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Thermal Systems and Oven Types on

Continuous Colour Coating Lines (CCCL's)

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With a worldwide overcapacity of steel production it is important that each CCCL is tailored to the exact needs of the user to ensure maximum productivity, highest quality and minimum overhead cost with the minimum necessary capital expenditure.

Successful implementation of anti-dumping regulations has seen many countries benefit from protection against cheap imports however good equipment selection is still imperative to ensure that the competitive advantage is maintained while at the same time ensuring a high quality product.

It is important to think carefully when compiling a specification for any capital equipment. In particular, the thermal equipment associated with a CCCL has to be specified with the greatest of care such that it can accommodate the requirement of both today's and tomorrow's product ranges and emissions criteria.

There are many different options that can be selected to build up the most optimised thermal system for a CCCL for a given application.

The most optimised system is determined by many factors and there is no one solution that will best satisfy all plants. Each customer is unique due to geographical location, size of factory, product type, production rate, available budget, skill level of operators, quantity of staff, environmental legislation and in-house regulations.

A typical CCCL will comprise the following main items and it is the responsibility of the thermal engineer to size and then integrate these pieces of equipment into a safe working thermal system that meets all the local health & safety and emissions legislation and the production requirements of the end user while at the same time installing best available technology to ensure maximum energy efficiency.

- Coater Room
- Paint Curing Oven
- Thermal Oxidiser
- Heat Recovery
- Interconnecting Ductwork
- Main Exhaust Stack

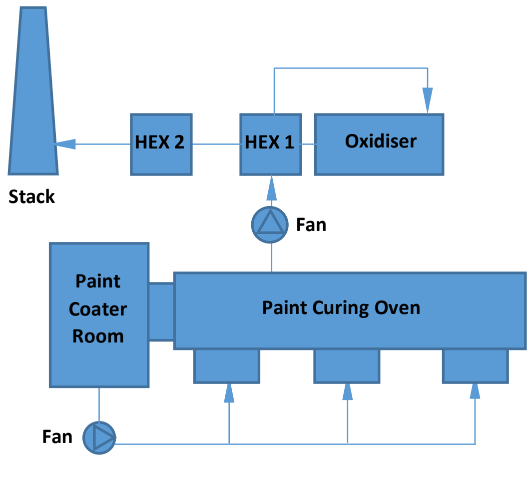

Figure 1.0: Typical CCCL Thermal System

One of the first issues to consider is whether or not local regulations require destruction of VOC's emitted from the CCCL. In many countries there is a requirement to destroy volatile organic compounds (VOC's) within a given destruction efficiency and hence a method of VOC destruction is required.

Even in countries where VOC destruction is still not a legal requirement it would be wise to install VOC destruction equipment as emissions legislation is rapidly being harmonised globally and any plant not fitted with a VOC destruction system could be left wanting within a few years of installation.

There are many types of systems available for the removal of VOC's from a paint curing oven exhaust stream but by far the most proven and reliable system for a solvent based CCCL is by thermal oxidation.

To adequately destroy the VOC's the contaminated exhaust stream has to be held at a minimum temperature of 760°C for a minimum of 0.5 seconds. However as emission regulations are becoming more stringent it is common for thermal oxidisers to be designed with dwell times of up to 1.5 seconds.

There are two commonly accepted types of oxidiser that are used on coil paint lines; namely a recuperative thermal oxidiser and a regenerative thermal oxidiser.

The recuperative thermal oxidiser uses an air-to-air heat exchanger of metallic construction (usually referred to as the primary heat exchanger) to pre-heat the curing oven exhaust gases before they enter the VOC destruction chamber.

Pre-heat temperatures can vary dependent upon the size of primary heat exchanger used and typically range from 300°C to 500°C.

The higher pre-heat temperatures, although requiring more capital expenditure, do reduce fuel consumption and overall plant running cost.

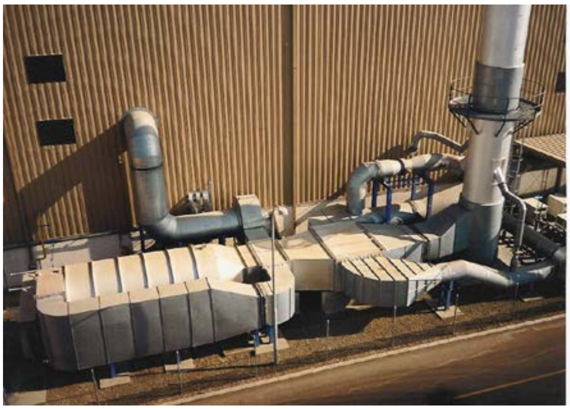

Figure 2.0: Recuperative Thermal Oxidation System with Primary and Secondary Heat Recovery

After pre-heating the oven exhaust gasses in the primary heat exchanger the exhaust enters the oxidiser VOC destruction (or dwell) chamber via the burner chamber where it is heated to 760°C and held for the required dwell time.

Figure 3.0: Three Canister Regenerative Oxidiser

In a **regenerative thermal oxidiser** (often referred to as an RTO) the oven exhaust gases flow over hot refractory bricks prior to entering the VOC destruction chamber. The direct contact between the exhaust stream and the hot refractory bricks provides a very efficient method of pre-heating the oven exhaust gases and pre-heat temperatures close to the oxidation temperature of 760°C can be achieved.

On a typical coil coating line application there will be sufficient solvent within the oven exhaust air stream for the auto-ignition of the solvent to generate sufficient energy to maintain the minimum required oxidation temperature without the burner being switch on.

This point is referred to as the Auto-Thermal condition.

After passing through the dwell chamber of the regenerative oxidiser the gases then exit via a second canister full of refractory brick identical to the first. As the exhaust gasses flow over the bricks heat will be transferred from the exhaust gases into the bricks.

After a period of about 90 seconds the bricks in the first canister will have reduced in temperature and the bricks in the second canister will have become hot and therefore the direction of the flow of the exhaust gases is reversed such that the bricks in the second canister are used for pre-heating the oven exhaust gases while the heat generated by the oxidation process is used to start re-heating the bricks in the first canister.

This cycle will continue to repeat itself during the operation of the regenerative oxidiser.

Due to the strict method of stack emission sampling used in some regions such as Europe and Australia a third canister of bricks has to be added to the regenerative oxidiser to avoid the 'spike' of VOC contaminated exhaust that occurs during the flow reversal process.

However in some countries such as the USA the sampling method differs and although the overall VOC emission limits are the same as Europe the 'spike' is not detected during sampling and thus a two canister regenerative oxidiser can be used.

If we assume that a three canister regenerative oxidiser is required (which is the most likely scenario) then the capital cost of a basic recuperative thermal oxidiser (i.e. no additional heat recovery to supply systems outside the CCL) that is used with a direct fired convective oven will be approximately half the capital cost and a regenerative thermal oxidiser used for the same application.

However the thermal efficiency of the regenerative oxidiser is around 95% and when compared with the thermal efficiency of a basic recuperative oxidiser which is less than 50% (again assuming no external heat recovery systems) then the overall running cost of the regenerative oxidiser based CCCL will be on average 30% less and thus the initial extra capital cost of the regenerative system can be recovered within a relatively short period of time.

It is a common misconception that regenerative thermal oxidisers are much larger than recuperative thermal oxidisers because although regenerative thermal oxidisers are taller they do not have a footprint any larger than recuperative thermal oxidisers when the primary heat exchanger is included within the dimensions of the recuperative system

The table shown in Figure 5.0 gives a comparison of typical overall sizes of a recuperative oxidiser, two canister regenerative oxidiser and three canister regenerative oxidiser.

Taking into account the thermal efficiency and the short payback period of the regenerative thermal oxidiser the regenerative thermal oxidiser based system is often the system of choice.

Figure 4.0: Two Canister Regenerative Oxidiser

Type of Oxidiser	**Typical Overall Dimensions**		
	Width (mm)	**Length (mm)**	**Height (mm)**
Recuperative with Primary Heat Recovery	3230	9500	2600
Two Canister Regenerative	2200	4450	6100
Three Canister Regenerative	2200	6650	6100

We should however mention that there is a well proven recuperative oxidiser based system available that takes advantage of the poor thermal efficiency of the recuperative thermal oxidiser in a way that allows all burners on the CCCL line with

Table 5.0: Comparison of Typical Overall Sizes of Various Types of Thermal Oxidisers

the exception of the oxidiser burner to be removed.

The system uses the high temperature recuperative oxidiser exhaust gases to indirectly pre-heat clean air to 650°C. The pre-heated air is subsequently used to provide all the heating requirements of convective ovens and then additional heat recovery is used to provide hot water for heating of the cleaning/pretreatment section holding tanks.

Thus neither the oven(s) or the cleaning/pretreatment section require the installation of burners as all the heat needed to run the line is recovered from the oxidation process of which the majority of the heat used comes from the combustion of the solvent that has been evaporated from the paint coating. This system is highly thermally efficient (assuming minimal duration at standby) but would normally only be applied to faster lines.

With the method of thermal oxidation now in place the thermal system can then be designed around the type of thermal oxidiser used. The next decision to make is what type of paint curing oven to use.

The following type of paint curing ovens have been successfully applied to the paint curing process on a continuous coil coating line:-

- Induction Ovens
- Flotation Convection Ovens
- Catenary Convection Ovens
- Catenary Infrared Ovens

Induction ovens have been applied successfully to the curing of paint coatings but are not commonly used; and unless there is a unique reason as to why an induction oven would be preferred such as to save space, electricity is cheaper than gas or gas is not available then the use of induction ovens on a continuous coil coating line would not be recommended.

Flotation convection ovens are ovens that use high velocity hot air jets flowing through specially designed nozzles to both lift the strip and provide the heating medium.

Flotation ovens avoid the need to tension the strip and prevent the creation of a catenary or sag in the strip which thus reduces the height requirement of the oven particularly on faster lines requiring long ovens.

Also because of the high jet velocities required to support the strip the ovens tend to be shorter than catenary type convection ovens.

However the distance between the nozzles and the strip is small and thus access for re-threading the strip is difficult and although the high velocity jet stream provides accelerated heating this is often at the sacrifice of the quality of the finished painted surface.

Catenary convection ovens rely on external bridles to tension the strip at both ends as it passes through the oven. The level of tension is controlled to maintain a pre-determined strip catenary position through the oven.

Because the strip is supported externally the jet nozzles within a catenary convection oven only have a single function which is to provide the hot air jet that cures the coated surface of the strip. This allows the jet velocities to be selected to better suit paint surface finish quality.

Although either flotation convection ovens or catenary convection ovens could be heated using electricity, oil or gas it is conventional for convection ovens used on CCCL's to be heated with natural gas or some form of bulk gas such as LPG or LNG. Further the gas firing can be either direct or indirect.

Figure 6.0: Gas Fired Convection Paint Curing Oven for 40 m/min Coating Line

There is often concern expressed about using direct gas firing to heat convection ovens especially when producing high quality requirement products such as appliance casings but modern gas supplies and ovens designs have proven that direct gas firing can be used even when a high quality painted surface is required.

It is also worth mentioning that if necessary convection paint curing ovens can be installed in the vertical plane however this is not common due to the additional cost of the supporting structure and increasing the building roof height.

Figure 7.0: Electric Infrared Paint Curing Oven

The development of **Infrared ovens** using short wave frequencies or frequencies below the infrared frequency range (often referred to as near infrared) have been successfully applied to the curing of paint coatings on coil painting lines.

Infrared oven curing times as low as 3 seconds have been achieved under laboratory conditions but for successful application in a production environment the addition of break zones between the banks of infrared emitters has been found to be necessary and thus overall infrared oven dwell times are typically 9 to 11 seconds (for polyester coatings).

As with convection paint curing ovens, infrared paint curing ovens can be installed in either the vertical or horizontal plane, however because infrared ovens are generally half the length of an equivalent convection oven and do not require bulky combustion boxes, infrared ovens can be more readily applied in the vertical plane and can be applied well into combination galvanising and painting lines that are often restricted for space

Another advantage of infrared ovens particular those in the near infrared range is the ability of the oven to switch the heating process on and off almost immediately.

The infrared ovens have thus been applied on non-continuous lines coil coating lines with great success

Type of Paint Curing Oven	Typical Overall Dimensions		
	Width (mm)	Length (mm)	Height (mm)
Gas Fired Catenary Convection	4,160	11,900	2,110
Electric Catenary Infrared	2,183	7,110	2,350

Table 8.0: Comparision of Typical Overall Sizes of Convection and Infrared Paint Curing Ovens suitable for Processing Polyester Top Coats on a Steel Substrate at 30 m/min

However the electric power requirements of infrared ovens can become excessive as the line speed increases and thus the running cost can also be excessive.

Further, as there is no requirement for the pre-heating of make-up air with infrared ovens as there is with convective ovens, then when used with a VOC oxidation process there is no possibility to recover energy from the exhaust stream to reduce the oven running costs; hence it is essential to use the most thermally efficient oxidation process available which means using a regenerative thermal oxidiser (unless there is some external heat requirement not associated with the CCCL such as supply of heat to a direct heating network, factory space heating, steam generation plant, etc., that would require the use of a recuperative thermal oxidiser)

Also, before opting to use an infrared paint curing oven, it is recommended that the paint suppliers are contacted to ensure that infrared curing is suitable for the paint coatings to be used. Typically modified paint formulations are required when using infrared ovens and some coatings may specify curing via convective heat transfer only.

In general infrared painting systems find suitable application when space is limited, gas is not available, and line speed is low or when the line is a low speed stop-start line. Even if gas is not available but, line speeds start to move above 40 m/min then it would be recommend that the installation of a bulk gas storage system is investigated such that gas convection ovens can be used.

It is worth mentioning that there are gas infrared ovens available on the market but as yet these ovens tend to be used for drying of water based coatings and have not been developed for use with the curing of solvent based coatings on a continuous coil coating line.

With the type of thermal oxidiser and paint curing oven selected the next item on the CCCL thermal system to be considered is the **paint coater room**.

The size of the coater room has a significant effect on the size and thus cost of the overall thermal system.

There are both a health & safety and emissions regulations to be satisfied when designing a coater room ventilation system.

To ensure a safe environment for the coater operators to work in the solvent concentration within a coater room, the solvent must be kept below certain limits and thus the coater room requires adequate ventilation.

Further the air exhausted from the coater room comes under standard emissions control and thus VOC oxidation of coater room air is required.

The general rule of thumb is to ventilate the coater room at 60

Figure 9.0: Typical Paint Coater Room

volume changes per hour and therefore every additional cubic metre of coater room volume could potentially increase the size of the VOC oxidation system

Experienced suppliers of CCCL thermal systems use specialist techniques that limit the amount of air that needs to be processed through the VOC oxidation system and thus limit the size and cost of the equipment.

Once the three main components of the CCCL thermal system, i.e. curing oven, oxidiser and coater room have been selected then the basic system flow diagram can be created and linked together with **interconnecting ductwork** and the **main exhaust stack.**

Air must be exhausted from the paint curing oven at a rate that guarantees that solvent concentration is always below 25% of the upper explosion limit (LEL) of the solvent being processed (i.e. Factor of Safety of 4:1) or if the appropriate continuous solvent monitoring is installed then the solvent concentration limit within the oven can be allowed to rise to 50% of the LEL (i.e. Factor of Safety of 2:1).

Knowing the size of the paint coater room the coater room exhaust rate can also be calculated and combined with the calculated curing oven exhaust rate the system flows can be specified and balanced both on a volume and energy basis to complete the basic system design.

Additional **heat recovery systems**, such as heat exchangers to provide hot water for heating the CCCL cleaning section or for general factory heating can then be added as required thus completing the concept design procedure.

Although the above selection procedure is relevant today but we must not fall under the misconception that this a final selection procedure. As emissions regulations become more stringent, fuel sources change and coatings advance then the selection procedure that is relevant today may not be relevant tomorrow.

The development of thermal systems for coil coating is not at its final destination it will continue to move forward and thus each time an application is presented to ensure that best available technology is used then the selection process must be reappraised by thermal engineers who are expert in the field of continuous coil coating.