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# Combustion Control by Pulse Firing

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## Introduction

Pulse firing is a relatively new combustion control method. It has been in widespread use in Europe for over a decade, and the number of pulse fired burner applications in the United States is growing steadily. This document will discuss the basics of pulse firing, how it compares to more traditional control methods, the advantages and disadvantages, and the considerations when selecting a pulse firing system. The document will also provide a list of recommended control equipment (valves and controllers) needed for a typical pulse fired burner system.

## Modulation

The primary function of a combustion control system is to change the heat input to a process in response to the needs of the process. In conventional systems, the burners are modulated between high and low fire and can be operated at any setting in between. This is an **amplitude-modulating control** approach and requires burners with a good turndown to meet the varying heat input of most applications. Typically, a group of burners are fired and controlled together. This approach offers good control and a great deal of flexibility for a reasonable price provided the burners have an adaquate turndown range.

With **frequency-modulating control (pulse firing)**, modulating the frequency of operation of the burners controls the heat input to the process. The burners are fired at high fire for a certain time and then cycled to either low fire (high-low control) or actually turned off (on-off control). This cycle is repeated quite frequently, typically every 15 to 60 seconds. The length of time the burner is at high fire and then at low fire (or off) is controlled by the process controller. This control method was originally developed to make it possible to use burners with a limited turndown in systems requiring a larger turndown than was possible with amplitude-modulating control.

By installing individual control valves at the burners, it is possible to control each burner independently of all other burners, resulting in a great deal of control flexibility. This can result in a more precisely controlled process than is possible with a more traditional approach. However, this comes at a price and considerable increase in system complexity.

## Control Methodology

Figure 1 shows a schematic of a typical amplitude-modulated combustion system. See Tech Note C-4 or the Eclipse burner design guides for more details about this control method.

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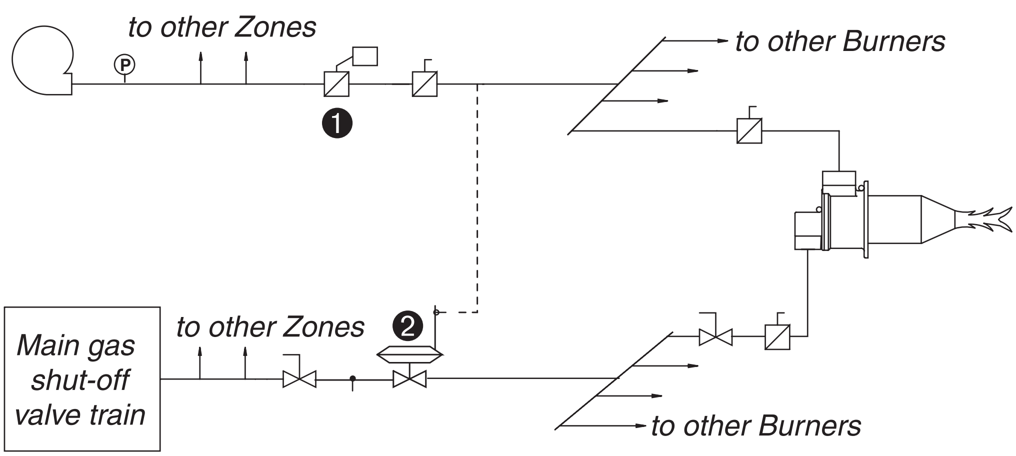


*Figure 1: Typcal amplitude-modulated combustion system*

This example shows one combustion air control valve ① and one air-gas regulator valve ② for the entire burner zone. As the process requires more heat input, the temperature controller signals the air control valve to open. The air pressure increases at the burner due to the higher air flow through the system. An impulse line located downstream of the air valve leads air into the upper chamber of the air-gas ratio regulator. The increased air pressure forces the diaphragm down, thereby opening the valve seat to allow more gas flow to the burner. As the gas pressure builds downstream of the regulator, this pressure acts on the regulator diaphragm to create a balance of pressure between the air and gas.

The gas outlet pressure is approximately equal to the air impulse pressure. The regulator is fitted with a factory set spring to compensate for the weight of the diaphragm assembly. This spring is also used to set low fire or minimum gas flow for the burner. In such a system, when the controller calls for full output, all burners are at full output. If the controller calls for 50% output, all burners are at 50% output.

The fuel flow is a function of air impulse pressure, which in essence is the air-gas ratio, and is dependent on the regulator characteristics. Most regulators are not truly linear, and as a result the ratio between high and low fire settings will vary somewhat from the desired value. Another drawback is the limited turndown ratio possible with this system, typically in the range of 6:1. Often in multiple burner zones it is necessary to have a gas regulator installed at each burner to minimize low fire set-up problems.

Figure 2 shows a schematic of a typical frequency-modulated or pulse firing system.

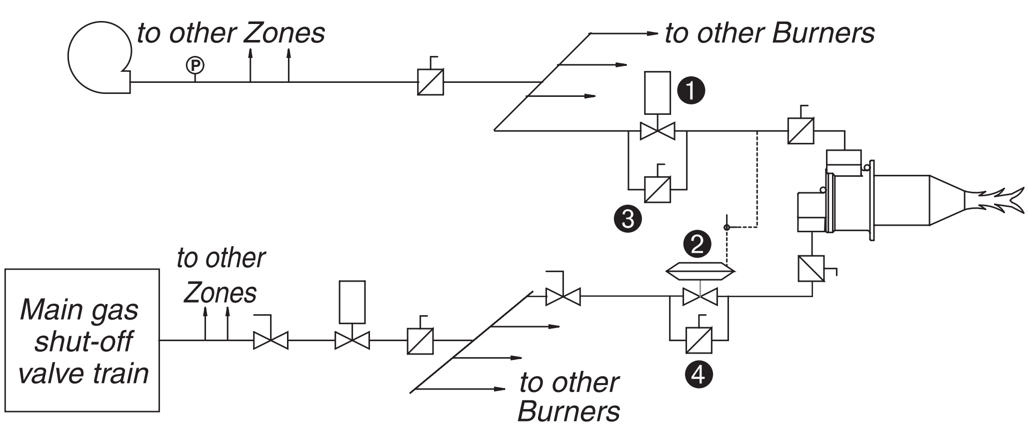


*Figure 2: Typcal high-low frequency-modulated combustion system*

In a typical fired pulse system, an air solenoid valve ① is used at each burner, replacing the zone control valve. When the control system demands more input, the air valve opens, and the air pressure downstream of the air valve increases. This pressure increase is transferred via the impulse line to open the air-gas ratio regulator ②. This regulator performs the same function as that used in an amplitude-modulated system. When the air solenoid valve closes, the impulse pressure to the regulator is reduced, and the valve closes. Low fire air and gas to the burner is now directed through the bypass lines around the air solenoid ③ and air-gas ratio regulator ④. Instead of a bypass around the ratio regulator, a ratio regulator with built in bypass orifice can be used as well.

The above description is for a high-low control system. A pulse system can also be set up for on-off operation by closing the gas solenoid valve ② at the same time the air valve ① closes. No bypass lines are needed with an on-off system (figure 3).

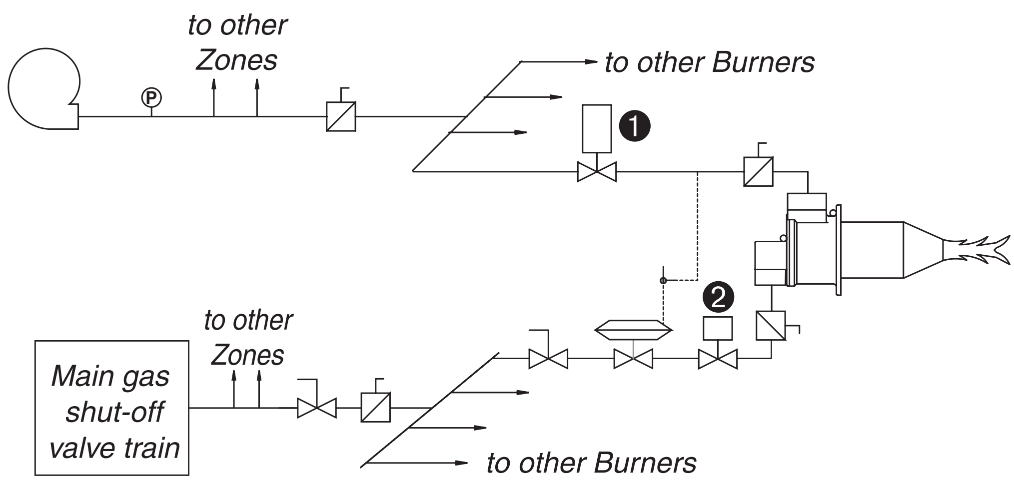


*Figure 3: Typcal on-off frequency-modulated combustion system*

## Pulse Firing

A pulse control system operates in a manner quite different from amplitude-modulated systems. The basis of all pulse control systems is the principle of programming "on" and "off" time in relationship to an input control signal from a controller. There is quite a bit of variation possible in the actual nature of the pulse control system hardware, and this can be varied to meet the specific needs of the customer. The following describes a traditional pulse control method.

In a pulse combustion system, a signal converter system controls the operation of the solenoid valves through a burner management system specifically designed for pulse firing. The pulse controller receives a 4-20mA signal from the temperature controller and, through a converter, changes this analog signal into a sawtooth voltage signal (figure 4). The frequency of this voltage signal varies proportionally with the temperature controller input.

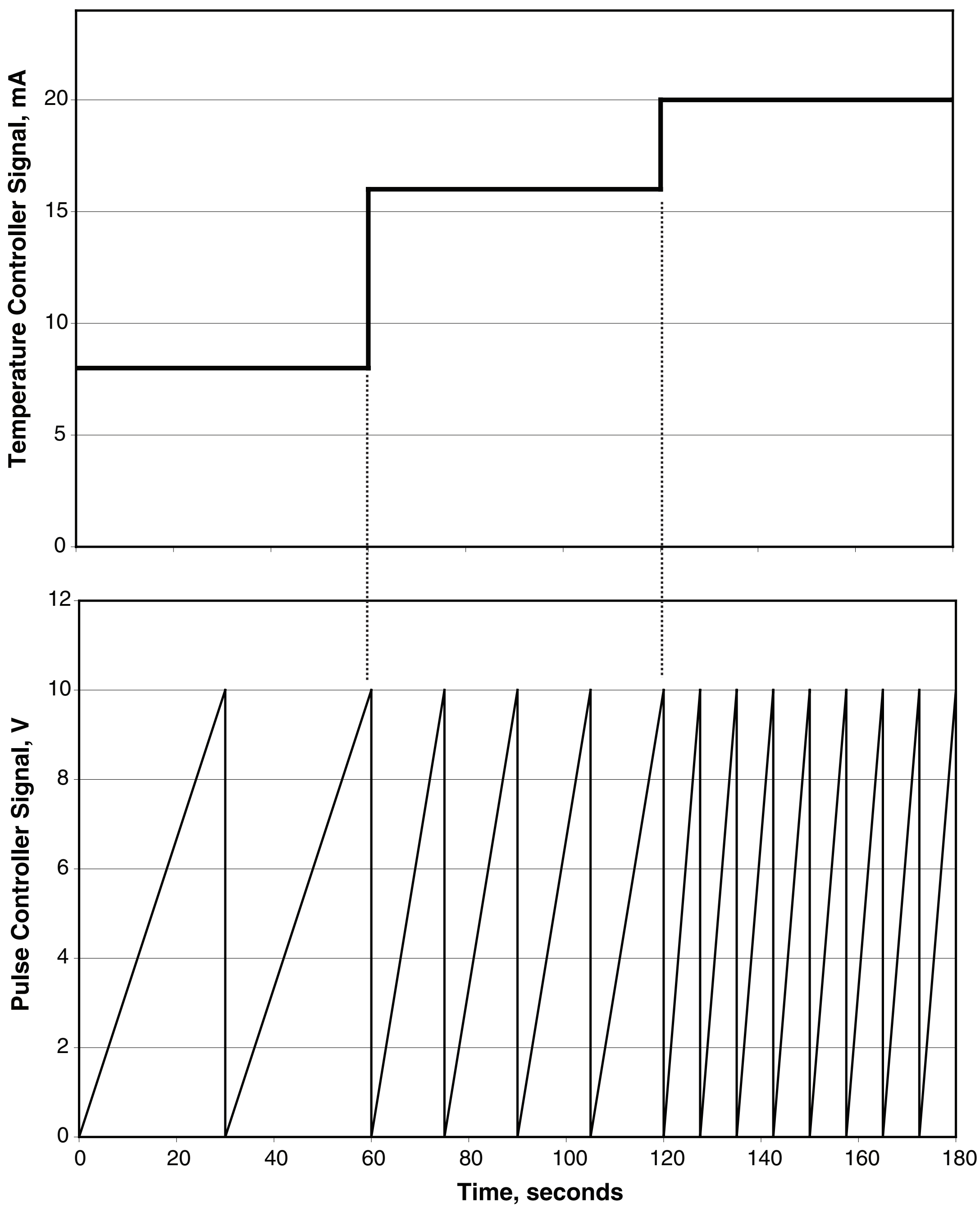


*Figure 4: Temperature cotroller signal conversion*

As the output voltage from the pulse converter increases with time, each burner in the zone is sequentially activated at a different voltage level. The maximum voltage level and number of burners determine the specific activation voltage level for each burner.  See figure 5 for an example for a four-burner system.

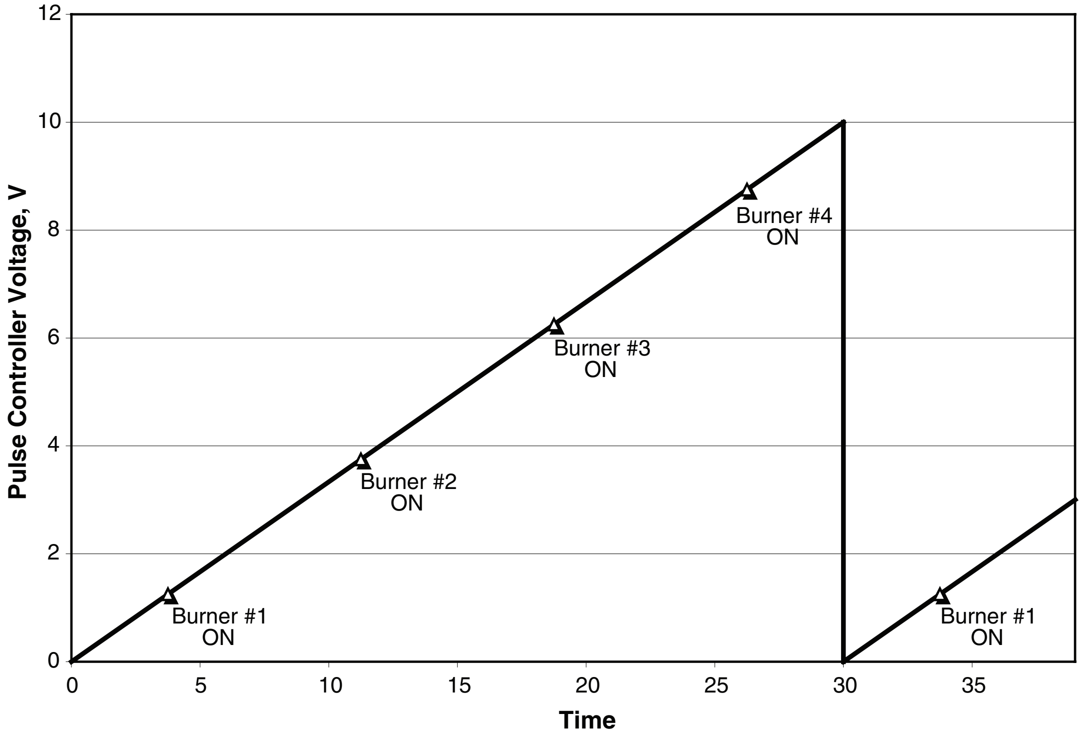


*Figure 5: Example of trigger voltage assigned to a specific burner*

The firing time is fixed and the next firing cycle for a given burner is only triggered when the output voltage again increases to the same level on the next cycle. When the controller calls for greater than 95% output, all burners remain on 100% of the time. Within a control loop, the burner control takes over the function of a continuous proportional control. A proportional dependency is obtained between the controller output and the burner capacity. In this example, a 4mA signal represents zero output, a 12mA output represents 50% output, and a 20mA output represents 100% output (figure 6).

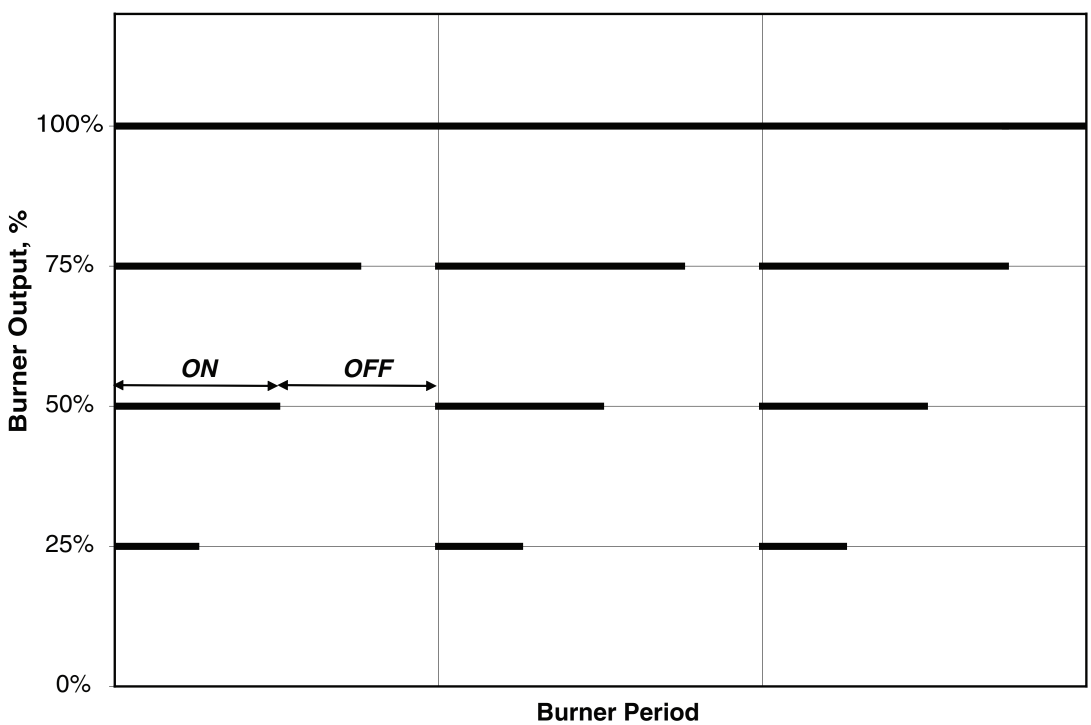


*Figure 6: Burner period as a function of required output*

Figure 7 shows a typical four-burner control system with a burner firing sequence for 25% and 50% output. The burner "on" time in this case is 7.5 seconds.

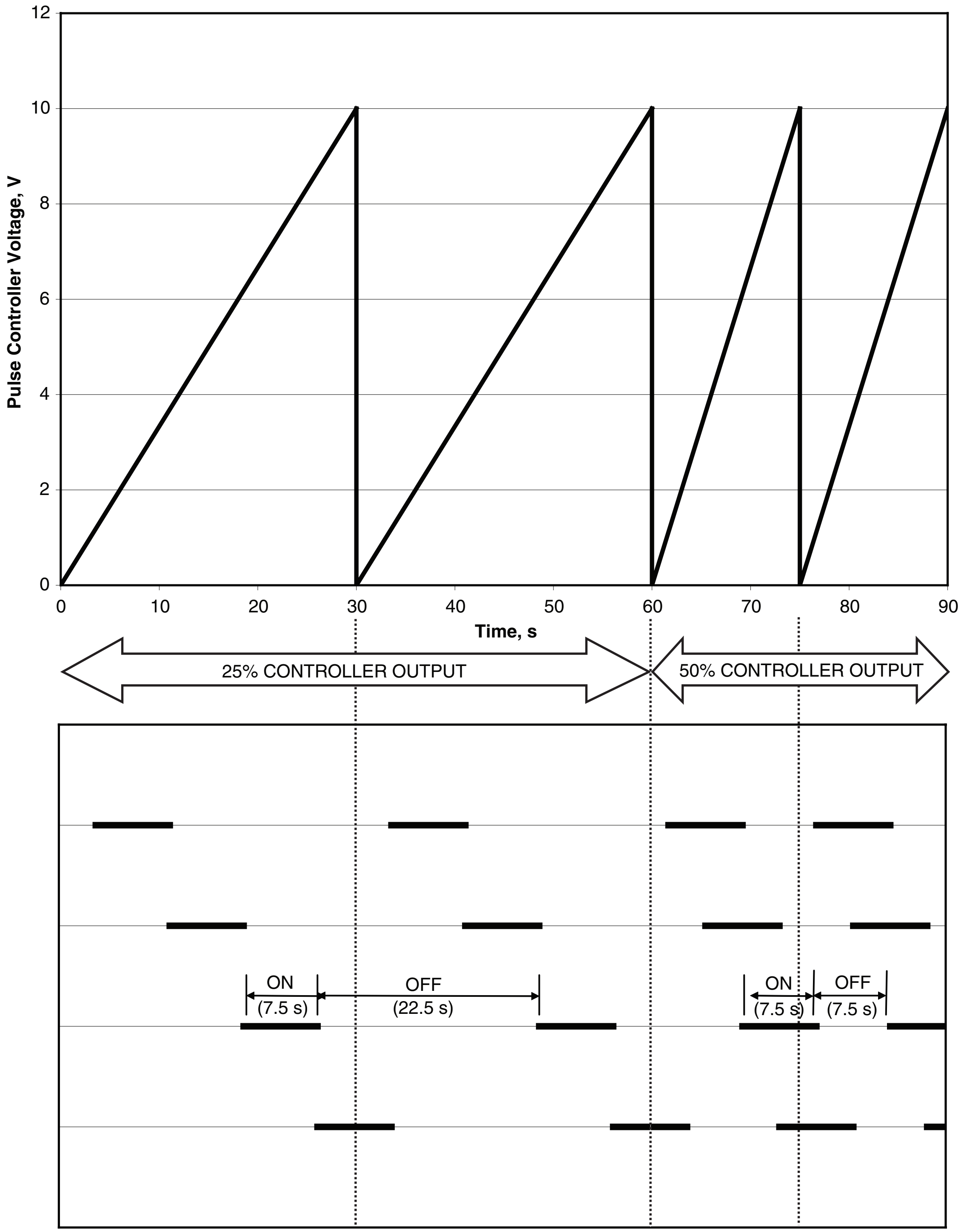


*Figure 7: Four-burner system with the burner firing sequences for 50% and 25% output*

The loss of one flame monitor signal, regardless of the cause, does not interfere with the operation of the other burners in the system. When heat is demanded, the pulse control system simply ignores any burner in the sequence without a safe flame monitor signal. The remaining burners compensate until the cause of the defective signal can be corrected.

## The Benefits of Pulse Firing

Pulse or frequency-modulated systems offer a number of benefits in comparison to amplitude-modulated systems**.**

Turndown

Rather than controlling the amplitude of the fuel input, the pulse system controls the frequency and timing of firing of each burner at predetermined fuel inputs. Each burner has its own air valve and its own gas regulator. When an individual burner is not being “pulsed” at high fire, it is either left firing at a preset low fire position or is completely turned off. If a low fire method is used, overall turndown ratios of twenty to one can be achieved. If the burner is cycled off and then restarted under control, an infinite turndown ratio can be achieved.

Temperature uniformity

Better temperature uniformity in the kiln or furnace is possible because the combustion system can be designed to maximize gas circulation in the furnace, thus enhancing temperature uniformity. Since burners are operated at high fire during the “on” cycle, the burner is always operated at the highest velocity ensuring that the maximum amount of furnace gases are entrained with the burner exhaust gases. This will bring the mix temperature of these gases closer to the furnace temperature, resulting in fewer hot spots.

Efficiency

Fuel savings of 20-25% are claimed for pulse-fired systems when they replace or are compared to proportional systems. One of the primary reasons given for this is better control of the air/fuel ratios during the firing process.

Emissions

Reduced air pollution is a result of the more precise control offered by pulse systems. Because most burners emit the lowest $NO_x$ levels when operating at high-fire, it is assured that the burner will always be operated under the ‘cleanest’ conditions.

Process Control

Greater process control flexibility can be achieved because the process lends itself to complete computer control. There is more opportunity to use different firing schedules from one firing to the next. The greater turndown ratios can allow faster heating rates without sacrificing control at peak soak temperatures.

A pulse system can not only be operated in a heating-only mode, but it can also be operated in a heating and cooling mode. The furnace temperature can be rapidly lowered if desired or needed by using a cooling mode in which the gas solenoid valve closes and only the air valves are controlled. If the temperature controller again calls for heat, the burners are re-ignited and a heating mode resumes.

In continuous furnaces or tunnel kilns, a greater numbers of burner zones can allow more flexibility in varying the temperature-time profile along the length of the kiln. Since zoning is not “hard-piped” into the kiln, it is feasible to provide more zones and to change the zoning much more easily than would otherwise be possible. Changes require mostly wiring and controller changes, not changes in piping and hardware.

## The Disadvantages of Pulse Firing

Because a pulse firing systems includes more components than typical amplitude modulated systems, the initial capital investment is higher. Also, the reliance on computer control increases the complexity of the system to higher levels than experienced with traditional control methodologies. This increased complexity requires better-trained system designers, installers and maintenance personnel. In addition, the use of computer control might give the end user a false sense of security about process control and safety.

## Equipment Selection

At the heart of a pulse firing system are solenoid operated control valves on the air and gas lines to each burner. These valves are designed to operate at a high enough frequency to respond to precise control inputs. At a frequency of ten cycles per minute, twelve hours per day, five days per week, the valves will be subject to 36,000 cycles per week. Typical solenoid valves are designed for one million cycles to failure, and at the frequency required for the pulse system just mentioned, the valves will last about six months. This is obviously not acceptable. Therefore, the valves selected need to be designed specifically for pulse firing applications. Table 1 provides an overview of air and fuel valves suited for most pulse fired applications.

| **Manufacturer** | **Model** | **Gas** | **Air** |
|---|---|---|---|
| Siemens | VG Series with SKP actuator | ● | ● |
| Dungs | MV-D safety shutoff valve | ● | |
| Dungs | DMV-D safety shutoff valve | | ● |
| Kromschröder | VG solenoid valve | ● | |
| Kromschröder | VR solenoid valve | | ● |
| Kromschröder | MK solenoid operated butterfly valve | | ● |

*Table 1: Air and gas valves for pulse-fired systems*

To assure that air is flowing through the burner at time of ignition, the air solenoid valve needs to be mounted close to the burner air inlet. In addition, to control the air-gas ratio at all times, it is critical that an air-gas ratio regulator is installed at each burner. Table 2 lists the most common models.

| **Manufacturer** | **Model** |
|---|---|
| Siemens | VG Series with SKP25, SKP55, or SKP75 actuator |
| Dungs | FRG ratio regulator |
| Kromschröder | GIK ratio regulator |

*Table 2: Air-gas ratio regulators for pulse-fired systems*

It is important that the main gas supply regulator is properly sized. Excessive pressure droop or inlet pressure into the ratio regulator is not permitted because it potentially will affect ignition reliability.

As previously described, pulse controllers are used to convert the temperature controller signal and control the operation of the air and gas valves. A number of specialized controllers are available: North American StepFire, Kromschröder PF 19", and Hans Hennig mini ERUST 8 to name a few. These controllers offer the advantages of a compact design requiring minimum programming by the user.

Because of the cost of these specialized controllers, there is a trend to build pulse fired burner management systems with PLC's. These systems offer the same functionality as the specialized systems, but at a cost that is typically 20-40% lower. The advantage of a PLC system over a specialized controller system is not only initial cost. Most components for a PLC system are off-the-shelf items. In addition, most maintenance personnel are familiar with PLC's and this makes set-up and maintenance of this equipment much easier.