Recommendations for Pilot Design and Equipment Startup in Incinerator Applications

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Introduction

Thermal oxidizer startups can be a complex and critical operating point for any facility. This activity requires attention to detail on many factors for consistent light off and startup of their equipment. As a result, proper design and operation of a pilot system is key to the long-term success of a facility. Unfortunately, while safe and reliable pilot design is addressed in several industry standards, the final implementation is often poorly understood and implemented leading to unsafe operating conditions and unplanned outages.

The goal of a pilot system is to ensure that end users have reliable, effective, and safe designs that will adequately light their main piece of fired equipment. Understanding the industry standards that cover ignition systems, their requirements and recommendations, can be challenging as they are not all consistent. This paper outlines the key requirements as noted in the current major industry guidelines that are commonly referenced for thermal oxidizers including: NFPS 85, NFPA 86, API standards, among others. These major standards typically outline the key concepts and the impact the guideline may have for unit design and operation. These impacts cover igniters, pilot design and general safety features that would be required for each. Please note that in some cases, the terms pilots and igniters are used interchangeably.

Outside of general industry guidelines we will identify techniques that can be used to control system firing and overall temperature control, especially at lower turndown conditions. These focus areas are generally not addressed in industry guidelines and often poorly managed in their implementation, which leads to reduced life expectancy of refractory and other equipment components. Additionally, we will address common ignition issues along with general troubleshooting and maintenance recommendations.

Industry Practices

Over the years several industry standards have outlined general recommendations for pilot design and use. These guidelines cover a wide range of general combustion use including process heaters, flare systems, air heaters and thermal oxidizers. In general, these guidelines provide good practices to consider when designing and operating applicable equipment, however at times the appropriate standard to use can sometimes be unclear depending on the specific intended requirements of a piece of equipment. As such it can lead to confusion as to determining which general practice you should adopt along with the corresponding design details for pilot use in incineration applications. This is critical to understand as the pilot system is such a key piece of operating equipment from both a safety perspective, as well as the overall larger purpose of plant production and. We have summarized several of the top industry guidelines that can be considered for use with thermal oxidizer design and options, along with key points addressed in each. It’s important to note that these industry standards and definitions are also important to consider for implementation in designing Burner Management Systems (BMS) and pilot designs, as these govern the overall safe operation of the equipment.

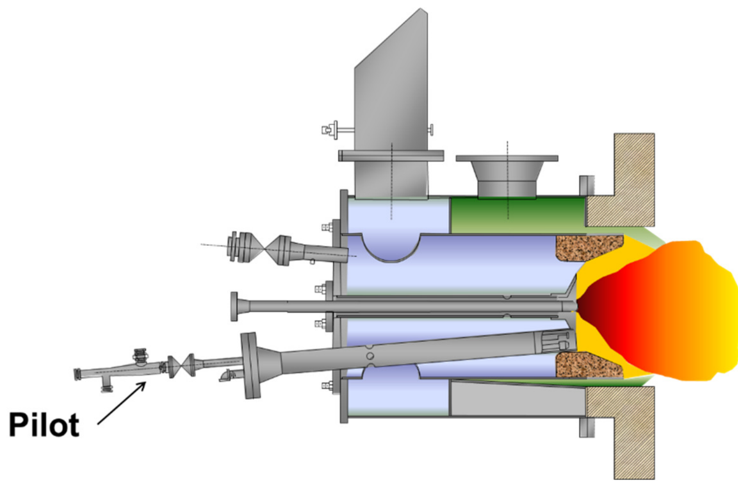


Image 1: Typical pilot in an incinerator application.

<u>From NFPA® 86-2019 Edition Standard for Ovens and Furnaces[1]</u>

NFPA 86 (2019) tends to be the most common recommended practice that is applied to a traditional incinerator. As such most systems traditionally reference this as the main reference point for pilot and BMS design. Key considerations of this practice include:

Definitions as defined by NFPA 86:

- Pilot: A flame that is used to light the main burner.
- Burn-off Pilot: A pilot that ignites special processing atmosphere discharging from the furnace or generator.
- Continuous Pilot: A pilot that burns throughout the entire period that the heating equipment is in service, regardless of whether the main burner is firing.
- Flame Curtain Pilot: A pilot that ignites a flame curtain.
- Intermittent Pilot: A pilot that burns during light-off and while the main burner is firing.
- Interrupted Pilot: A pilot that is ignited and burns during light-off and is automatically shut off at the end of the trial-for-ignition period of the main burner.
- Proved Pilot: A pilot whose flame is supervised by a flame detector that senses the presence of the pilot flame.

It's important to note that this document does not list any special considerations or limitations for designing a pilot as "continuous" or "interrupted" pilot operation. Many other industry guidelines require special considerations for heat release as they relate to the main burner.

NFPA 86 also notes that "burners shall have the ignition source sized and located in a position that provides ignition of the pilot or main flame within the design trial-for -ignition period". This is a key consideration as the initial light off in a system is often one of the most dangerous conditions due to the potential availability of air and fuel gas in the system prior to an established flame. As such the ignition trial period is often short to minimize the amount of time fuel gas is injected into the presence of air without a standing flame. NFPA 86 requires a trial for ignition sequence shall not exceed 15 seconds unless:

> (1) A written request for an extension of the trial-for-ignition period is approved by the authority having jurisdiction.
> (2) It is determined that 25 percent of the LFL cannot be exceeded in the extended time.

The presence of a flame is to be determined with the use of either a flame scanner, flame rod, or other suitable sensor equipment. This practice also notes that if the type of spark ignition system can cause a potential false flame signal that additional safeguards need to be implemented to ensure that flame presence is confirmed.

From NFPA® 85 2015 Edition-Boiler and Combustion Systems Hazards Codes[2]

NFPA 85 is generally the key design system for boiler burner applications. While it is typically not the optimum selection for use in thermal oxidizer design there are some scenarios where its use and implementation could be considered. For example, a thermal oxidizer with the use of a boiler for heat recovery may require some potential safeguards to be considered from this document. As a result, below are some relent design considerations as NFPA defines for safe pilot and ignition design.

> Class 1 Igniter: An igniter that is applied to ignite the fuel input through the burner and to support ignition under any burner light-off or operating conditions. Its location and capacity are such that it will provide sufficient ignition energy, generally in excess of 10 percent of full load burner input, at its associated burner to raise and credible combination of burner inputs of both fuel and air above the minimum ignition temperature.
>
> Class 2 Igniter: An igniter that is applied to ignite the fuel input through the burner under prescribed light off conditions. It is also used to support ignition under low load or certain adverse operating conditions. The range of capacity of such igniter is generally 4 percent to 10 percent of full load burner fuel input.
>
> Class 3 Igniter: A small igniter applied particularly to fuel gas and fuel oil burners to ignite the fuel input to the burner under prescribed light-off conditions. The capacity of such igniters generally does not exceed 4 percent of the full load burner fuel input.
>
> Class 3 Special Igniter: A special Class 3 high energy electrical igniter capable of directly igniting the main burner fuel.

The key item to note from these definitions are the various heat releases recommended to meet the class requirement for a given system.

From API 535 - 2014 Burners for Fired Heater in General Refinery Services[3]

Fired heater applications tend to be one of the most common applications for burner design and expertise. As such API 535 is well known amongst many experts in the industry and a quick reference for other potentially similar burner designs. The use of this recommended practice may depend on the exact applications but generally it is not recommended for traditional incinerators. However due to its prevalence within the industry it is worth noting some of the key guidelines for how they may be implemented or differ from other similar practices.

Section 7 of the document outlines some of the following key principles,

- Pilot burners shall be gas fired. The fuel for the pilot should be from a reliable, independent fuel source. Natural gas is preferred fuel gas for the pilot.
- Pilot flame shall be visible at all times.
- Pilot burners shall be removable for cleaning and maintenance when the heater is in operation.
- Positive indication of the pilot flame shall be made upon ignition.

In general these are good design considerations for any burner, however the exact design of an incinerator and it's operating conditions may limit the ability to meet each of these conditions; for example the presence of potentially dangerous vent gases may prevent the ability to fully remove a pilot during operation.

API 535 also requires that a pilot shall be in continuous operations with a minimum head release of 65,000 BTU/Hr and must be supplied constantly during operation, even with a main burner not in service. Additionally, any "high intensity burner" with a heat release over 15 MMBtu/hr must get additional approval from the owner.

From API 560-2016 Fired Heaters for General Refinery Service[4]

Similar to API 535, there are occasional references of API 560 in potential use for incinerator design. API 560 likely is not the best practice to refence its use on fired heaters is sometimes applied to other similar combustion burner technologies.

The biggest items to note from API 560 are as follows:

- The pilot shall have a nominal heat release of 22 kW (75,000 Btu/h). The minimum heat release shall be approved
- by the purchaser if it is for a high capacity burner whose heat release is 4.4 MW (15×10^6 Btu/h), or greater.
- The pilot burner shall be provided with a continuous supply of air under all operating conditions. This includes
- operation with the main burner out of service.
- The pilot burner shall remain stable over the full firing range of the main burner. It shall also remain stable upon
- loss of main burner fuel, with minimum draft, with all combustion air flow rates, and for all operating conditions.
- The pilot shall be positioned and sized to ensure that it is capable of lighting any of the main burner fuels. The
- purchaser shall specify the minimum main fuel flow rate during cold-burner light-off.
- The pilot shall be capable of relighting an individual main burner over the full range of fuels. The combustion air

The biggest highlights are the minimum heat release requirement as well as flexibility for various fuel compositions.

Pilot Types

Among the industry there are generally three main types of pilot ignition technologies[5]:

- Natural draft pilots
- Premixed (forced draft) pilots
- Direct spark pilots

Determining the appropriate type of ignition will depend upon the given application of the incinerator. Key considerations should include, available fuel gas, operating pressure, main burner primary firing waste, potential for liquids or condensate, among others.

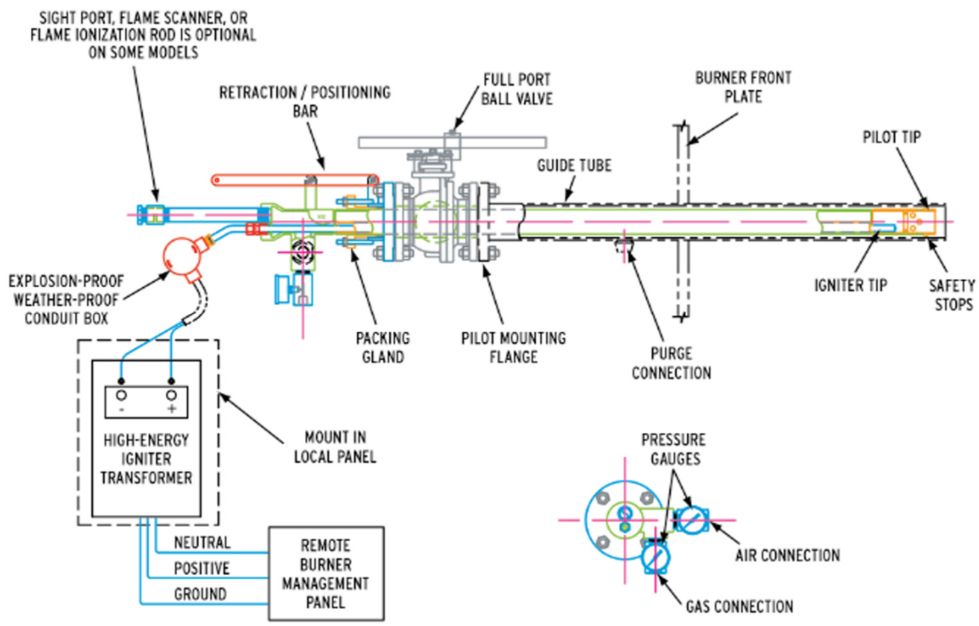


Image 2 Typical pilot features.

<u>Natural Draft Pilots:</u>

For many years, typical pilot design would include the following:

- A naturally inspirited pilot with air/gas mixer with a gas orifice/spud (Image 2 and 3)
- A high voltage ignition (HVI) rod with ceramic insulators (Image 4)
- Either a flame ionization rod or flame scanner to prove the pilot flame
- Insulating spark plug

Gas fired pilots will typically have a gas orifice that is drilled for a specific heat release at a given operating gas pressure. Refer to the documentation on the specific pilot to confirm the proper operating pressure and capacity for the pilot.

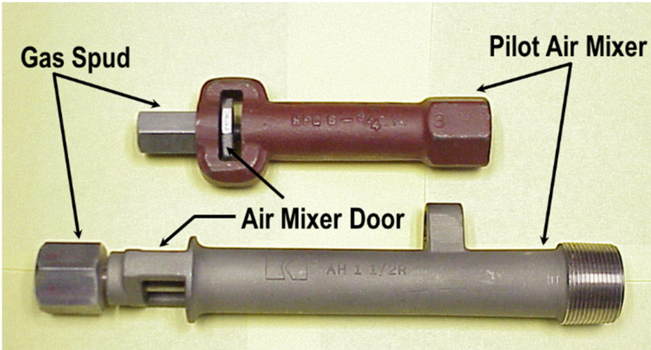


Image 3: Typical naturally inspirited pilot mixer.

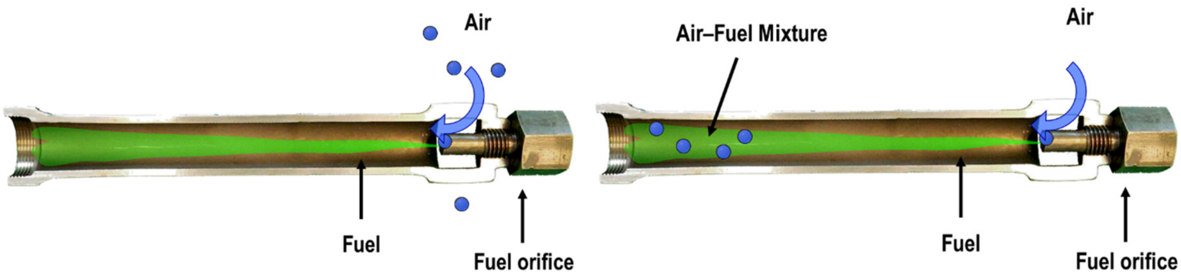


Image 4: Demonstration of how air/fuel mixer functions.

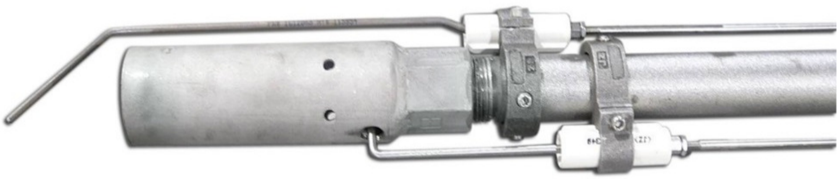


Image 5: Typical pilot assembly with high voltage igniter (lower portion) and flame rod for flame proving (upper portion).

Some of the advantages of natural draft pilots are:

- Can handle several different fuel types
- Only require a fuel source

Some of the disadvantages of natural draft pilots are:

- The ignition rod, tip, and ceramic insulators can have the igniter spark grounded out to the pilot due to moisture, dirt, and cracked ceramic insulators.
- The air mixers obtain the pre-mixed air from the combustion air blower, so operation is dependent of the flow rate set by the combustion air control.
- Not ideal for applications operating under high pressure

Premixed Pilots:

Premixed pilots use compressed air, instead of ambient air or are from a combustion air blower. Compressed air is metered through fixed orifices through fixed orifices and predetermined pressure to provide the proper air to fuel ratio to produce a more stable pilot flame. Typically the compressed air can be either instrument air or plant air if the available source is relatively clean.

Premixed pilot designs are often very stable and can operate in very difficult environments, even fully inert due to their premixed air/fuel mixture. Premixed pilots often can handle a wide range of fuel gases and can fire with up to 60% hydrogen in the fuel gas.

Image 6: Example of a premixed pilot design.

Some of the advantages of premixed pilots are:

- Can handle several different fuel types
- Very stable in many different environments
- Can be used in high pressure applications

Some of the disadvantages of premixed pilots are:

- A consistent and reliable compressed air source must be available
- Above 60% hydrogen the premixed environment can lead to excessive flashback in the pilot

Direct Spark Pilots:

Direct spark Pilots differ from traditional pilots in that it utilizes only the presence of an electrical spark at a predetermined location near the primary burner, nor pilot fuel gas or standing pilot flame is required. Generally direct spark pilots utilize high energy type ignition transformers.

Currently, direct spark pilots are not commonly used in the industry, however, there is growing desire in the market for feedback on these designs due to the perceived benefits. While operation of these systems is often simpler in concept, the lack of a standing and proven flame before introduction of fuel or waste gas to a primary burner tip may require a change in operating philosophy to safely implement.

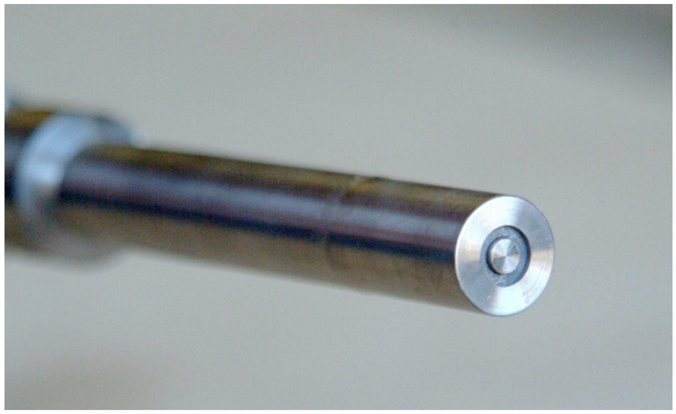


Image 7: Example of a direct spark igniter tip.

Some of the advantages of direct spark pilots are:
- Simpler to operate then traditional natural draft or premixed pilot designs
- Typically, can spark in turbulent and high moisture environments
- Can be used in high pressure applications

Some of the disadvantages of direct spark pilots are:
- Lacks a proven standing flame prior to waste or fuel introduction, potentially leading to unsafe operating conditions during trial for ignition
- Point of ignition can be difficult to determine prior to ignition attempts

Types of Electronic Transformers

There are two main types of ignition transformers frequently implemented for incinerator combustion systems. One being the High Voltage Ignition (HVI) and the other is the High Energy Ignition (HEI).

High Voltage Ignition (HVI) Modules

The commonly known "spark plug" ignition module is a standard high voltage 6KV to 10 KV transformer (Image 7) to create a spark across a spark gap. The spark is then created between the spark tip and the side of the pilot which is connected to ground through the burner mounting plate. These modules operate on a very low current (20 mA) and provide many low energy sparks.

One disadvantage of HVI systems is the ceramic isolators that hold the spark rod in place. If a ceramic isolator breaks, the spark will follow the path of least resistance, which will occur before traveling to the spark gap.

Some of the advantages of HVI modules are:
- Relatively inexpensive
- Long history of use in the industry

Some of the disadvantages of HVI modules are:

- Prone to shorts, especially in high moisture environments
- Generally considered more dangerous to maintain and operate due to the potential for high voltage exposure

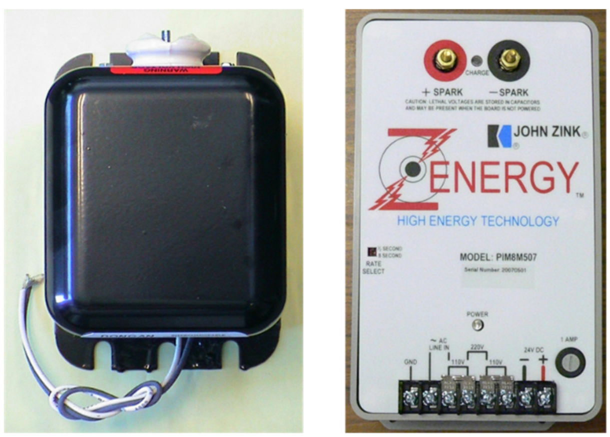
<u>High Energy Ignition (HEI) Modules</u>

Many modern style pilots utilize the more reliable High Energy Ignition (HEI) (Image 8) which can spark even if the tip is immersed in water.

HEI was originally developed for the aviation industry in the 1950`s after research on re-ignition of aircraft gas turbines. This ignition system must have very high reliability. If a jet engine stalls in flight, it must be re-ignited immediately in potentially turbulent and wet environments.

The HEI system uses higher current that's produced for a very short period of time. The power comes from several capacitors that become charged. The stored energy is then rapidly discharged through high powered transistors.

The advantage of the HEI system has become the most common type of electronic sparking as water or dirt will not affect the performance because the high energy from the spark will "blast" the dirt off.



High Voltage Transformer   High Energy Transformer

Image 8: Comparison of a typical high voltage type and high energy type transformer

Some of the advantages of HEI modules are:

- Very reliable across many different environments
- Available in many sizes and energy outputs

Some of the disadvantages of HEI modules are:

- Generally, more expensive as compared to HVI units

Operation Between Pilot Light off and Primary Burner Firing

While the primary purpose of a pilot is to ignite the primary burner, there is an area of operation that occurs before the main burner is ignited that is often overlooked in system design. Thermal oxidizers and incinerators are often comprised of downstream combustion chambers that are refractory lined due to the high heat the systems operate at. This refractory material often requires well controlled warm up and cool down for maximum life expectancy[6]. If this stage of operation is poorly controlled it can significantly reduce the life of the refractory, leading to unplanned shutdowns for repair or replacement of the refractory and other parts of the incinerator system. This is especially true for the initial "cure-out" (dryout) of refractory of new units which can often take several days to complete a controlled warm up (Table 1). However, this warmup period even applies to cold starts long after a system has been initially cured where many refractory materials require warm up of no fast than 75°F (27°C) - 200°F (93°C) per hour (Table 2).

Increase Temperature From Ambient To	100℃	At	25℃	Degrees Per Hour
Hold Temperature At	100℃	For	6	Hours
Increase Temperature To	(500℉) 260℃	At	25℃	Degrees Per Hour
Hold Temperature At	(500℉) 260℃	For	6	Hours
Increase Temperature To	(1000℉) 535℃	At	25℃	Degrees Per Hour
Hold Temperature At	(1000℉) 535℃	For	6	Hours
Increasing To Furnace Operating Temperature	(1800℉) 980℃	At	35℃	Degrees Per Hour

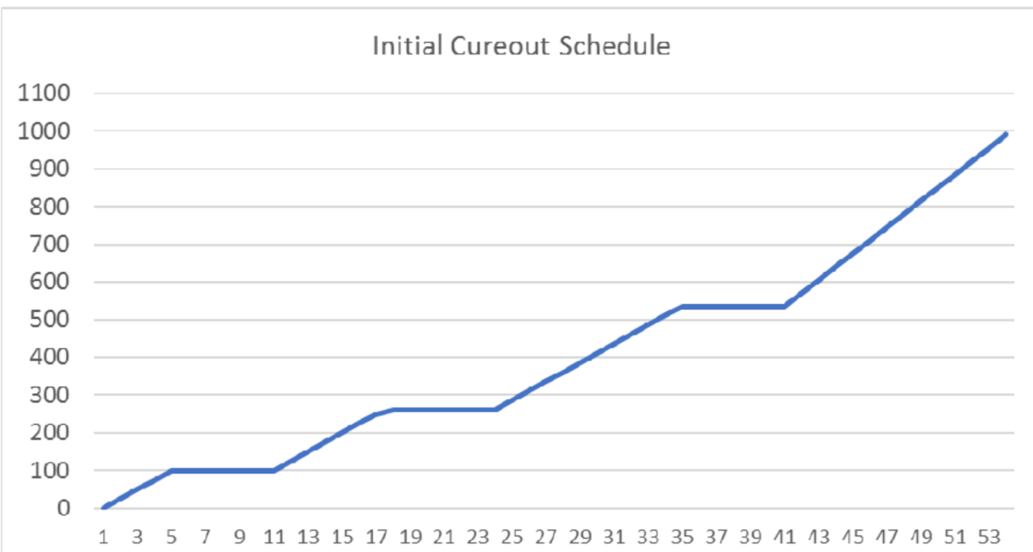


Table 1: Typical initial refractory cure out schedule.

Cold Start Up Of Unit After Initial Heat Cure. Ambient To	150°C	At	25°C	Degrees Per Hour
Hold Temperature At	150°C	For	4	Hours
Increase To Furnace Operating Temperature	(1800°F) 980°C	At	35°C	Degrees Per Hour

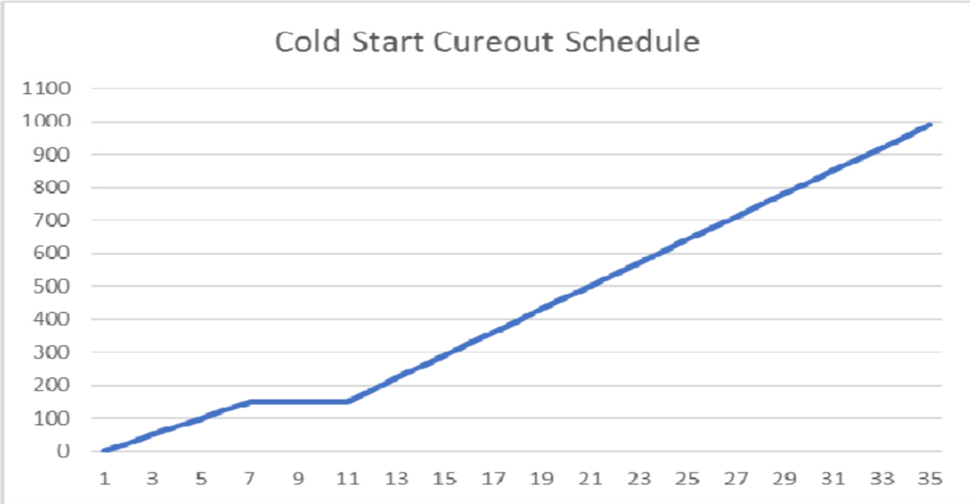


Table 2: Typical cold start schedule.

For most applications the system relies on the burner turndown to achieve these controlled temperature warm up and cool downs, however in systems with fairly large burner heat releases the turn down of the burner may not be sufficient to adequately control the hear at lower temperatures. As a result some systems rely on a secondary burner to bridge this gap in operating conditions properly. In practice most systems do not have a secondary firing and must operate in very manually controlled scenarios to attempt to meet the temperature requirement, often very poorly.

As a result of deficiencies in this operating stage there are options available in the market that add additional heat release from the pilot, or a staged primary burner. These provisions allow for operation at a wider turndown range between the pilot and burner and help prevent premature refractory and equipment damage. These provisions should be considered for any system with a limited turn down, or a high heat release burner.

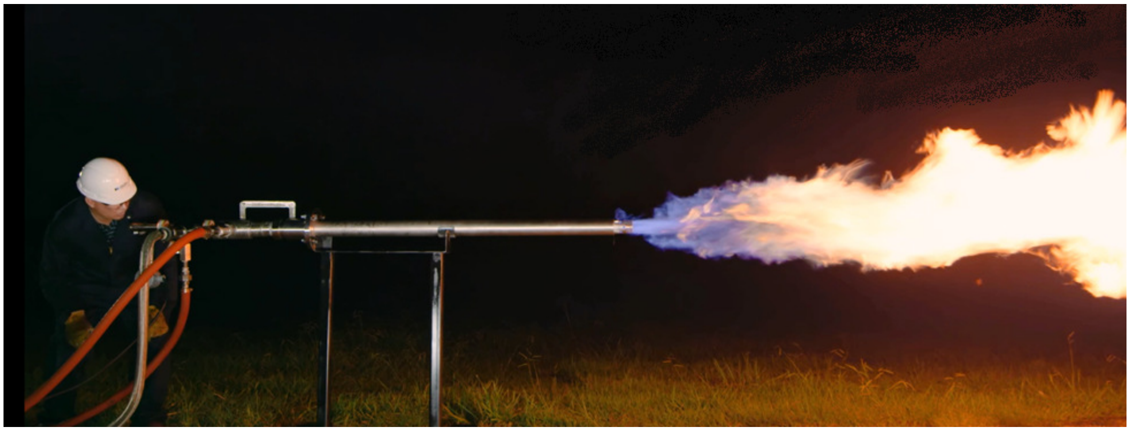


Image 9: Example of a high heat release pilot which can fire between 200,000 BTU/Hr to 20,000,000 BTU/Hr to cover a gap in heat control between a pilot and burner turndown

Pilot Troubleshooting

Considering the challenging nature of incineration applications, it is almost inevitable that maintenance or repairs will be required for pilot and ignition equipment. For any application the implementation of a detailed inspection and maintenance plan is key for ensuring long life of the equipment. Below are some general recommendations that should be considered for a typical pilot and ignition system.

Pilot Maintenance

Inspect the pilot assembly approximately every six months or during a planned outage for the following[6]:

A. Inspect pilot fuel gas/air orifice spud(s). Ensure that the fuel gas/air spud(s) is (are) straight and plumb. Check for plugged orifices, clean orifices, and confirm drilling. Replace in kind if necessary.
B. Inspect for pilot tip damage
C. Inspect ignition rod tip damage or out of tolerance
D. Inspect ignition rod insulators being cracked or broken
E. Inspect ignition rod grounding out along the side of the pilot
F. Check high voltage or high energy ignition wire(s) and replace as needed
G. Inspect ignition transformer for proper spark every six months or during a planned shutdown.
H. Inspect pilot mixer for cracks. Replace in kind if necessary.

Image 10: Example of Damaged Pilot Tip

Troubleshooting

Pilot Troubleshooting Matrix **Problem/Symptom** / **Possible Cause/Solution**	Check electrical connections	Button stuck	Check fuse	Check transformer	Tube or orifices plugged	Air/Fuel pressure ratios set incorrectly	Improper valve setting	Adjust depth pilot is inserted into burner	Adjust scanner angle	Adjust scanner settings	Check incoming supply for air and fuel	Ignitor tip damage	Pilot tip plugged	Supply pipping is too small
No Spark	✓	✓	✓	✓								✓		
No Flame					✓	✓	✓						✓	✓
Scanner won't pick up Pilot	✓							✓	✓	✓				
Pulsating Flame					✓	✓					✓		✓	✓
Lazy Flame						✓							✓	✓

Table 3: Typical Pilot Troubleshooting Matrix

Failure of a pilot to ignite and burn steadily within a 10-15 second timed trial for ignition interval indicates a problem. Only after locating and correcting the problem should relighting of the pilot be attempted.

Visually observe the pilot through the sight port during the ignition period. If no sparks are seen at the ignition spark gap at the pilot tip, check for improper spark gap or shorting in the spark system. If sparks can be seen, but the pilot will not light, check for air in the natural gas supply line, insufficient natural gas pressure, plugged pilot and/or air orifice or incorrect combustion air damper setting.

If a pilot lights, but the flame sensing device does not activate the “Flame On” light, misalignment between the pilot flame and the scanner sight tube is the most probable cause. Slight misalignment can often be overcome by simply turning up the pilot gas pressure to produce a larger flame body which the scanner can “see” without difficulty.

If the proceeding step fails, carefully remove flame scanner from scanner tube and look into scanner tube. When properly aligned, the pilot flame body will completely cover the viewing area of the scanner tube. If the flame cannot be seen, or it is off center of the sight tube, realign the pilot by carefully bending or shimming. If alignment is correct, but scanner does not activate “Flame On” light, check the flame scanner by holding a match or other flame (flashlight will not work) in front of scanner eye.

If scanner does not respond to flame, see the scanner troubleshooting guide.

Conclusion

This paper is not meant to guide the reader into choosing any one specific standard or type of ignition system, rather it is to educate them on current available guidelines in the industry and how they may be considered for their potential operation. When designing any incinerator system, it is important to use the available resources and technologies to determine what is the most appropriate for a specific installation.

Image 11: A properly operating pilot in an incinerator application.

References:

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