TxOGA
Flare Operation Discussion

April 28, 2009

Discussion Objectives

- Define the need for plant flares
- Describe the components of a typical flare system
- Discuss the limitations and hazards associated with operating flare systems
- Discuss maintenance requirements of flare systems

Flares – What are they? Why do we need them?

"The primary function of a flare is to use combustion to convert flammable, toxic or corrosive vapors to less objectionable compounds." (API 521 paragraph 6.4.1)

Safely during both…

emergency and routine operations.

Flare Systems - Purpose

- A system of Process Safety Management (PSM) critical mechanical equipment that gathers and safely burns hydrocarbons from pressure-relieving and vapor-depressurizing systems
- Must be continuously available
- Must be reliable for years
- Capable of performing through all operating-plant emergency conditions, including a site-wide general power failure or a weather event including a hurricane
- Difficult to add equipment or modify because they are very infrequently out of service as they serve many units that are infrequently out of service.

(API 537 paragraph 4.1)

Typical Flows to Flare Systems

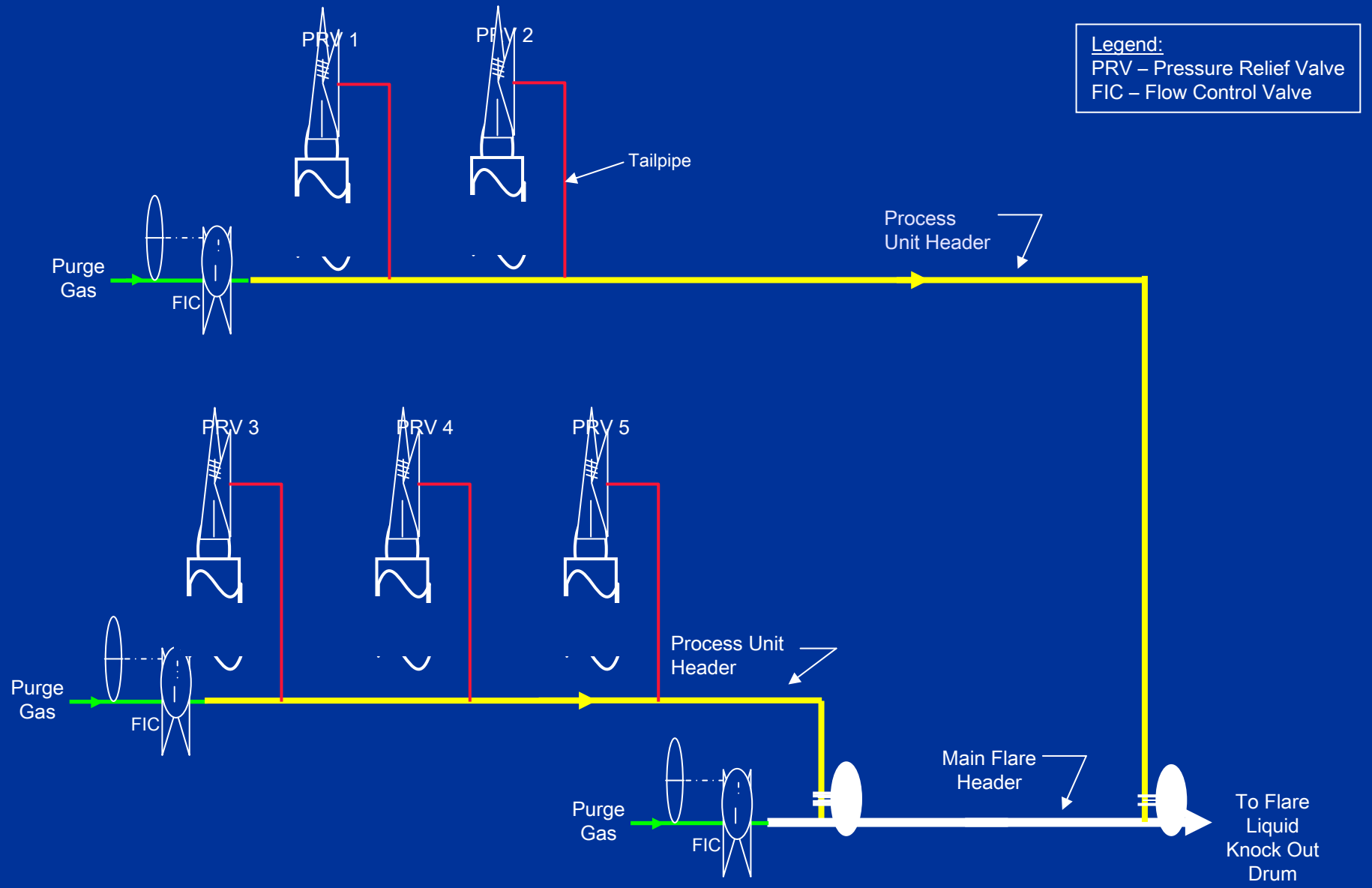
- Emergency
  - Pressure relief flows
  - Emergency depressurization
- Episodic
  - Venting required for maintenance
  - Venting required for regeneration
  - Shutdown/Start-up operations (de-inventorying)
- Continuous – 99+% of Typical Operation
  - Sweep gas through the flare system piping
  - Process venting (continuous analyzer flows, gas seals, certain types of pressure control)
  - Pressure Relief Valve leakage

Typical Flare System

Flare System Major Components

- Every flare system is unique and different
- Every flare system contains differential components
  - Series of collection headers from sources
  - Knockout drum
  - Stack
    - Flare Tip
    - Liquid seal
    - Purge reduction device (stack seal)
  - Integrated pilot system
  - Monitoring and operation instrumentation
  - Flare hydrocarbon recovery systems

Typical Flare Header System



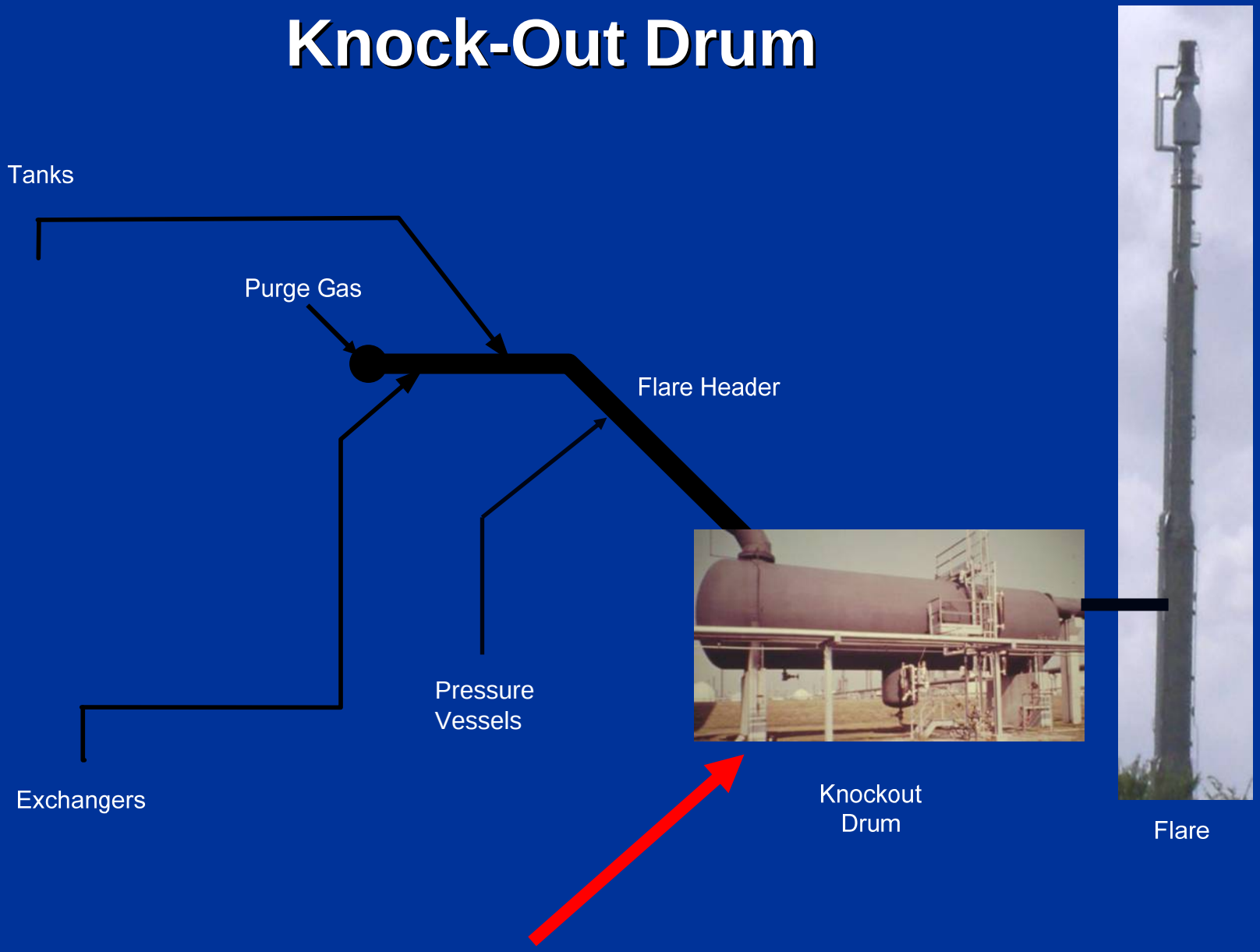
Hydraulic Design

- Flare header is sized to limit the back pressure of each pressure relief device during various emergency events.
- The hydraulic design is a line sizing / rating problem
  - Design minimizes the differential pressure to ensure each pressure relief device functions properly
  - Design is based on specific line size, line length and maximum expected relief load for each relief event

Hydraulic Issues

- Hydraulic issues specific to flare header design:
  - Different relief events govern the size of various sections of the collection header
  - A variety of materials discharge to the flare system
  - Potential pressure discontinuities where pipe flows meet
  - Volume expansion throughout header piping
  - High velocity and significant acceleration effects

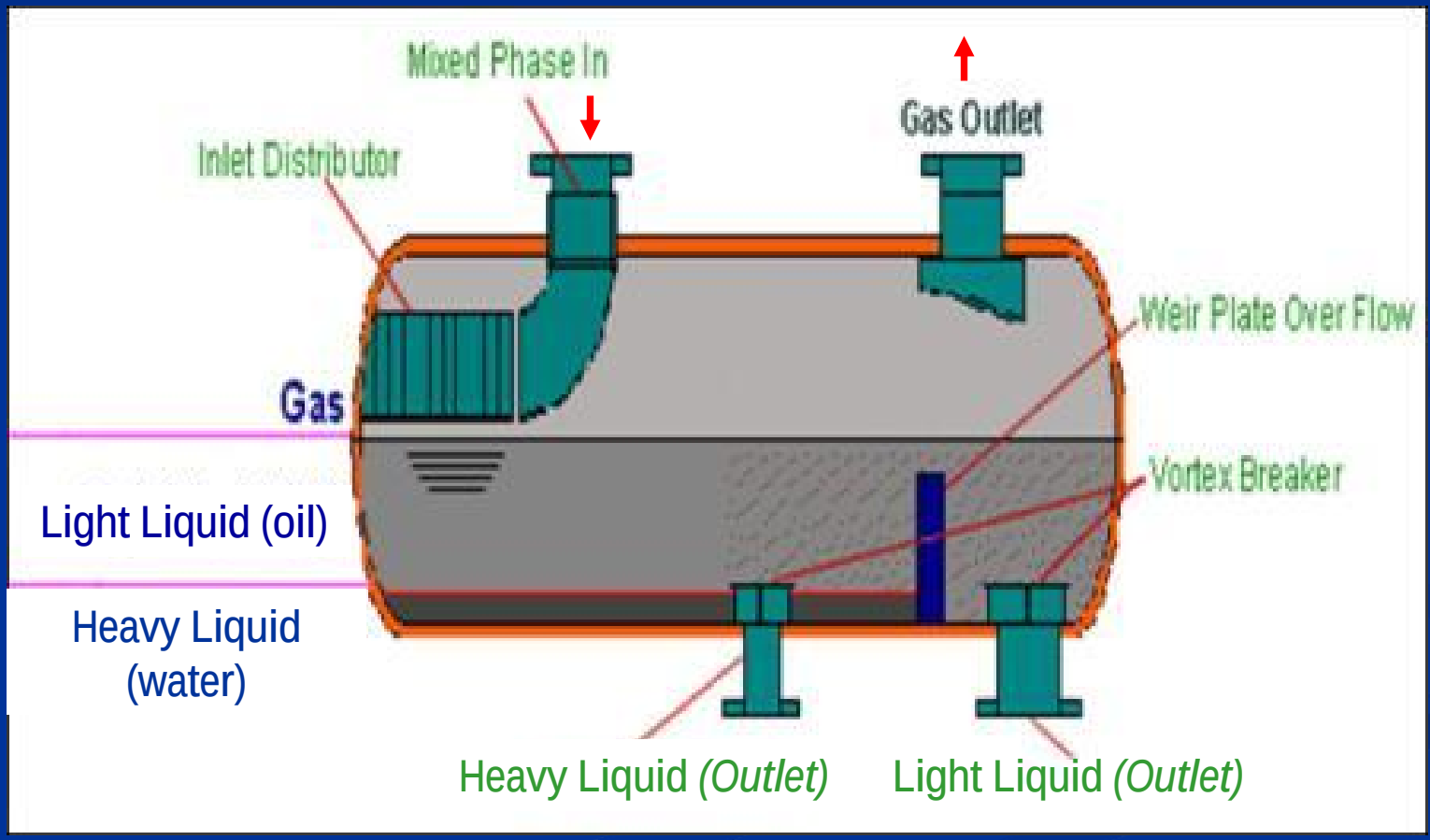
Knock-Out Drum



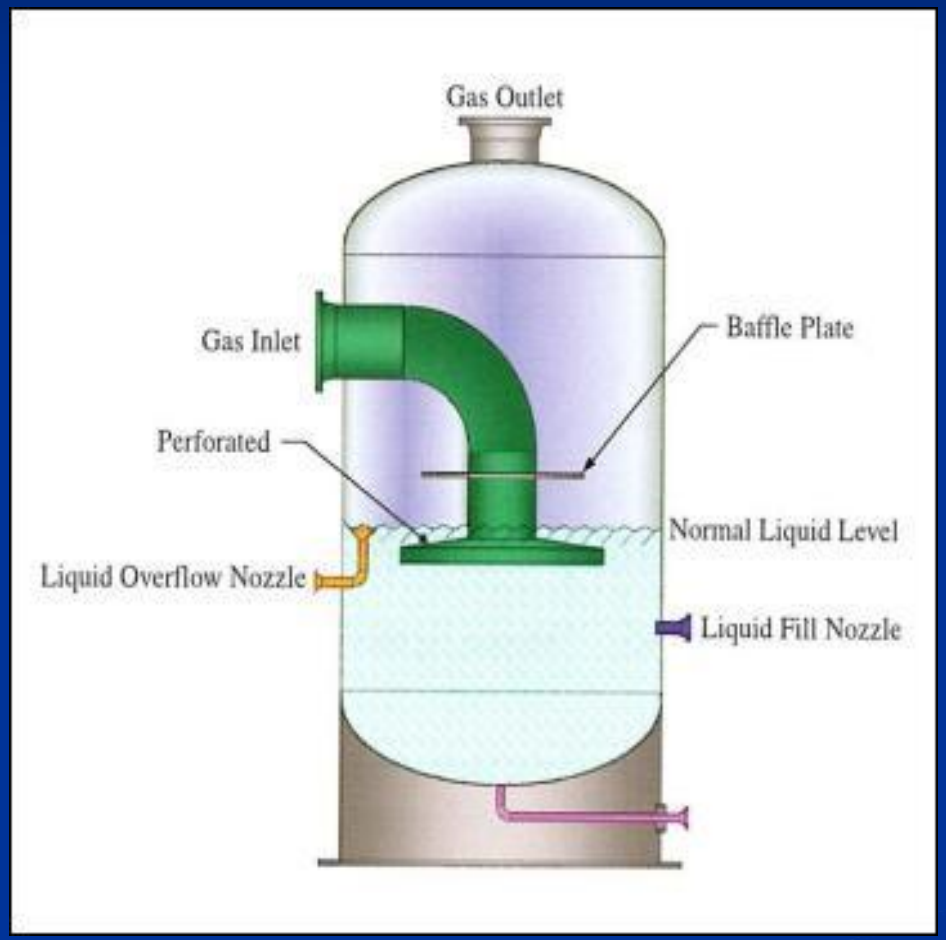
Knock-Out Drum

- Separates liquid from gas (2 phase separation)
  - Prevents liquids from being discharged to atmosphere
  - Prevents or reduces smoke because of reduced liquid in the flame
  - Increases flare tip life
- Allows draining of liquid prior to flare
  - For reprocessing
  - For disposal

Typical Knock-Out Drum



Liquid Seal



- Flashback prevention
- Prevent air infiltration
- Helps maintain positive header pressure
- Staging device
- Some systems include an additional flame arrestor

Courtesy: John Zink Company

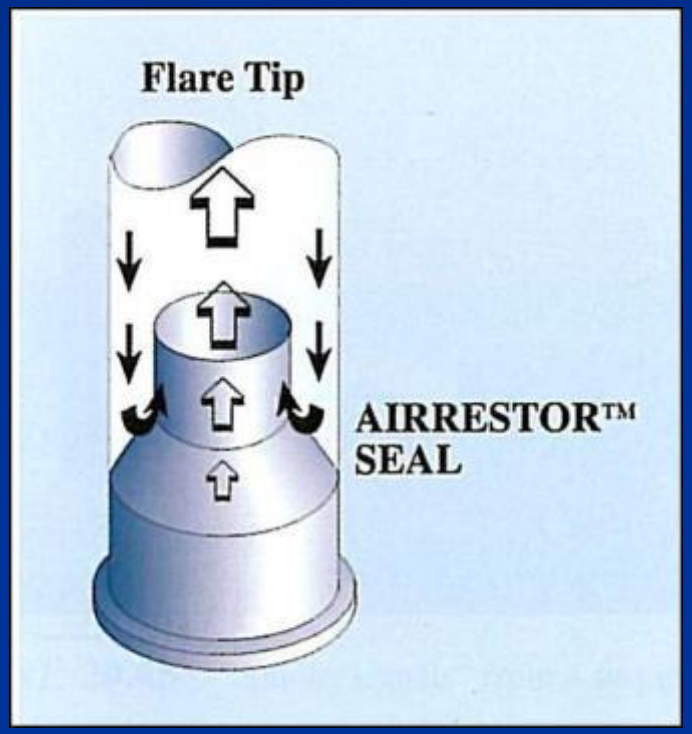
Flare System Purge Requirements

- Purge gas composition
  - Non-condensing – typically natural gas or nitrogen
  - Non-corrosive
  - Non-reactive to other gasses in the system
- Purge gas locations
  - Upstream or downstream of a liquid seal
  - End of major header or branch
- Purge must be continuous and measurable
- Purge gas sweeps the header of O_2, corrosive, reactive, or inert components

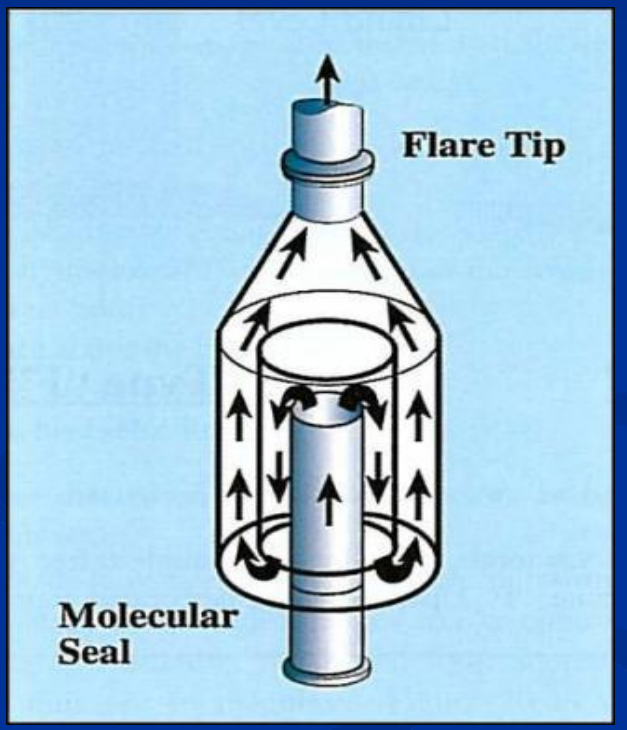
Purge Requirements

- System Requirements (manufacturer specified)
  - Type of stack seal for air intrusion
  - Flame stability
- Flare System Cooling
  - Offset pressure reduction after a hot release
  - Protect system until liquid seal can be re-established

Purge Reduction Devices
(Stack Seal)



Velocity Seal



Density Seal

Courtesy: John Zink Company

Flare Types

- Single point
  - With or without smoke suppression
  - Vertical, elevated discharge point, but may be horizontal (pit)
  - May stage two single point flares for better control
- Multi-point
  - Improved burning through multiple burning points
  - Smokeless
  - Divided into stages to facilitate better burning
  - Must operate with high back pressure
- Enclosed
  - Conceals flame from direct view
  - Reduction in noise level
  - Minimization of radiation

Flare Tip Design

- Provides safe and efficient burning of flare gases over wide flow conditions
- Steam or air injection provided for smokeless operation for most operating scenarios
  - Smokeless operation a function of flow
  - Smokeless operation a function of gas composition
- Maintain flame stability
- May require multiple flares and types

Single Point Flare

Air Flare

Staged Flare

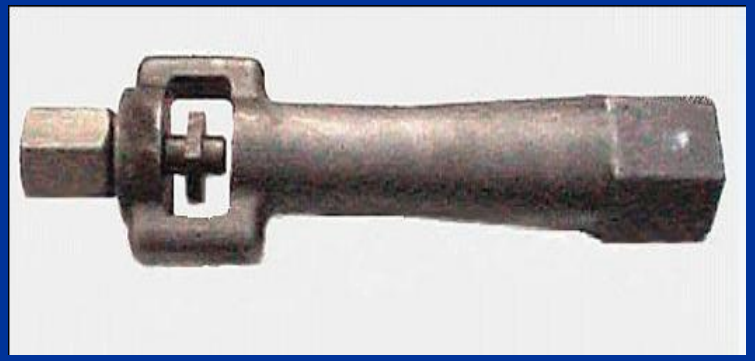
Multi-Point Flare

Enclosed Ground Flare

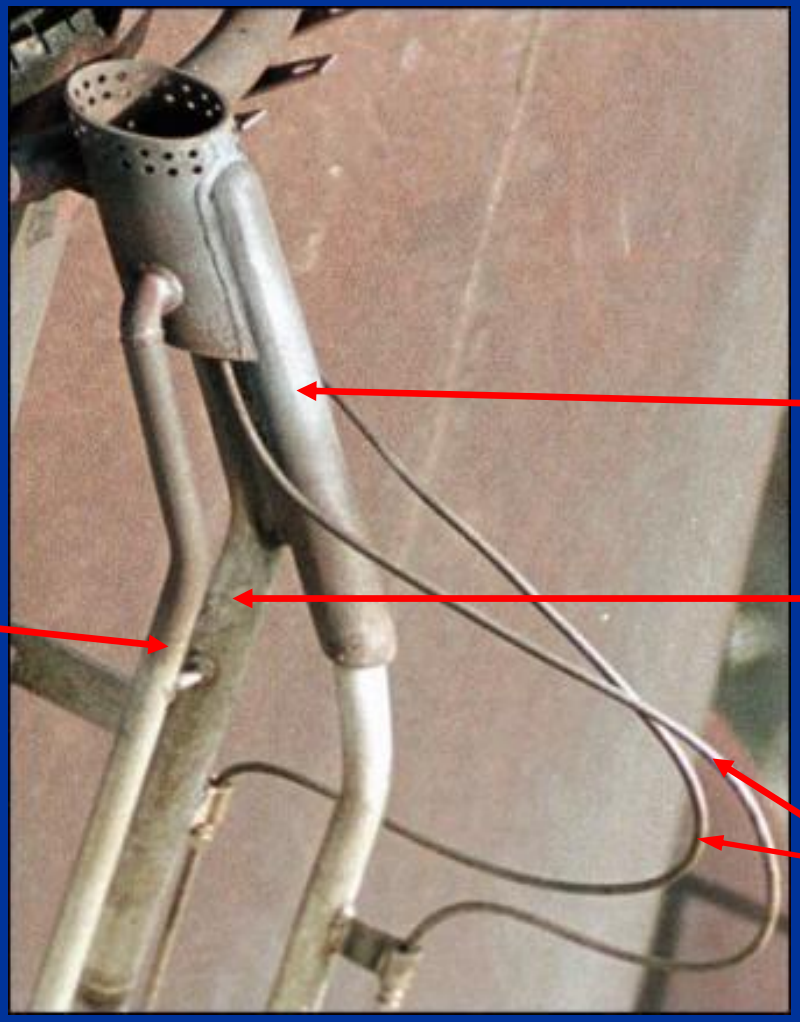
Integrated Pilot System

- Pilots
  - Premix burner
- Pilot igniters
  - Direct spark
  - Flame Front Generator (FFG)
- Pilot monitors
  - Heat: Thermocouples
  - Light: Infrared camera
  - Sound: Acoustic monitoring
  - Flame ionization

Pilot Assembly



Pilot Assembly



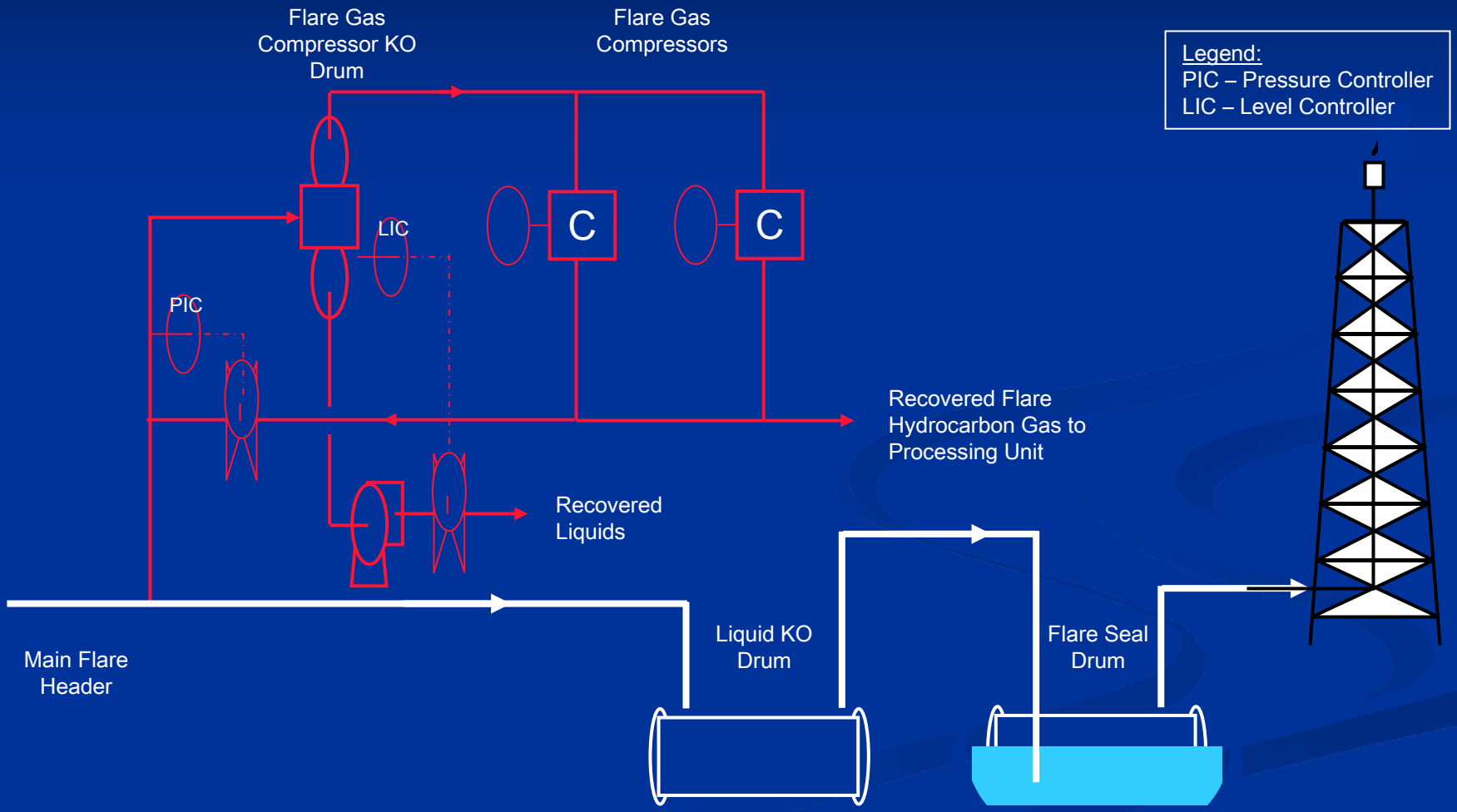
Flare System Operational Controls

- Steam or air flow to flare tip
  - Cooling (minimum flow)
    - Protection for metal
    - Eliminate internal burning (center steam)
  - Smoke control
    - Upper steam
    - Steam Air tube steam (larger tip size only)
    - Center steam
  - Keep steam hot (minimize condensate)
- Water seal level
  - Flow and temperature control
  - Staging control
- Knock-out drum liquid flow
- Assist gas flow
- Collection header purge
- Oxygen level in flare header
- Pilot ignition

Flare System Monitoring Instrumentation

- Flare system operation monitoring
  - Video camera
  - Pilot gas flow and temperature
  - Relief gas flow, pressure, temperature and composition
  - Knock-out drum level
  - Water seal level, pressure, and temperature
  - Steam flow to flare
  - Collection header purge gas flow
  - Flare gas recovery
- Control and monitoring equipment may not be available for maintenance with flare system in service
- Each flare system monitoring requirement is unique and can be different

Typical Flare Recovery System



Flare Recovery System

- Gas collection for routine operations limited in outlets when pressure is low
- Low pressure streams generally have 1 of 4 outlets
  - Lower pressure system (often not available)
  - Eduction to higher pressure system
  - Compressor to increase pressure
  - Flare
- Eduction has some, but limited, applicability
  - Pressure of eduction must be considered
  - Acceptability of stream being educted
    - High H2S in stream is often a factor
- Compressor can be a viable option
  - Wet Gas compressor for FCCs is an example of viable option
  - If no compressor nearby, cost of new compressor often is prohibitive

Flare Recovery System

- Flare hydrocarbon gas recovery systems
  - More common in refineries
  - Less common in chemical plants
- Flaring generally last preferred destination
- Any gases sent to flare are lost product for company
- Flaring has regulatory, environmental and community impacts that companies prefer to not have

Other Flaring Reduction Best Practices

- Leak source monitoring and control
  - Acoustic monitoring
  - Temperature monitoring
  - Flare gas analysis
- Start-up/shut-down planning
- Flare minimization best practices
- Load shed plans, routine operating practices
- Root cause analysis of flaring events

Flare Operation

- Maintain stable flame - EPA 40 CFR 60.18 defines requirements for stable flame:
  - Have a continuous pilot with monitoring
  - Limits minimum heat content of flare gas:
    - 200 BTU/scf for non-assist flare
    - 300 BTU/scf for assist flare
  - Maximum exit velocity based on heat content of flare gas (60 – 400 FPS)
- Flame may not always be visible
  - Hydrogen
  - Low BTU gas - e.g. CO

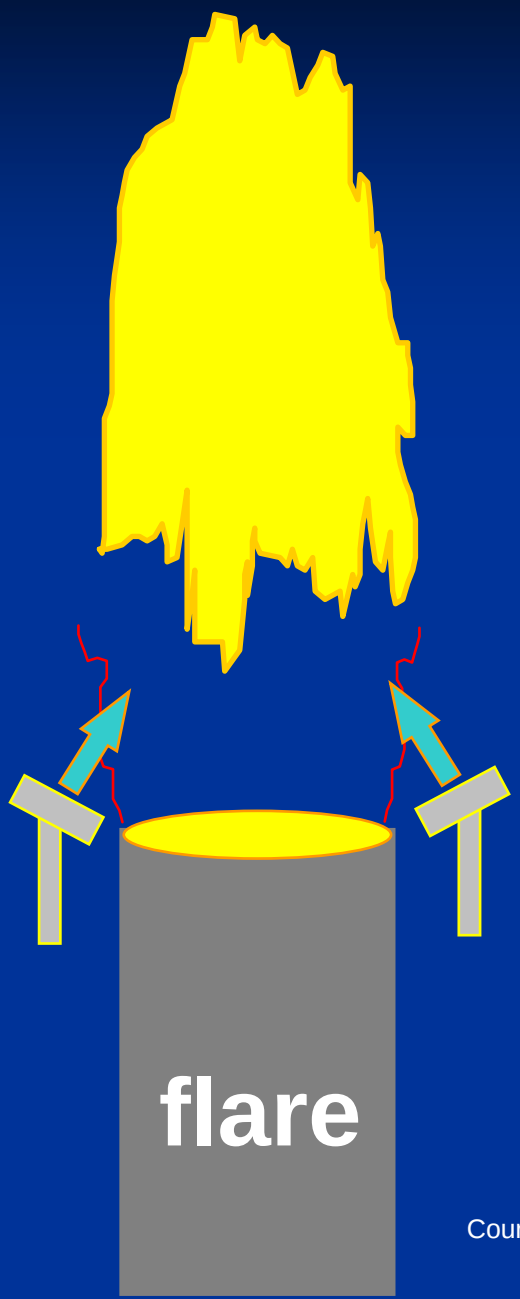
Operation - Weather Effects

- Wind
  - Alter flame shape
  - Sheer unburned hydrocarbons
  - Extinguish pilot flame
  - Physical damage to equipment
- Rain
  - Extinguish pilot flame
- Extreme conditions (i.e. hurricane)
  - Loss of steam
  - Loss of power
  - Extinguish pilot & main flame

Operational Flow Control

- Emergency – Maximum Hydraulic Flow
  - May not be able to control smoking
  - Able to maintain destruction efficiency
- Episodic – Medium Flow
  - Mostly able to control smoking
  - Able to maintain destruction efficiency
- Continuous – Extreme Turn-Down Condition
  - Able to control smoking
  - May not be able to control destruction efficiency
    - Cooling steam to hydrocarbon ratio
    - Weather effects

Factors that can Affect Flame Stability



- Flame stability
  - Fuel exit velocity
  - LHV of fuel
  - Pilot(s)
  - Weather
- Operation
  - Maintenance
  - Steam Control
  - Air Control

Courtesy: John Zink Company

Operating Hazards and Limitations

- Loss of flame/pilot
- Liquid carry-over
- Flashback - air intrusion
- Loss or insufficient purge
- Steam control – under/over
- Freezing condensate in cold climates
- Inconsistent composition, pressure, and temperature
- Brittle fracture of material for cold relief
- Blockage
  - Soot
  - Freezing condensate in cold climates
  - Mechanical failure
- Noise
- Light
- Thermal radiation
- Limited ability to perform maintenance while in service

Flare Maintenance

- Most major maintenance has to occur during a turnaround
- Consideration for T/A inspection, PM, repair or replacement
  - Pre T/A survey – e.g.. drone technology
  - Pilots
  - Thermocouples
  - Clean/check fuel and FFG piping for leaks and pluggage
  - Critical instrumentation
  - Stack riser
  - Guy wire connections at stack
  - Water seal
  - KO drum
  - Aviation lights

Questions?