Flare Technology & Applications

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Outline

What is a flare ?	How many flares ?	Types of Flare	Flares' issues	Flare performance and design
Background on flare.	Number of flares around the world	The differences between flare types	Emissions	Design requirement and factors

What is flare ?

- Flares are **safety** equipment used to burn high pressure gas from oil and gas production fields or from **chemical** and **petrochemical** plants

- Flares combust unwanted flammable gases in an open environment to avoid deadly **fires** and **explosions**.

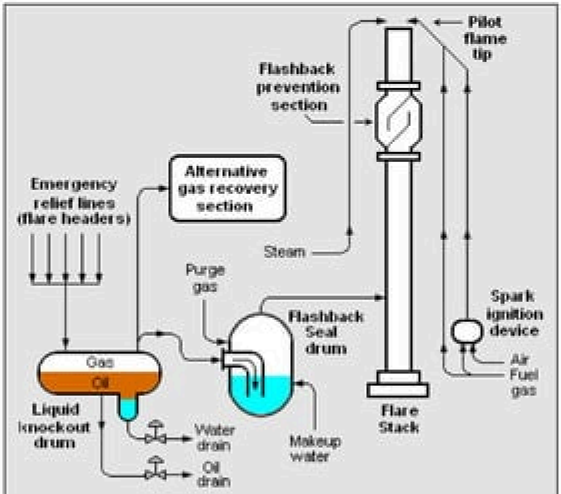
- **Industrial flaring has increased over** the past several years due to increased oil production.

- Flares operate cleanly at **high flows** but not at **low flows**.

- **Proper** flare design for low flow is **critical**.

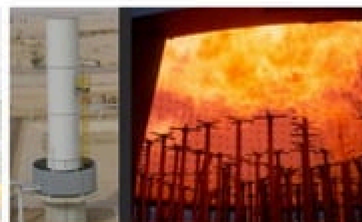
- **Environmental** regulations dictate flare operating conditions and **API** recommends flare design practices.

General Process Overview for Flare Applications



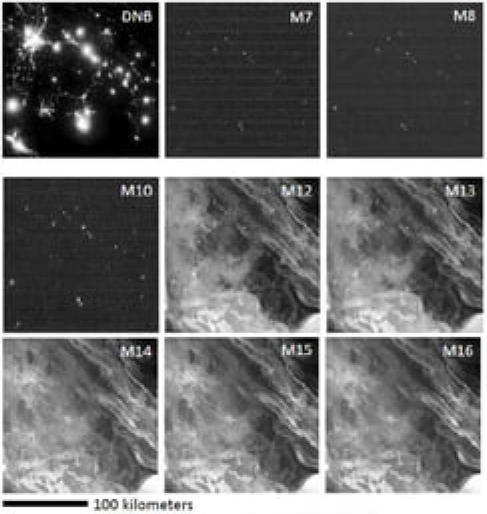
In industrial plants, flare stacks primarily used for burning flammable gas released by pressure relief valves during unplanned over-pressuring of plant equipment. During plant **startups** and **shutdowns**, flare stacks also used for planned combustion of gases over relatively short periods.

Gas flaring protects against over-pressuring plant equipment. During crude oil production (onshore or offshore), gas from well must also be flare if gas transportation infrastructure not available - gas commonly flared at top of flare stack or in multi-point ground flares.



How Many Flares are there?

Figure 2. Sample images of Southern Iraq from the nine VIIRS spectral bands which collect data at night. The area has a large number of persistent gas flares.



Basra Gas Flares, Iraq. 17 July 2012

Data Applications Include:

- Record amount of regional natural gas flaring
- Determine if flaring is chronic in region (community)
- Track active gas-producing regions
- Identify source of noxious air emissions
- Minimize world-wide flaring by focusing on routine flare operation regions
- Informing public health research on impacts of flaring related to respiratory health

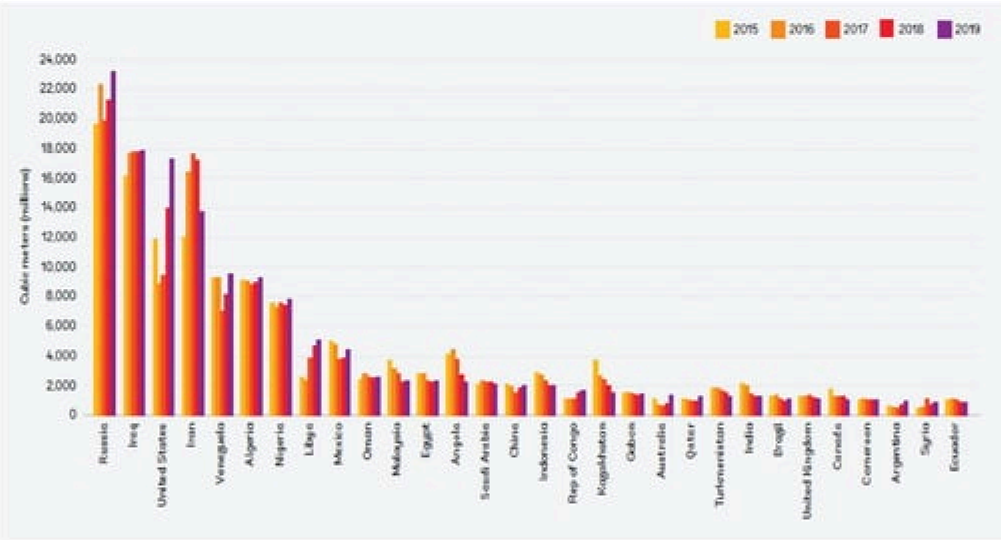
Flaring Maps

(a)

(b)

SkyTruth Flaring Maps; (a) Global, (b) Iraq

Top 30 Flaring Countries (2015-2019)



Source: NOAA, Colorado School of Mines, GGFR, BP, EIA

Flaring volume & oil production

Gas Flaring volume (billion m^3/year) and oil production (kb/d) in the world (2016-2019) (The World Bank, 2020).

Years	Gas Flaring (Billion m^3/year)	Oil Production (kb/d)
2016	148	92
2017	141	93
2018	145	95
2019	150	95

Flaring volume, Flare intensity and oil production in Iraq (2016-2019) (The World Bank, 2020; British Petroleum, 2020).

	Flaring Volume (Million m^3/year)	Flare Intensity (m^3 gas flared per barrel of oil produced)	Oil Production (1,000 barrels per day)
2016	17,730	10.93	4,423
2017	17,843	10.98	4,538
2018	17,821	10.58	4,632
2019	17,914	10.38	4,779

Issues with flaring

- Each year, **billions** of cubic meters of flare gas is burned globally which generates a significant amount of **greenhouse gases**.
- Besides **greenhouse gases**, inefficient gas flaring can also produce **toxic combustion by-products**.
- Several flare designs have been developed to improve **combustion efficiency** including flares using assistant media such as air
- As a result of **increased mixing and combustion**, less black carbon is produced resulting in improved smokeless operation
- Understanding how **ambient conditions** and **flare operating conditions** effect flaring efficiency is essential to finding ways to reduce their impact on the environment.
- **Combustion efficiency (CE)** has been used as an indicator of flare performance. Highly efficient flares operate with CE > 96.5 or greater.

Gas Flaring in the downstream process

(a)

(b)

(a) flaring with smoke, (b) faring without smoke

Flare Emissions

Table 2: Factors affecting heat radiation from flares

An increase in parameter "A" gives an increase (↗), a reduction (↘), no effect (→) or unclear effect (?) on "B"								
«B» ↓ «A» →	Combustion efficiency	Flame temperature	Gas density	Heating value of the gas	Gas velocity	Diameter of flare tip	Turbulent mix	Crosswind speed
Radiation	↗	↗	→	↗	↗	↘	↘	↘

Table 3: factors affecting noise from flares

	An increase of parameter "A" increases (↗), reduces (↘), has no effect (→) has an unclear effect (?) on "B"							
«B» ↓ «A» →	Combustion efficiency	Flame temperature	Gas density	Heating value of the gas	Gas velocity	Diameter of flare tip	Turbulent mixing	Crosswind speed
Noise level from flaring	↗	↗	↗	→?	↗	↘	↗	↘

Table 5: Factors effecting NOx emissions from gas flaring (in g/kg)

	An increase of parameter "A" increases (↗), reduces (↘), has no effect (→) has an unclear effect (?) on "B"							
«B» ↓ «A» →	Combustion efficiency	Flame temperature	Gas density	Heating value of the gas	Gas velocity	Diameter of the flare tip	Turbulent mixing	Crosswind speed
Emissions of NO_x (g/kg)	↗	↗	↘	↗	↗	↘ ?	↗	↘

Flare Emissions

Table 6: Factors affecting emissions of methane and nmVOC from gas flaring

	An increase in parameter "A" increases (↗), reduces (↘), has no effect (→) has an unclear effect (?) on "B"							
«B» ↓ «A» →	Combustion efficiency	Flame temperature	Gas density	Heating value of the gas	Gas velocity	Diameter of the flare tip	Turbulent mixing	Crosswind speed
Methane & nmVOC emissions	↘	↘	↗	↘	↘	?	↘	↗ ?

Table 7: Factors affecting emissions of CO from flaring

	An increase in parameter "A" increases (↗), reduces (↘), has no effect (→) has an unclear effect (?) on "B"							
«B» ↓ «A» →	Combustion efficiency	Flame temperature	Gas density	Heating value of the gas	Gas velocity	Diameter of flare tip	Turbulent mixing	Crosswind speed
Emissions of CO	↘	↘	↗	↘	↘	?	↘	↗ ?

Flare minimizing strategies

- Maximize gas recovery from the flare header
- Minimize contributions to the flare header
- Optimize flare combustion & destruction efficiencies.

Flare types

Elevated

- Utility flare
- Air assisted flare
- Steam assisted flare

Ground

- Multi point ground flare
- Enclosed ground flare

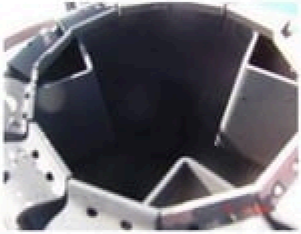
Flare type is selected according to:

- Space availability
- Flare gas composition, pressure & quality
- Operational costs & investment
- Economics
- Regulations & public concerns

Utility Flares (i.e., Olympic flare)

- Low Capital Cost
- Tip Sizes from 2 – 100" ID
- Stainless steel for excessive radiation flux
- Stable Flames (high reliability) for low flow (purge) to high flow (sonic pressure) conditions
- Large heating values ranges (0 - 100% HC)
- Gases with high flame speeds (0.2 – 0.8 cm/s; HC to H2)
- Ignition system critical to prevent flash back or vapor explosions*
- **Sufficient exit velocity** to prevent smoking and wake stabilized flames
- Windshield with flame retention rings and continuous pilots to withstand wind

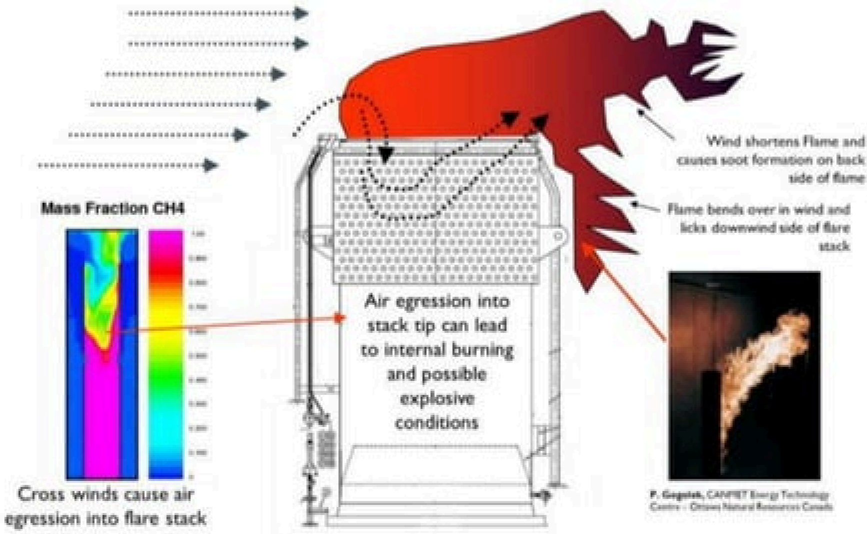
Standard Utility



Sonic Utility

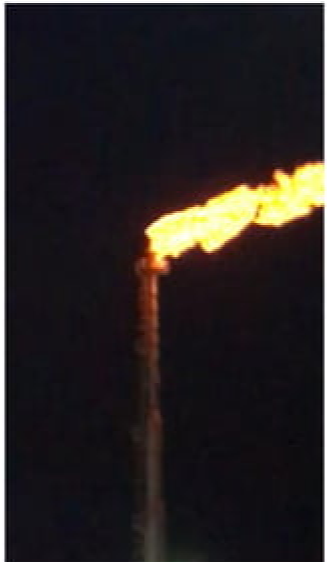
Low BTU Utility

Flare performance issues at low flow conditions



Wake Stabilized Combustion of a Utility Flare

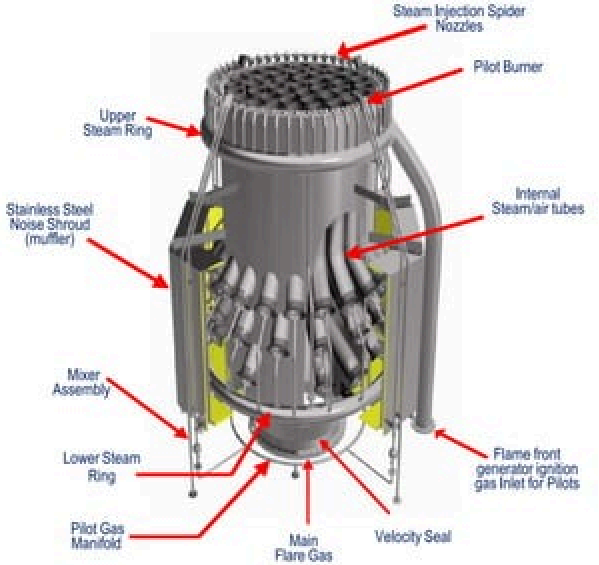
Wind



Caused by high cross winds blowing on low flow flame

Steam-Assisted Flares

- Higher Capital Costs
- Tip Sizes from 2 – 100" ID
- No Moving Parts
- 310 SS in High Heat Areas
- High Flame Stability for wide turndown range (purge to sonic)
- High Smokeless Range for wide variety of flare gas compositions
- **<u>Increases air in combustion zone</u>** (high combustion efficiency)
- Center steam injection extends Flare Tip Life
- Muffler reduces jet noise



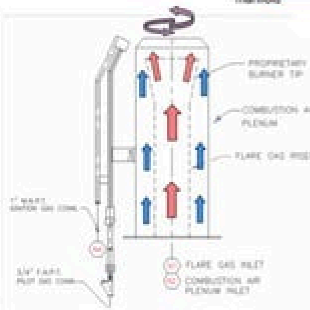
Example Steam Flare Tip

Looking down on steam flare tip

Ethylene steam flare without the steam

Air-Assisted Flares

- Lower Utility Costs
- Tip Sizes from 2 – 120" ID
- No Moving Parts
- 310 SS in High Heat Areas
- Flare Gas through Center Riser/Air through Outer Riser
- Shorter flame due to enhanced combustion
- Cooler tip temperatures by convective cooling (longer tip life)
- Variable speed fans for staged firing (Vane-Axial, Engine Driven, Centrifugal Blowers)
- Lower jet noise than steam flare
- High Flame Stability over wide operating range (Purge to Sonic flows)
- Can handle wide range of Flare Gas compositions
- Well suited for Arctic environments (steam freezes) or Desert environments (water scarce)

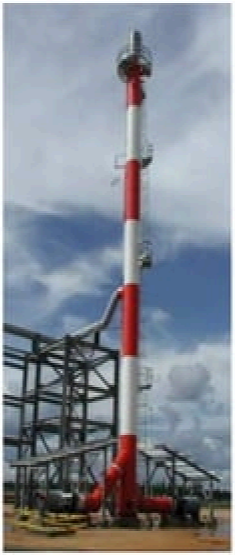


Field Installed Air-Assisted Flares (Vane-Axial Blowers)

KOC; Kuwait

Aramco; Saudi Arabia

Godley, Texas USA



ExxonMobil; Venezuela

Air assisted Vs Steam assisted flares

Smokeless operation

- Enhance mixing
- Introduce additional air to the vent gas

Before selecting assisted medium

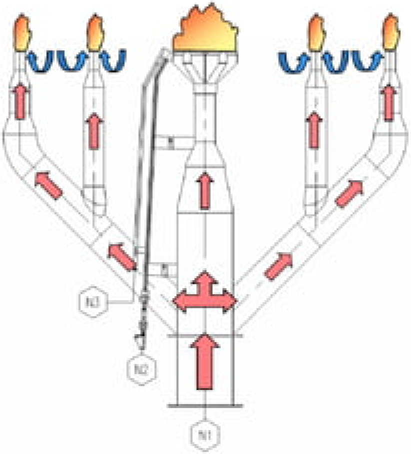
- The reliability of the assist medium
- The availability of the assist medium during an emergency
- The cost of the assist medium

Air assisted flares Vs steam assisted flares

- Less maintenance problems
- Less annual energy costs
- Less maintenance costs
- Longer flare tip life

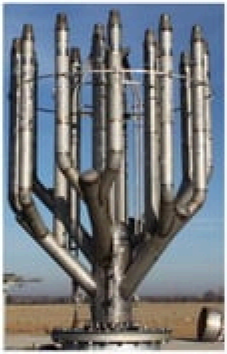
Pressure-Assisted Flares

- Single or Multi-stage configuration
- High Pressure operation
- Combustion occurs away from Tip (lower tip temperature extends tip lifetime)
- Flare gas nozzles operate at sonic condition
- Can have entrained liquids
- **<u>Jet velocity</u>** entrains extra air that improves combustion efficiency (higher smokeless rate)
- Can use with low pressure gas source



Pressure Assisted Flares – Variable Exit Area

- High Pressure (>25 psig)
- Sonic jet nozzles / Spring Arm Design
- Varying exit area allows for higher smokeless turndown rate with higher MW flare gas
- Combustion occurs away from tip for extended Tip lifetime

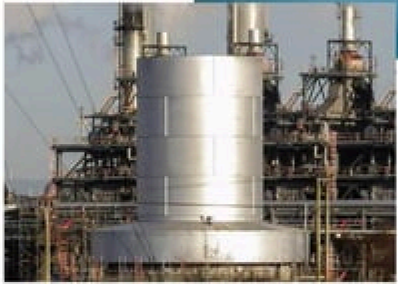


Multi-Point Ground Flares

- Used for applications which require very high flaring rate
- Requires large remote space
- High line pressure creates high tip velocity that increases air entrainment
- High jet velocity improves mixing (combustion efficiency)
- Tip and row spacing critical to provide sufficient air and allow tip cross-lighting along row

Others: Liquid Flares, Enclosed Ground Flares

- Liquid Flares:
  - Burn liquid jets with high Smokeless rate
  - Use various atomizing media (Air, Gas, Steam)
  - High Flow Rates with no burning liquid rain
- Enclosed Ground Flares:
  - Onshore (Landfills) and Offshore (FPSO) Applications
  - Higher capital costs
  - Less atmosphere effects (better combustion control)



Flare Types & Applications

Utility (non-assisted) Flare (single tip without assist media to enhance mixing)

- **Applications**: Gas streams with low heat content and require less air for complete combustion
- **Advantages**: low initial capital costs; low operating costs
- **Challenges**: more effected by ambient conditions, shorter tip life

Steam-Assisted Flare (single elevated tip, steam induces extra air in combustion zone)

- **Applications**: Refineries and Chemical Plants
- **Advantages**: steam cooled extends tip life, high smokeless rate
- **Challenges**: not economical for large flares, requires dedicated steam boiler (water supply)

Air-Assisted Flare (single elevated tip, fan air increases mixing, variable speed fans)

- **Applications**: Refineries and Chemical Plants
- **Advantages**: can be used where steam not available/useable (artic, desert)
- **Challenges**: not used on large flares because not economical

Pressure-Assisted (use line/air pressure to promote mixing)

- **Applications**: used when high flows must be flared (gas plants, oil/gas wells, chemical plants)
- **Advantages**: less operating costs (sufficient line pressure to replace steam/air flares)
- **Challenges**: remote location required for space requirement, tip/row spacing for air supply and tip cross lighting along row

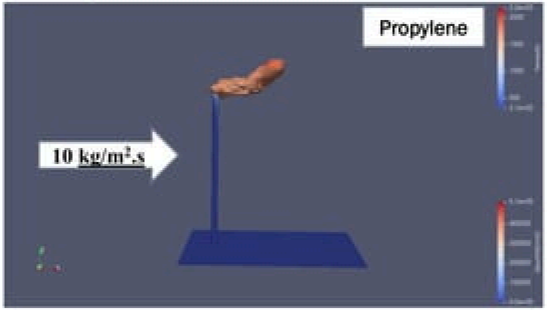
Flare performance

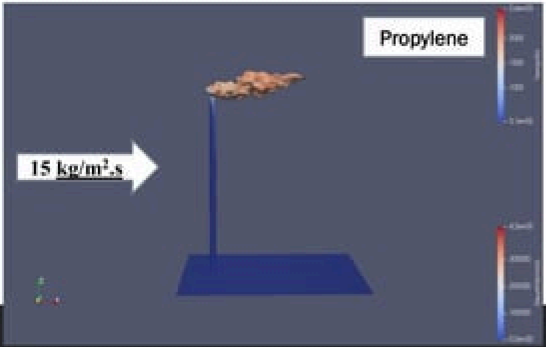
Table 1: factors affecting flare combustion efficiency

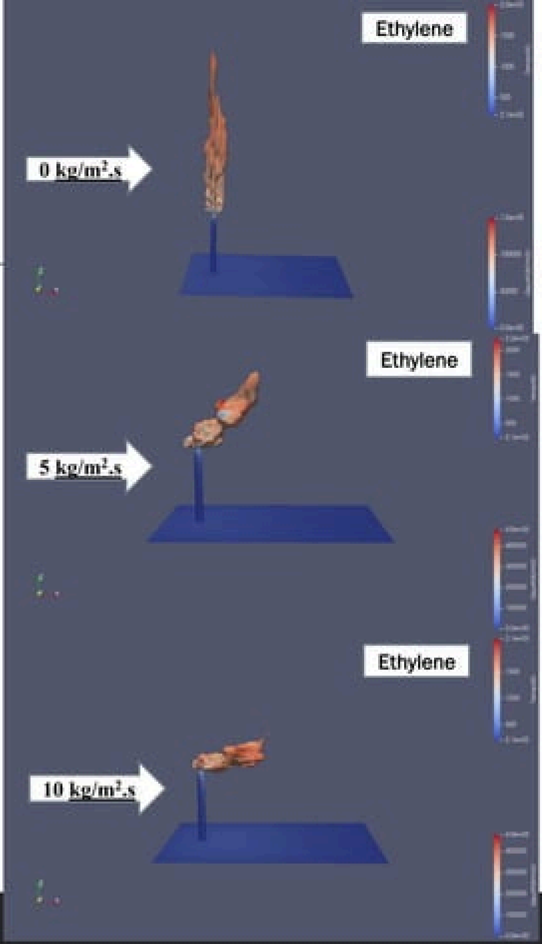
	An increase of parameter "A" increases (↗), reduces (↘), has no effect (→) has an unclear effect (?) on "B"							
«B» ↓ «A» →	Combustion efficiency	Flame temperature	Gas density	Heating value of the gas	Gas velocity	Diameter of the flare tip	Turbulent mixing	Crosswind speed
Combustion efficiency		↗	↘	↗	↗	?	↗	↘ ?

- **Over steaming & aeration**
- **Heating Value**
- **Crosswind & Vent Gas velocity**
- **flare flame lift-off**
- **Dilution**

Crosswind effect (CFD)



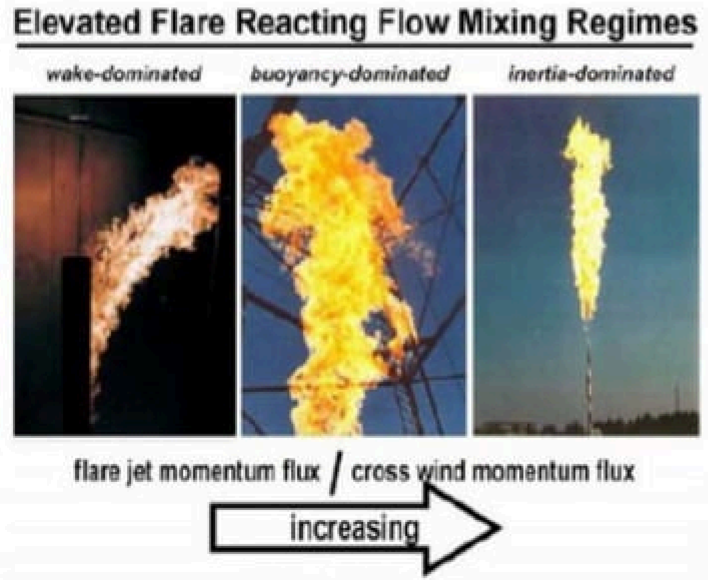




Flame stability

Flame stability

- flame speed
- flammability limits
- ignition temperature



Flare system & Design factors

Flare system	Design factors
• Collection piping in the unit • A flare line to the site • A knockout drum • A liquid seal • A flare stack with flare tip • An assist system • A fuel gas system for pilots and ignitors • Controls & instrumentation.	• Flow rate • Gas composition • Gas temperature • Gas pressure • Utility cost and availability • Environmental requirements • Safety requirements • Social requirements

Design requirements

Design requirements

- Flares have to be at least as high as any platform within **150 m** horizontally, and in no case less than **15 m high**.
- The base of flares should be installed at least **60 m** away from any source of flammable hydrocarbons for example floating roof or separators.
- Flare spacing & elevation should be such that permissible radiation heat intensities for personnel at grade will not exceed under condition of maximum heat release, where it should be installed in locations where the maximum heat intensity at ground level is **1.6 kW/m^2** in any property line.
- The minimum distance from the flare stack base to nearby property line should be **60 m**.

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THANK
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AND
ANY
QUESTION?