

# **Pulsed Combustion Technology and Its Benefits**

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## **Pulse Combustion**

### What is it?

Pulse combustion is the consequence of a combustion instability that is driven into resonance by the geometry of the burner. Normally combustion engineers avoid combustion-generated instabilities at all costs, since they can very quickly lead to catastrophes. Here we actively utilise the instability to gain a number of advantages. This resonant driving locks the combustion instability into a very stable repetitive pattern at the resonant frequency, which can be anywhere between 1Hz to 20000Hz, but more frequently lies in 20Hz and 1000Hz range. The burner can become self-aspirating and there is no need for a fan to continuously supply the combustion air to overcome the acoustic pressure waves. The flame is not continuous but a series of discrete flamelets, that are ignited on the hot remnant gases of prior flamelets. Here we actively utilises the combustion instability to gain a number of advantages.

As a result, overall heat transfer and mass transfer coefficients are two orders of magnitude higher than conventional systems. The implications of this are that the size of the equipment can be reduced, i.e. the heat transfer area can be more than halved to carry out the same duty as a forced convection conventional combustion system supplying heat to an industrial/agricultural processes.

The acoustic pressure waves cause the gases (fuel, air and combustion products) and material in the combustion chamber and exhaust to oscillate rapidly. This has at least three known effects that cause an increase in the transfer rates:

- the boundary layer never gets a chance to establish itself and consequently it is always trying to develop,
- the temperature and concentration gradients at right angles to the mean flow are periodically extremely large, and
- thirdly, the heat transfer surfaces experience micro-vibrations that increase the heat transfer.

These effects are more than additive and as a result the transfer coefficients are at least two orders of magnitude greater than in conventional systems. We have seen evidence of a fourth effect increasing the heat transfer rate in which there is a thermal wave travelling into the material being heated. This has also been theoretically postulated by Merkin & Pop, whose theoretical work indicates that there should be thermal waves assisting the heat transfer into the bulk of the material being heated.

### 2. Why use pulse combustion and what gains does it give?

1. Overall heat transfer and mass transfer coefficients that are two orders of magnitude higher than conventional systems. The implications of this are that the size of the equipment can be reduced for industrial process.
2. Exhaust gas emissions from pulse combustion are amongst the lowest available in the world, NO<sub>x</sub> levels about a quarter of those proposed for the latest Californian emissions. Most people are only worried about the nitrogen dioxide (NO<sub>2</sub>) emissions, but they should also be concerned about the

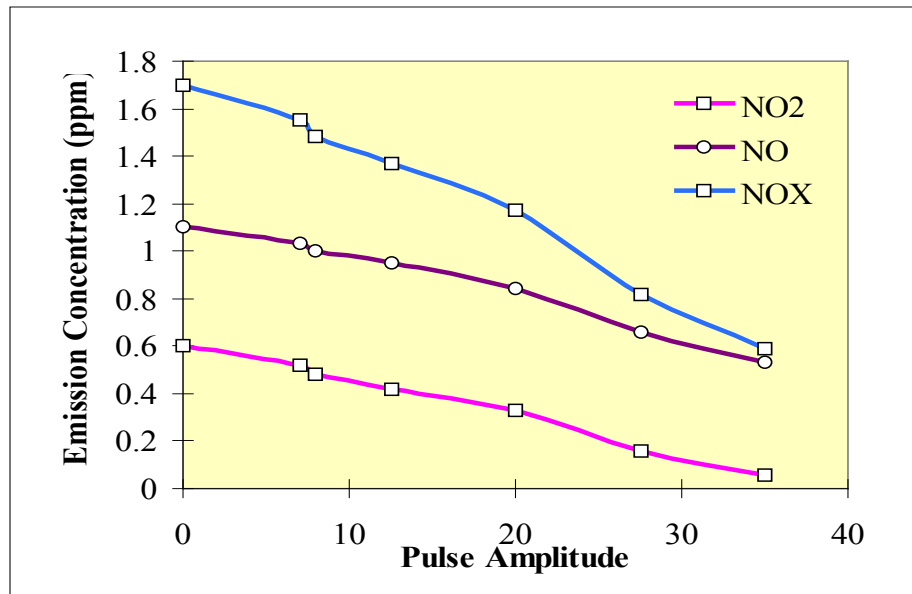
nitric oxide (NO) emissions as they can rapidly turn into NO<sub>2</sub>. Pulse combustion systems can deliver NO<sub>x</sub> emission levels (i.e. NO plus NO<sub>2</sub>) as low as 2 to 3ng/J of useful heat. Current mandated levels of total NO<sub>x</sub> are at the 40ng/J of useful heat level. The proposed levels for California are 9ng/J of useful heat. Raising the inlet air temperature, to conserve energy, does not increase the NO<sub>x</sub> levels, as would normally be expected with conventional systems.

3. Total hydrocarbon (THC) and carbon monoxide (CO) levels of zero attainable. In the best of conventional combustion systems there are usually small quantities of unburnt hydrocarbons and CO present in the exhaust gases.
4. SO<sub>x</sub> emissions could possibly be reduced as well, for the same mechanism should also be present as in the NO<sub>x</sub> formation chemistry. What the reductions might be is very hard to put a figure on it, as no measurements have been made with sulphur containing fuels.
5. Thermal efficiency of systems can be as high as 97%. This includes parasitic energy, which in the case of pulse combustors is minimal and only occurs at start-up. For other high efficiency combustion systems, forced convection, via fans, is used to increase the efficiency, but these consume about 3% of the energy supplies (9% if the primary energy is considered).
6. Greenhouse gas emissions per unit of desired duty can be dramatically reduced. There are many processes that can have their thermal input supplied by pulse combustion. They cover the following areas, which is by no means exhaustive:
  - heating of gases, liquids and granular solids (10 to 25%)
  - rotary kilns (10 to 50%)
  - fluidised beds (20 to 60%)
  - metal re-heat, annealing, etc (10 to 35%)
  - absorption refrigeration (40 to 75%)
  - chemical reactor driving (20 to 40%)
  - spray drying (10 to 35%)

The figures in brackets are the potential fuel savings/greenhouse gas reductions that can be obtained. The particular process involved causes the range. The reasons for the reductions are several:

- (a) Physical size of process equipment is smaller and hence energy losses are reduced. The corollary of this is that production can be increased for a given size of equipment when the thermal input is via pulse combustion.
- (b) Throughput can be increased. In some situations the flow of product through a process is limited by the need to minimise the pick-up of material into the exhaust stream. As a result of the high heat transfer rates attainable with pulse combustion, the product stream can be separated from the combustion products and exhaust streams. This can result in the elimination of expensive dust removal facilities, such as electrostatic precipitators, and an increase in the throughput of product.
- (c) Equipment tends to be self cleaning, i.e. as-new performance throughout the life of the plant. This effect results from the micro-vibrations that are generated. Even if the transfer equipment is fouled, in some instances it can be cleaned as soon as pulse combustion starts. In many process operations, fouling of equipment can represent an added cost as well as being a bottleneck in the process.

### 3 NO<sub>x</sub> reductions as a function of the pulse combustion amplitude



The above figure shows what happens to the NO<sub>x</sub> in a flame as the amplitude of the pulsing is increased. This causes two things to happen:

1. The flame gets stretched. As a consequence fuel fragments or radicals such as -CHO are no longer produced or their concentration is greatly reduced that their contributions to NO<sub>x</sub> production chemistry is almost eliminated.
2. The resulting acoustic flow field also causes local exhaust gas recirculation. This suppresses NO<sub>x</sub> formation by making it much harder for more NO<sub>x</sub> to be produced.

It is because these two effects are occurring in pulse combustors, that it is possible to preheat the incoming combustion air without causing the NO<sub>x</sub> levels to substantially increase.