GALVANIZING LINE
with Continuous Anneal Capabilities

Fueled by Dever International and SMS Group

INTRODUCTION

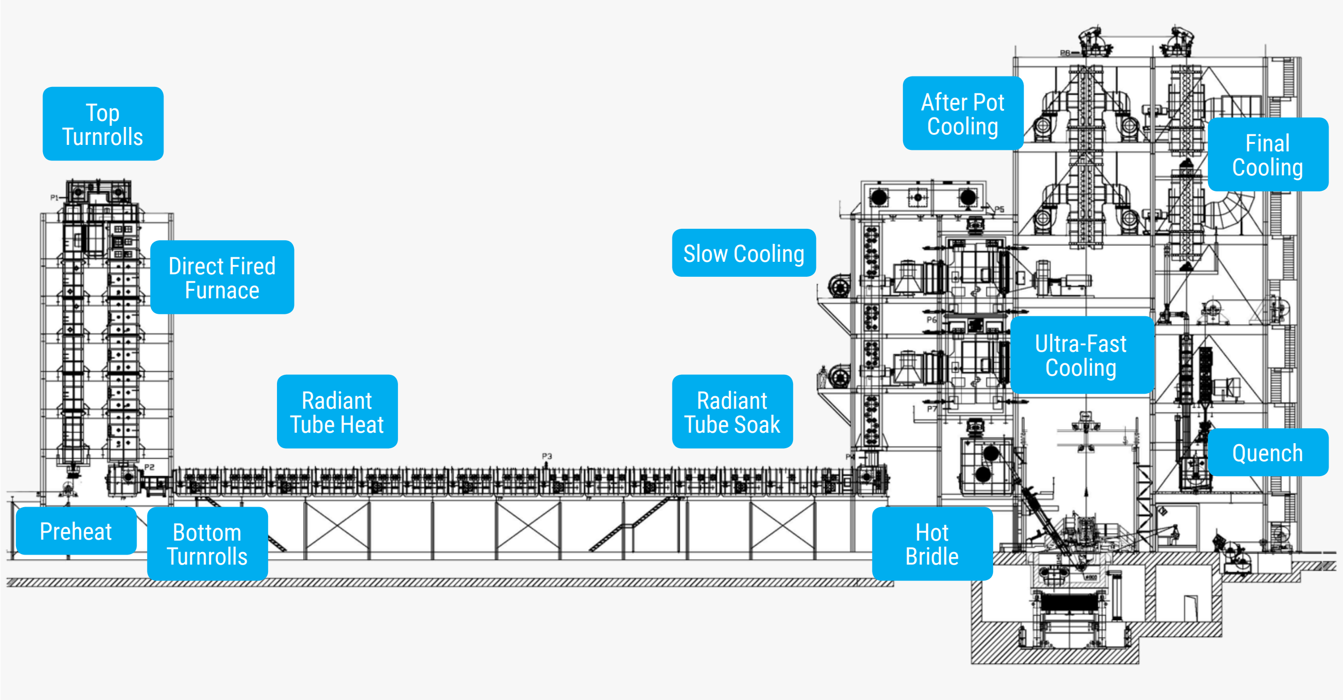
The Drever annealing furnace installed in the Big River Steel's galvanizing line is designed to produce over 475,000 metric tons per year of cold rolled products for the production of IF/CS/SS, DS/HSLA and Dual Phase steels for construction and automotive applications. The unique furnace arrangement includes a bottom entry vertical preheat section, a double top turnroll section, and a six zone direct fired furnace (DFF) section. The coil passes out of the DFF and is directed in a horizontal passline by the bottom turnroll. As the coil is transported through a restricted throat, it enters the four zone radiant tube heating furnace (RTH) where it is heated to annealing temperature. The coil is held at temperature in the seven zone, electrically heated soak section and then directed in an upward passline by a deflector roll into the slow cooling section. Depending upon the material being processed, the slow cooling section can be used to provide gentle cooling of the coil or use its electrical heating capability to maintain the coil at annealing temperature.

Upon exiting the slow cooling section, the coil enters a heated tunnel and passes over two deflector rolls before being directed downward into the ultra-fast cooling section (UFCS). The process parameters of the UFCS are governed by the material quality being treated. Upon exiting the UFCS, the coil is directed vertically down into an electrically heated hot bridle chamber.

From this point, the coil can take two different paths. In the continuous galvanizing mode, the coil is directed downward through the snout, into the zinc bath and then passes upward through the air knife equipment. In the continuous annealing mode, the zinc pot is lowered and the sink roll assembly is removed and replaced with a deflector roll assembly. The coil exits the furnace through a snout that is equipped with a coil sealing and nitrogen purge arrangement to preserve the furnace atmosphere. The coil travels upward through the after pot cooling equipment and then passes over a set of turn rolls through the final cooling section and into the water quench. An overall furnace arrangement is illustrated in Figure 1. (see next page).

FIGURE 1 – FURNACE GENERAL ARRANGEMENT

BIG RIVER STEEL CGL#1 FURNACE



The galvanizing line is able to process coils ranging from 900 to 1850 mm / 35 to 73 inches in width, and 0.36 to 3 mm / 0.014 to 0.12 inches in thickness. The maximum production rate for galvanized product is 85.7 metric tons per hour (for CS/SS quality). Furnace production is based on the product mix shown in Figure 2.

FIGURE 2 – FURNACE PRODUCTION

PRODUCT	COATING	PMT (°C)	PRODUCTION TIME (HOURS)	TV (MM-MPM)	MAX SPEED (MPM)	METRIC TONS PER YEAR
CS/SS	GI	730	1,114	121.3	150	67,677
DS/HSLA	GI	780	2,409	100.2	150	169,883
Coated DP	GI	830	2,659	92.3	150	160,155
Uncoated DP	CR	830	1,307	92.3	150	78,742
Total	–	–	**7,489**	–	–	**476,457**

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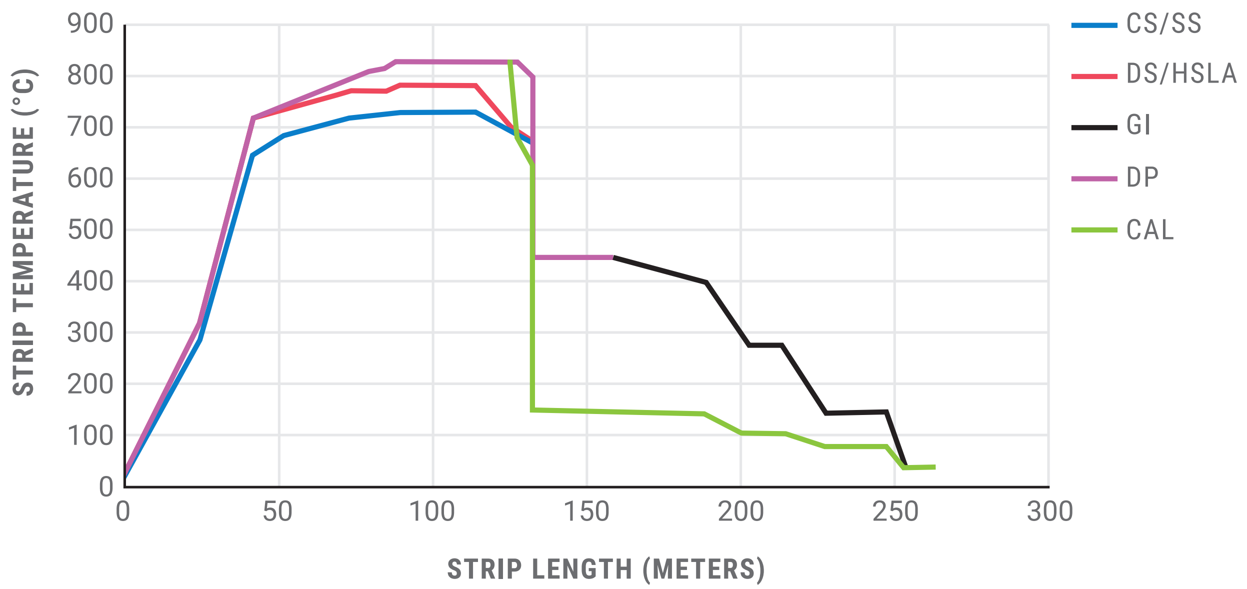
As mentioned above, the furnace is designed to process carbon steel coils in a continuous galvanizing mode (GI), as well as a continuous annealing mode (CA). Process parameters are presented in Figure 3 below. The corresponding graphical representation of the process thermal cycles is shown in Figure 4.

FIGURE 3 – PROCESS TEMPERATURES

PRODUCT	COATING	DFF TEMP. (°C)	RTH TEMP. (°C)	SLOW COOLING EXIT (°C)	UFC EXIT TEMP. (°C)
CS/SS	GI	650	730	670	460
DS/HSLA	GI	700	780	670	460
Coated DP	GI	750	830	800	460
Uncoated DP	CA	750	830	630	150

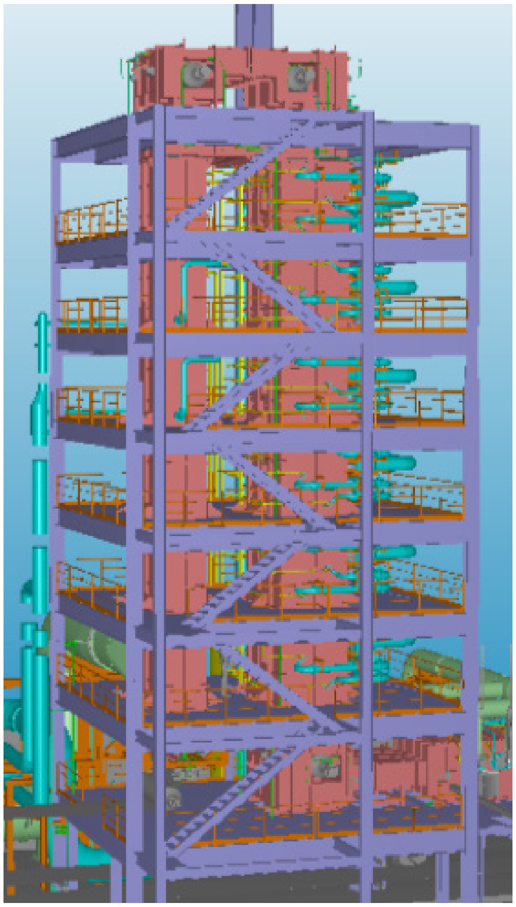
FIGURE 4 – THERMAL CYCLES



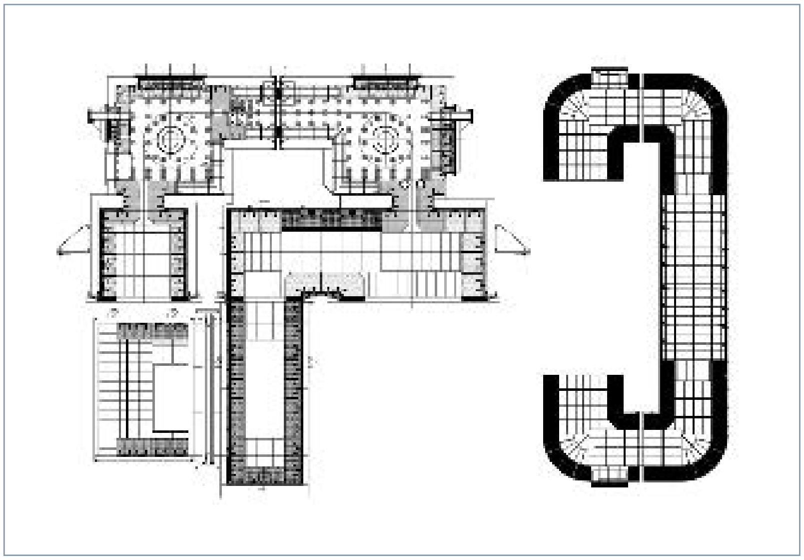
Equipment Description

PREHEATING SECTION

The coil enters the bottom of the preheat section through a double seal roll assembly which serves to limit the escape of hot waste gases from the furnace into the plant environment, to prevent the entry of ambient temperature shop air, and to provide an adjustable roll opening to facilitate threading of the furnace. The preheating arrangement consists of six fabricated and preassembled modules each lined with ceramic fiber modules providing a total preheating length of 18.85 meters. The preheat chambers are supported from the entry tower steel structure and are connected to the entry tower in a manner to allow free vertical expansion of the preheat section modules. Flexible compensators are used to absorb this expansion.

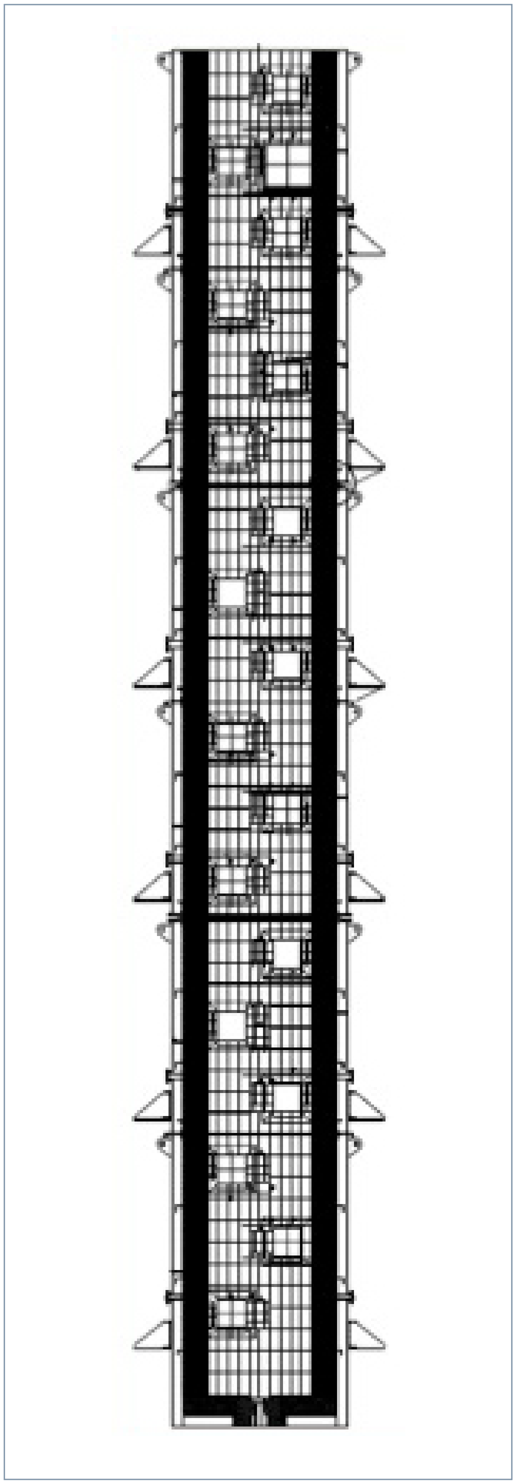


The coil is preheated as it travels vertically up through this furnace section utilizing waste gases from the direct fired furnace (DFF) section. The bottom preheat module is connected to the main furnace exhaust system through which furnace waste gases are exhausted out of the building. The temperature in the preheat section is not directly controlled and the hot waste gases from the DFF provide the energy for the ignition of unburned gas. A secondary combustion process occurs when combustion air is injected into the post-combustion chamber located in the bypass flue between the DFF and preheating sections. This air reacts with the unburned fuel in the waste gases to recapture energy that would otherwise be lost through the exhaust system. Since in normal operation the temperature of the post-combustion chamber is well above the normal auto ignition point of the unburned gases, no additional ignition source is required in this section itself. These waste gases are directed vertically downward into the top of the preheat section and results in the coil being heated to a temperature of approximately 250°C. A thermocouple is provided in this chamber in the area of air injection and is designed to automatically switch off when the chamber temperature falls below auto-ignition temperature.



ENTRY TOP TURNROLLS

As the coil travels vertically out of the preheat section, it passes through a restricted opening and into the top turnroll hood where it is transported across a double turnroll arrangement and the coil exits this section traveling down into the first zone of the DFF. The turnrolls measure 800mm in diameter and are equipped with roller bearings with water cooled jackets. Each is driven by a gearmotor synchronized with line speed. A separate bypass flue and post-combustion chamber are arranged below the turnroll hood and connects the top of the DFF with the top of the preheat section to permit the exhausting of furnace waste gases.



DIRECT FIRED SECTION

The coil exits the top turnroll section through a restricted opening and travels vertically down into the DFF (also called the NOF or non-oxidizing furnace). The DFF consists of a six-zone configuration that is 18.77 meters in total length and fabricated with mild steel panels, properly reinforced with angles and profiles and assembled with gastight welding. The DFF modules are supported from the entry tower in a similar manner as the preheat sections. Internal walls and top of the DFF sections are lined with ceramic fiber modules. The individual furnace zones are preassembled providing for easy installation at the customer site.

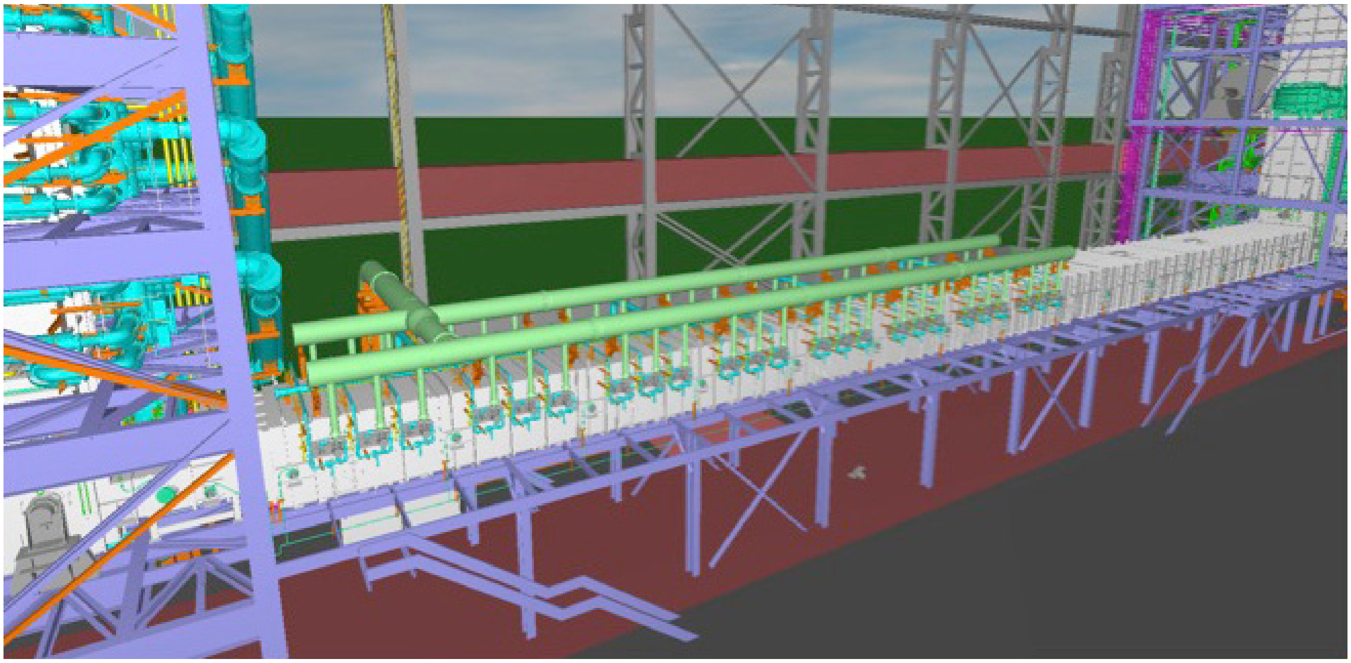
As the coil travels through the DFF zones, it is heated to the temperature required by the process in the range of 650 to 750°C by open flame burners that fire across the width of the coil in a parallel orientation on both sides of the coil surface. The DFF control zones are operated under fuel rich (deficient air) conditions in order to achieve oxide reduction that results in a thermo-chemical cleaning effect on the coil.

The burners are operated with hot air preheated with exhaust gases through a gas/gas recuperator installed in the waste gas exhaust flue. The heat input to the furnace system is matched to the process heating requirements by a sequential "cascade" firing strategy. Each of the six furnace zones utilize a very precise temperature and fuel/air ratio control to accomplish its heating and coil cleaning function. The DFF chamber temperature is controlled by zone thermocouples which receive a set point signal from the central control system from the coil temperature pyrometer, or the furnace mathematical model. The pyrometer is located in the horizontal tunnel section between the bottom turn roll and the radiant tube heating section.

The combustion air fan delivery pressure is maintained constant by a variable frequency drive. The airflow to each zone is temperature and pressure compensated in order to accurately achieve the proper air gas ratio. Each burner is supplied with a limiting orifice on both the air and gas inlets to balance the power in each zone to all burners. The DFF zone 6 burners are provided with spark ignition and a UV sensor for flame monitoring through an individual ignition transformer and burner control unit. Each zone 6 burner is also provided with an automatic shut-off valve on the burner gas and air feed piping in order to provide individual shut-off in case of flame failure without any disturbance of the other burners. The burners in zones 1 through 5 are ignited when the zone temperature is above the self-ignition temperature of 760°C (1400°F).

BOTTOM TURNROLL SECTION

As the coil exits the last DFF zone, it enters the bottom turnroll section through a restricted opening and provides a transition between the DFF and the horizontal section of the furnace by changing coil travel from a vertical downpass through 90° to the horizontal direction. The turnroll section is shop constructed of reinforced steel casing which is internally insulated with a layer ceramic fiber blanket configuration. This section is equipped with a single deflector roll measuring 800mm in diameter, equipped with roller bearings with water cooled jackets and driven by a gearmotor synchronized with line speed.

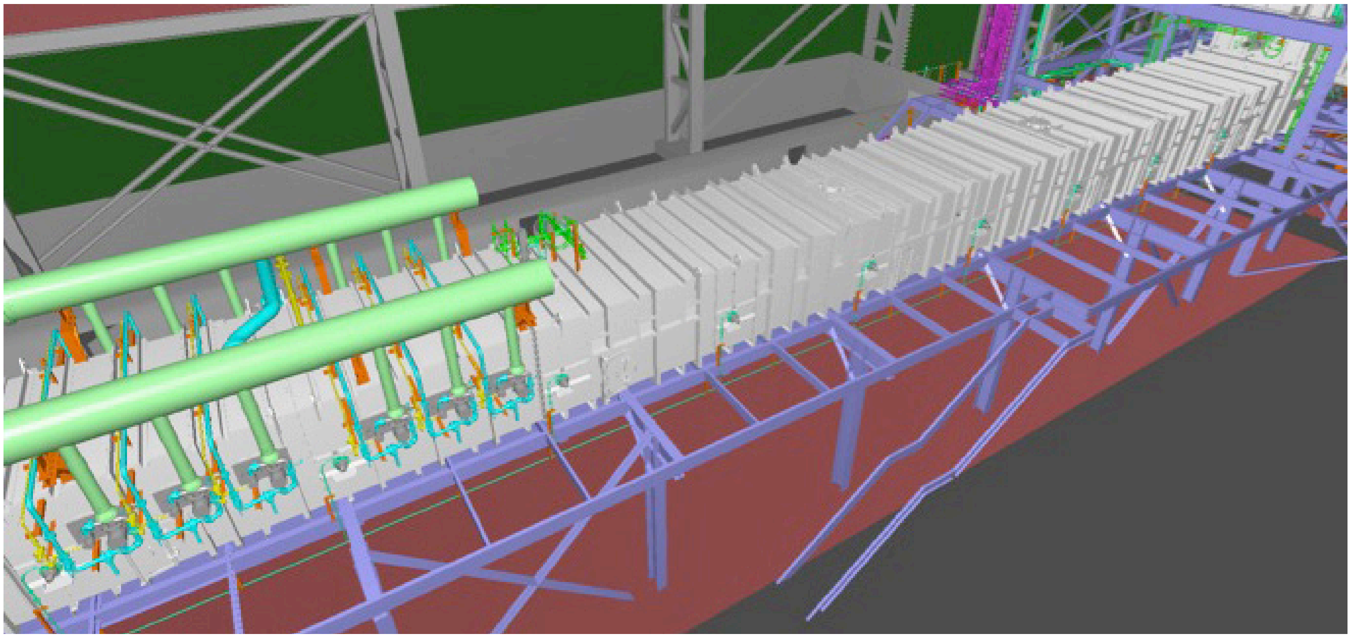


RADIANT TUBE HEATING SECTION

The coil enters the radiant tube heating (RTH) section through a reduced height tunnel section designed to restrict the flow of HNx atmosphere through the waste gas exhaust system. The heating section is designed to heat the coil to the required peak metal temperature and is 28.6 meters long. The preassembled furnace modules are fabricated with panels made with reinforced mild steel plate and are internally lined on the walls and ceiling with a layered ceramic fiber lining and with refractory brick on the bottom. The tunnel section and the eight RTH modules each contain a 150mm diameter coil support roll driven by a gearmotor which is synchronized with line speed.

The coil temperature is increased in the heating section by means of U-shaped, gas fired radiant tubes arranged above and below the coil. Each of the 48 cast high temperature alloy tubes is provided with a recuperator installed in the exhaust leg capable of preheating the combustion air up to 450°C. Each burner piping assembly also includes a flue gas recirculation device which mixes exhaust gas and heated combustion air to reduce emissions to the atmosphere.

The burners are divided into four independent control zones with temperature control accomplished by varying the combustion airflow to the burners. Zone thermocouples provide furnace temperature feedback to the central control system while an optical pyrometer assembled to a water-cooled site tube provides coil surface temperature feedback at the exit of the RTH section. The zone gas flow is proportioned to the airflow with a pressure balance, ratio-regulating system to maintain a 2% to 3% oxygen level in the waste gases. Each burner is provided with spark ignition and a UV cell for flame monitoring through an individual ignition transformer and burner control unit. The burners are of a push-pull type and combustion air is supplied to them by means of combustion air fan driven by a variable frequency drive. The exhaust gases are evacuated from the radiant tubes through a collector system.



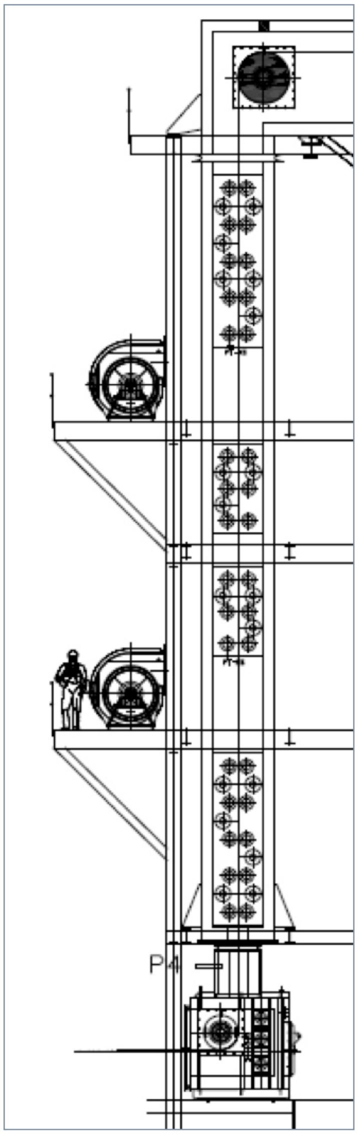
RADIANT TUBE SOAK SECTION

After the coil has been heated to its peak metal temperature, it is transported through a six zone, 25.3 meter long soaking section. The steel and refractory construction of the soak section modules is similar to that of the heating section modules. The temperature of each soak zone is held at the annealing temperature by means of bayonet heaters installed in straight radiant tubes arranged on the top and bottom of the coil in each of the soak sections. Each of the radiant tube soak modules contains a 150mm diameter coil support roll driven by a gearmotor and synchronized with line speed.

Soak section power flow is controlled by means of thyristor drives which supply power to each section. The desired power flow rate is determined by the control system and is based on a temperature control loop using feedback from thermocouples placed in the zones and a zone temperature setpoint determined by the operator or the mathematical model. Coil temperature feedback is provided by an optical pyrometer installed in a connecting throat section located just below the entry of the slow cooling Section.

SLOW COOLING SECTION

After the coil is discharged from the radiant tube soak section, it travels through an insulated tunnel and enters a heated bottom turnroll section which deflects the coil upward into the two zone slow cooling section. Depending upon material processing requirements, the coil will be either slow cooled to the required ultra-fast cooling entry temperature, or held at the peak metal temperature defined by the process.



The cooling of the coil is performed by the impingement of cold atmosphere gas flowing through slotted tubes arranged transversally across the furnace chamber and facing the coil on both sides. The flow of cooled gases to the tubes is accomplished with two recirculation fans drawing the furnace HNx atmosphere from the furnace chamber through two water cooled heat exchangers. The chamber is also provided with electric heating elements necessary for start-up or soaking operation. A pyrometer is mounted to the casing at the exit of the section to provide coil temperature feedback to the control system.

The bottom turnroll section is constructed with panels made with mild steel plate reinforced with profiles and angles and assembled by continuous welding in order to form a complete gastight enclosure. The casing is internally lined on walls and ceiling with a layered ceramic fiber lining and with refractory brick on the bottom.

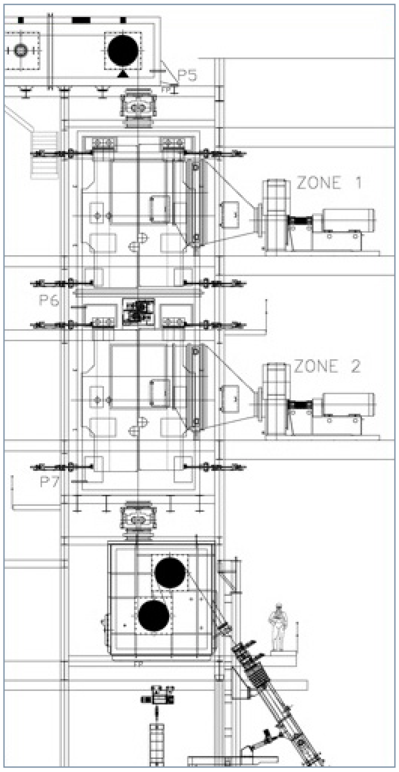
The slow cooling section is installed into a gas tight enclosure fabricated from modules made from mild steel panels reinforced with profiles and angles and assembled together by external gas tight welding. The chamber is internally lined with ceramic fiber material blanket protected against erosion from the atmosphere gas circulation with a high temperature fabric covering. The cooling tubes are made from heat resisting steel, centrifugally cast and provided with machined longitudinal slots. They are supported on the gas intake side by the bung and on the opposite side by a heat resistant steel cast support welded to the casing. The circulation ducts are of mild steel construction and are connected together with welded flange in order to guarantee the gas tightness.

ULTRA-FAST COOLING SECTION

As the coil exits the slow cooling section, it enters a horizontal tunnel equipped with two deflector rolls to transport the coil from a vertical uppass, down into the ultra-fast cooling section (UFCS). To accelerate start-up and prevent cooling of the ends on deflector rolls during operation, the entry, exit and top roll tunnels are equipped with electrical heating elements, mainly in the area surrounding the roll openings.

The UFCS performs multiple coil cooling functions depending on the product being processed as follows:

- For DP coated material, the coil will be cooled from 830°C to 800°C in the slow cooling section and then down to the coating temperature of 460°C in zone 2 of the UFCS.
- For DP uncoated material, the coil will be cooled from 830°C to 630°C in the slow cooling section and then down to 150°C in zones 1 and 2 of the UFCS.
- The balance of steel grades are processed from their peak metal temperature to pot entry temperature through zones 1 and 2 at a very low rate of power consumption.



The UFCS is specially designed to achieve high cooling rates and incorporates the following features:

- Profiled nozzles with uniform transverse gas speed distribution, stable pressure on the coil and large escape surface on the edges
- A gas circulation and distribution circuit which is symmetrical to the coil
- Seal rolls installed at the entry and at the exit points of the section to reduce the flow of cold gas to the adjacent sections
- Guide rolls between the plenums to avoid scratches on the coil

The UFCS consists of two zones, each provided with a pair of 5,200 mm long plenums facing the coil. The plenum distance to the coil is adjustable by remote control with gear motors between 120 and 30 mm in order to increase the cooling capacity and achieve higher cooling rates. Each zone is equipped with a pair of fans to circulate the furnace atmosphere through the system. The coil is cooled by a strong blast of cold atmosphere gases on both faces through shaped slots arranged across the width of the plenums. To prevent fluttering of the coil through the rapid cooling section, three guide roll sets are provided to guide the coil through the cooling zones along the vertical coil pass line. The cooling gases are circulated through side outlets and water coolers by special gastight centrifugal fans.

FIGURE 5 – COOLING RATES FOR DUAL PHASE STEELS

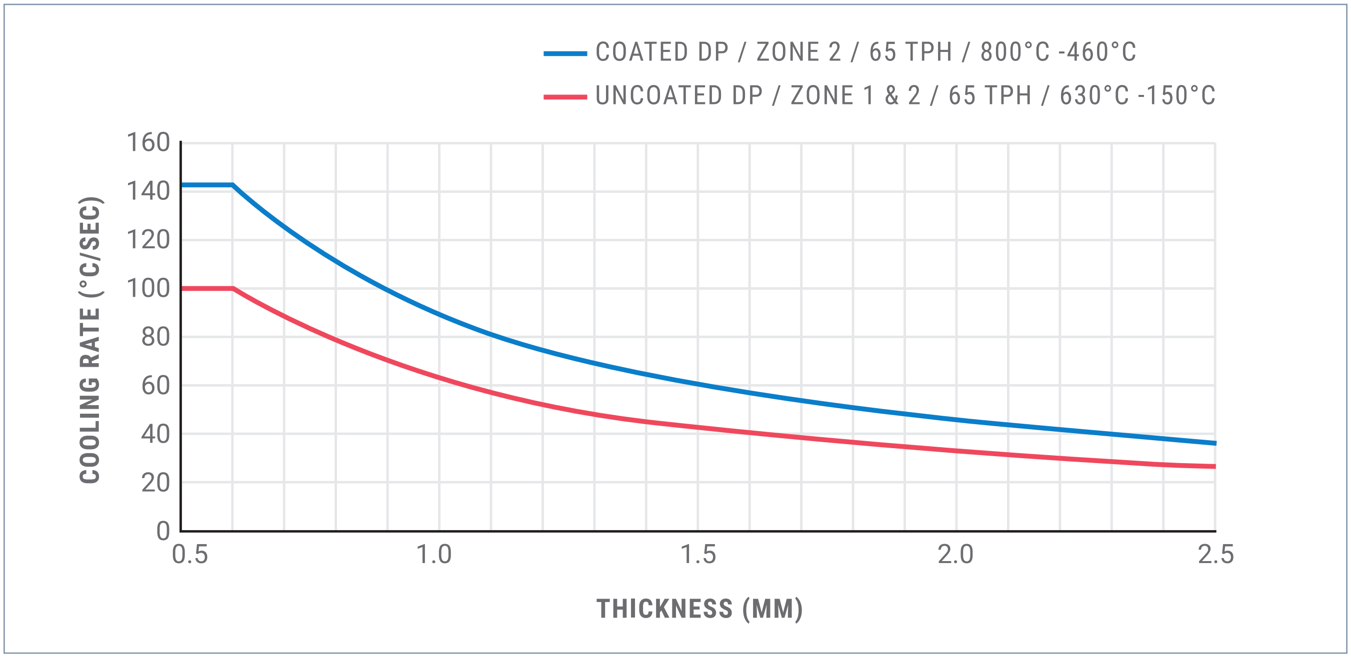
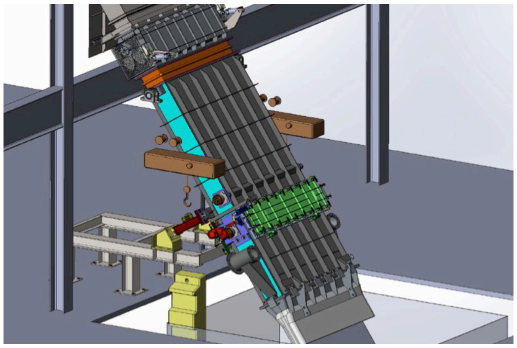


Figure 5 illustrates the cooling rates that can be achieved in the UFCS for DP products.

EXIT SECTION AND HOT BRIDLE

When the coil exits UFCS, it is conveyed downward into the exit section where the coil wraps around a two roll hot bridle arrangement and the coil tension is increased with an amplification factor of about 2.5. The coil temperature is equalized across its width by electric heating elements installed in the sidewalls of the module and holds the coil at the pot entry temperature. In the galvanizing mode, the coil discharges from the exit section downward off of the second bridle roll, through a snout arrangement which creates a gas tight seal with the zinc bath.



EXIT SNOUT

The snout is a long, inclined, moveable enclosure which provides a sealed passage for the coil from the exit section down into the zinc bath. During normal galvanizing operation, the snout is immersed in the molten zinc creating a seal and prevents air infiltration. The snout angle is adjustable approximately 2° to accommodate air knife sink roll wear using a cylinder actuated oscillation system. At the exit section outlet, the snout is also equipped with a shutter assembly which consists of a pair of pneumatically actuated dampers that seal against the coil and the injection of a high volume of nitrogen preserve the furnace atmosphere when the line is stopped and when snout tip is not immersed in the zinc bath.

The snout is also appointed with a coil sealing and nitrogen purge arrangement that is utilized when the pot is lowered while running in the continuous annealing mode.

AFTER POT COOLING

As the coated coil passes through the galvanizing section, it must be cooled to a low enough temperature to prevent pick-up on the cooling tower rolls. This is accomplished by the two zone, after pot cooling section. The equipment arrangement consists of individual inlets for each zone, each equipped with an inlet filter. Each zone is furnished with two plenums, each of which are fed outside air drawn in by centrifugal fans which are mounted to the cooling tower structure and driven by variable speed motors. Cooling air flows from the outside, through the filter, interconnecting ductwork, through the fan itself and is ultimately delivered to the cooling plenums. There are two plenums per zone, one arranged on either side of the coil uppass. The plenums are designed with profiled nozzles with individual transverse slots which deliver cold air to the coil with a uniform flow velocity for effective cooling. Figure 6 shows the temperature targets in the after pot cooling area for the galvanizing mode of operation.

FIGURE 6 – AFTER POT COOLING TEMPERATURES (GI MODE)

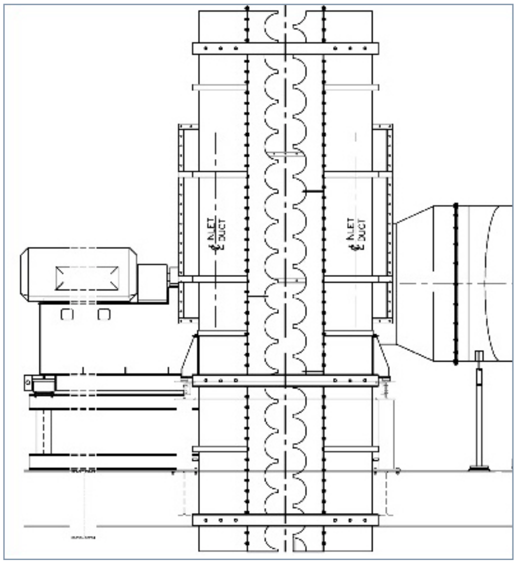
COATING	BATH EXIT TEMP. (°C)	TOP ROLL INLET TEMP. (°C)	FINAL COOLING EXIT TEMP. (°C)	WATER QUENCH EXIT TEMP. (°C)
Galvanized	450	< 280	< 170	< 40

COOLING TOWER ROLLS

After the coil exits the second after pot cooling zone, it is deflected over a pair of 1500mm diameter rolls located on the top level of the cooling tower structure. These rolls are driven by a gearmotor, synchronized with line speed and are mounted to a heavy duty steel frame and supported with double spherical roller bearings. Each roll is equipped with a 300mm diameter pinch roll, pneumatically actuated to hold the coil against the deflector roll during threading or line stop, thus prevent it from falling if the coil breaks. These pinch rolls are also driven in order to help with the coil threading operation.

FINAL COOLING SECTION

As the zinc coated coil turns in a downward pass over the second tower deflector roll, it enters the top of the final cooling section. This section consists of two pairs of coolers which are fed with cold air drawn from outside the building. Two centrifugal fans are adapted to a vertical collector inlet air system and interconnecting ductwork to deliver cooling air to each of the plenums arranged adjacent to the coil. The plenum nozzles are a profiled shape with transverse slots through which the outside air flows on to the coil. A pair of 200mm diameter guide rolls located between the cooling zones stabilizes the coil as it is transported through the system. These guide rolls are chrome plated and supported by bearings mounted on guides and actuated by pneumatic cylinders. They are retractable to allow for easy coil threading and to avoid deformation in case of line stop.



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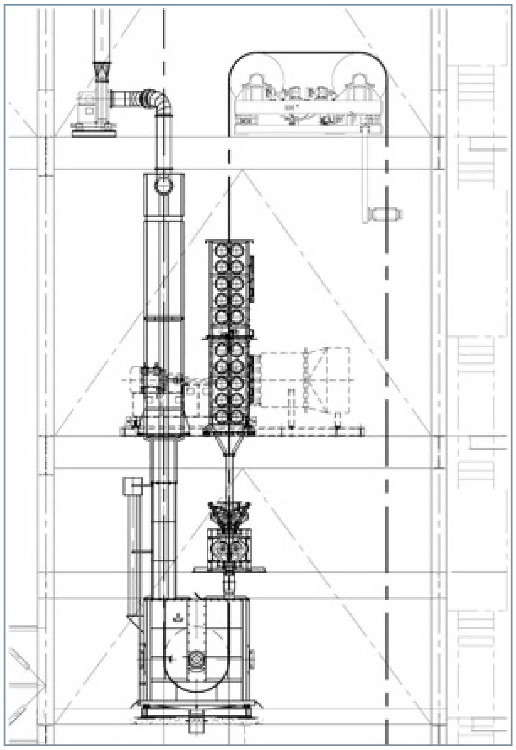
QUENCH TANK AND DRYER



The air cooled coil exits from the bottom zone of the final cooling section and enters the quench tank where it is further cooled down to 40°C. The quench tnk consists of a stainless steel enclosure equipped with multiple spray headers which impinge cold demineralized water on the coil. The water drains to the bottom of the quench enclosure into a water storage tank and is recirculated in a closed loop system. The coil passes over a gearmotor driven, 1500mm diameter deflector roll as it is processed through the tank. The closed loop water system consists of two filters, two pumps, two water/water heat exchangers, and associated control instrumentation. The steam that is generated by the process is extracted at the top of the tank by a small centrifugal fan and exhausted out of the building. As the coil exits the tank, it passes through a pair of rubber coated, driven wringer rolls and then through a hot air dryer to produce a dry coil at the exit.

FURNACE EXHAUST SYSTEM

The furnace exhaust system is designed to evacuate the products of combustion generated during the annealing process and consists of two parts. First the DFF exhaust system is connected to the bottom preheat module (as described above) and consists of an assembly of mild steel ducts lined with insulating refractory. A combination of DFF products of combustion plus the HNx atmosphere from the radiant tube, slow cooling and ultra-fast cooling sections of the furnace are drawn through the system by an exhaust fan and are directed to the furnace stack which exhausts the waste gases outside the building. The variable frequency driven exhaust fan is used in tandem with a butterfly damper installed in the exhaust ductwork to control furnace pressure as well. The exhaust system is also equipped with a flue type recuperator which is designed to increase combustion efficiency by preheating the combustion air for the DFF burners supplied from a combustion air fan. The exhaust arrangement also includes a dilution air fan which provides thermal protection for the recuperator and the main exhaust fan.

The second exhaust system supplied with the furnace is designed to evacuate the products of combustion generated in the radiant tube heating section. The gases flowing through the exhaust leg of the radiant tube are directed into a vertical duct arranged to allow the inspiration of plant air for dilution purposes. The vertical exhaust duct installed on every burner links to a horizontal duct arrangement running along the length of the RTH section which is connected to a common collector and an exhaust fan which delivers the waste gases to the furnace stack for discharge from the building.

FURNACE ATMOSPHERE SYSTEM

The furnace is supplied with an atmosphere control system designed to maintain a protective HNx atmosphere in the horizontal radiant tube sections, the slow cooling, UFCS and exit section. Nitrogen is supplied to the slow cooling section and the snout, while the UFCS is fed with a supply of pure hydrogen. The hydrogen diffuses to the adjacent furnace sections resulting in a concentration sufficient to reduce the iron oxide on the coil surface and prepare it for coating. The hydrogen content in the UFCS can be as high as 20% which makes possible the processing of product at high cooling rates.

The atmosphere system is also designed to flow nitrogen only to furnace to ensure a thorough flushing of all chambers prior to start up for safe working conditions and to restore a low dew point necessary for product adhesion quality. The DFF gas and air piping are also equipped with a nitrogen injection system that is utilized during line stop conditions to provide fast cooling of the coil to prevent breakage, to limit coil oxidation and to help maintain a positive pressure in the furnace and prevent air infiltration.

The protective atmosphere gas of the furnace is continuously monitored by a gas analysis sampling system consisting of pumps, a trace O2 analyzer, and a dewpoint analyzer installed in a common electrical enclosure.

MATHEMATICAL MODEL

The furnace mathematical model works in close communication with the control system of the furnace and analyzes information transmitted by various sensors and transmitters, compares them with the chosen parameters, and adjusts the settings of the various pieces of equipment to hone in on the parameter set points. The math model is installed in a separate calculation unit and is designed to optimize line operation in the following ways:

- Improves the production of the line
- Generates the desired speed of the line to achieve the maximum capacity of each product
- Improves the product quality
- Generates set points in order to reach the correct heat cycle temperature
- Calculates the transition from one product to the next in order to produce the material within required quality constraints and to minimize yield losses
- Helps the operator with line operation
- Provides a dynamic graphic interface which shows the variation of coil heating as a function of the set points required to produce the material

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ABOUT BIG RIVER STEEL

Big River Steel is the world's first Flex Mill™, combining the best attributes of integrated and mini mills. When complete in 2016, the mill located in Osceola, Arkansas will supply 1.6 million tons of steel, including many of the most demanding niche steels currently under supplied by domestic producers. For more information, please visit www.bigriversteel.com.

ABOUT DREVER INTERNATIONAL:

Drever International has been dedicated to advancing the technology of heat processing equipment since 1966. Many of the innovations developed by Drever International engineers are recognized as industry standards today. Drever International S.A. located in Liège, Belgium are part of SMS Siemag Group. Drever International is a market leader for continuous annealing furnaces and galvanizing plants for steel and stainless steel strip. Drever International has a workforce of about 120 at its headquarters in Liège.

This information was developed by Nick Lagios of Drever International USA and Denis Hennessy of Big River Steel. It was first presented at the 2015 Galvanizer's Association Meeting.