

# ***Western Technologies, Inc.***

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## **PRINCIPLES OF THE PULSE FIRED HIGH VELOCITY FURNACE**

The basic principle of the pulse fired high velocity furnace is simple.

High velocity gas or oil-fueled burners are mounted into one, or two diagonally opposite corners of a continuous gallery running 360° around the kettle. The output momentum of the burners, firing at up to 500'/sec, causes a rapid recirculation of hot gases around the kettle, producing high rates of heat transfer for all available points on the kettle. At the same time, this bulk flow of recirculating gases absorbs the intense local burner heat, redistributing it evenly around the periphery of the kettle. The result is high operating efficiency and uniform heat transfer; both around the kettle and over its depth, leading to low, uniform kettle wear.

Efficiency is considered a little later but, with regard to heat distribution around the kettle, let us take a typical design with a total gross heat input of 4,000,000 Btu/hr heating a kettle 33' long x 4' wide with a throughput of 22,000 lbs per hour. Here, the burner output temperature is around 1,470°F higher than the flue temperature yet measurements confirm that the gas temperature actually 'seen' by the kettle – that of the recirculating flow – is maintained within a 200°F range.

As we have observed, the principle is simple. However, the actual design of an individual furnace is complex, taking into account such variables as gallery width, burner size, precise burner location and optimum gas velocity for safe heat transfer levels with an avoidance of damage to insulating materials. These and many other factors must be considered in the design process, which is guided both by practical experience and by applied theory.

Everyone recognizes the value of practical know-how and the kind of experience that can only be gained by putting a wide range of furnaces into the field over a long period of time. But the theoretical element is also essential. High velocity furnaces differ widely in kettle dimensions and required production rates. Their design depends on a large number of parameters so each new high velocity furnace is likely to require a new tailored design, something which cannot be achieved by applying experience alone.

In addition, innovations and improvements to the high velocity furnace design at Western Technologies have nearly always begun with theory, for instance, the development of furnaces for extra long, and extra deep kettles.

## **FURNACE EFFICIENCY**

At this point, it is perhaps worth elaborating on one of the more basic theoretical aspects of galvanizing furnace design, since it is often a source of confusion. This aspect is the derivation of system efficiency based on a calculated flue temperature.

When a gaseous fuel is mixed with air within its limits of flammability, the mixture can be burned to release heat. The efficiency of this combustion should always be referred back to the total potential heat production of the gas: its gross calorific value – for natural gas approximately 955 Btu/ft<sup>3</sup>. Only 90% of this heat is usefully available under normal circumstances; the other 10% is lost in the production of steam in the products of combustion.

Of the useful heat remaining, a proportion is lost through the furnace insulation, a proportion heats the kettle and a further proportion leaves the furnace as flue losses – actually a valuable source of energy which can be used, for example, in a drier.

Because insulation losses are very small, we define the system efficiency as the percentage of gross heat input, which is transferred from the combustion products as they pass through the furnace.

Thus, the system efficiency can be simply derived as a function of the volume of excess air used in combustion and of the temperature of the flue gases upon exiting the furnace. Complete combustion of the fuel cannot be achieved with less than 0% excess air – the one theoretical limit is the zinc bath temperature of 840°F, the flue gases cannot exit at less than 840°F. From these parameters, we can calculate the maximum theoretical system efficiency for a furnace operating on natural gas to be 74%.

The flue gas temperature in the Pulse-Fired High Velocity Furnace depends on the kettle size and required production, but rarely ever exceeds the zinc temperature by more than 360°F. In addition, excess air levels (required in practice to ensure complete combustion and minimize CO emission) are precisely monitored at values of 65%. For individual furnaces this figure can often approach 70%. An improvement on this would, therefore, be almost impossible without adding regenerative or recuperative equipment.

## **DESIGN THEORY FOR UNIFORM KETTLE WEAR**

A great deal of research has been carried out by Western Technologies engineering into the thermodynamic and fluid mechanic relationships underlying the gas flows and heat exchangers of the high velocity furnace. With little published material available, a lot of the research has been conducted from first principles, using fundamental equations to formulate mathematical models of

varying degrees of complexity. Models range from simple conservation of momentum to the combined effects of radiation and convection of a system of multiple surfaces surrounding a 'gray' gas. The use of personal computers with proprietary programming has greatly accelerated this research and makes it possible to perform lengthy design calculations in an acceptably short time.

The design formulae used at Western Technologies also draw upon an extensive database of empirical information collected from high velocity furnaces working in the field. This data serves both to supply correction factors for purely theoretical equations and to confirm the validity of the fully assembled design formulae.

In this way, we are able to target our design procedure towards meeting the first three criteria of fuel efficiency, low kettle wear and thermal capacity. For the fourth criterion – constant zinc temperature – we must also investigate the control requirements of the high velocity furnace.

## **TEMPERATURE CONTROL**

The first factor to consider is that it is advantageous at all times to provide heat to furnace under maximum input conditions. In other words, it is imperative to run the burners at their maximum design setting (known as high fire) for as great a proportion and for the time that is necessary to meet the furnace mean heat demand, and for the remainder of the time to run the burners at their lowest possible input (known as low fire).

There are several advantages to running the high velocity furnace with short bursts of high fire rather than running continuously on some medium burner input. For example, burner mixing efficiencies are higher at maximum input conditions and significant reductions in kettle wear can be achieved.

Long-term kettle wear is a function not only of the temperature to which the kettle is over-heated but also of the time for which that over-heating occurs. Running at constant medium input gives problems in both areas; lower burner momentum causes low recirculation gas velocities and thus a reduction in kettle protection near the burner, and kettle corrosion can act over a much greater period of time on areas near the burner or even some distance from the burner. Having decided that this high/low burner input is the preferable mode for running the high velocity furnace, it is necessary to consider the method of control to be used.

A conventional high/low temperature control system is inadequate for the following reasons:

The conventional high/low system operates as follows: the temperature of the zinc is sensed by a thermocouple and an electrical signal is sent to an ON/OFF

temperature controller. When the temperature rises above a preset high limit, the burner output will be automatically reduced to its minimum setting. When the zinc temperature drops below a preset low limit, the burner output is increased to its maximum setting. But owing to the effect of the time delay from the switching, this system actually caused the zinc bath temperature to follow a sinusoidal (or sine wave) pattern – continually rising and falling and even with close switching limits the temperature overshoot and undershoot is unavoidable making it difficult for the galvanizer to achieve a consistent product.

In fact, from a control point of view, in order to maintain very close tolerances on the zinc temperature, the mean rate of heat input to the high velocity furnace must be adjustable in small steps between maximum and minimum output. Yet, any modulation of the burner input is immediately at odds with the furnace requirement for high/low input only.

Western Technologies has resolved this contradiction by utilizing a control system where the adjustable variable in the mean heat input equation is not burner input . . . but time. With this system, known as the ‘pulse-firing’ system, the burner input follows a square waveform of a constant period with regular step changes between the low fire and high fire states. In this waveform, the high fire peaks are known as ‘pulse’. The mean heat input to the furnace is adjusted by varying the duration of the high fire pulses. Since the wave period remains constant, the effect of lengthening or shortening the pulses is, respectively, to provide a greater or lesser mean rate of heat input, corresponding to the changes in galvanizing production rate.

Western Technologies utilizes a state of the art controller to regulate the duration of the high fire pulse and so attain the desired sensitivity in control of the zinc temperature. We wish to reiterate that this is not a conventional high/low control system, it is a unique technology available with every Westech furnace.

### **Summary:**

To summarize, we believe that this type of furnace meets – in the most comprehensive way to date – all the criteria for a successful galvanizing system: and that it offers, both in theory and in practice, the most durable, reliable and efficient furnace for hot dip galvanizing available in the world today.