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Milton Keynes Regional Committee

Flare System Design for Oil and Gas Installations

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Flare System Design for Oil and Gas Installations

Sometimes it is necessary to get rid of excess gas, and occasionally liquids from a facility. The safest way to do that is with the Flare System

What is a Flare System?

- A Flare System is an arrangement of piping and specialised equipment that collects hydrocarbon releases from relief valves, blowdown valves, pressure control valves and manual vents and disposes of them by combustion at a remote and safe location

- A gas flare, or flare stack, is a gas combustion device used in industrial plants such as petroleum refineries, chemical plants, natural gas processing plants, and at oil or gas production sites with oil wells, offshore oil and gas rigs/platforms and landfills

Additionally;

- A well test burner disposes of hydrocarbons during drilling operations either onshore or offshore

Gas Flaring

- Gas flaring is the controlled burning of natural gas that cannot be processed for sale or use because of technical or economic reasons.
- Gas flaring can also be defined by the combustion devices designed to safely and efficiently destroy waste gases generated in a plant during normal operation
- Sources include associated gas, gas plants, well-tests and onshore and offshore processes
- Gas is collected in piping headers and delivered to a flare system for safe disposal
- A flare system can consist of multiple flares to treat the various sources of waste gases i.e. HP and LP Flares, Cold Flares, Wet and Dry systems
- Most flaring processes usually take place at the top of a stack by burning of gases with a visible flame
- The height of the flame depends upon the volume of released gas, while brightness and colour depend upon composition.

Onshore and Offshore Flare Systems

Gas flaring systems are installed on onshore production fields, offshore platforms, on transport ships and in port facilities, at storage tank farms and along distribution pipelines. So what are the main differences between an onshore (refinery) Flare System and an offshore (platform) Flare System?

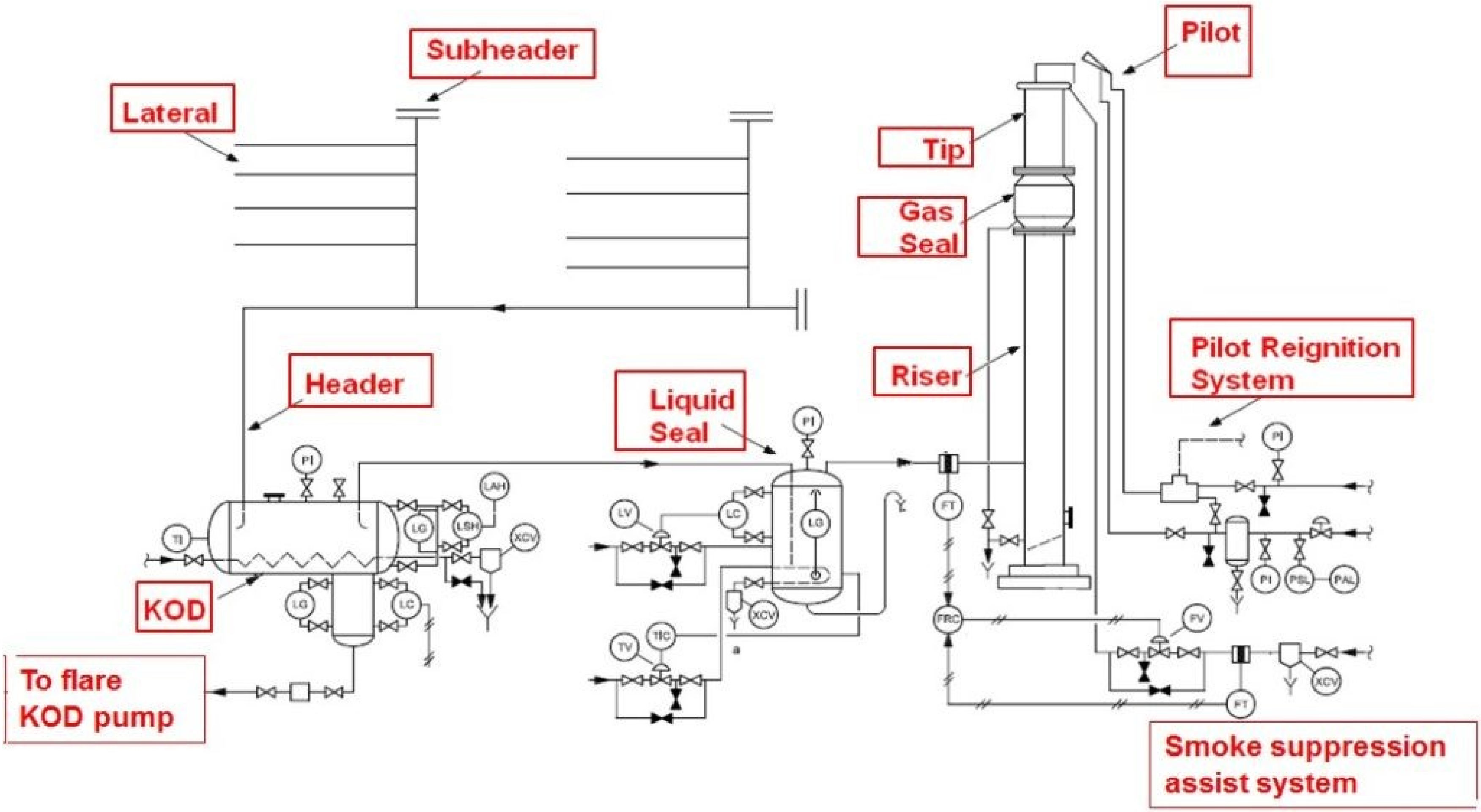
The equipment required for both onshore and offshore Flare Systems is essentially the same. However:

- Noise and radiation is more of a problem for an offshore facility due to the closer proximity of personnel
- More space availability for an onshore facility allows flare tips to be located away from the main process site
- Additional space onshore allows for the installation of spare flares if required and the potential use of Ground Flares

Typical components of a Flare System include:

- Pressure safety valves, blowdown and manual vent valves, pressure control valves, tail pipes, sub-headers and headers inside battery limits (ISBL)
- ISBL flare knockout drums (KODs) and pumps
- Outside battery limits (OSBL) main flare headers
- Flare area KODs and pumps
- Liquid seal drums (offshore, KOD's are generally designed for internal explosion to eliminate the need for a seal drum)
- Molecular or velocity seals
- Header end and emergency gas purge
- Flare risers, tips and associated hardware (fuel gas, ignition, steam or air)
- Associated monitoring and safety systems including infra red monitors

Onshore Flare System



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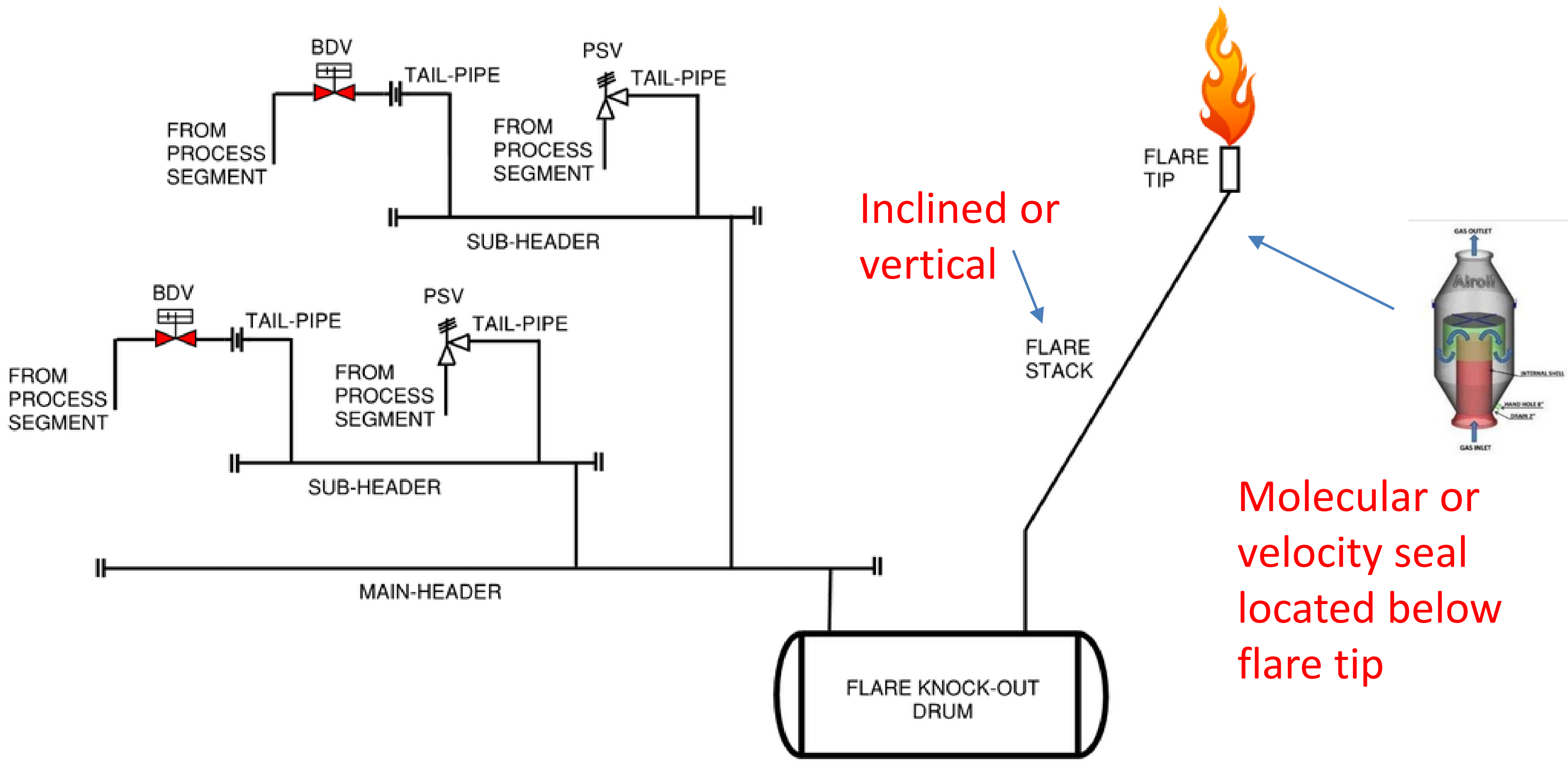
Offshore Flare System



Design Requirements for a Flare System

Flare systems provide for the safe disposal of gaseous wastes. Depending on local environmental constraints these systems can be used for:

- Extensive venting during start-up or shutdown
- Venting of excess process gas
- Handling emergency releases from safety valves, blowdown and venting systems
- Causes of emergency relief are many and can include fire, blocked outlets, utility failures (steam, electricity, instrument air, cooling medium etc.) abnormal heat input, chemical reaction and so on

Flaring Scenarios

Fire relief
- Example – PSV to protect separator in the event of a pool fire under the vessel

Start-up flaring
- Example – flaring of separator gas prior to compressor start

Emergency depressurisation / blowdown
- Example – Requirement to depressurise system due to confirmed fire

Manual venting
- Example – final depressurisation of vessel prior to purging and entry

Early Stage Design Considerations

The requirement for typical greenfield projects is to have a preliminary plot plan and to achieve a Class 4 (+/– 30%) estimate. At this stage, the estimate of flare system capacity and configuration is based on data from similar past projects and any local regulatory requirements. High-level flare system configuration decisions should be taken at this stage. Typically, such decisions include:

- Ground vs. elevated flare
- Segregation and number of flares [e.g., high pressure, low pressure, acid gas flare, low temperature]
- Sparing and maintenance requirements
- Mounting flares on a common derrick vs. a mix of derrick and guy-wired flares, etc.

HP or LP Flare?

Equipment connected to a flare system for relief, venting or blowdown purposes will be connected to either a high pressure flare or a low pressure flare

In general, equipment with a design pressure > 10 barg will be connected to an HP Flare system featuring:

- High allowable back pressure
- Reduced header sizes
- High DP Sonic flare tip
- Typical DP for a sonic flare tip is 2 - 4 bar

HP or LP Flare?

In general, equipment with a design pressure < 10 barg will be connected to an LP Flare System featuring:

- Low allowable back pressure
- Increased header sizes
- Low DP pipe type or subsonic flare tip
- Typical DP for a pipe type flare tip is 0.2 – 0.5 bar

Why not combine all flaring requirements into a single (LP) Flare System? The arguments against include:

- Inefficient and very large LP tips
- Excessive noise and flare radiation
- Very large header sizes
- Excessive smoke generation
- Generally uneconomic

Typical Flare System Design Considerations:

- Flow Rate
- Temperature
- Header sizing
- Back pressure
- Smokeless operation
- Flash back protection
- Ignition system
- Fuel gas system
- Location
- Unignited gas dispersion
- Environment

Flow Rate and Header Sizing

Primary considerations for calculating the size of the flare pipework include:

- Relief and blowdown valve flowrates
- Flare tip back pressure
- Allowable velocity of gas in network
- Set pressure of relief device
- Higher set pressures = increased allowable back pressures and reduced line sizes
- Calculated back pressure will determine the type of relief device selected

Header Design Considerations

The architecture of the flare network will depend on the layout of the plant

- System architecture will affect system back pressure and relief device selection
- To minimise noise and vibration, gas velocities in flare headers should not exceed 0.5 Mach
- Similarly relief valve tail pipes should not exceed 0.7 Mach
- Sub headers for different areas i.e. compression area, separation area, gas treatment area
- Purge gas injection required at each header end to ensure no air can enter the system through the flare tip

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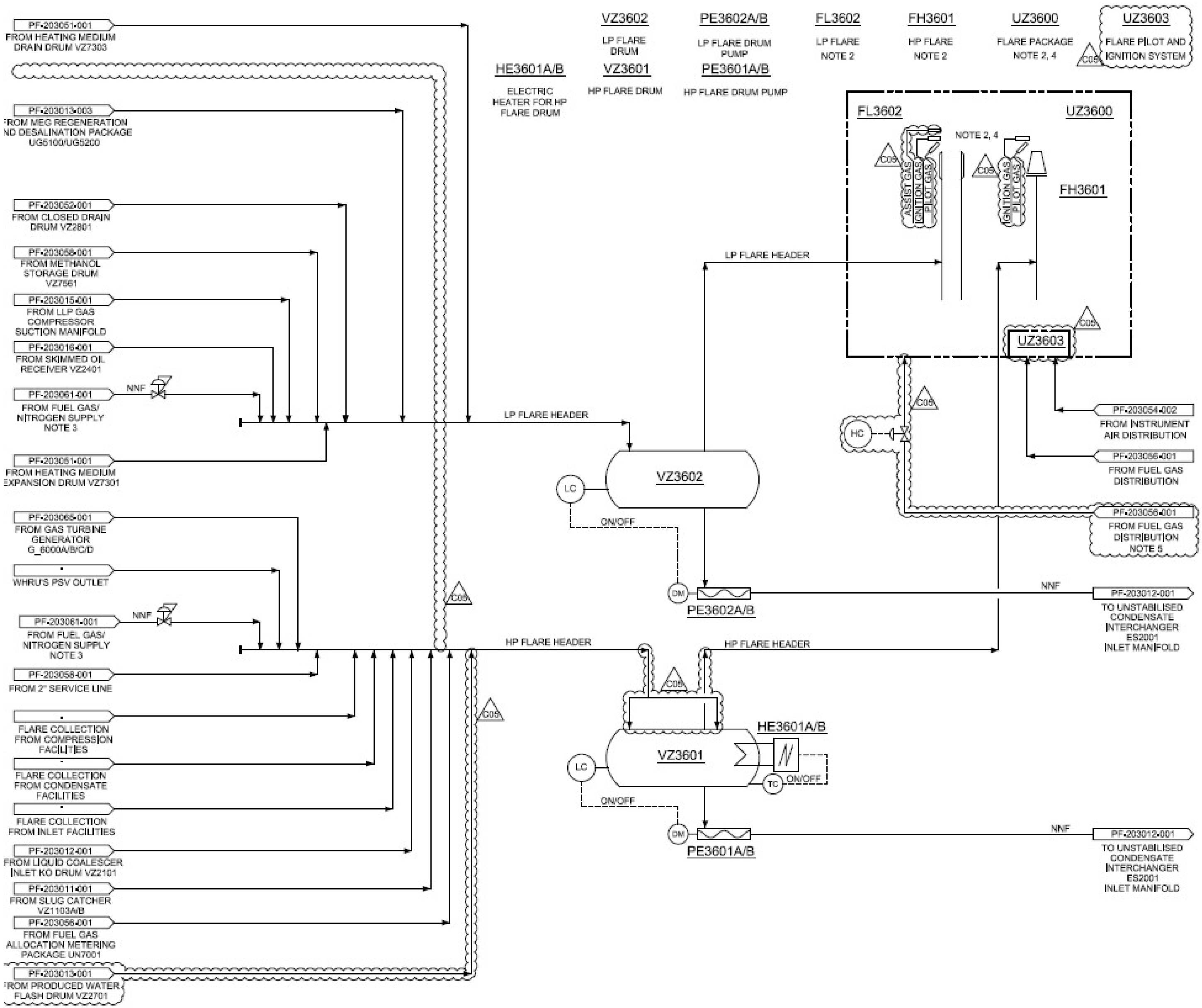

Typical HP/LP Flare System arrangement

Types of Relief Valve

Various types are available including conventional spring loaded, balanced bellows, pilot and three way pressure/vacuum

- Conventional spring loaded valves – suitable for back pressures of no more than 10% of set pressure
- Balanced bellows valves – suitable for back pressures of up to 50% of set pressure
- Pilot valves – suitable for installations where the pressure drop in the inlet pipework to the valve cannot be reduced below 3% of set pressure
- Pressure/Vacuum valves – for pressure and vacuum relief in a single body - generally installed on storage tanks
- Rupture discs – not considered further here as they are not generally specified except for specific applications such as tube rupture in heat exchangers where the rate of pressure rise in the protected equipment can be very high

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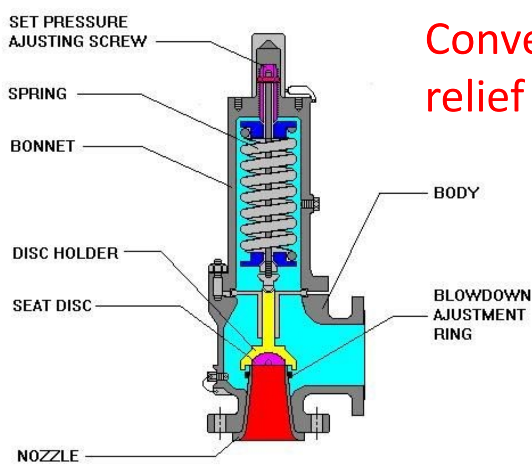
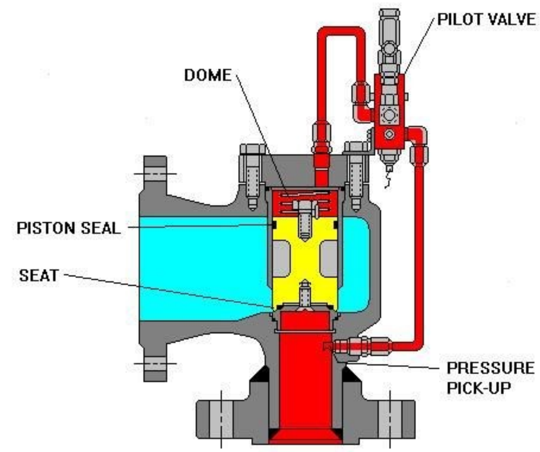
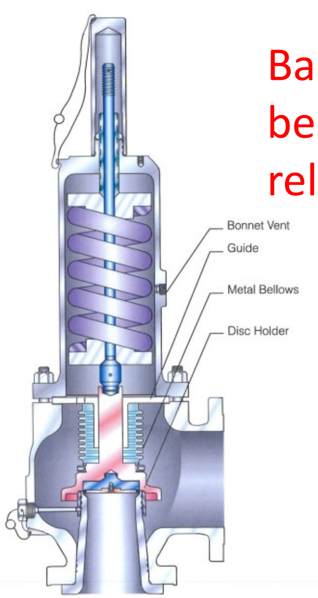


Conventional relief valve

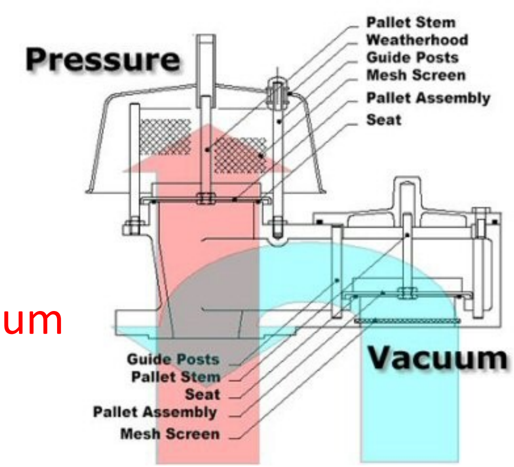


Pilot relief valve



Balanced bellows relief valve

Pressure/vacuum valve



Temperature and Materials

- High pressure relief or blowdown into a Flare System can result in very low temperatures due to the Joule-Thomson expansion effect.

  N.B. The Joule-Thomson effect describes the temperature effect of the adiabatic expansion of a real (not ideal) gas through a valve or porous plug

- It is therefore necessary during design to ensure that all potential low temperature effects are considered and appropriate materials selected
- For low temperatures down to -29C, select CS. Below -29C, select LTCS. For lower temperatures select SS316 or suitable grade of SS
- On the other hand it is also necessary to ensure that the Flare System is designed for the effects of high temperature during, for example, fire relief. Fire relief temperatures can be very high

Flare Knock Out Drum

Primary Duty

- To separate bulk liquid from gas
- To limit liquid droplet size entrained with gas to the flare
- To provide adequate residence time for liquid

Sizing Basis

- Based on API RP 521
- Stokes Law separation of liquid droplet size of 300-600 microns considering the design case for the flare
- 20-30 minutes of liquid hold-up time based on a relief case that results in maximum liquid
- No internals to facilitate separation and to eliminate potential for blockages
- Many orientations / options possible, horizontal KODs most preferred
- Liquids removed by Flare Pumps

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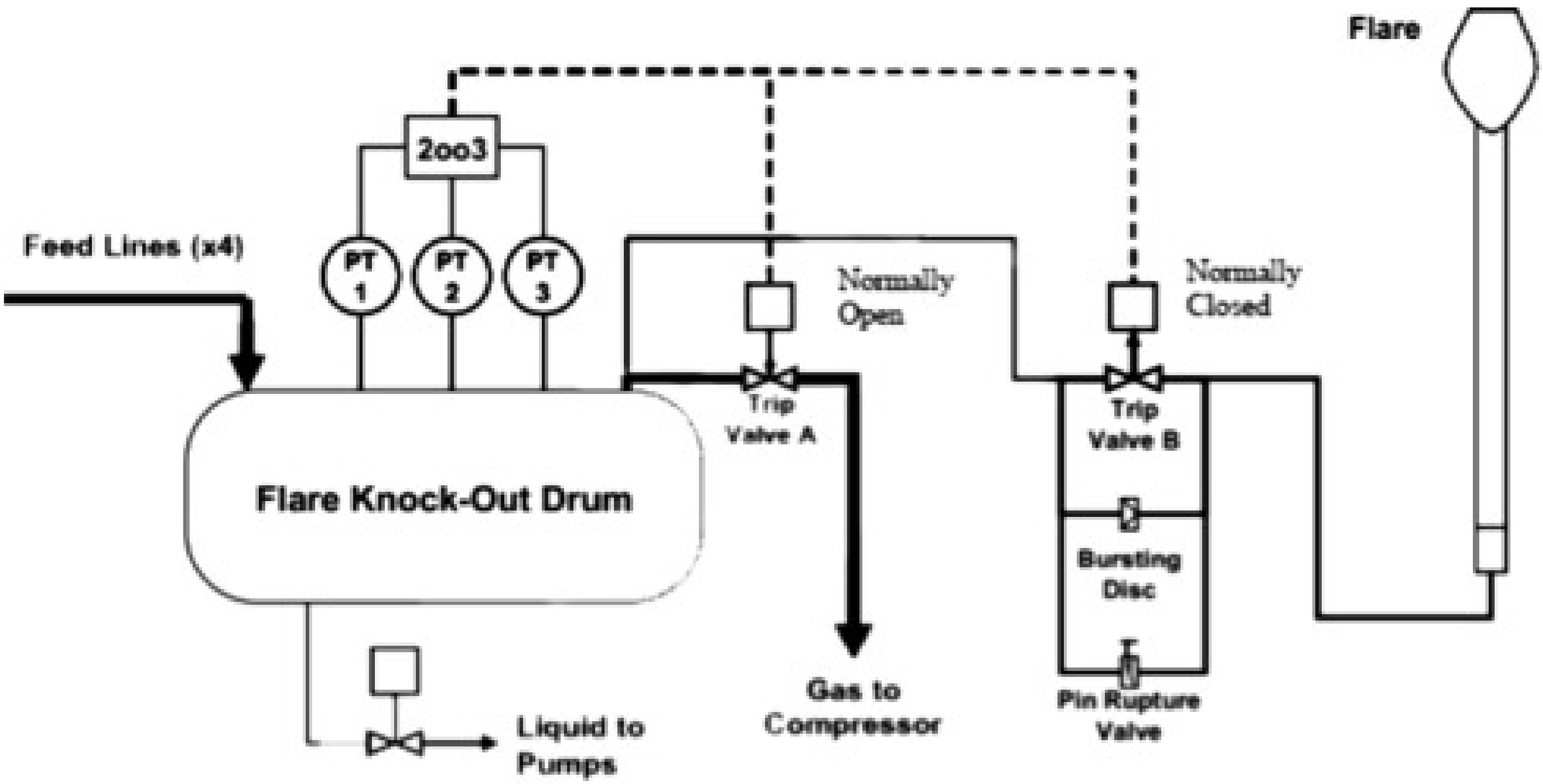
Flare Knock Out Drum and Flare Gas Recovery



Flare Seal Drum

Primary Duty

- To prevent flashback from flare tip back to flare headers
- To avoid air ingress into flare system during sudden temperature changes and to maintain positive system pressure

Design Specifications

- Water as liquid sealing fluid not recommended for extremely cold releases; water-glycol mixtures of sufficient concentration used instead

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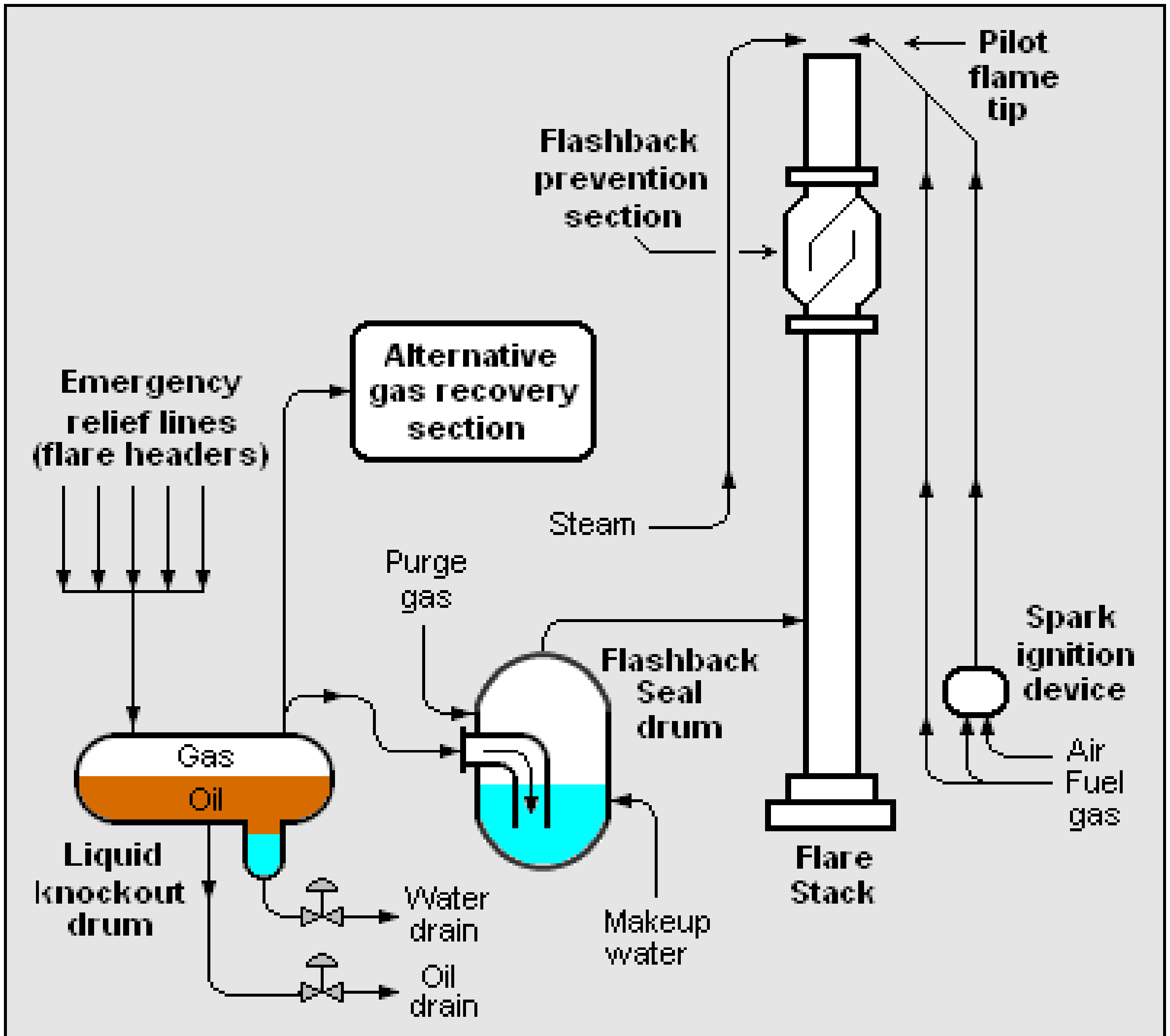
Flare Seal Drum



Flare Tips - Smokeless Operation

- The apparent density or opacity of smoke is defined as the Ringelmann number where 0 = clear air and 5 = totally opaque
- A low Ringelmann number is easier to achieve for a sonic or HP tip and harder to achieve for a pipe type or LP tip
- Most applications specify a Ringelmann number of 0 or 1
- This can be hard to achieve at low flare rates and therefore steam or air can be injected to reduce the smokiness

Flare Tip Design

Various types of tip are available depending on the location and specific design requirement

- Sonic flare (Coanda type)
- Pipe type (sub sonic) flare
- Combination flare
- Steam or air assist

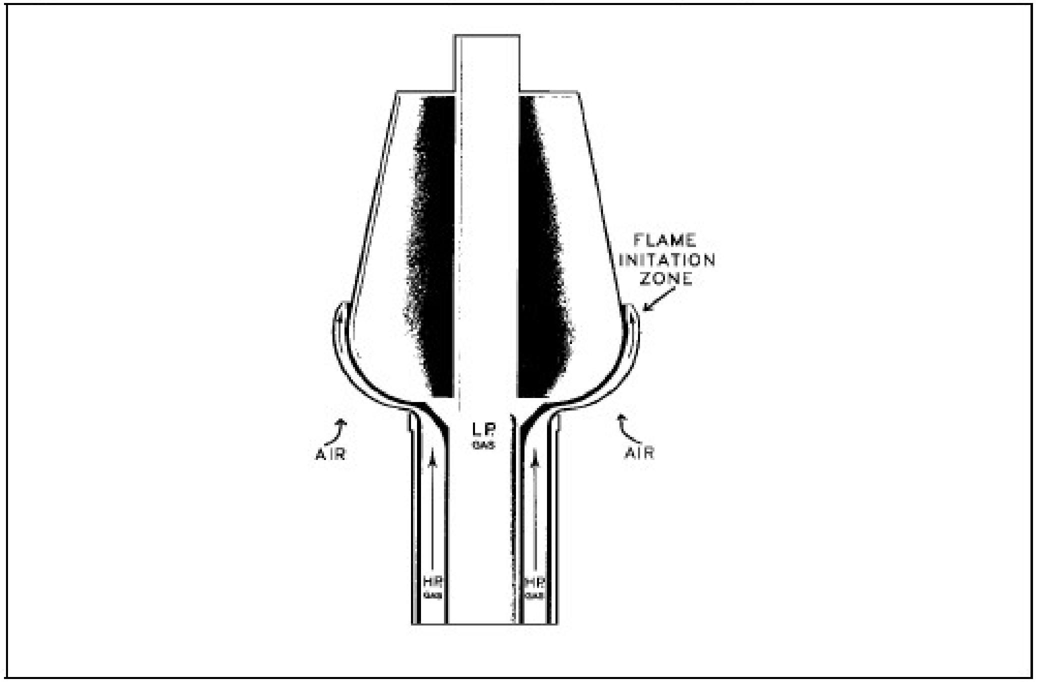
Sonic flares are usually employed for HP systems where available pressure is high. The emissivity (or F factor) of a sonic flare at between 0.07 – 0.15 is generally much lower than a pipe type flare resulting in reduced radiation levels for a given gas rate and therefore a lower flare stack . Emissivity is the fraction of heat generated at a flare tip that is radiated to the surroundings

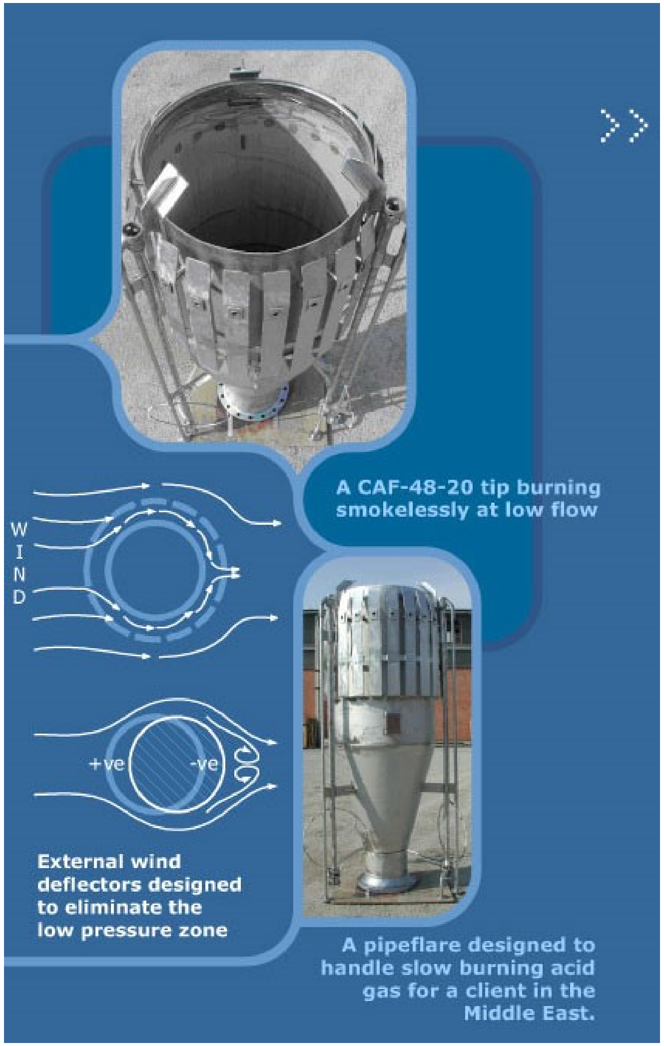
Pipe type flares are usually employed for LP systems where available pressure is low. The typical F factor for a pipe type tip is generally between 0.2 – 0.35

Flare Tips

Coanda Flare Tip

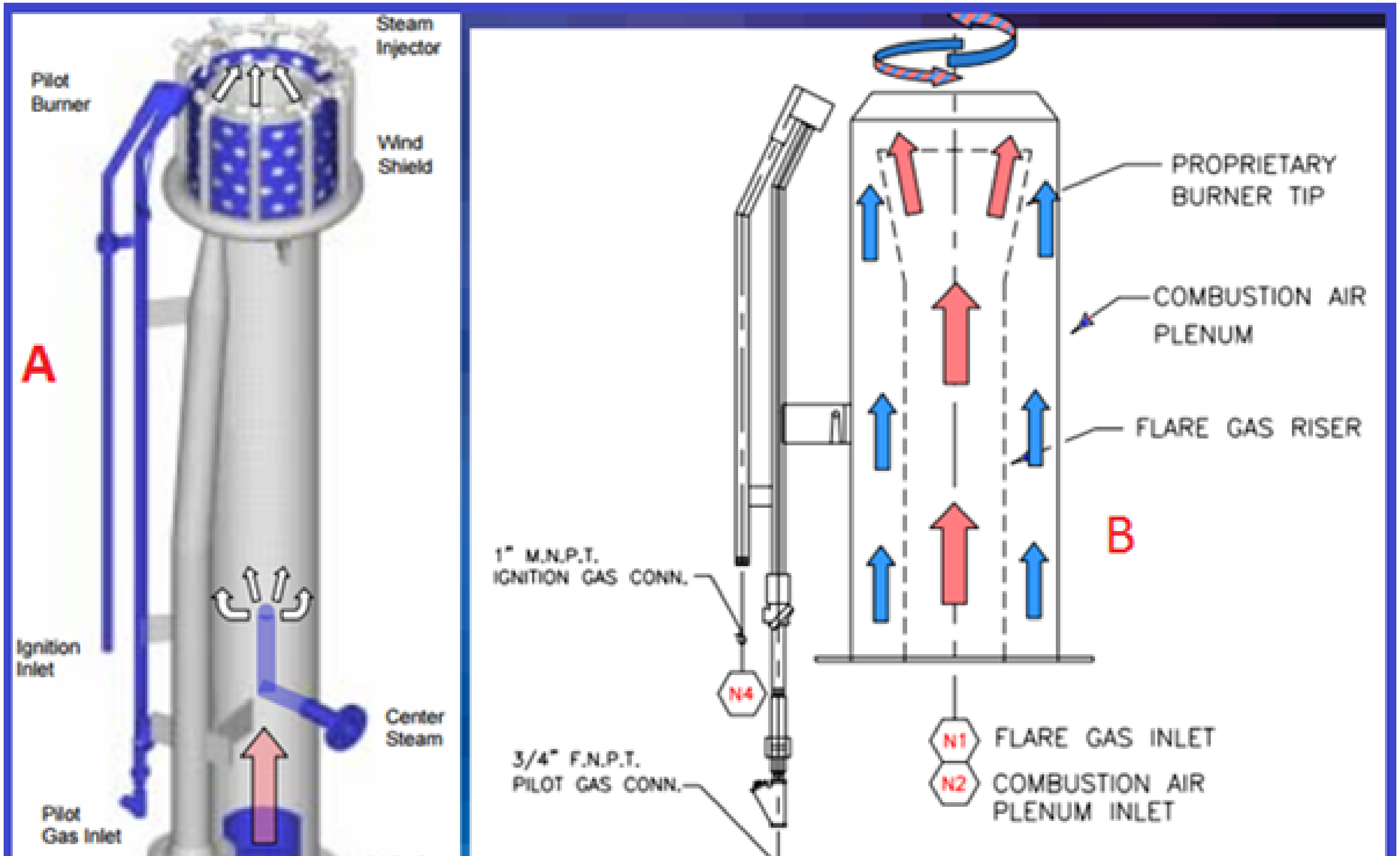
Fig. 1200-30 Coanda-Profile Flare *(Courtesy of Kaldair, Inc.)*





Pipe Type Flare Tip

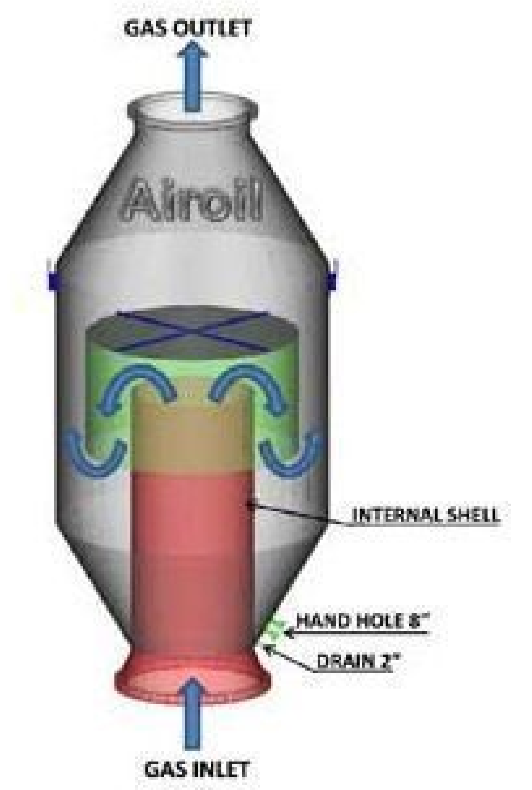
Steam and Air Assisted Flare Tips



A: Steam Assisted; B: Air Assisted

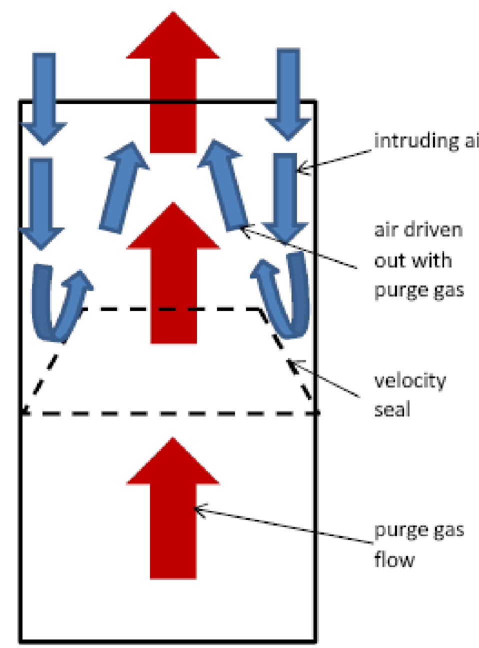
Molecular (Purge Reduction) Seal

- The molecular seal is located just below the flare tip and is designed to prevent the ingress of air into the flare stack at low flow rates
- The molecular seal minimises the amount of continuous purge gas usage
- Gas normally flowing in an upward direction is turned through 180 degree to the direction of flow. Gases lighter then air will tend to collect in the upper bend sealing off the stack against the back flow of air. Heavier gases will tend to settle in the lower bend
- A small continuous bleed of gas must be maintained to ensure that air does not penetrate the seal
- A drain connection is required in the base of the outer cylinder for the removal of any accumulated liquids



Velocity Seal

- The velocity seal work works on the premise that when air infiltrates the flare tip, it tends to hug the inner walls of the flare tip
- The velocity seal is a cone-shaped obstruction placed inside the flare tip so as to obstruct the infiltrating air from 'hugging the inner wall'
- Purge gas coming through the cone sweeps away the infiltrating air. This seal normally reduces the purge gas velocity through the tip to between 0.006 m/s to 0.012 m/s and maintains the oxygen level below the seal under 4-8% level
- However the normal purge gas requirement to prevent burn back of the flare tip is much higher than this.



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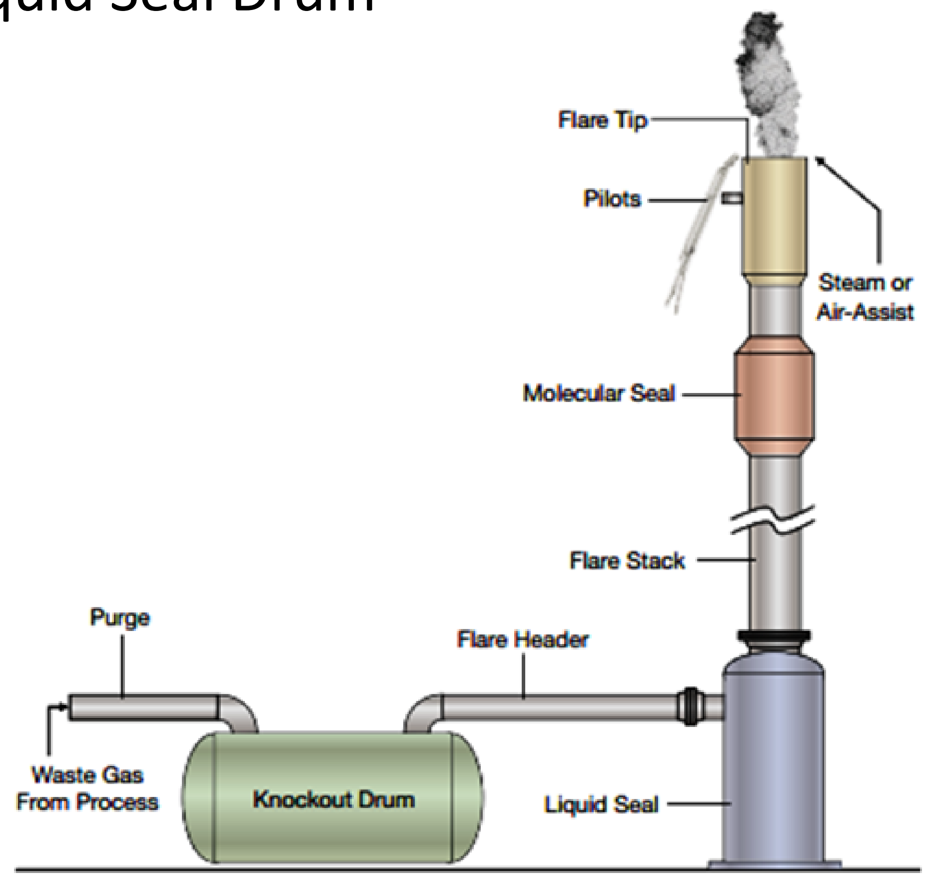
Air or Steam Assisted Flare Tip with Molecular Seal, Liquid Seal Drum and KO Drum



Flare Stack Design Considerations

- Radiation: Limit radiation, either continuous and peak, on off-site properties and persons, equipment, buildings and personnel on the installation. Applicable to impacted area, restricted area and equipment lay-out
- Flammable gas: Avoid ignition of a flammable gas cloud released from a cold vent or in case of flare flame out
- Toxic hazards and gas dispersion: (Mainly for H2S and SO2, but not limited to) limit the risk of a toxic gas cloud to reach off-site population, provide means of alarm and adequate protection to personnel present in the restricted area
- Noise: Limit both continuous and peak noise
- Stack height is determined by HSE group based on permissible radiation level as per project philosophy or API 521
- A taller stack will result in smaller sterile zone. The available sterile area generally sets the flare stack height requirement
- Locate process plant upwind of flare

Flare Stack Design

Onshore flare stack options include:

- Enclosed ground flare - The flare is surrounded by an enclosure to reduce external noise and radiation. Suitable for low and medium gas flows
- Open ground flare - Gas and liquids are released to flares on the ground. Surrounded by a radiation fence. Suitable for large gas flows
- Vertical elevated flare - More cost effective than ground flares which are expensive to build and service. Also require less ground space as the flame is elevated reducing ground level radiation
- Ground flares are equipped with several stages of burners, each set at a different pressure
- As the flare gas rate increases and the flare tip back pressure increases, more burners open up

Flare Stack Design

Offshore flare stack options include:

- Enclosed ground flare – Only really suitable for low flowrates. Not often installed offshore
- Vertical stack or inclined boom - The type of stack selected will depend on a cost comparison. Liquid carryover leading to possible ‘burning rain’ is more likely with a vertical stack
  - Gas flowing to the flare often contains entrained liquids, particularly during an emergency blowdown
  - If liquids are allowed to flow up the flare they will catch fire and come down as ‘burning rain’ creating a very hazardous situation around the base of the flare
  - ‘Burning rain’ is particularly dangerous on a platform due to the enclosed space. Despite this, some of the early platforms featured vertical stacks

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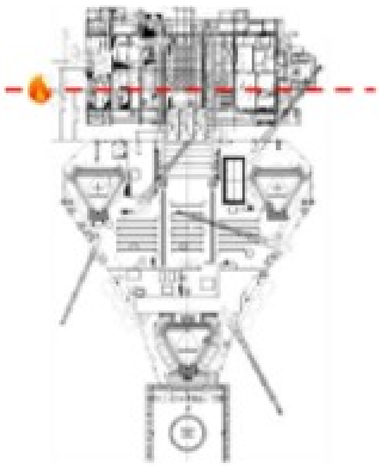
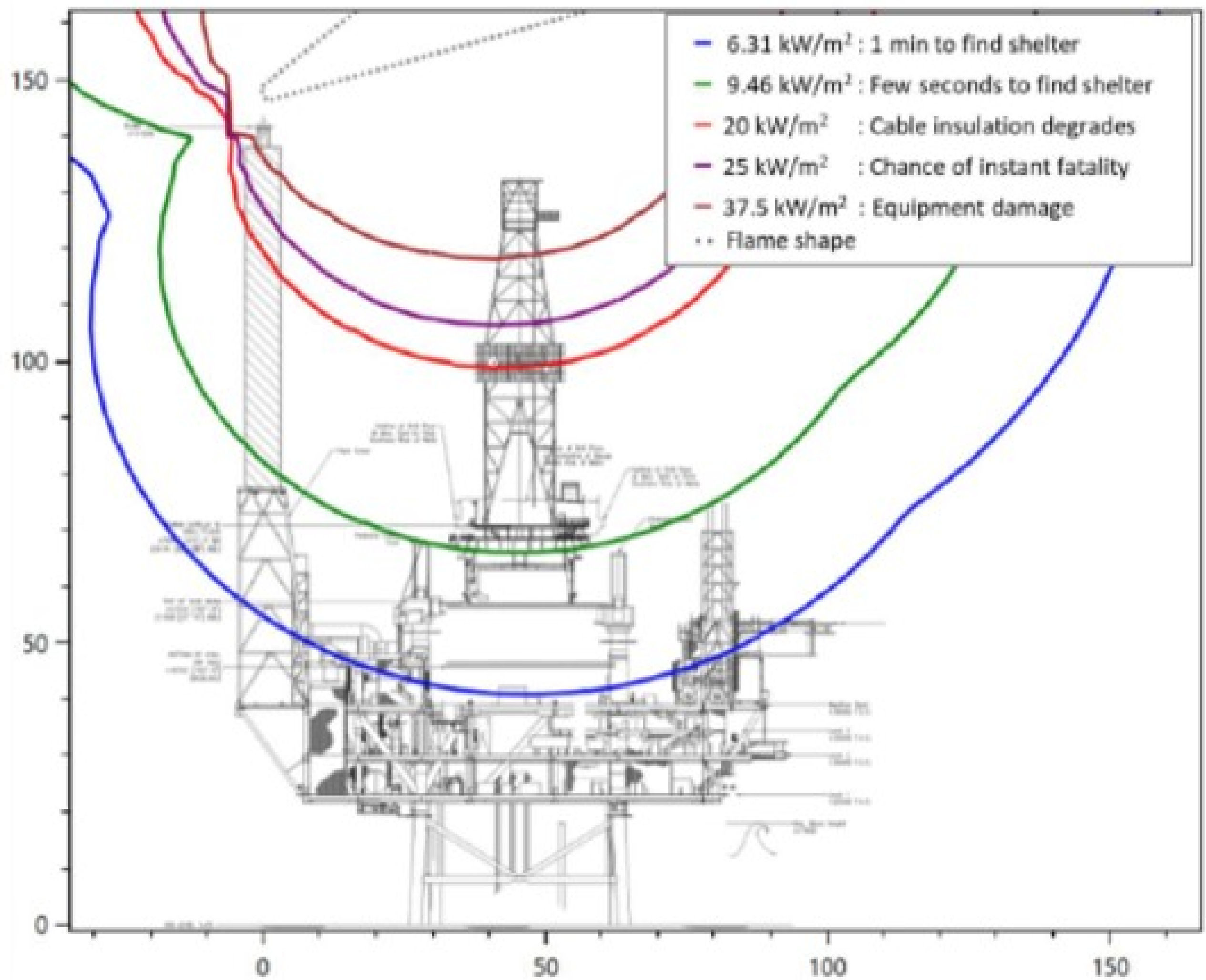
Flare Radiation

- To estimate the required height of a flare stack, normal practice is to generate radiation plots for various radiation levels
- The different radiation levels represent permitted exposure time of personnel to these radiation levels
- According to API RP 521, 1.58 kW/m^2 (500 $Btu/hr.ft^2$) is generally know as continuous full shift exposure, i.e., where personnel with appropriate clothing may be continuously exposed
- A radiation level of 4.73 kW/m^2 (1500 $Btu/hr.ft^2$) is considered the limit in areas where emergency actions lasting two to three minutes may be required by personnel without shielding but with appropriate clothing
- A radiation level of 6.31 kW/m^2 (2000 $Btu/hr.ft^2$) is considered the limit in areas where emergency actions lasting up to 30 seconds may be required by personnel without shielding but with appropriate clothing
- Solar radiation which varies from location to location must also be considered when generating the radiation plots

Flare Radiation Plots





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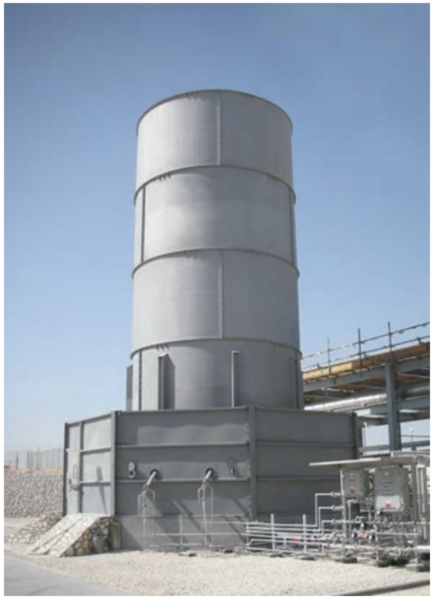
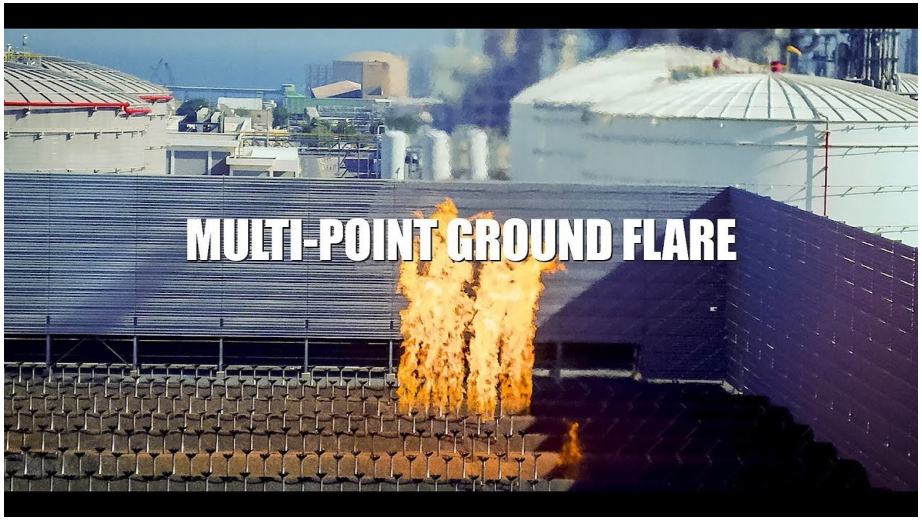
Onshore

Ground flare - enclosed



Elevated flare



Ground flare - open

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Offshore

Well test burner

Vertical flare stack

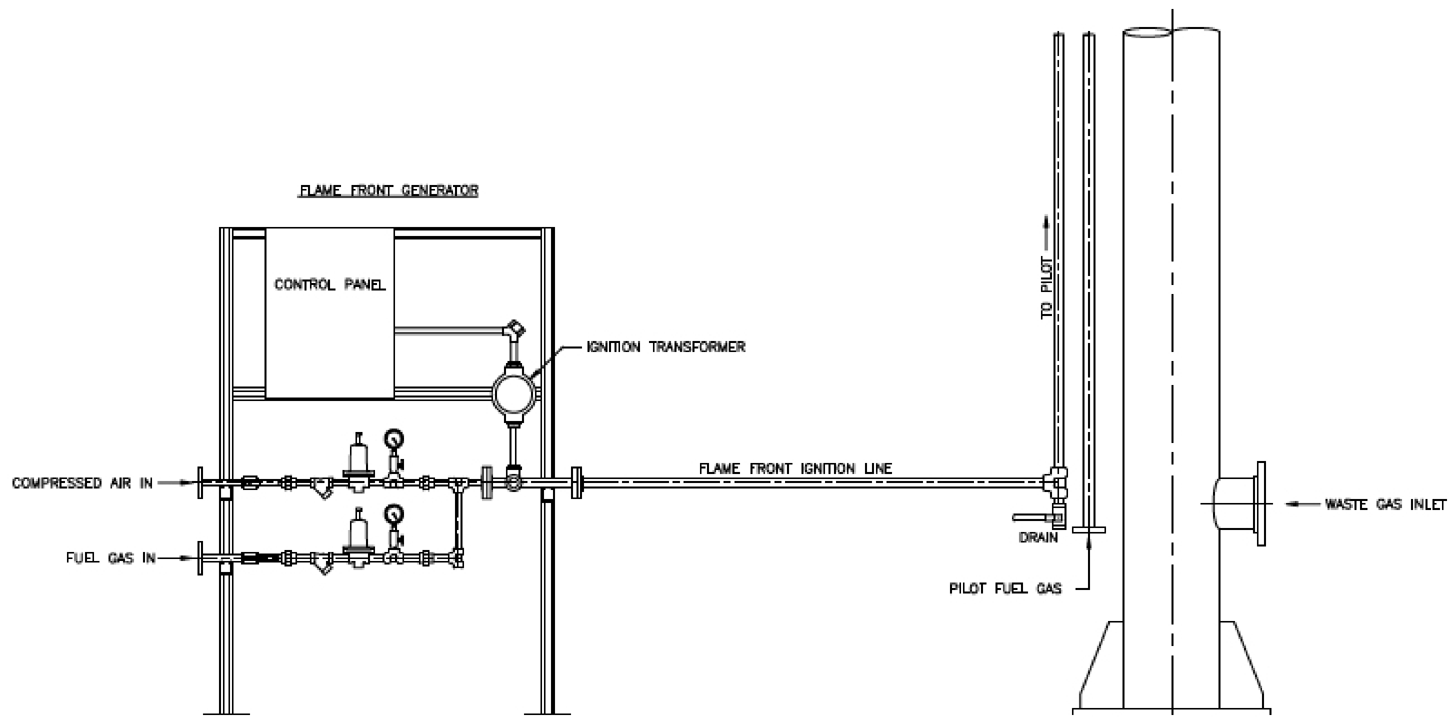
Inclined flare boom

Ignition Systems – Keep the Flame Burning!

- All onshore and offshore flares are equipped with strategically located ignition and continuous pilots to ensure the flare is ignited immediately there is a gas release
- Pilot burners are provided to ensure a continuous ignition source at the flare stack. The system consists of multiple pilot burners arranged around the flare tip, supplemented by remote controlled pilot ignition systems to ensure against flame failure
- Back up propane bottle rack provided to ensure pilots always have available gas
- Typical ignition systems are the flame front generator and the electronic ignition system
- Electronic ignition systems eliminate the need for flame front generation by introducing a spark within the pilot nozzle. They can be configured for either manual or automatic operation

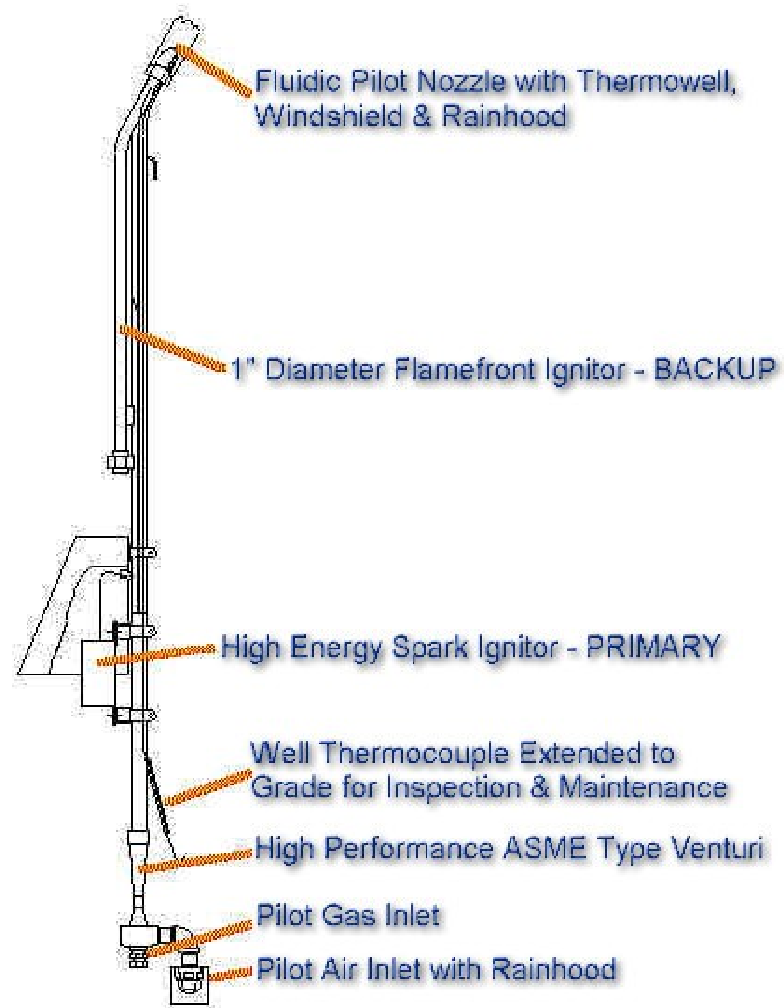
Flame Front Generator

A flame front generator is a system in which a gas/air mixture is introduced at ground level and flows up a one-inch line to the pilot burner. After filling this line with the mixture it is ignited by a spark. The resulting flame travels to the top of the flare where the pilot burner is ignited



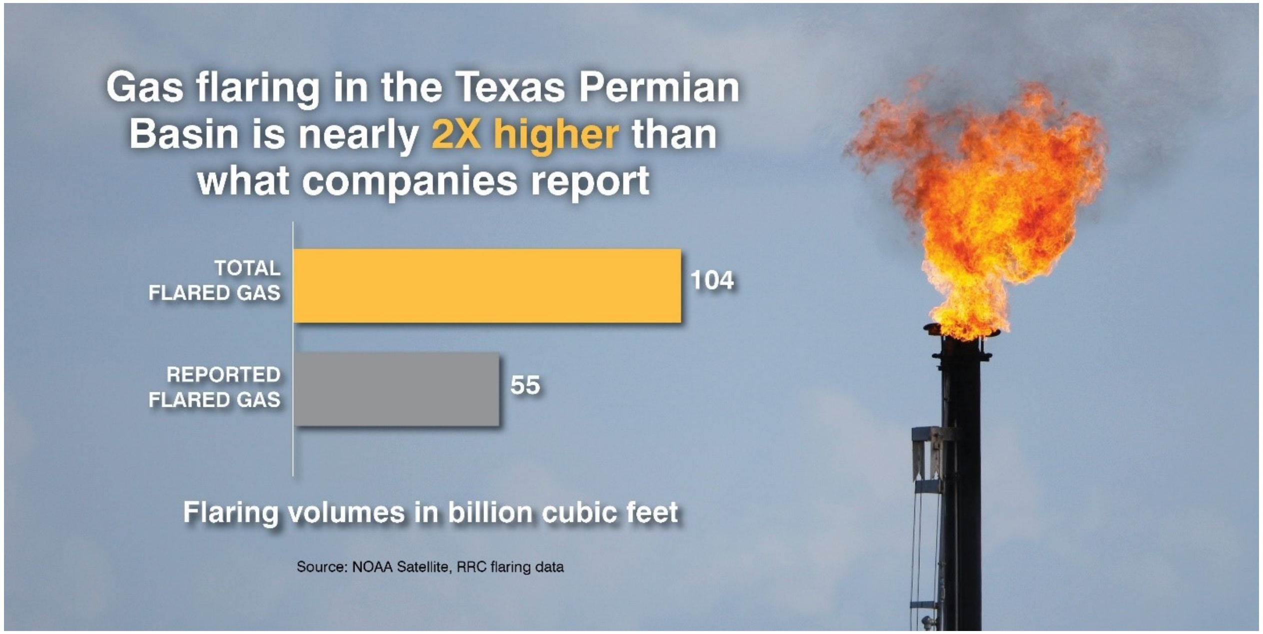
Electronic Ignition System

Electronic ignition systems eliminate the need for flame front generation by introducing a spark within the pilot nozzle. They can be configured for either manual or automatic operation



Environmental Considerations

- Under Reporting?
- Global Warming due to CO2 emissions
- Methane from unburnt gases
- Acid rain caused by emissions of sulphur dioxide and nitrogen oxide
- Main source is burning of sulphur rich coal



Q & A’s