system can react much faster to changes in glass loading and furnace conditions. As the furnace walls become hotter, the element voltage is reduced to save energy since the furnace walls become a secondary source of infrared.

The third and least efficient type of heat transfer is **convection**. This type of heat transfer can be beneficial but can also cause problems. Convection heat is basically air that has entered the furnace through building drafts or quenches air. As the air enters the furnace it is heated by the elements, the furnace walls and rolls and crosses the surface of the glass. If the air is not the same temperature as the operating temperature it can cool the glass and cause cold spots. It is very important to maintain the roll seals and entrance and exit doors to minimize outside air currents or drafts from entering the furnace. As in all normal cases, hot air rises and cold air falls, therefore there are natural convection currents always at work in the furnace. These natural currents aid in heating the top surface of the glass but, convection air only heats the outer surface of any substrate. The thermal conductivity of the glass transfers the surface temperature into the glass. Since glass has a very low thermal conductivity, the effect of the convection heat is minimal but helpful (see page 12 and 13 for Low “E” convection systems).

As a rule of thumb the heat time has been equated to one second of furnace time to .001 inch of glass thickness; i.e. 1/4" (.250") glass would take 250 seconds to reach approximately 630 degrees C. Depending on the furnace design, glass properties and other variables, exit temperatures for glass generally range from 610 degrees (1130 F) to as high as 675 degrees C (1247F).

HEATING OVERVIEW

The type of furnace being discussed is a single bay oscillator which moves the glass back and forth until the glass reaches the required exit temperature. By entering the estimated heat time and the main conveyor oscillation speed the PLC automatically calculates the number of reversals it will take for the time and speed. A radiometer mounted at the exit end of the furnace reads the exit temperature of the glass. In two and three bay furnaces, the temperature for each bay can be profiled but due to its single bay configuration we must control the temperature of a single chamber. Once the furnace reaches operating temperature, the glass can be loaded into the furnace. As the furnace lining and rolls normalize to the operating temperature, the elements are automatically reduced in temperature. As loading conditions, glass size or furnace conditions change, the elements react to the furnace temperature set point to minimize large temperature changes. The JFS Tempering System can hold the furnace temperature within 2°C (3.6°F) under normal operating conditions. Later we will explain how to react and make changes to different temperature problems that affect glass quality, breakage or yields.

The furnace is divided into multiple zones of control; the number of zones is dependent on the load size of the furnace. The upper and lower zones are of the same size and power but each zone is controlled by it’s own thermocouple and SCR power controller. The initial heat profile would have the upper center elements set at the highest set point. The upper edge elements would be set slightly lower than the center elements. Because of the hot rolls heating the lower surface of the glass and the initial problem of glass bowing up when it enters the furnace, the lower elements would be set lower than the upper edge and center heat.

No matter what the furnace settings are, we usually maintain some kind of temperature differential between the top and bottom heat with the top temperature set point usually being the highest. It is very important to try and heat both surfaces of the glass as evenly as possible. We need to minimize the bowing and also bring the glass to full temperature without large temperature differences between the top and bottom surfaces. As we have mentioned before, medium wave infrared has some ability to assist heating the glass from below the surface to the outside but when glass reaches approximately 450°C (842°F) the glass will begin to heat itself from the core to the outside.

Remember that annealed glass is very weak under tension and glass will break under tension. When a piece of glass enters a furnace with a temperature of + 630°C (1166° F) to as high as 760°C (1400°F) the outer surfaces expands putting the glass into compression which exerts force on the core or center of the glass. The more evenly we heat the glass the less chance we have of creating tension and breaking the glass in the furnace. When the glass becomes hotter and starts to become soft, all of the stresses are relieved and we can begin the cooling or quenching if the entire piece of glass is over 630°C (1166°F). Glass becomes soft at approximately 538°C (1000°F) but at this temperature it is extremely difficult to cool the glass without having breakage.

It is also important to remember that the thermocouples located in the furnace area only a reference to control their respective zone elements and do not represent a true glass temperature. The radiometer, located at the exit end of the furnace reads the true glass temperature when the glass exits the furnace.

WHAT IS COOLING OR QUENCHING OF THE GLASS?

As important as it is to have the glass thoroughly and evenly heated it is just as important to quench or cool the glass thoroughly and evenly. **When glass is being tempered, the object is to cool the outer surface as quickly and evenly as possible and keep the core temperature as hot as possible.** As was mentioned earlier, the outer surface starts its thermal shrinkage when it is cooled. The outer surfaces become cool and hard before the center creating the outer shell or shield. With the outer surface already hard and stable the inner core begins to cool and it begins its thermal shrinkage. This differential in cooling and shrinkage puts the outer surface in compression and the inner core in tension. To accomplish this, the most critical part of the process, there are several items that must be considered and understood.

As the hot glass passes from the furnace to the quench, it must be conveyed at a much higher speed than the oscillation speed in the furnace. One reason for this is that as the glass enters the quench, high amounts of air are impinged on the glass at speeds in excess of 20,000 ft/min (6,096 meters/min. This air has a tendency to "blow back" along the trailing portions of the glass and begins to cool the glass before it reaches the quench nozzles. This can create unwanted, slow and uneven cooling of the trailing portions of the glass. The surfaces of the glass will become solid within the first second or so of being exposed to the quench air. The faster the glass is transported to the quench, the less effect the unwanted cooling air will have on the quenching process. If the glass should enter the quench too slow, the temperature differential from the leading edge to the trailing edge could have a negative effect on the glass or break the glass in the quench.

In theory, if all conditions are correct it only takes about 2.7 seconds to temper the glass, the remaining time in the cycle is for cooling. In most cases the actual quench time is longer for various reasons.

A. Index time
B. Type of quench, sweep quench or full bed quench.
C. Quench nozzle design. Pattern and spacing.
D. Type of fan control, variable speed fans or inlet vane control

All tempering system manufacturers limit the size of thinner glass that can be tempered because of this “blow back” condition. Usually 3.2 mm (.125”) and thinner glass is limited to the largest piece of 40” by 80” (1016 mm by 2032 mm). Some manufacturers specify even smaller sizes.

Another reason we accelerate the glass into the quench, is to minimize the amount of unwanted cold air entering the furnace. As mentioned before, this cooler air becomes a convection current that is not at the furnace temperature and could disturb the heating profile or cycle.

The quench design is very critical to the process and relates to glass yields, glass flatness and quality. Since the outer surfaces become hard almost immediately after entering the quench, we must insure that the entire width of the glass sees maximum coverage of quench air within the first second of exposure. The JFS quench design requires that the glass be exposed to the first four nozzle rows to insure the entire width of the glass has been exposed to the proper quench air. This will require a minimum conveyor index speed of 228.6 mm/sec (540 inch/min). By increasing the conveyor index speed we can quench the glass faster and minimize blow back over the glass and into the furnace.

Glass bow (water shedding or water holding) is generally controlled by the upper and lower quench pressure. Although the furnace tries to heat the glass evenly there are upper and lower temperature differential, one side is hotter than the opposite side. The hotter side will have a tendency to expand and the cooler side contract causing the glass to bow

- **A. WATER HOLDING: Hot bottom / cold top.**
- **B. WATER SHEDDING: Cold bottom / hot top.**

To off-set these temperature differences and force the glass to a flat state the quench air is adjusted to cool the hotter side faster and the cooler side slower. These different cooling rates are not drastic and usually will remain constant when processing a certain type and thickness of glass.

Another issue is quenching thin glass on large or wide systems.

- A. When tempering large pieces of 3.2 mm (.125”) thick glass on wider systems (+84” / 2133 mm) the upper quench air is forced to the outside of the quench area. As it passes towards the outer area the hotter air from the center of the quench tends to reduce the cooling temperature of the air at the outer areas. This can cause different stresses in the outer surface area of the glass. When tempering smaller pieces the air will escape in the gaps.
- **B.** Another issue is flatness and keeping the glass in contact with the rolls so it moves forward during the quenching process. The amount of air and pressure to temper 3.2 mm glass is almost twice as much as the amount required to temper 4 mm glass. The amount of air and pressure for 3.2 mm glass introduces several problems in a quench.
  - **a.** The bottom surface of the glass is resting on quench rolls. The quench roll restricts the area the lower quench has to escape while the upper quench air is free to escape in all directions. This condition allows the lower quench air to push up the lower glass surface making the glass raise off the rolls and float.

- **b. This becomes even more of a problem if the lower side of the glass is hotter than the upper side since the lower air pressure will need to be increased and the upper pressure decreased to cool the glass evenly.**
- **c. On smaller or narrower systems this effect is less noticeable since the air has less distanced to travel to the outside and dissipate.**
- **d. Larger systems require devices to minimize this affect such as:**
  - **i. Upper roll mimics that simulate the restricted area of the lower quench.**
  - **ii. Another set of driven rolls located above the upper glass to move the glass forward should it leave the lower rolls.**

QUENCH SETUP AND ALIGNMENT

The proper quench set-up and alignment are very critical to good, efficient quenching. Once the furnace is placed in operation, minor adjustments may be required for the optimum distance and alignment. The purpose of this section is to explain procedures and why they are important should the quench need to be realigned in the future.

As a general rule of thumb, the distance from the quench blast head nozzle to the glass surface should be approximately six diameters of the quench nozzle hole. The JFS quench heads have been carefully fabricated so the upper and lower quench nozzles are directly across from each other. This alignment insures that both sides of the glass are being cooled evenly, at the same time. During the initial installation, these nozzles were aligned across from each other. If these nozzles would become off-set, up and down stream, it could cause the glass to float or become unstable in the quench, especially at the higher pressures required to quench thinner glass. If the nozzles were off-set from side to side, the top and bottom surfaces of the glass would be cooled in different areas.

Another critical alignment is to make sure the blast heads are level with each other. Should one side or one end be farther apart or closer than the other portion of the quench, the air velocity at the point of impact on the glass would be greater or less depending on the distance. This situation would have an adverse effect on the cooling rate and could cause quench breakage or an uneven break pattern.

Quenches that temper 3.2 mm glass run at very high volumes and pressures. When introducing large volumes of air at high pressures into a quench area, it is critical that the air has a place to exhaust evenly and efficiently. Without proper exhaust, the quench area becomes unstable. The lower quench head blows air on the bottom surface of the glass and the room it has to leave the lower quench area is restricted by the rolls. Even though the lower blast head pressure is usually lower than the upper pressure, the area for exhaust is much smaller. Since the lower air has a restricted exhaust area it tends to want to lift the glass off the rolls as means of escape.

The upper quench pressure is greater but it has no exhaust restrictions and therefore has a larger area to escape allowing the lower quench air to lift the glass off the rolls causing the glass to move or float.

To relieve this problem, "deflectors" are placed in the upper quench cavities between the quench nozzle rows and over the quench roll. These "deflectors", mimic the lower rolls located under the glass and restrict the exhaust flow of the upper quench air. By limiting the upper exhaust flow, we create equal or greater pressure on the top surface of the glass. This condition forces the lower quench air to escape downward and prevents the glass from floating.

When using "deflectors" caution must be used. If the exhaust flow is too restrictive it can keep warmer air in the quench area and slow the cooling process. If the deflectors are not properly designed and placed, they can cause problems when running larger pieces of glass verses running many small parts. A good balance is always required. "Deflectors" should be checked periodically to insure they are in the proper position and have not become damaged or warped.

Glass breakage in the quench is part of tempering and no matter how much we try to minimize the problem it is a fact of life. This system incorporates a “sweep” type quench so the majority of any breakage will occur in the cooler. When breakage occurs, it is necessary to use some kind of heavy steel poke to break the larger pieces of glass and clear the glass from the area before the next load indexes into the cooler or quench. Failure to clear the glass can cause backups in the furnace or quench which may require stopping the loading process, raising the furnace top and clearing the backup from the rolls. Over a long period of time the quench or cooler heads or deflectors can move or become damaged due to the roughness that is sometimes required to remove glass. Although the JFS quench and cooler system is a rugged, heavy duty piece of equipment, designed for this type of harsh abuse, it is possible that movement or damage could occur. Periodic inspection of the quench area, good housekeeping and maintenance are crucial to minimizing problems.

CONVEYOR SETUP AND ALIGNMENT

Just as important as the quench set-up and alignment is the set-up and alignment of the conveyors. The purpose here is to give insight as to how critical the conveyors are to the system. Maintenance and alignment procedures are covered in the maintenance portion of this manual.

Many components have a direct effect on glass quality and part of the total system is the roll bed. The load and unload conveyors are usually not associated with glass quality but do have some effect. As mentioned earlier, it is very important to keep the roll surfaces clean. Glass marking and scratches can also be caused by a speed difference between adjoining conveyors. The glass could be dragged or pushed to another conveyor, the unnecessary friction can cause miss-positioning and scratches.

All of the conveyors are designed and machined to insure that the roll bed is flat with little or no roll bounce or vibration. Once the system is installed and adjusted, the conveyors are set and should require no further adjustment. During the installation great care has been taken to make sure that all rolls are level and parallel to each other. High or low rolls can cause kinks in the glass or cause the corners to chip. Rolls that are not parallel can cause the glass to move or shift unnecessarily causing marks or scratches. The interface between the last ceramic furnace roll and the first quench is also very important since the glass is at its most malleable state. A high or low roll at this interface can cause the glass to be distorted with noticeable waves or could cause serious chipping to occur.

The quench and cooler rolls are wrapped with a high temperature, rugged Kevlar rope. Every other roll is wrapped in the opposite direction and it is very important this arrangement be maintained. By alternating the direction of the wrap the glass stays in the quench area. If we were to place several rolls with the same wrap direction next to one another, the glass would travel to either side of the quench and could possible run off the side of the conveyor. Be sure the rolls are always alternated down the conveyor.

For a more efficient exhaust flow from the quench area a smaller roll core is used and supported by a precision support mechanism. This roller, idler system should always be kept approximately .002 of an inch below the roll. Should it be set higher than the outer drive and idler stub the quench roll may not turn or operate properly.

There will be times when there will be a bad ceramic or quench roll. If the roll cannot be repaired or replaced it is better to relocate the roll. Ceramic rolls should be moved to the entrance end of the furnace conveyor and quench rolls should be moved to the exit end of the quench conveyor.

There are several items that need to be understood or at least considered when talking about glass tempering systems

A QUICK AND SIMPLE OVERVIEW OF TYPES OF GLASS AND GLASS HEATING FOR TEMPERING

TYPES OF GLASS

A. CLEAR OR NORMAL GLASS: Standard glass but can have a tint or color applied to a surface or color throughout the glass. The emissivity is ranges from approximately +/- .60% to .95%.
    a. Heat times are approximately 40 seconds per mm of glass thickness or 1 second per 1/1000 of thickness. 6 mm X 40 = 250 seconds. 6 mm ÷ 25.4 = .236 inches X 1000 = 236 seconds.
    b. Heat times in an aspirated assisted infrared furnace can be reduced by as much as 10%.
    c. Heat times in a properly designed low “E” furnace designed to heat Soft Coat Low “E” products can be reduced by as much as 40%.

B. LOW “E” GLASS:

  a. SOFT COAT: Generally applied to the glass using vacuum deposition. Soft coat low “E” glass has a low emissivity coating applied to only one side of the glass. Soft coats have an emissivity of approximately .01% to .05% which makes one side difficult to heat with infrared (radiant) heat. The coating requires special handling.
    i. In a radiant only furnace heat times can be as much as 50% longer.
    ii. With an aspirated assisted infrared furnace heat times are about 20% longer.
    iii. Heat times in a properly designed low “E” furnace designed to heat Soft Coat Low “E” products can be heated at “normal” heat times for clear glass or slightly faster.
  a. HARD COAT: Generally applied to the glass as a coating in a normal atmosphere. Hard coat low “E” glass has a medium emissivity coating applied to only one side of the glass. Hard coats have an emissivity of approximately +/- .40%. Usually these coating can be heated in a normal infrared (radiant) furnace with little increases in heat time but are not very popular. Hard coat Low “E” products to not require the special handling associated with soft coat Low “E” products.
    i. In a radiant only furnace heat times are approximately the same or slightly longer than “normal clear glass.
    ii. With an aspirated assisted infrared furnace heat times are can be up to 20% faster.
    iii. Heat times in a properly designed low “E” furnace designed to heat Soft Coat Low “E” products can be reduced by as much as 40% from “normal” heat times for clear glass.

TYPES OF FURNACES AND HEATING METHODS
“All tempering furnaces have an upper and lower heat source and hot ceramic rolls that the glass travels on”. There are three methods used to heat glass; (1) infrared (radiant heat), (2) conduction (direct heat transfer) and (3) convection (heated air) which includes “aspiration”. All furnaces use conduction and one and/or a combination of radiant and/or convection. “GAS INFRARED is covered at the end of this section and has certain advantages over other heating methods.

INFRARED: A heating source that heats materials. All materials (substrates) have an emissivity value from 0 (complete reflectivity) to 1(an absolute black body). Normal or clear glass has an emissivity of +/- .95 which means in theory it can absorb .95% of the available infrared. Tinted or colored glass may have a higher emissivity since dark colors absorb infrared at a faster rate. Low “E” glass can have an emissivity of .01 (soft coat) to .50 (hard coat) on one surface. The lower the emissivity value the more the infrared is reflected away fro the surface and not allowed to heat the glass. The vast majority of glass tempering furnaces uses a medium wave infrared heating source.

Infrared or radiant heat, in theory, heats the glass from inside out. As the medium wave energy tries to go through the glass the inside of the glass is heated as well as the outer surfaces. Larger furnaces using infrared heat must me zoned so that the edge and center temperatures of the glass can be controlled.
NOTE: Normal glass does react slightly different than other materials to infrared (radiant) heat. Given a constant specific infrared furnace temperature there are calculated heat times for various thicknesses of normal clear glass. Generally this is not understood throughout the industry but can be a helpful tool when understanding heat times for clear glass.

NOTE: Infrared is the least expensive energy source. Operating cost will vary depending on electric and gas utility cost.

CONDUCTION: Direct heat transfer such as glass touching a heated ceramic roll. In the ideal furnace the ceramic rolls will heat to the temperature of the furnace. When the bottom of the glass comes in contact with the rolls the heat from the ceramic rolls is transferred to the glass or the cold glass sucks the heat out of the rolls. As the glass gets hotter the amount of heat taken from the rolls becomes less allowing the rolls to recover lost heat from the furnace heat source. The bottom of the glass is also heated from the bottom heat source. In the initial heating of cold glass the class can become water shedding or water holding after initially entering the furnace. These conditions can cause the outside edges (water shedding) to get hotter from the roll contact or the center of the glass (water holding) to get hotter from touching the rolls.

NOTE: Conduction heat is the most efficient method of heat transfer but the cost is factored in to the primary source of heat.

CONVECTION: Convection heat uses either and electric or gas source to heat air. The air is then circulated in and out of the furnace cavity using high temperature recirculating fans. As the glass heats the hot air looses temperature and must be reheated by passing the colder air past the heating source. The emissivity of the product does not have any influence on the performance of convection heat so it is very desirable for heating Low “E” glass. The rate that the heat is reheated and how it is impinged on the glass will effect the heat time. In theory, because all of the air is touching all surfaces of the glass at a constant temperature and the glass is being heated from the outside in, zoning is not required as long as all areas of the furnace are kept at the same temperature. Newer convection systems use a nozzle design inside the furnace cavity to accelerate the velocity of the air as it touches the glass or impinges the air on the glass surface to accelerate the or shorten the heating time.

NOTES:

A. Convection heat is the most expensive to operate and can be 2 to 5 times more expensive than radiant heat. Additional operating cost is the operation of high temperature recirculating fans. Convection systems typically have a minimum of 8 fans that can have individual horsepower ratings in excess of 25 HP, depending on the size of the system.

B. There is some recent concern over the by-products of gas “convection heat” being harmful or interacting with “Soft Coat Low “E” products. This not true of electric infrared.
C. Even in a strictly infrared furnace there will always be some amount of air movement and natural convection currents but they do not impact the heating of the glass as forced convection does. Convection currents from the outside of the furnace that enter the furnace can adversely affect the temperature of the glass by cooling the area of the glass the air passes across.

ASPIRATION: Usually compressed air forced through small holes in stainless steel pipes that are placed in the upper portion of a furnace and supplements the infrared or radiant heating. Used primarily as a modification to older furnace to assist in heating Low “E” products. Some newer systems are designed specifically with combination infrared and in furnace aspirators for specifically heating Low “E” products.

NOTE: Aspirated systems almost always are used in conjunction with infrared or radiant heating. Operating cost are higher due to the added amount of kW required to heat the cold compressed air and the cost of operating a 50 to 100 hp air compressor. The same is true when replacing an air compressor with a “supercharger”.

GAS INFRARED: Gas infrared can out perform all of the above when heating all types of glass including “Soft Coat Low “E” products including heat time, operating efficiency product control. Just by the nature of how gas infrared works; premixing air and gas outside of the furnace eliminates the need for costly recirculating fans and interior furnace nozzles. Since all of the gas is burned at the point of combustion on the surface of the infrared tile, no by-products of combustion are introduced in to the furnace cavity. Gas infrared can be controlled or ramped smoothly for specific zone control while introducing convection air in to the furnace by means of a combustion blower. A properly tuned gas infrared system in can be operated outside of an enclosure since the emission of CO and NOx are far below the safe limits.

NOTE:

OTHER INFORMATION

CERAMIC ROLLS:

A. US and European rolls are equivalent. They all must meet certain tolerance specifications. Customer preference is usually the only issue but some manufacturers do have better service and quality controls. JFS uses Vesuvius or George Ford rolls or as specified.
B. End caps can be very costly and can make roll replacement expensive. JFS uses a straight cap or no cap, depending on the system and the cost is extremely low when compared to other systems and extremely reliable.

C. Roll caps will have more influence on how straight a roll operates. End caps are fastened using high temperature silicones and/or pins depending on the manufacturer. If the end cap becomes loose the roll no longer will roll true in the furnace. The more complex the end cap or overhung load, the higher the chances are the cap will become loose.
D. All new systems have flat roller conveyors, no one manufacture is superior to another, just different designs. The issue is what does it take to adjust a roll bed should it become out of specification and at what cost? JFS conveyors are easily aligned and stay aligned for longer periods of time.

CERAMIC ROLLER CONVEYORS:

A. The simpler the system the easier it is to maintain. Many other systems use complex end caps and exclusive drive mechanisms and components.
B. JFS uses off-the-shelf components which provide long and reliable service and are easily replaced should there be failure.

ROLL SEALS:

A. Good roll seals keep the heat in and cold air out. Many systems use exclusive roll seals that are expensive and difficult to replace.
B. JFS roll seals can be made by the customer and are easily replaced.

ABOUT ELECTRIC INFRARED HEATING

The focus of the next few pages is to give some background and definition to how infrared heat is used to heat products, substrates, coatings and other process applications. Electric infrared was first developed by Ford in the 1930s to cure paint on car bodies. Since its inception, gas and electric infrared has been used for many in heat processing applications. Although it is very cost efficient and has many uses and features, infrared is not always applicable to all processes.

There are three types of infrared, short wave infrared, .76 to 2.3 microns of the Electromagnet Spectrum, which has emitter temperatures as high as 2600°C (4712°F) at 300 KW/m2. Medium wave infrared which is between 2.3 to 3.3 microns at 70 KW/m2 and emitter temperatures up to 1300°C (2372°F) and long wave infrared that operates between 3.3 microns to 1 mm at 40 KW/M2 with emitter temperatures up to 600°C (1112°F).

When infrared is directed at a product the amount of infrared that is absorbed, reflected or transmitted through the product is determined by the wavelength of the infrared or radiant source and the product. Only the absorbed radiant energy will contribute to the heating process and efficiency of heat transfer. As an example, short wave infrared will transmit through glass and will not be absorbed. Long wave infrared has lower temperatures and shallow penetration, tends to be more conductive, and would not allow as much radiant energy to transmit through the glass. Although it is possible to match an ideal wavelength to a product, it may not lend itself to the actual production requirements. Many processes can be accomplished using any of the three types of infrared but the heat time or desired result may take much longer to accomplish.

Medium wave infrared is generally used to cure water and solvent based coatings and to heat plastics, glass, textiles, paper, and related substrates because it is less intense than short wave infrared and covers much of the required absorption rates and operates within the required temperature ranges of many applications.

Short wave infrared is usually a tungsten filament which is almost instantaneously on but with an inrush of up to 17 times it normal current until it reaches its maximum output. Medium wave infrared usually has some type of nichrome winding which is a pure resistive load with no inrush. Heat up times can be from 30 seconds to 2 minutes, but once at temperature, they control quickly, relative to their mass. Long wave infrared is also a pure resistive load with no inrush. Heat up times can be from 8 minutes to 20 minutes, once at temperature, it can take minutes to completely adjust to a temperature change requirement.

In theory, infrared only heats what it sees and the distance to the product or product shape will change the transfer efficiency. Absorption of the infrared is determined by the physical and chemical properties of the product, the rate of heating and maximum temperature. Other factors are color, thickness, humidity and air currents. Short and medium wave infrared will not heat air. Air passing over the element can be heated through conduction. Cold air passing over a radiant heated surface will cool depending on the temperature differential of the air to the heated surface.

In most infrared applications, the radiant energy penetrates the item to be heated thus shortening the time to heat the product. As an example, a common process is to cure coatings on substrates.

The radiant energy penetrates the coating, which brings the coating to the desired cure temperature. The substrate will also be heated through some conduction and radiant penetration but does not reach the temperature of the coating. Unlike convection systems, it is not necessary to bring the substrate and coating to the same temperature to obtain a required cure or adhesion. In many cases there can be a large temperature differential from the bottom of the coated substrate to the top of the coating, the coated surface being the hotter side. Usually, the thinner the coating the faster the desired cure. Infrared curing times are generally 3 to 5 times faster than convection curing times.

Infrared processes are a time and temperature relationship. A product exposed to a constant infrared source for a given time will reach a certain temperature. If the product is exposed to the source for a longer or shorter period of time or is closer or farther away, the end temperature will be different with respect to the condition affecting the temperature.