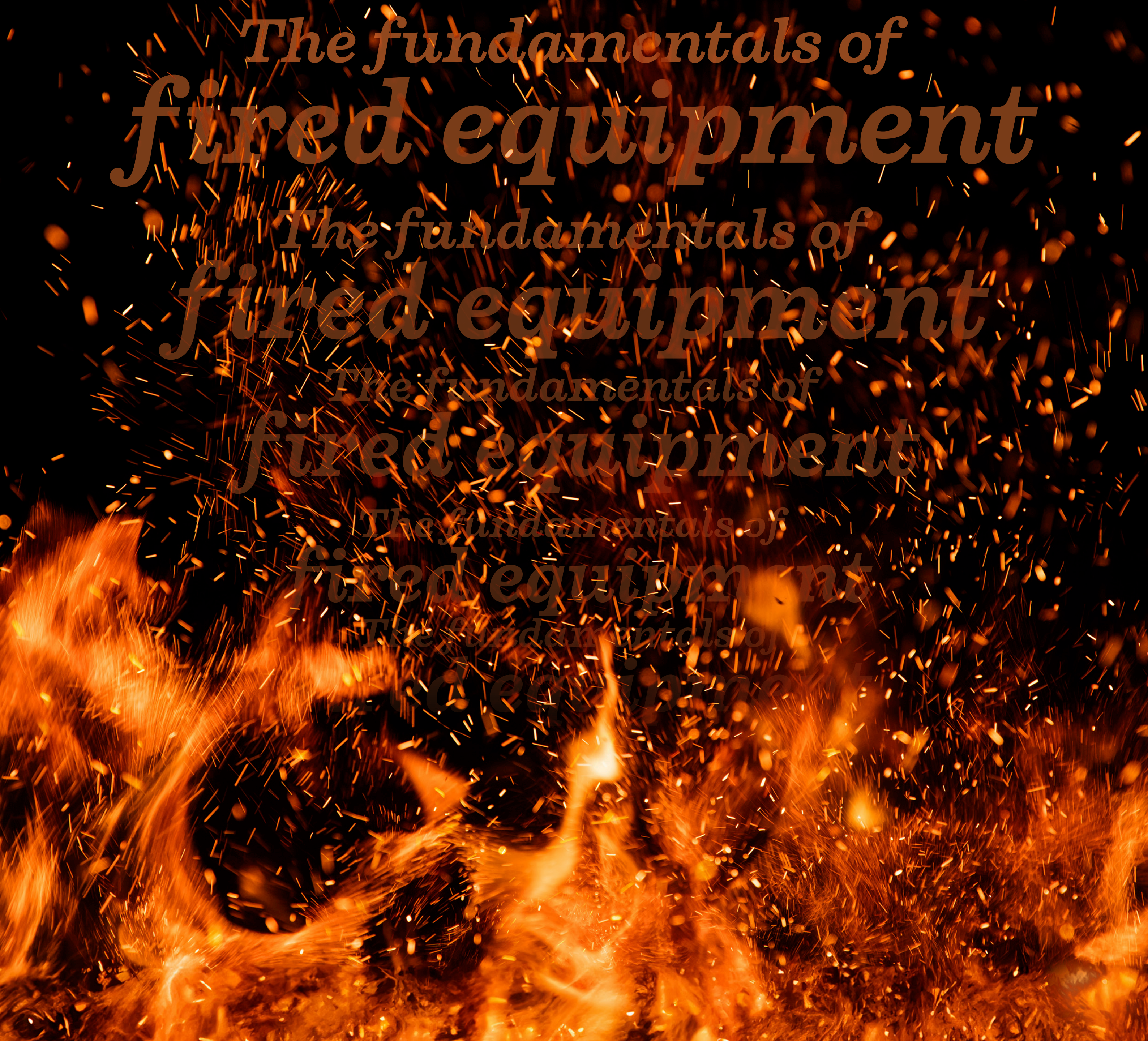
The fundamentals of fired equipment

Sreeram Krishnan, Zeeco, Inc., explores safety systems for fired equipment in the LNG industry.

Fired equipment can be found in most operating facilities around the world, regardless of the industry. Technically, fired equipment is defined as any device that combusts fuel to generate heat or energy. This article will specifically focus on three types of fired equipment commonly used as safety, process, or emissions control devices within the LNG industry: flares, incinerators, and fired heaters.

Each of these combustion devices can be utilised in a variety of different LNG applications, from upstream natural gas production and liquefaction to downstream transportation, storage, and regasification. Despite their numerous uses, fired equipment does tend to have a reputation for being among the more specialised and complex units within any operating facility.



Still, their fundamental design principles are actually very simple. Even the name 'fired equipment' is pretty straightforward – fire is literally used to operate the equipment.

Although the word 'fire' can have negative connotations in the plant operations and maintenance world, fired equipment systems are some of the safest units within any operating facility. This article will address the specific engineering codes, standards, and safety features commonly implemented into the design of flares, incinerators, and fired heaters within the LNG industry. It is also important to have the ability to distinguish between these three major types of fired equipment items, so this article will highlight the similarities and differences between each one. Although they are used in similar applications, these combustion devices differ in overall design, performance, and operation.

Flares

When driving by an LNG plant at night, it might be possible to see a reddish-yellow flame seemingly suspended in the air – the source of this flame is most likely an elevated flare.

There are a wide variety of flare systems that can be found in petrochemical plants and LNG facilities around the world. Still, the most common are elevated flares, multi-point ground flares (MPGF), and enclosed ground flares (EGF). In general, flares are considered the most responsive and versatile type of fired equipment compared to an incinerator or fired heater. Flares boast significantly higher turndown rates and can also combust and destroy a sudden, large volume of volatile gases or liquids at destruction removal efficiencies (DRE) of 98% or greater. For those reasons, flares are commonly used as backup or emergency pressure relief devices at an LNG plant or operating facility to protect plant assets and personnel.

Two critical design features must be considered for a flare – a continuous purge and a safe and reliable pilot and ignition system. Nitrogen or fuel gas must be continuously purged through the flare and header piping to prevent oxygen ingress, which could potentially result in an inadvertent accumulation of highly flammable gases inside the flare header. If the flare's pilot ignites these gases, a flashback or explosion event could occur, posing additional risks to plant personnel and surrounding equipment. A safe and reliable pilot and ignition system is equally as important as a flare's continuous purge because the pilot system ensures a continuous and stable pilot flame is maintained at all times. If the pilot flame is extinguished and an emergency flaring event occurs, hazardous waste vapours from the upstream process could be vented to the atmosphere without being properly combusted and destroyed. Those vapours could be highly explosive and toxic in nature, which could pose additional safety risks to plant personnel and nearby residents.

In order to prevent flame failure, ZEECO® flare pilots have been developed and tested under the most severe global weather conditions to ensure that they can produce and maintain a continuous and stable flame at all times – even in hurricane-level winds and rain. Flame detection devices such as thermocouples and the ZEECO VerifEye™ system are most commonly used to detect and confirm the presence of the flare's pilot flame. However, more complex devices such as the ZEECO FlareGuardian™ and ViZion™ can be used to detect both the flare's pilot and primary flames. These devices can also monitor and control key performance metrics such as combustion efficiency and smoke opacity.

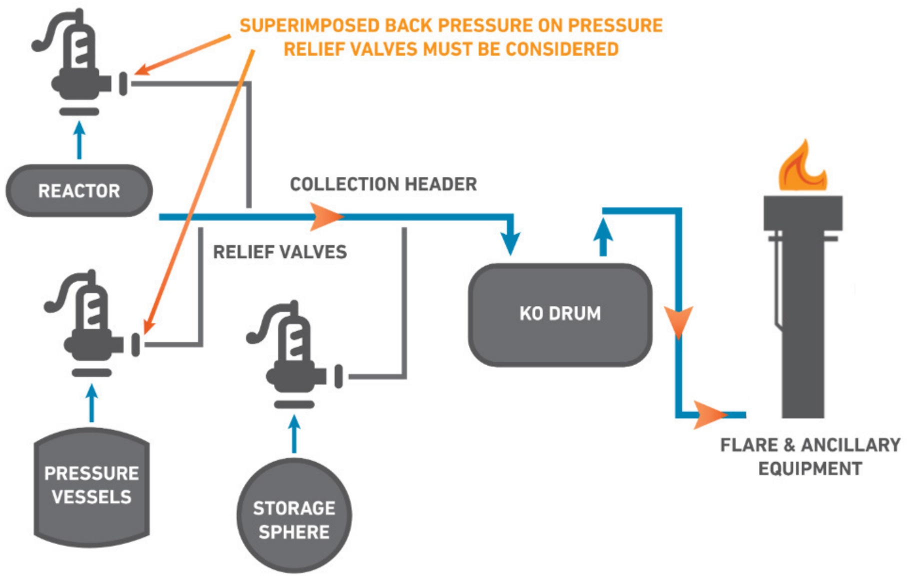


Figure 1. Typical emergency pressure-relief flaring system.

It is also common for a flare to be equipped with an ignition and control system certified for use within a Class I, Division II hazardous area and designed per API-521 and 537 standards, providing plant personnel with inherently safe methods to ignite and operate the unit. Additional safety devices, such as detonation or deflagration arrestors, can also be implemented into the design of a flare system. However, these items are not as crucial as the others already discussed. That said, it is important to evaluate the overall necessity of these devices for every flare application based on its individual process and supply conditions.

Incinerators

People often wonder whether there is a difference between an incinerator and a thermal oxidiser, but these terms are used interchangeably to describe the same type of fired equipment. It can be difficult to identify an incinerator in broad daylight, let alone at night. Unlike the exposed flame of an elevated flare, an incinerator's flame is enclosed and is not externally visible during operation, making it hard to distinguish within any given refinery or LNG plant.

Incinerators are typically regarded as the most complex and highly automated fired equipment devices in comparison to a flare or fired heater. While incinerators are not as responsive as a flare, they are capable of combusting and destroying multiple continuously generated gas or liquid feed streams at very high temperatures, allowing them to boast impressive DREs of 99.9999% or higher. Incinerators are also commonly supplied with an NFPA-86 compliant controls and instrumentation package and a burner management system (BMS) with a programmable logic controller (PLC) that governs the unit's purge, ignition, heat-up, waste introduction, and shutdown sequence. NFPA-86 standards serve the same general purpose for incinerators that API-537 standards do for flares – providing plant personnel with inherently safe and easy methods to operate the unit without assuming additional risks.

One of the most critical safety features stipulated by NFPA-86 is the pre-ignition purge, which removes potentially combustible compounds from the incinerator prior to ignition. Flame scanners are a common safety feature that verifies the presence of both the pilot and main burner flames during ignition and after waste introduction. Blower/fan run signals, combustion air flow switches, and setpoint temperature and fuel pressure trips are also critical safety features that are governed by NFPA-86 and are commonly implemented into the incinerator's BMS to further ensure personnel and equipment safety.

Some of the largest and most complex incinerator systems worldwide are found at natural gas liquefaction plants. These systems can be equipped with a wide range of post-combustion treatment devices that enable the incinerator to comply with more stringent SO_X, NO_X, and CO air permitting requirements. It is also common for these systems

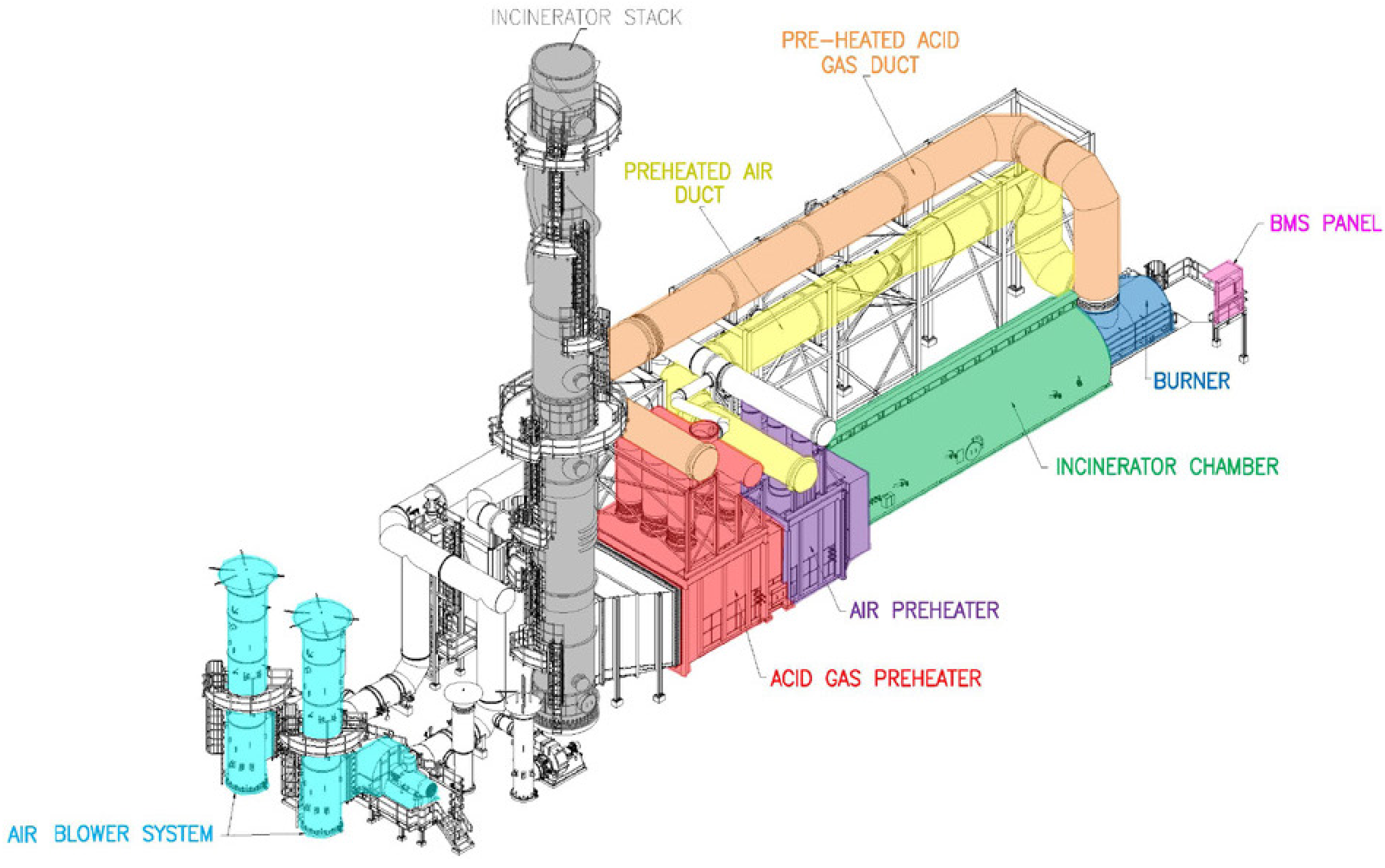


Figure 2. Complex incinerator system with acid gas and air preheaters (WHRU).

to be supplied with waste heat recovery units (WHRU) that utilise hot flue gases from the incinerator to reduce overall fuel consumption and generate utilities required for downstream LNG processes.

Complex incinerator systems provide the end user with a significant number of benefits but come at a price. Larger and more diverse equipment packages are usually governed by more stringent engineering codes and standards to further ensure the safety of personnel and equipment, which is why they are commonly assigned with a safety integrity level (SIL) 2 or 3 classification following completion of the process hazard analysis (PHA) or hazard and operability study (HAZOP). Post-combustion treatment devices and WHRUs usually contribute to higher internal static operating and design pressures that commonly require more stringent mechanical and structural design criteria, such as those listed in ASME Section VIII and Section I design codes. It is also common for blowers/fans within these systems to be designed per API-560 or 673 standards, which require a higher level of margin on both design flow rates and pressures, and require additional instrumentation items for monitoring and control purposes. Keep in mind that while these design codes and standards are not necessarily applied to all complex incinerator systems within the LNG industry, every system should be evaluated based on its specific application and service.

Fired heaters

Fired heaters are very similar to incinerators in design and overall complexity and are also commonly used in downstream LNG processes, such as glycol dehydration and regasification.

This type of fired equipment combusts fuel within a radiant section to generate hot flue gases that transfer heat into a series of tubes or coils within the convective section. These coils typically contain a liquid heat-transfer fluid such as Therminol®, which is eventually distributed to various downstream LNG processes. It is also possible for fired heaters to combust waste byproducts from other processes, but unlike an incinerator, they are usually limited to a single exothermic waste gas that only accounts for a maximum of approximately 10% of the total system's heat release. This is done to ensure that a continuous and stable burner flame is maintained at all times. Flue gases at the outlet of a fired heater are discharged to the atmosphere at DREs of 99.9% or greater, and, like an incinerator, fired heaters can be equipped with selective catalytic reduction to further reduce NO_X emissions if needed.

Fired heaters are typically designed per API-560 standards and are usually supplied with an NFPA-87 compliant controls and instrumentation package and BMS PLC. Although NFPA-87 is specifically geared to fired heaters, it is similar to NFPA-86 – they both address the same general sequences and safety requirements, with a few differences. Skin-type thermocouples are additional safety devices that are commonly installed onto tube coils within the fired heater. These devices are used to monitor tube coil temperatures to prevent them from overheating or rupturing, which could result in an unsafe and unplanned release of hazardous hydrocarbons. Differential pressure transmitters can also be used for similar reasons – they reduce the overall likelihood of overpressure events within the fired heater casing that could result in the unplanned release of hazardous hydrocarbons.

Additional controls and instrumentation items can be implemented into a fired heater's BMS to further ensure personnel and equipment safety. For instance, oxygen analysers can be used as trim control devices to ensure that a minimum oxygen level is always maintained within the unit (usually ≥3 vol. %). Combustibles and/or methane analysers can also be implemented to monitor concentrations of volatile organic compounds within the flue gas products to prevent the potential release, accumulation, or ignition of hazardous hydrocarbons. These features are not exclusive to fired heater applications – they can also be utilised on an incinerator system for the same general purposes.

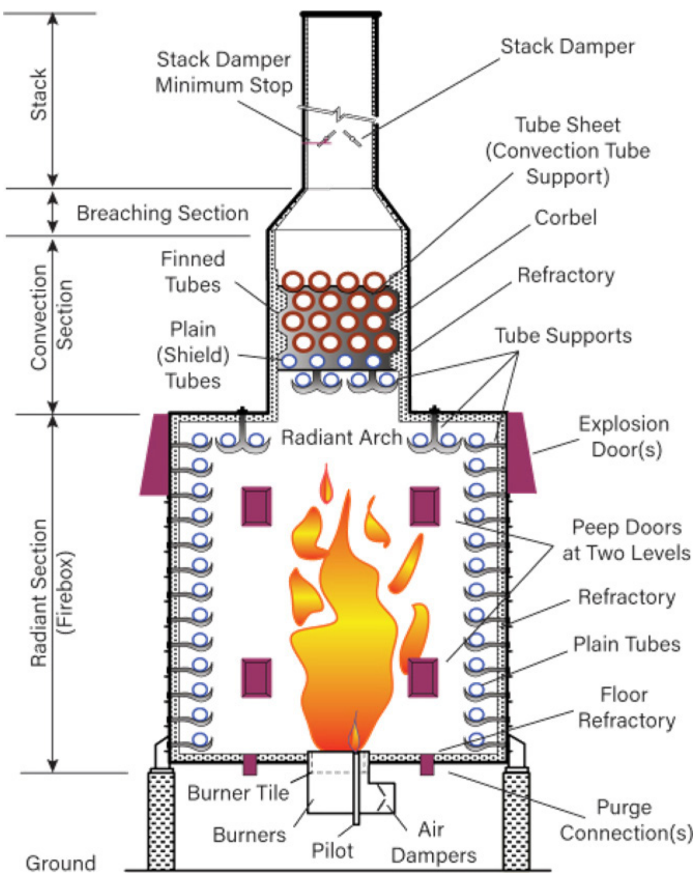


Figure 3. Typical direct fired heater components.

Conclusions

Fire can be dangerous, but that does not mean that fired equipment is inherently dangerous as well. A trusted design and manufacturing partner can make the choice less daunting, such as the experts at Zeeco which have nearly 50 years of experience designing custom flares, incinerators, and fired heaters.

These devices are safely operated every single day at countless operating facilities around the world. They are not only incredibly effective emissions control devices, but can also be used to produce or recover utilities for downstream processes at an additional benefit to the end user. **LNG**

Description	Flare	Incinerator	Fired Heater
General Features			
Typical LNG Applications	Back-Up / Emergency Relief	Natural Gas Liquefaction Glycol Dehydration Amine Regeneration SRU Tail Gas Treatment	Glycol Dehydration Regasification
VOC Destruction Efficiency(1)	≥ 98%	≥ 99.9999%	≥ 99.9%
Start-Up Time (Required)	Continuous / Instantaneous	≥ 12-24 hours(1)(2)	≥ 12-24 hours(1)(2)
Footprint / Plot Size(1)	Small	Large	Average
Draft Type	Forced(1) or Natural	Forced(1) or Natural	Forced, Natural, or Balanced
Design Codes / Standards	API-521	ASME Section VIII(1) ASME Section I(1) ASME STS-I (1) API-936 API-560	API-560
Controls System			
Type(1)(2)	PLC or DCS	BMS PLC	BMS PLC
Design	API-537	NFPA-86	NFPA-87
Safety Integrity Level	Not Applicable(1)	2(1) or 3	2(1) or 3
Hazardous Area(1)(2)	Class I, Div. II	Class I, Div. II	Class I, Div. II
Automation Level / Complexity	Low	Very High	High
Reactivity / Responsiveness	High	Average	Average
Waste Characteristics			
Source Type	Single	Multiple	Single
Supply Phase	Liquid or Vapor	Liquid and/or Vapor	Vapor Only
Supply Condition	Continuous or Intermittent	Continuous	Continuous
Heating Value (Min. Required)(1)(2)	Endothermic or Exothermic (≥ 200 Btu/SCF)	Endothermic or Exothermic (≥ 50 Btu/SCF)	Exothermic Only (≥ 300 Btu/SCF)
Fuel Characteristics			
Supply Phase	Liquid or Vapor(1)(2)	Liquid and/or Vapor	Liquid and/or Vapor
Consumption Level(1)	Low	Low	Low
Flame Characteristics			
Visibility (Source Location)	Visible (External)	Non-Visible (Internal)	Non-Visible (Internal)
Ignition Source (Continuous / Intermittent)	ZEECO® HSLF™ Pilot (Continuous)	ZEECO® AR/GS Pilot ZEECO® Direct Spark Ignitor (Intermittent)	ZEECO® JM-1S Pilot ZEECO® SM-1S Pilot (Continuous)
Detection Devices / Safeguards	Thermocouples(1) ZEECO® VerifEye™	ZEECO® ProFlame™ ZEECO® ProFlame+™	ZEECO® ProFlame™ ZEECO® ProFlame+™
Recovery & Treatment Options			
Waste Heat Recovery	Not Applicable / Available	Waste Heat Boiler Superheater Hot Oil Heater Air and/or Waste Preheater	Air and/or Waste Preheater
Post Combustion Treatment	Not Applicable / Available	Absorber / Scrubber SCR / SNCR ESP / Baghouse	SCR
Additional Design / Safety Features			
Flashback Prevention	Continuous Purge(1) Detonation / Deflagration Arrestors	Detonation / Deflagration Arrestors Differential Pressure Transmitters	Detonation / Deflagration Arrestors Differential Pressure Transmitters
Overpressure Prevention	Not Applicable	Differential Pressure Transmitters	Differential Pressure Transmitters
Safety / Emissions Monitoring Devices(1)(2)	ZEECO® FlareGuardian™ ZEECO® Contour™ ZEECO® ViZion™ ZEECO® IdentifEye™	Oxygen Analyzer Combustibles Analyzer Methane Analyzer	Oxygen Analyzer Combustibles Analyzer Methane Analyzer

(1) Most commonly considered for applications within the LNG Industry
(2) Alternatives may be available, depending on the Process Design Conditions for the specific application