

Flare Details for General Refinery and Petrochemical Service

API STANDARD 537
FIRST EDITION, SEPTEMBER 2003



**Helping You
Get The Job
Done Right.SM**

Flare Details for General Refinery and Petrochemical Service

Downstream Segment

API STANDARD 537
FIRST EDITION, SEPTEMBER 2003



American
Petroleum
Institute

**Helping You
Get The Job
Done Right.SM**

SPECIAL NOTES

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations under local, state, or federal laws.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. Sometimes a one-time extension of up to two years will be added to this review cycle. This publication will no longer be in effect five years after its publication date as an operative API standard or, where an extension has been granted, upon republication. Status of the publication can be ascertained from the API Standards [telephone (202) 682-8000]. A catalog of API publications and materials is published annually and updated quarterly by API, 1220 L Street, N.W., Washington, D.C. 20005.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this standard or comments and questions concerning the procedures under which this standard was developed should be directed in writing to the standardization manager, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the general manager.

API standards are published to facilitate the broad availability of proven, sound engineering and operating practices. These standards are not intended to obviate the need for applying sound engineering judgment regarding when and where these standards should be utilized. The formulation and publication of API standards is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Note: The Publisher hereby grants users of this work the right to reproduce, store in a retrieval system, or transmit the Flare Data Sheets contained in Appendix A of this document as long as there is an attribution to API. Users may modify the Data Sheets and Instructions as necessary to indicate the name of their company or organization.

All rights reserved. No part of this work may be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, N.W., Washington, D.C. 20005.

Copyright ©2003 American Petroleum Institute

FOREWORD

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to the standardization manager, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

CONTENTS

	Page
1 SCOPE.....	1
2 REFERENCED PUBLICATIONS.....	1
3 DEFINITION OF TERMS	2
4 FLARE EQUIPMENT OVERVIEW	4
4.1 System Purposes	4
4.2 Types of Flares.....	4
4.3 Selection Considerations	9
4.4 Major Components	10
4.5 Mechanical Design	10
4.6 System Design Criteria	10
5 ELEVATED FLARE EQUIPMENT COMPONENTS.....	11
5.1 Flare Burner	11
5.2 Pilots.....	17
5.3 Fuel Gas	21

	Page
7.5 Maintenance.....	55
7.6 Troubleshooting.....	55

Figures

1 Self-Supported Structure.....	5
2 Guyed-Supported Structure.....	5
3a Fixed Derrick-Supported Structure.....	5

ICBO⁹*Uniform Building Code*SSPC¹⁰SP-3 *Power Tool Cleaning*SP-5 *White Metal Blast Cleaning*SP-6 *Commercial Blast Cleaning*SP-10 *Near White Blast Cleaning*United States Code of Federal Regulations¹¹

40 CFR 60

20 CFR 1910.27 (OSHA)

3 Definition of Terms

Terms used in this Standard as they relate to flares are defined in 3.1 through 3.68.

3.1 air seal: A device used to minimize or eliminate the intrusion of air back into the riser from the exit.

3.2 assist gas: Fuel gas that is added to relief gas prior to the flare burner or at the point of combustion in order to raise the heating value.

3.3 back blowing: The procedure by which the dry air seal drain line is blown back from the base of the drain into the buoyancy seal to ensure the line is clear.

3.4 blowoff: The loss of a stable flame where the flame is lifted above the burner. This occurs if the fuel velocity exceeds the flame velocity.

3.5 buoyancy seal: A dry vapor seal that minimizes the required purge gas needed to protect from air infiltration. It functions by trapping a volume of light gas in an internal inverted compartment. This prevents air from displacing buoyant light gas in the flare.

3.6 burnback: Internal burning within the tip. This might result from air backing down the flare burner at purge or low flaring rates.

3.7 burn-pit flare: An open excavation normally equipped with a horizontal flare burner that can handle liquid as well as vapor hydrocarbons.

3.8 burning velocity: The speed at which a flame front travels into an unburned combustible mixture.

3.9 coanda flare: A flare burner that is designed to employ the aerodynamic effect where moving fluids follow a curved or inclined surface over which they flow. Flares of this

type generally use steam or pressure to achieve smokeless performance.

3.10 combustion air: Air required to combust the flare gases.

3.11 combustion efficiency: The percentage of the combustible fluid totally oxidized in the burner. In the case of hydrocarbons, combustion efficiency is the weight percent of carbon in the original fluid that oxidizes completely to CO₂.

3.12 condensable gas: A vapor that can condense at the temperature and pressure expected in a flare header during or after a flaring event.

3.13 derrick support: A support system for the elevated flare riser normally used for very tall flares or when plot space is limited. Various derrick supported arrangements are available: a fixed system has its riser permanently supported to the derrick; a demountable derrick has multiple riser sections that are designed to be lowered and removed to permit lowering of the flare burner to grade; a demountable derrick with one fixed riser provides for a single piece design to be lowered to grade as a single component.

3.14 design flare capacity: The maximum design flow to the flare normally expressed in kilograms per hour (pounds per hour) of a specific composition, temperature, and pressure.

3.15 destruction efficiency: The weight percent of the fluid vapor that can be oxidized that is at least partially oxidized. In the case of a hydrocarbon, destruction efficiency is the weight percent of carbon in the fluid vapor that oxidizes to CO or CO₂.

3.16 detached stable flame: A flame which is not in contact with the flare burner itself but burns with a stable flamefront in the vicinity of the flare burner.

3.17 direct ignition: Ignition of a pilot by a spark at the pilot rather than by a flame front generator.

3.18 dispersion: A scattering of the products of combustion over a wide area to reduce ground level concentrations of the combustion products.

3.19 electronic ignition: See direct ignition.

3.20 enclosed flare: An enclosure with one or more burners arranged in such a manner that the flame is not directly visible.

3.21 endothermic flare: A flare that utilizes outside energy—usually assist or enrichment gas—to maintain the combustion reaction.

3.22 enrichment: The processes of adding assist gas to the relief gas.

⁹International Conference of Building Officials, 5360 Workman Mill Rd., Whittier, California 90601-2298, www.icbo.org.

¹⁰Steel Structures Painting Council, 40 24th Street, Suite 600, Pittsburgh, Pennsylvania 15222.

¹¹U.S. National Archives and Records Administration, 700 Pennsylvania Avenue NW, Washington, D.C. 20408. www.archives.gov

3.23 elevated flare: A flare where the burner is raised high above ground level. It is elevated to reduce radiation intensity and to aid in dispersion.

3.24 excess air: Air provided to a flame in excess of stoichiometric requirements.

3.25 flame detection system: A system that verifies a flame is present.

3.26 flame front generator: A means of lighting the pilot. A combustible gas-air mixture is created and allowed to fill an ignition line connecting the flame front generator and the pilot. Igniting the mixture allows the flame front to travel through the ignition line to the pilot.

3.27 flame monitor: See flame detection system

3.28 flame retention device: A means to prevent flame blowoff from a flare burner.

3.29 flame velocity: See burning velocity

3.30 flare: A general term used to designate a device or system used to safely dispose of relief gases in an environmentally compliant manner through the use of combustion.

3.31 flare burner: The part of the flare where fuel and air are mixed at velocities, turbulence and concentration required to establish and maintain proper ignition and stable combustion. It is also referred to as the flare tip.

3.32 flare header: The piping system that collects and delivers the relief gases to the flare.

3.33 flare tip: See flare burner

3.34 flashback: The phenomenon that occurs in a flammable mixture of air and gas when the local velocity of the combustible mixture becomes less than the flame velocity, causing the flame to travel back to the point of mixture.

3.35 ground flare: Any non-elevated flare. It is normally an enclosed flare but may also refer to a ground multi-burner flare or a burnpit.

3.36 guyed flare: An elevated flare with the riser supported with cables.

3.37 heat release: The total heat liberated by combustion of the relief gases based on the lower heating value, expressed in kilowatts (British thermal units per hour).

3.38 heating value, higher (HHV): The total heat obtained from the combustion of a specified fuel at 16°C (60°F), expressed in kilojoules per kilogram or per cubic meter (British thermal units per pound or per cubic ft). It includes the latent heat of vaporization of the water formed by the combustion of hydrogen in the fuel. The Higher heating value is synonymous with the gross heating value.

3.39 heating value, lower (LHV): The higher heating value minus the latent heat of vaporization of the water formed by combustion of the hydrogen in the fuel. It is also called the net heating value, expressed in kilojoules per kilogram or per cubic meter (British thermal units per pound or per cubic ft).

3.40 ignition air: Pressurized air, normally instrument air, used only during pilot ignition via a flame front generator.

3.41 ignition gas: Fuel gas used only during pilot ignition via a flame front generator.

3.42 knockout drum: A vessel in the flare header designed to remove and store condensed and entrained liquids from the relief gases.

3.43 liquid seal: A device that directs the flow of relief gases through a liquid (normally water) on their path to the flare burner. It can be used to protect the flare header from air infiltration or flashback, to divert flow, or to create backpressure for the flare header.

3.44 mach number: The ratio of the fluid's velocity (measured relative to some obstacle or geometric figure) divided by the speed at which sound waves propagate through the fluid.

3.45 manifold: A device for the collection and or distribution of a fluid to or from multiple flow paths.

3.46 motive gas: Any vapor injected into the flared gas to minimize smoke, normally steam.

3.47 multi-burner flare: A group of burners designed to burn all or a portion of the design flow capacity. The burners are often arranged in stages to facilitate better burning. Multi-burner flares are capable of high smokeless flow rates with lower radiation levels.

3.48 muffler: A device that mitigates noise.

3.49 multi-exit flare: A single flare burner with multiple separate exits.

3.50 opacity: Lack of transparency to the rays of light or translucency. Also, see Ringelmann number.

3.51 orifice seal: See velocity seal

3.52 peak exit velocity: The actual velocity at which the design flare capacity exits the burner, expressed as ft per second (meters per second) or as a Mach number.

3.53 pilot: A small continuously operating burner that provides ignition energy to light the flared gases.

3.54 pin actuated device: A non-reclosing pressure relief device actuated by static pressure and designed to function by buckling or breaking a pin which holds a piston or

plug in-place. Upon buckling or breaking of the pin, the piston or plug instantly moves to its full open position.

3.55 purge gas: A fuel gas or a non-condensable inert gas added to the flare header to mitigate air ingress and burn-back.

3.56 radiation intensity: The local radiant heat transfer rate from the flare flame. The rate is usually considered at grade level and expressed in kilowatts per square meter (British thermal units per hour per square ft).

3.57 relief gas: Gas or vapor vented or relieved into a flare header for conveyance to a flare. Sometimes called waste gas, flared gas or waste vapor.

3.58 Ringelmann number: A scale used to define levels of white, gray and black, where white is 0, black is 5 and 1 through 4 are increasing levels of gray. Often used to describe the intensity of smoke.

3.59 riser: The pipe or other conduit that conveys the relief gas to the flare burner of an elevated flare.

3.60 smokeless capacity: The maximum flow to a flare system that can be burned without smoke. Normally expressed in kg/hr (lb/hr) of a specific gas composition, temperature, and pressure.

3.61 staged flare: A group of two or more flares or burners that are controlled so that the number of flares or burners in operation is proportional to the relief gas flow.

3.62 stoichiometric air: Chemically correct ratio of fuel to air, i.e., a mixture capable of perfect combustion with no unused fuel or air.

3.63 supplemental gas: A fuel gas burned external to a flare burner in order to facilitate the burning of low heating value relief gas.

3.64 thermocouples: Temperature-measuring devices used to detect the heat produced by a pilot flame.

3.65 velocity seal: A dry vapor seal that minimizes the required purge gas needed to protect against air infiltration into the flare burner exit.

3.66 water seal: See liquid seal

3.67 wind fence: Structure surrounding an enclosed flame flare at ground level to modify the effect of crosswinds on the combustion process and/or to prevent unauthorized access.

3.68 windshield: A device used to protect the outside of a flare burner from direct flame impingement. External flame impingement occurs on the down-wind side of an elevated flare burner, hence the name windshield.

4 Flare Equipment Overview

4.1 SYSTEM PURPOSES

A flaring system is provided in a refinery or petrochemical plant to ensure the safe and efficient disposal of relieved gases or liquids. The disposal fluids are collected in a flare header and routed to the flare. It is extremely important in the event of a plant emergency such as a fire or power failure. A properly operating flare system is the critical component to prevent a plant disruption from turning into a disaster.

A flare is expected to operate twenty-four hours a day. Flare must be in service for several years without a need to shut it down. It always be available for flaring whenever a plant disruption occurs.

Proper design, operation and maintenance of emergency flaring systems are extremely important. These can ensure the safety of personnel, facility, and the surrounding community. The intention and operational limitations of the Flare System should be documented clearly and all operational staff made aware of this documentation.

The flaring system must be designed to do the following:

- Reduce ground level concentrations of hazardous materials.
- Provide the safe disposal of flammable materials.
- Reduce volatile organic compound (VOC) and hydrocarbon emissions.

4.2 TYPES OF FLARES

Flares can be grouped under the following major categories:

4.2.1 Vertical

Vertical flares are generally oriented to fire upward. The discharge point is in an elevated position relative to the surrounding grade and/or nearby equipment.

There are several types of support methods for vertical flares. These include:

4.2.1.1 Self-supported (see Figure 1): A mechanically and structurally designed riser supports the flare burner.

4.2.1.2 Guyed (see Figure 2): An elevated flare with the riser supported by cables. Cables are attached to the flare riser at one or more elevations to limit the deflection of the structure. The cables (guy-wires) are typically positioned in a triangular plan to provide strong support.

4.2.1.3 Derrick supported (see Figure 3a): steel trussed structure that supports one or more flare risers.

a. Fixed Derrick:

The riser is permanently supported by the structure. The tip can be maintained by lowering it with a davit or crane.

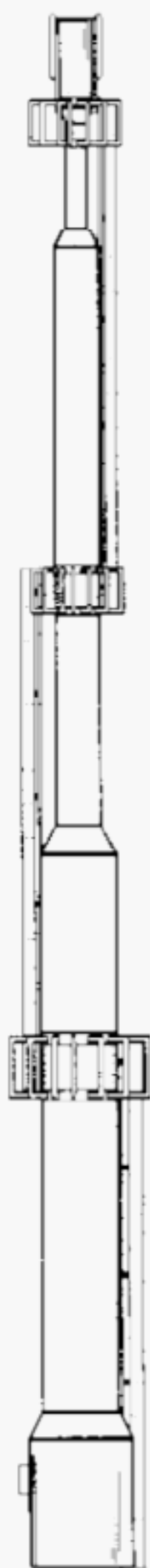


Figure 1—Self-Supported Structure

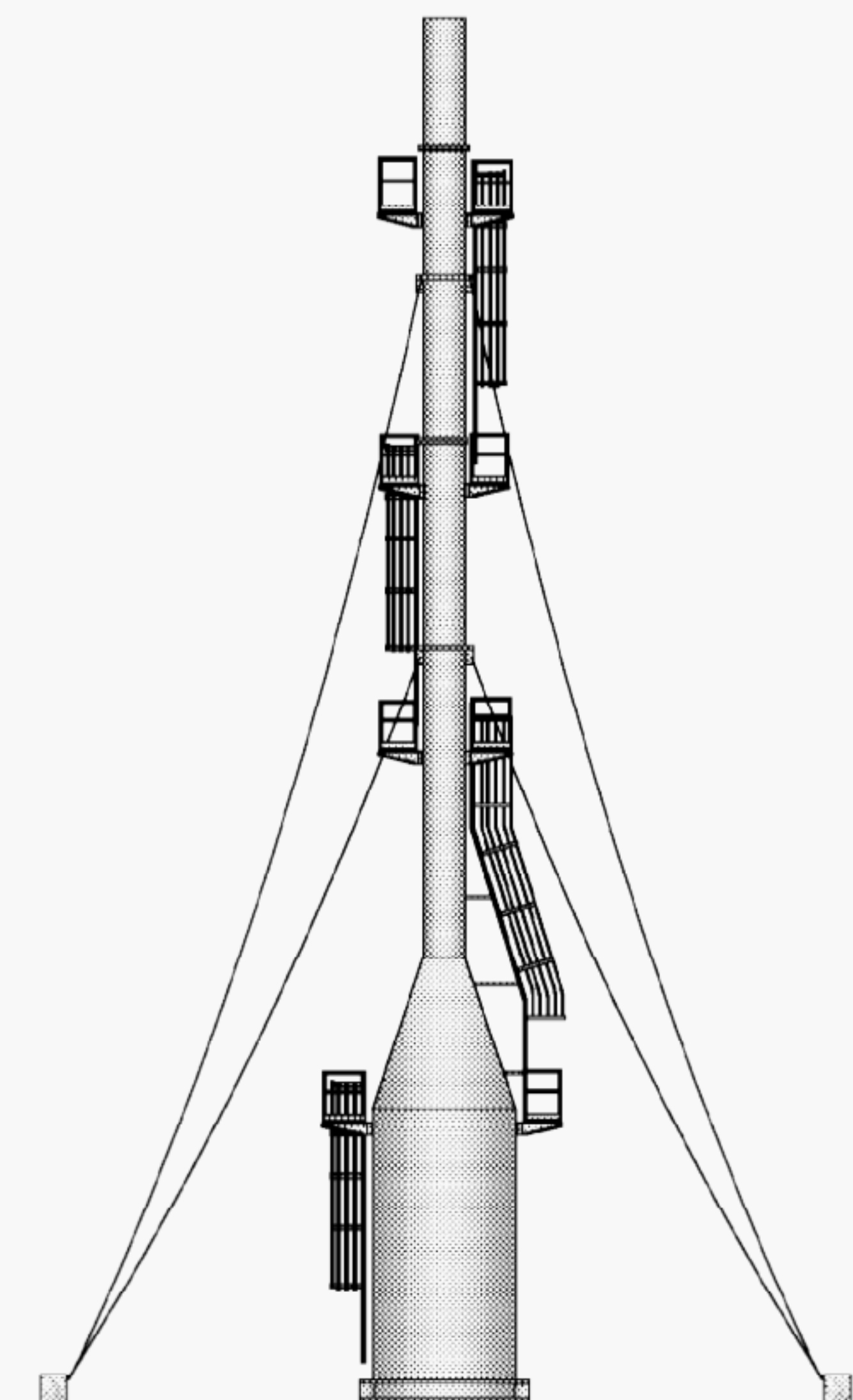


Figure 2—Guyed-Supported Structure

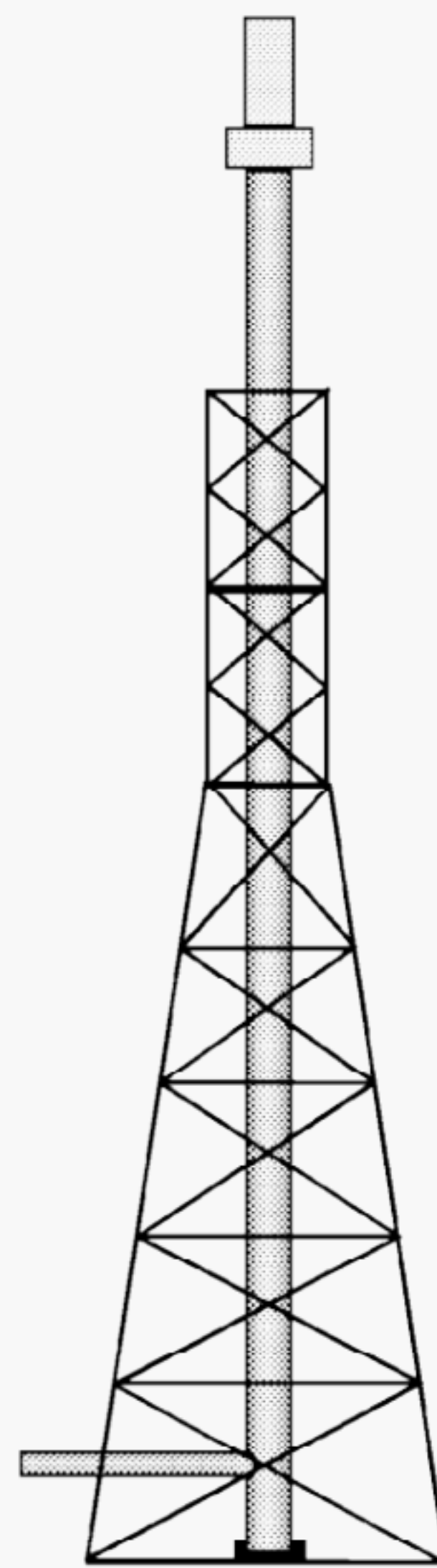


Figure 3a—Fixed Derrick-Supported Structure

The flare system must be out of service when the tip is removed. Refer to Figure 3a for a typical fixed derrick support structure.

b. Demountable derrick (multiple section riser):

A derrick with the riser(s) mounted to permit lowering the flare burner to grade for service. The riser is typically assembled in sections that can be raised and lowered using a track and guide system. This allows grade level access to the flare burner. Many demountable derricks are designed to support multiple risers with their flare burners. Such a derrick can be designed so that all the flares, except the one being maintained, can be operational during the maintenance.

Figure 3b illustrates a derrick with a multiple section demountable riser in operation position (A), with upper sections slightly lifted at the start of the lowering operation (B), during the process of lowering the bottom section (C), and with the bottom section completely lowered (D).

c. Demountable derrick (single section riser):

A derrick with a single riser utilizing a track and guide system which allows the flare riser and burner to be lowered to grade in a single piece.

Figure 3c illustrates a derrick with a single section demountable riser in the normal operating position (A), during the lowering process (B), and completely lowered to allow grade level access to the flare burner (C).

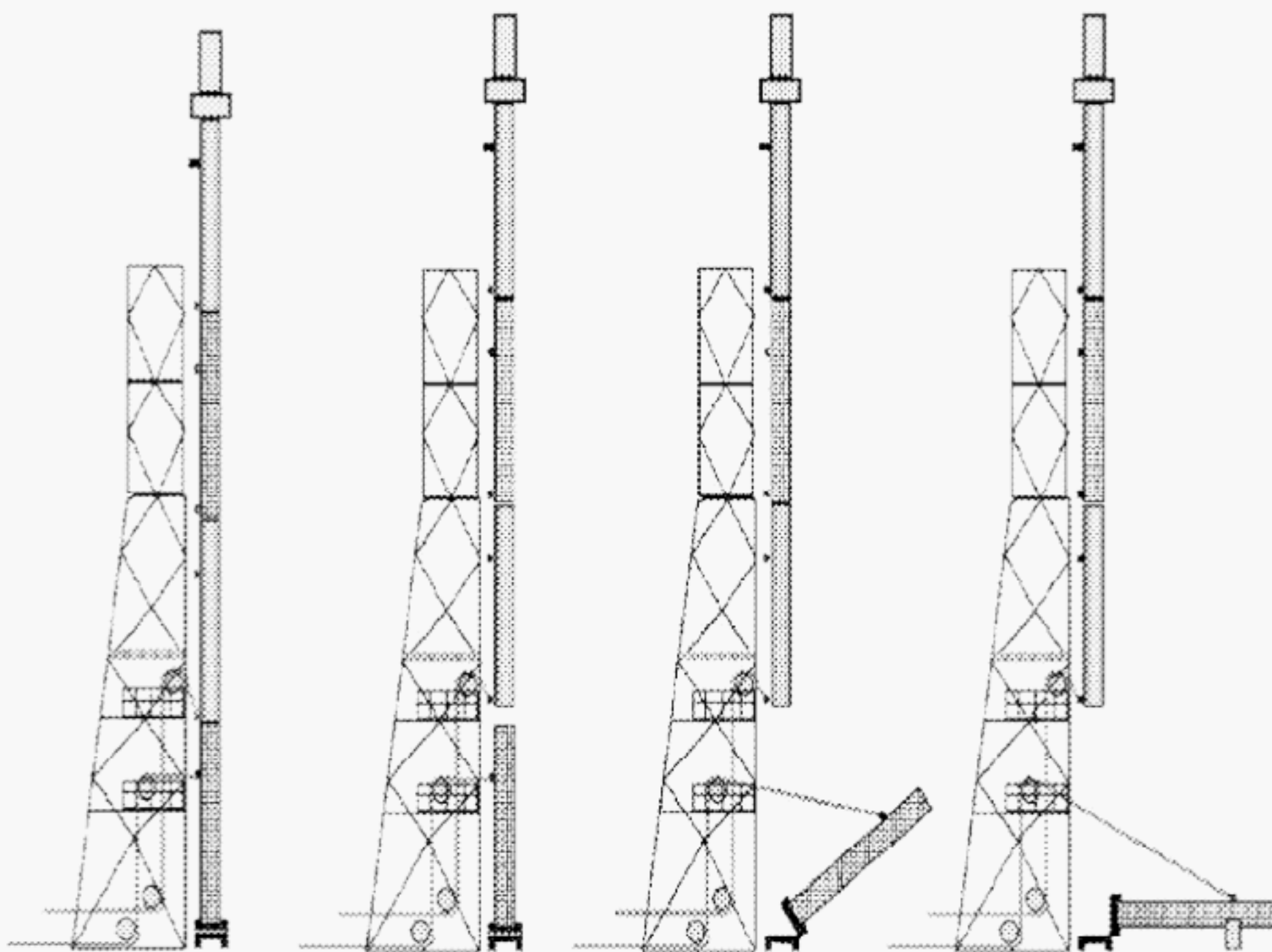


Figure 3b—Demountable Derrick-Multiple Section Riser

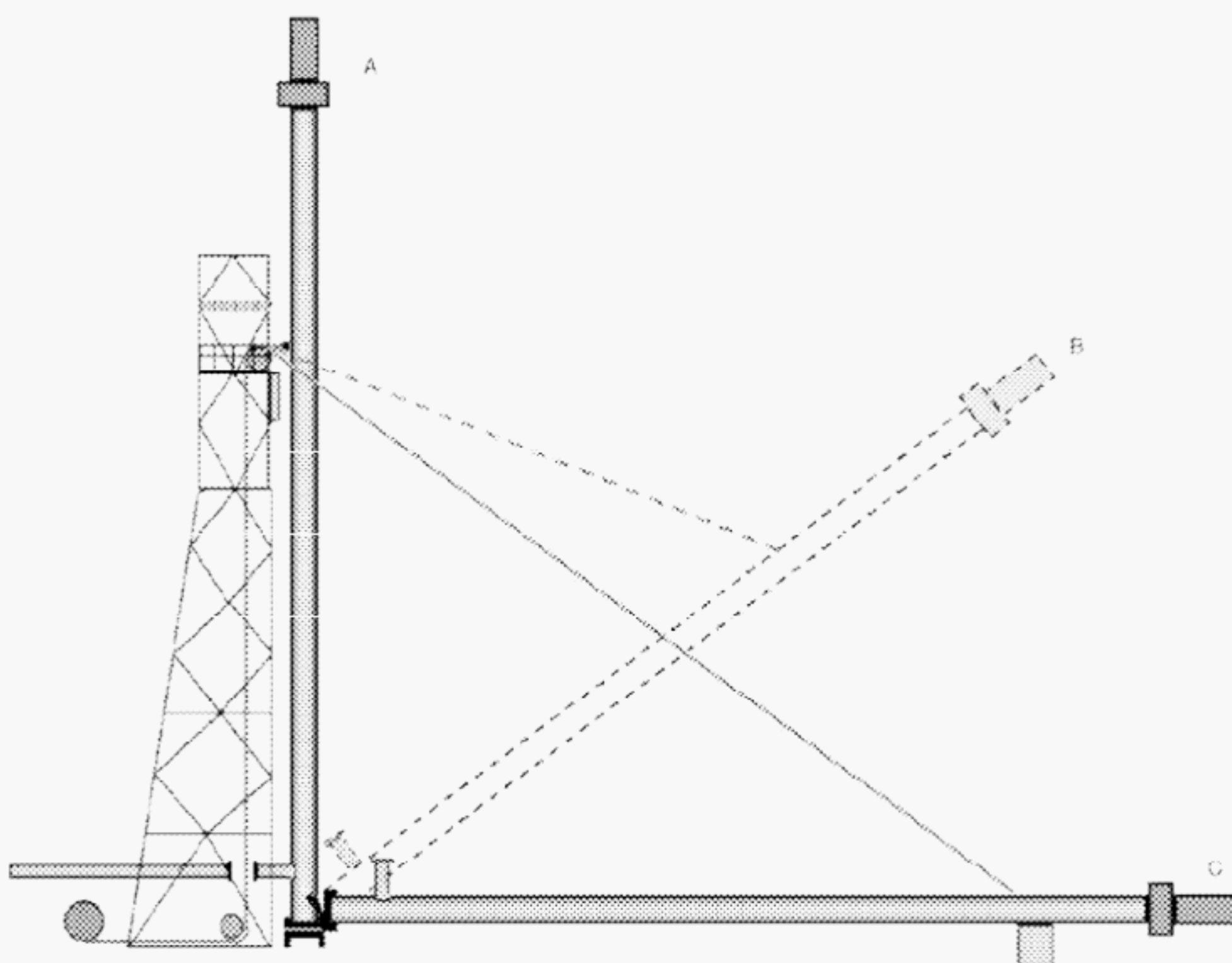


Figure 3c—Demountable Derrick-Single Section Riser

4.2.2 Horizontal

The flared liquids and gases are piped to a horizontal flare burner that discharges into a pit or excavation (see Figure 4).

4.2.3 Enclosed Flame Flares

Enclosed flares are constructed to conceal the flame from direct view. They can reduce noise and minimize radiation. Unlike an incinerator, a wide turndown is inherent with these systems. The normal flow rate allows the connected facility to start up, shutdown, and operate on a day to day basis without exposed flame flaring. Multiple stages within the enclosed flares are sometimes used. Figure 5 illustrates a side-fired enclosed flare.

4.2.4 Single-point and Multi-burner

Single and multi-burner flares may be provided with each of the above flare categories.

4.2.4.1 Single-point Flares

A single-point flare is an open pipe tip with a single exit point. Single-point flares may be of the smokeless or non-smokeless design. They are generally vertical types. A single-

point flare usually has a lower pressure differential than a multi-burner flare

4.2.4.2 Multi-burner Staged Flares

Multi-burner flare systems utilize the available pressure energy of the gas to entrain additional air. This improves combustion as flare gas is better mixed with the air. Multi-burner flares are usually designed to achieve smokeless combustion if adequate pressure and space are available. The multiple burning points may be arranged in arrays located near grade or at an elevated position. Figure 6 illustrates a multi-burner staged flare.

Figure 7 illustrates the performance of a three-stage flare system. Each stage adds incremental exit area. Staging allows operation of each stage to be at pressures where smoking will not occur. As the flow increases in the first stage, the system pressure increases. When the system pressure reaches a maximum for the first stage, the second stage opens providing additional capacity. The additional capacity decreases the system pressure while maintaining the same flow. This process then repeats with the third stage. Decreasing flow reverses the staging process. The chart illustrates 3 steps of operation: $1 = 20\%$, $1+2 = 50\%$, and $1+2+3 = 100\%$. Other variations of staging

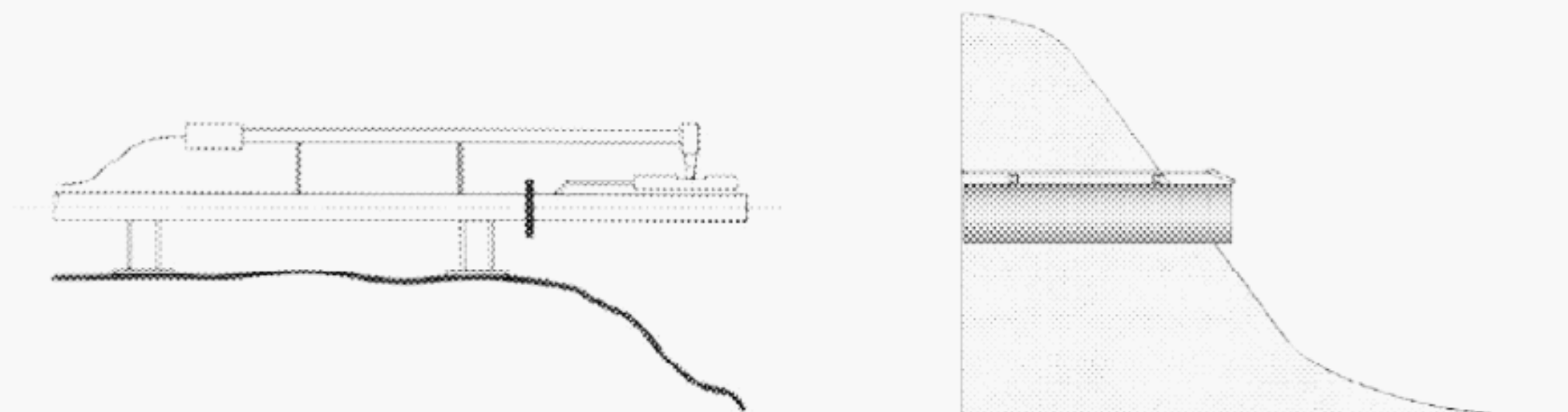


Figure 4—Horizontal Flares

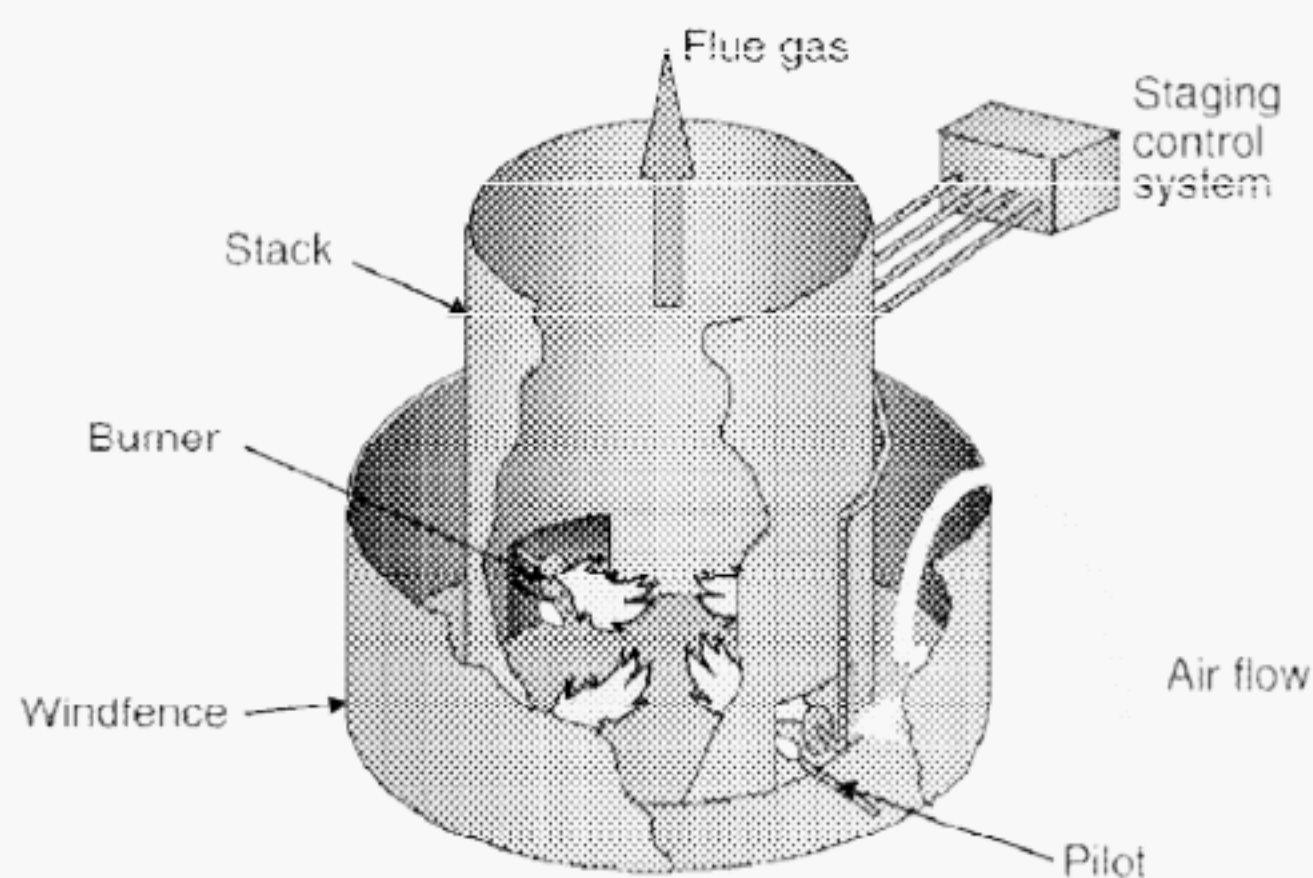


Figure 5—Enclosed Flare

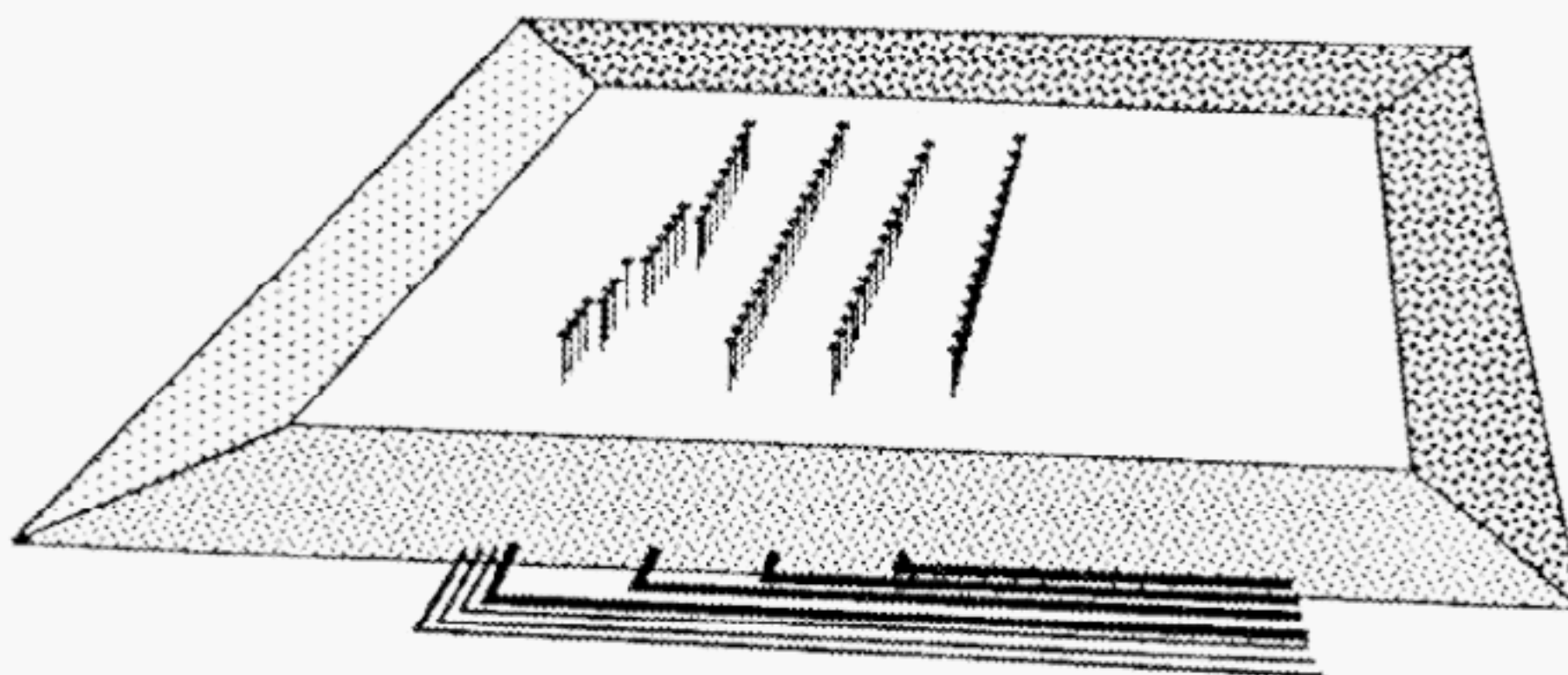


Figure 6—Multi-Burner Staged Flare

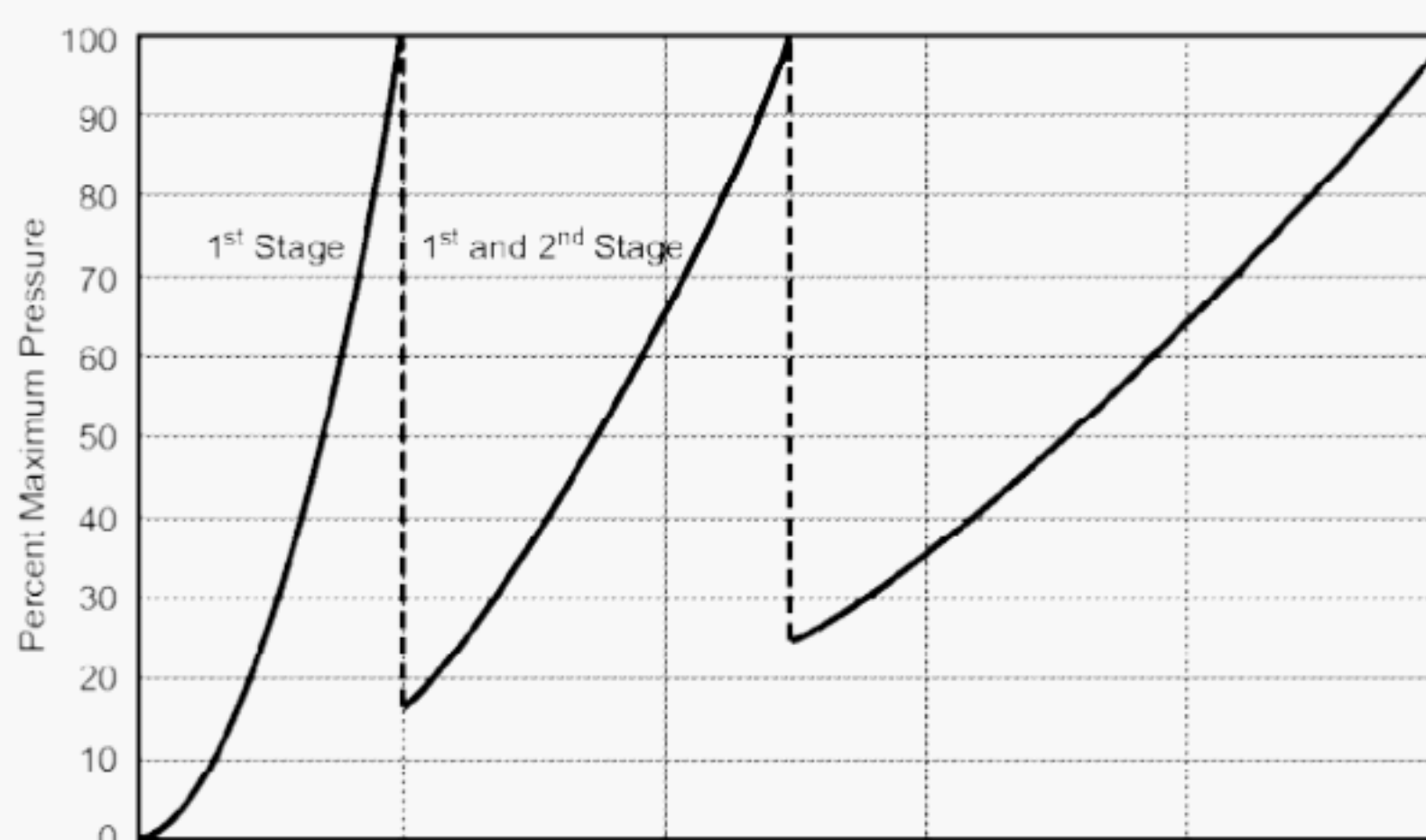


Figure 7—Multi-Burner Flare Staging Curve

size, pressure and sequence are also possible. See Section 5.10 and Figure 14.

Single and multi-burner, staged flares are fed from a manifold. The manifold distributes the flow of flare gas to individual branches containing one or more burner tips. ON/OFF valves direct the flow of flare gas to each branch. The operation is described above.

Flare system safety considerations require valve bypasses, each of which must contain a fail-safe device e.g., rupture disc, pin actuated device. Smokeless or non-smokeless flares are applicable to all of the above types of flares.

4.2.5 Smokeless and Non-smokeless Flares

4.2.5.1 Smokeless Flares

Smokeless flares eliminate any noticeable smoke over a specified range of flows. Smokeless combustion is achieved by utilizing air, steam, pressure energy, or other means to create turbulence and entrain air within the flared gas stream.

Local regulations and plant specific requirements generally define smokeless burning. Opacity is defined by Ringelmann numbering scale (#1 Ringelmann is 20 percent opacity; Ringelmann 0 is clear).

Typically the smoking tendency is a function of the gas calorific value and of the bonding structure of the hydrocarbons. The Paraffinic series of hydrocarbons have the lowest tendency to produce smoke, whereas olefins, diolefinic, and aromatic series of hydrocarbons have a much higher tendency to produce smoke.

Smokeless flares can be provided with a steam-assist or air-assist system to improve combustion. An air-assist system utilizes fans to provide mixing energy at the tip.

4.2.5.2 Non-smokeless Flares

Non-smokeless flares utilize no outside methods (air, steam, etc.) to improve combustion. This sometimes results in the presence of some smoke at certain operating conditions. Non-smokeless flares are typically, but not exclusively, sin-

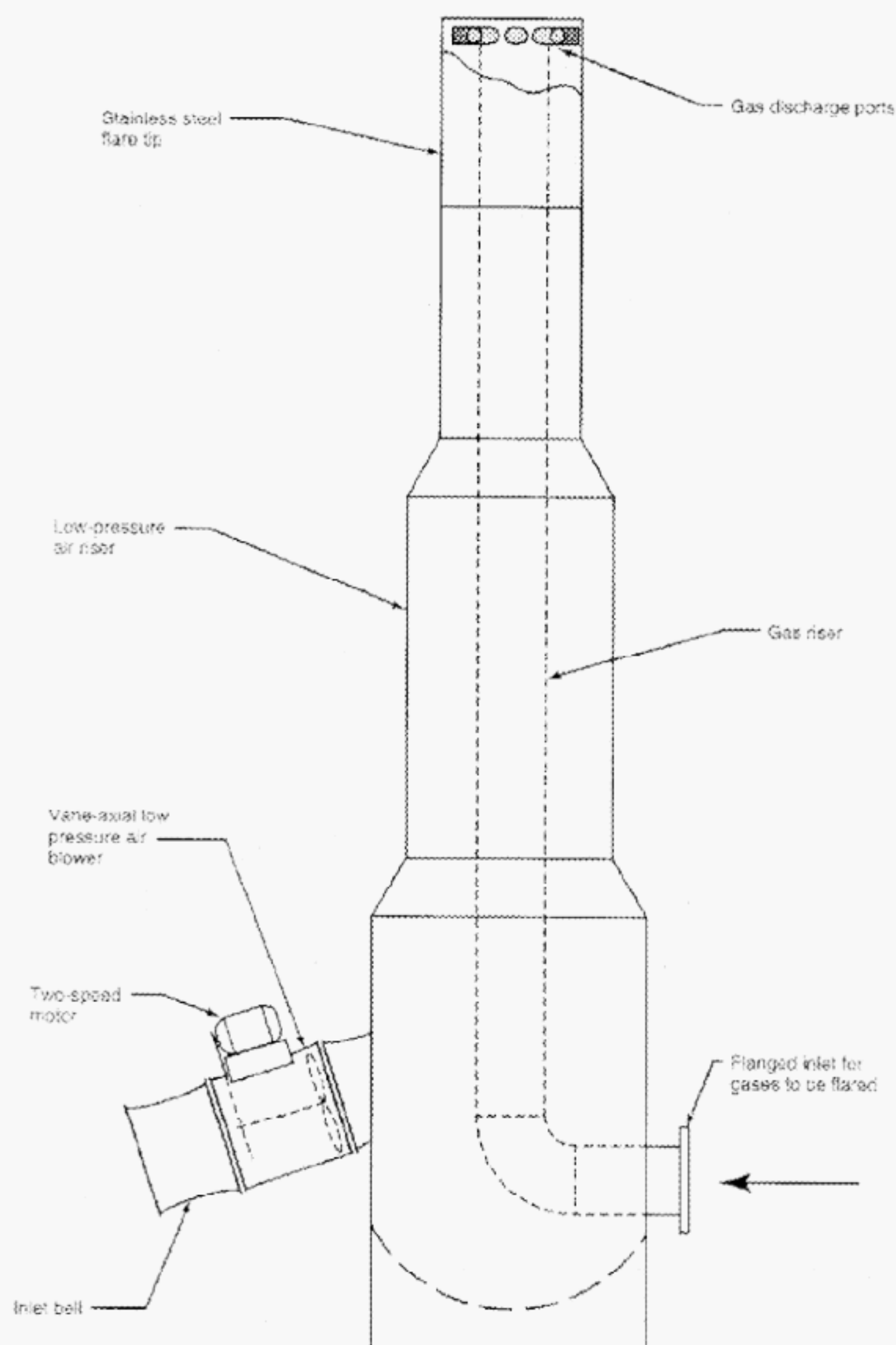


Figure 8—Air-Assisted Flares

gle-point flares. Non-smokeless flares can be used to supplement smokeless flares when the capacity on the smokeless flare is exceeded.

Non-smokeless flares are used for hydrocarbon or vapor streams that do not cause smoking (i.e., methane, hydrogen, carbon monoxide, clean coke oven gas, ammonia, hydrogen sulfide) or when smoke is not a concern.

4.2.6 Endothermic (Fuel Gas Assisted) Flares

Endothermic (fuel gas assisted) flares require supplemental heat when flaring low heating value waste streams (such as tail gas). An endothermic flare with a high-energy assist gas or high output pilots should be considered when:

- The heating value of the waste stream is below 5590 to 7450 kJ/Nm³ (LHV) (150 to 200 BTU/scf).
- As required to be in compliance with environmental regulations.

4.3 SELECTION CONSIDERATIONS

4.3.1 Selection of the types: Important considerations when selecting type(s) of flare to be used are:

4.3.1.1 Safety Requirements and Environmental Regulations must be satisfied when designing and selecting the flare.

4.3.1.2 Initial capital cost and operating and maintenance expenses.

4.3.1.3 Gas flow rates and Characteristics (composition, pressure and temperature) that are functions of process design.

4.3.1.4 Neighborhood Relationships, Availability and Cost of Utilities, Space Availability

4.3.1.5 Function of the overall plant design and location. This information is usually generated during the process design, layout or permitting of a facility.

Flare data sheets located in Appendix A should be used to convey information on the above factors to the flare designer and to the end user.

4.3.2 Interrelationships

The need for smoke suppression is influenced by the gas composition. Smokeless flares are used for hydrocarbon or vapor streams that cause smoking (i.e., paraffinic gases heavier than methane, all olefinic and diolefinic gases).

Gas composition influences flare system hydraulics. Pressure drop will be lower for a higher molecular weight gas (at equivalent mass flow rates) because of its greater density.

Gas system hydraulics (i.e., the gas pressure drop available for the flare equipment) can influence the method chosen for smoke suppression. The pressure (kinetic energy) of the flare gas can be used to make the flare operate without smoke if sufficient. The smoke suppression method is dependent on the utility availability and cost.

4.4 MAJOR COMPONENTS

4.4.1 The major and optional components for an elevated flare are:

- Flare burner with or without smoke suppression capability
- Pilot(s)
- Pilot igniter(s)
- Pilot flame detectors (optional)
- Buoyancy or velocity seal (optional)
- Support structure
- Knock-out drum (optional)
- Flame/detonation arrestor (optional)
- Liquid seal (optional)
- Piping
- Smoke suppression control system (optional)
- Blower(s) (optional)
- Flow, composition, heat content or video monitoring (optional)
- Ladders (caged or with safety-climbing system) and platforms (optional)
- Davit for tip removal (optional)

- Aircraft warning lights and painting (optional)
- Radiation heat shields (optional)
- Rain shields (optional)

4.4.2 The major required and optional components for multi-burner flares and tips are similar to those for elevated flares plus the following:

- Staging equipment and instrumentation (optional)
- Heat shielding for gas manifolds and headers (optional)
- Fence (type and purpose will be site-specific) (optional)

4.4.3 The major required and optional components for an enclosed flare are similar to those for multi-burner flares plus the following:

- Enclosure (structure, dike or fence)
- Refractory (optional)
- Heat shielding for gas manifolds and headers (optional)

4.5 MECHANICAL DESIGN BASIS

The mechanical design should consider the following:

- Flared stream temperature, pressure and composition (cryogenic considerations must be examined)
- Corrosive nature of the flared stream
- Ambient conditions (maximum and minimum)
- Wind, snow and ice loading
- Seismic loading
- Site conditions
- Proximity to equipment, structures, thoroughfares, and site boundaries
- Maintenance and inspection criteria
- Contraction/growth of stack due to ambient or process changes
- Design pressure in consideration of flashback

4.6 SYSTEM DESIGN CRITERIA

4.6.1 The design of a flare should be approached from a systems viewpoint. Each of the design criteria must be evaluated for its impact on other criteria and for conformance with Section 4.1. The major design criteria for a flare system are listed below:

4.6.1.1 Reliable effective burning:

Effective combustion is necessary to reduce emissions to permitted levels.

4.6.1.2 System hydraulics:

System hydraulics shall be sufficient to deliver all of the waste gas and auxiliary fuel gas, steam and air to the flare burner with sufficient exit velocities. System pressure cannot

exceed maximum allowable operating pressures at any active relief source, vent, or utility supply.

4.6.1.3 Liquid removal:

Liquids shall be removed sufficiently to prevent poor combustion, burning liquid droplets, and clogging of the flare burners.

4.6.1.4 Air infiltration:

Air infiltration into the system can cause internal combustion within the riser. It can cause flashback.

4.6.1.5 Flame radiation:

Flame radiation can cause damage or injury to nearby equipment, structures and personnel.

4.6.1.6 Smoke suppression:

Smoke suppression may be required where environmental or aesthetic considerations warrant.

4.6.1.7 Flare gas recovery:

A portion of the waste stream can be recycled to the plant fuel gas system after compression.

4.6.1.8 Noise and visible light:

Noise and visible light should be limited to permitted levels. System design should address neighbors concerns in this area.

4.6.1.9 Refer to API Recommended Practice 521, *Guide for Pressure Relieving and Depressurizing Systems* for additional flare system design considerations and criteria.

5 Elevated Flare Equipment Components

5.1 FLARE BURNER

5.1.1 Purpose

Its design must provide for the safe discharge of the maximum specified relief gas flow rates at the system allowable pressure drop as detailed by API RP 521. The flare burner mixes fuel and air at velocities, turbulence and concentration required to establish and maintain proper ignition and stable combustion. The flare burner ignites and combusts vapors discharged for process relief, for plant upset and emergency conditions. This mechanical device must control the combustion process for the specified relief conditions, and must produce the desired destruction/combustion efficiency. The mechanical components of typical flare burner designs are described in this section.

5.1.2 Unassisted Pipe Flare

An unassisted pipe flare is used where smokeless burning assist is not required. Ignition of the flare flame is by pilots. The pilots are ignited by a pilot ignition system.

The pipe flare burner may have a mechanical device or other means of establishing and maintaining a stable flame. The ignition fire from the gas discharge is initially ignited by interaction with the pilot(s) flames. Once the pilot lights the flare stabilizing flame, the flare should maintain flame stability over the operating design range.

Some flares are subject to regulations that limit exit velocity. For example, when Pipe Flares are applied in the USA as Control Technology for VOC emissions, the gas exit velocity may be limited by 40 CFR 60.18 (United States *Code of Federal Regulations*). The exit velocity per 40 CFR 60.18 is a function of flare gas properties. It is important to note that there are many flare applications that do not involve VOC control. Such flares are not required to meet the exit velocity requirements of the CFR.

The flame produced by an unassisted pipe flare will be a function of the relief gas composition and the gas exit velocity. At higher gas velocities, the gas discharge energy will pull combustion air into the flame, and will produce a shorter more erect flame that has greater resistance to wind deflections. At lower gas exit velocities, air will primarily be drawn to the flame by the buoyancy of the heated products of combustion. A buoyant flame is typically softer, longer and more wind affected than a flame that uses higher gas exit velocities.

Low gas exit velocities and buoyancy dominated flames may be employed for successful combustion of low heating value relief gas conditions. High gas exit velocities can be employed for hydrocarbon relief gases of higher heating value or for relief gases rich in hydrogen content.

Flare combustion noise is influenced by gas exit velocity. Increased relief gas exit velocity can produce greater combustion turbulence and have higher combustion noise levels. The highest combustion noise levels are realized when a flare burner is allowed to operate at a gas exit velocity where combustion instabilities occur. Combustion instability is defined as a flame that lights, lifts off, goes out and re-ignites in a semi-cyclic mode.

The prime operating concerns with unassisted pipe flares are that the relief gas discharging from the flare burner must occur within the hydraulic design for the flare system (within the allowable pressure drop, and flame combustion velocity limits), and is ignited and burned with the designed flame characteristics.

Wind actions at low flaring rates can produce internal burning and/or external flames that remain attached to the flare burner. The flare burner should be designed to withstand the effects of such internal and attached external burning. On larger size flare burners, internal refractory linings are sometimes employed to mitigate the thermal effects of internal burning. Refractory linings reduce the high thermal gradients that produce buckling in flare burners. Buckling of the flare burner shell is the first sign of almost all flare burner failures.

Windshields may be employed on pipe flares to help mitigate wind-induced attachment of flames to the external flare burner surfaces.

For plant design, the full range of relief gas compositions and flare burner exit velocities must be engineered to operate successfully with the size of pipe flare selected.

5.1.3 Steam Assisted Pipe Flare

The basic flame stabilization for a steam assisted smokeless pipe flare is similar to that of the basic pipe flare described above. The steam assist equipment should not disrupt the basic flame stabilization mechanisms of the flare burner and can in some cases be made to assist in the flame stabilization.

Gas exit velocities are limited for steam assisted flare tips in a means similar to that of basic pipe flares. Steam injection adds potential dilution to the relief gases, even steam operated at minimum purge rate. Steam assisted flares thus typically require a more combustible gas mixtures to achieve desired VOC destruction efficiencies. As a 40 *CFR* 60.18 regulated VOC Control Device, a steam flare requires a minimum of 11175 kJ/Nm³ (300 BTU/scf) versus 7450 kJ/Nm³ (200 BTU/scf) for unassisted pipe flares.

The flame produced by a steam assisted pipe flare is a function of the relief gas characteristics, the gas exit velocity and the steam injection design.

Steam assist is used to control the formation of smoke that accompanies the relief of many hydrocarbon gases. Section 4.2.5.1 describes the smoking tendency considerations. The steam injection functions to produce smokeless combustion by educting combustion air, thus increasing momentum and turbulence in the flare flame. The addition of combustion air, momentum and turbulence can produce flame characteristics for smokeless flaring rates where shorter more intense flames are produced. These flames will have greater resistance to wind deflection and may have reduced radiation fractions.

The quantity of steam required for smokeless burning is a function of the gas composition, the flare burner size and design, the steam injector design and operating pressure, and

design of the flare burner. API RP 521 provides guidance on typical steam rates for elevated flares.

The upper steam injection functions to inspire air and to force the air mixture into the relief gas discharging from the flare burner. The steam injection pattern also must enhance fuel air mixing and can add to the momentum of the relief gas discharge. The steam and air acts to dilute the hydrocarbon fuel content that also reduces the smoking tendency. The steam vapor can also participate in the combustion kinetics assisting in the conversion of carbon to carbon monoxide.

Compressed air or other high-pressure gases, including light molecular weight hydrocarbon vapors, can be used in an upper "steam" ring, but steam has been found to be the most effective medium.

Effective addition of steam from an upper steam ring increases the turbulence of combustion. The combustion noise level will increase. There will also be jet noise from the steam nozzles. Steam assisted, smokeless flares may have significantly increased overall noise levels in comparison to flares with no steam assist.

In addition to the operating concerns mentioned previously for the pipe flare, attention must be given to the rate of steam injection. If too little steam is added to the flare burner, a smoking, softer, more wind-deflected flame will be produced. Proper steam injection will proportion the steam injection rate to the relief gas flow rate. The lowest cost operation for steam injection will be to operate just above the incipient smoke point for the gas composition and flow rate.

Higher steam injection rates will make the flame harder, cleaner and less wind deflected. Higher steam injection rates will also increase the noise levels. Excessive steam injection rates will produce combustion instability accompanied by excessive flare noise (low frequency, pulsating). At an extreme, over-steaming can extinguish the flame.

The addition of steam injection equipment does not change the purge gas requirements for a flare burner.

The upper steam ring will be subjected to flame impingement due to wind action. Cooling steam flow is utilized to mitigate this. This minimum steam flow is also set to maintain temperature in the steam system to avoid condensation

A center steam injector may be used to mitigate internal burning. A properly designed center steam injector will add steam to the low relief flow rate gases. This will help push the

from the internal steam/air injection point and from any muffler surrounding these tube assemblies in areas where long periods of freezing temperatures are expected to occur.

proportioned to the gas flow by a blower damper or blower speed control. Alternately, the forced airflow can also be controlled in discrete steps by the use of multiple speed blowers or multiple blowers. At low relief gas flow rates, a minimum continuous airflow may maintain cooling airflow and proper aerodynamic design across the tip. Airflow can be increased as the relief gas flow rate increases. Care should be taken not to over-aerate the flame. Over-aeration can produce combustion instabilities that increase flare noise and vibration. At an extreme, excessive assist airflow can extinguish the flame.

The purge rate of the air-assisted flare should consider the tip design, size, and how the forced airflow interacts at turn-down conditions with the wind and environmental factors. A minimum airflow rate is required to protect the spider arms or internals of the burner from overheating.

A blower system should be designed to produce the design airflow rate and velocity at the flare burner considering the air delivery system. The blower power should be selected with regards to the delivery of the densest air (coldest ambient temperature). Blowers of all types including axial, centrifugal, etc., have been used for air assisted smokeless flares.

5.1.6 High Pressure Smokeless Flares

High-pressure smokeless flares are used where smokeless burning is required and the relief gases are discharged from the flare burner at a high pressure. The pressure required is dependent upon the gas composition, burner design and other factors. The pressure of the relieving gas is converted to kinetic energy to promote air entrainment and mixing which produces smokeless burning. The advantage is that supplemental energy from a steam supply or a forced draft blower can be eliminated or minimized.

High-pressure flare flames can be stabilized using the aerodynamic effects of the relief gas discharge and its entrained air. Mechanical flame holding devices are often not required. As high-pressure flares operate with high gas exit velocities, the gas compositions flared with this equipment must be rich in hydrocarbon fuel content and/or hydrogen. High-pressure flare technology should not be used for combustion stability limited relief gas cases, such as those containing high inert content. For relief gas cases of sufficient hydrocarbon fuel content, high-pressure flares have been shown to produce very high hydrocarbon destruction efficiencies exceeding 98%.

The flame produced by a properly designed and operated high pressure flare tip effectively converts the gas pressure to kinetic energy that entrains and mixes combustion air with the fuel to produce a smokeless flame that is resistant to wind deflection. Proper use of the gas pressure energy requires that the gas kinetic energy have access to entrain combustion air. For some gas flow rates and compositions this requires the use of multiple nozzles or gas distributors.

If a flare burner is designed for high-pressure operation, there may be some turndown gas flow rate at which the pres-

sure conversion to gas kinetic energy is insufficient to properly entrain and mix combustion air. At this turndown condition, the high-pressure flare may have a smoking flame that is subject to wind deflections. To improve turndown, high-pressure flares are often staged to promote smokeless burning with design flame characteristics over a wider operating range (multi-burner flare systems).

High-pressure flare technology is particularly effective for oil and gas production facilities. High-pressure flares can greatly reduce the flare flame radiation.

High pressure flare operations have a prime operating concern that the relief gas rate discharging from the flare tip(s) occurs within the hydraulic design for the flare system (within the allowable pressure drop and flame combustion velocity limits) and is ignited and burns with the desired flame characteristics. If multiple nozzles are used, these nozzles must be located to assure proper ignition for the gas discharge from each nozzle. Gas compositions and/or flow rates that are not compatible with the high-pressure flare design must be avoided.

High-pressure flare operations will produce both combustion noise (due to the high intensity flame produced) and jet noise due to the high-pressure discharge of the relief gas to the atmosphere. With proper high-pressure flare design, the combined flare noise level can be managed. Overall noise levels for a properly designed high-pressure flare may not exceed the noise level of a comparably rated steam assisted smokeless flare.

High-pressure flare operations produce flames that are dominated by the kinetic energy of the gas discharge. These flames have significant upward momentum and are not unduly effected by cross winds. High pressure flare tips, though, should be designed to accommodate any flame impingement that can possibly occur at low relief gas flow rates and thus at low pressure operation.

5.1.7 Mechanical Details of Flare Burners

5.1.7.1 Flare Burner Dimensions and Connections

Flare burners are typically dimensioned from their attachment point at the flare support structure to the gas discharge point.

Flare burners are often nominally described by their connecting pipe size, i.e., a 600 mm (24 in.) flare burner for a 600 mm (24 in.) pipe riser, a 1500 mm (60 in.) flare burner for a 1500 mm (60 in.) pipe riser. The upper diameter of a flare burner can be larger than the nominal diameter to accommodate for internals.

Elevated pipe flares with or without steam assist tips are either flanged to the flare riser or can be welded. Flare burners sized 100 mm (4 in.) or less may be attached by threaded connections. Steam supply connections should be forged flanges of a rating appropriate for the steam service connection. Pilot

gas and FFG connections 25 mm (1 in.) or less may be threaded, socket welded, or butt-welded.

Internal gas connections on air assisted flare burners are often welded to avoid obstruction of airflow.

High-pressure flare attachments should consider the thrust load produced from the gas discharge.

5.1.7.2 Flange Ratings

For gas risers to flare burner connections, flanges are normally used. Mechanical suitability must be confirmed for specific application. Recommendations are as follows or according to purchaser requirements:

- For 24 in. NPS and smaller tips: Class 150, RFSSO in accordance with B16.5
- For greater than 24 in. NPS: Forged flanges or fabricated plate flange drilled to industry standard dimensions as provided in the following table. For other flange sizes greater than 1500 mm (60 in.), follow flare manufacturer's standard.
- Auxiliary connections greater than 25 mm (1 in.) such as steam and natural gas: Flange ratings to ANSI B16.5 shall be used.

The attaching flange should meet the metallurgical requirements of the flare support structure. For a carbon steel stack a carbon steel tip flange is acceptable.

Flange bolting dimensions for flare burners larger than 24 in. are shown in Table 1.

Flanges may be forged or fabricated from plate of an appropriate material.

Air ducting associated with air assisted flares may be assembled using manufacturer's standard plate flanges (including air connections at the flare burner).

5.1.7.3 Flare Burner Handling and Lifting Lugs

Flare burners are often equipped with lifting lugs or brackets for initial attachment. These lugs or brackets should be removed prior to placing the flare burner in service. The lug or bracket, if left attached, will be subjected to the flare operating conditions, including possible internal or external flame attachment. The initial installation bracket should not be trusted for removal of a flare burner after it has been placed in service. Often such lifting lugs are made of carbon steel, designed to "burn off" in operation.

5.1.7.4 Materials

Flare burner components need to possess acceptable fatigue and elevated temperature strength. They may need to be resistant to thermal cycling, stress corrosion cracking, high temperature corrosion (in reducing or oxidizing atmospheres) or ambient temperature corrosion. Tip materials would nor-

Table 1—Flange Bolting Dimensions for Flare Burners Larger Than 24 in.

Flare burner O.D. at Connection ¹	Bolt Circle Diameter	No. of Bolt Holes	Bolt Hole Diameter
26	29.875	28	0.875
28	31.875	28	0.875
30	34.125	36	0.875
32	36.125	36	0.875
34	38.375	36	1.000
36	40.375	36	1.000
38	42.375	36	1.000
40	44.375	40	1.000
42	46.875	40	1.125
44	48.875	40	1.125
46	50.875	40	1.125
48	52.875	44	1.125
50	54.875	44	1.125
52	57.250	44	1.250
54	59.250	44	1.250
60	65.250	48	1.250

¹Bolting dimensions are based on Industry Standard Flanges; Class 175.

mally consist of austenitic stainless steel or high nickel alloy depending on the particular service.

The upper section of the flare burner, steam assisted or not, is typically fabricated of heat resistant alloys. Grade 310 stainless steel is a normal standard. Alternative materials for greater heat resistance or to improve resistance to fuel and combustion product corrosion and erosion can be supplied. The lower flare burner section material including the attachment flange can be fabricated of carbon steel or lower grade 304 stainless steel where flare process conditions do not warrant alternative materials for temperature, corrosion, erosion or other factors.

The use of alternative materials entails a cost/benefit analysis. The initial cost of a more expensive material should be compared against the cost of unit outage, gas freeing procedures, crane rental and the risks associated with having a flare out of service.

Air assisted flare burners may use shorter lengths of 310 stainless steel and/or alternative materials as the flare burner is normally cooled by the forced airflow.

High-pressure flare burner material is a function of the flare burner design and flame impingement that could occur at low rates.

It should be noted that many flare burner material failures occur at low relief gas flow rates. At these low rates, the flare burner is most subjected to the detrimental effects of internal or external attached flames. At higher gas flow rates in a pipe flare, an air assisted flare or a high-pressure flare burner, the flame is lifted out of and off of the flare body. In fact, at high flow rates, the convective effects of the gas flow effectively cool the flare body.

The material of the upper steam ring and ejectors shall be selected on the basis of exposure to the flame and cyclic conditions. The material selection for the flare burner steam piping should consider the effects of intergranular corrosion due to the wet, cyclic, high temperature service.

5.1.7.5 Welding Requirements

Flare burner barrel and welded attachments should be fabricated to ASME and AWS welding requirements.

5.1.7.6 Flare Burner Piping

Flare burner piping is per ASME B31.3 or at the superior requirements of a user or flare manufacturer specification.

5.1.7.7 Hydro Testing for Flare Burners

Hydro testing for flare burners is not required nor recommended.

5.1.7.8 Attachments to Flare Burner

Any piping load applied to the flare burner connections must be clearly defined. Thermal load, dynamic loads and dead loads (including the weight of water in the steam lines) must be considered. Only auxiliary piping associated with the flare tip should be supported off of the flare burner. The attachment of pilots, steam injection equipment, windshields and the like, should accommodate the differential thermal growth that can occur during service.

5.1.7.9 Wind Shields for Flare Burners

Windshields are applied to unassisted pipe flares. A properly designed steam assisted flare, air assisted flare or high-pressure flare tip should not require a windshield. Windshield design is somewhat proprietary to flare tip manufacturers. As a basic consideration, wind shields for pipe flare should be considered sacrificial equipment. The windshield is likely to burn up sacrificing itself to promote improved service life of the pipe flare tip.

Windshield designs located above the gas exit of the tip may require special design considerations.

5.1.7.10 Muffler for Flare Burners

Mufflers for flare burners should be designed to prevent damage from excessive flame conditions. Muffler design

should not restrict the flow of combustion air into the flare flame. Mufflers for lower steam/air injection locations are effective in reducing steam jet noise. These mufflers, if properly designed, will improve airflow into the internal steam/air tubes by mitigating wind effects. Mufflers, if required, for air assisted flares are typically applied to the forced draft blower air intakes.

Noise from high-pressure flare designs is controlled by proper nozzle design factors.

5.1.7.11 Refractory for Flare Burners

Refractory is not always used for flare burners.

However, it is sometimes used for large diameter (greater than 42 in.) pipe flares to mitigate the effects of internal burning. External refractory has been used to protect the flare tip barrel from flame pull down.

The refractory used for flare tips must be temperature and thermal shock resistant. Flare tips experience rapid changes in temperatures. Internal refractory should be well anchored and it is recommended that the refractory material include metal needles to help hold it in place. External refractory linings are similar in application.

With any refractory installation, consideration needs to be given to the consequences of a refractory failure. For dense refractory material, this consideration concerns where failed refractory will fall. The refractory might fall inside the flare and potentially obstruct the relief gas flow. External refractory falling to grade will limit potential access to the base of the flare structure.

Should a lined tip be specified, experience has shown that no single refractory material or attachment method is suitable for all cases. In fact vendors are continually modifying their specifications based on user experience and material improvements. Therefore when approving a lining specification, attention should be paid to the following list:

- a. Refractory material—the refractory temperature range, stability, and cycling characteristics, its optimum thickness and castability, and its susceptibility to moisture
- b. Attachment method—There are various methods of anchoring refractory. Typically “bull horns” or hexmesh are used. Consideration should be given to installation procedure and the potential for the anchoring system to create shear planes in the lining.
- c. Refractory reinforcement—This is typically in the form of stainless steel needles. The needles reduce cracking and hold the refractory together.

Proper steam assisted flares can use center steam to eliminate the need for internal refractory linings. Air assisted and/or high-pressure flare burners are not typically refractory lined.

5.1.7.12 Maintenance Issues

Flare burners generally should be removed when maintenance is performed. All auxiliary-piping connections should be designed to facilitate flare burner removal. When a flare burner has buckled, a temporary patch repair will only last for a short term.

In some cases, a spare flare tip is kept to replace flare tips that are undergoing maintenance.

A portable crane is normally used to remove and replace the flare burner. In remote locations where cranes of sufficient height are not available, consideration should be given to providing a retractable davit on the flare structure. In normal operations, the davit is lowered below the level of the top platform or below the gas seal, to a position where the flame will not affect it. Lifting tackle should be provided to raise the davit into the lifting position.

Consideration will have to be given to the additional wind loads resultant from the flare-mounted davit.

5.1.8 Operations

5.1.8.1 Steam control for a flare burner equipped with both an upper steam ring and a center steam is typically controlled in the following manner:

a. Set the center steam manually to effectively mitigate internal burning and to produce the desired smokeless burning for normal, daily, minimum relief gas flow rates. Avoid excessive center steam quantity, as it will create excessive flare noise levels.

b. Operate the upper steam ring to control other relief gas flow rates to produce smokeless burning and the desired flame characteristics. Excessive upper steam will also produce excessive flare noise levels.

5.1.8.2 A flare burner equipped with internal steam/air tubes and upper steam ring and center steam rings is typically controlled in the following manner:

a. Set the center steam manually to effectively mitigate internal burning and to produce the desired smokeless burning for normal, daily, minimum relief gas flow rates. Avoid excessive center steam. It will create excessive flare noise.

b. Allow the internal steam/air tubes to operate before adding steam to the upper steam ring. Adjust the steam/air to produce the desired smokeless burning rate at the lowest possible noise levels.

c. Start the upper steam ring to increase the smokeless burning rate above that achievable with the internal steam /air tubes. The upper steam ring may also be used to act as wind-shield to reduce wind effects on the flare flame and on the flare burner.

5.1.8.3 For pipe flare operations, the only plant control is to maintain flare pilot ignition and maintain proper flare tip purge rates.

5.2 PILOTS

5.2.1 Purpose

The flare pilot must reliably ignite the flare. If the pilot fails, unburned hydrocarbons and/or toxic gases could be released to the atmosphere, potentially resulting in a vapor cloud explosion, odor problems or adverse health effects. In most elevated flare applications, the pilot cannot be accessed for service or replacement while the flare is in operation. The pilot system must be reliable enough to operate for years without maintenance.

5.2.2 General Description

A multitude of pilot designs exists. The majority can be described as fixed heat release, self-inspiring, pre-mix burners. The principle advantages of such pilots are:

- a. The pilot reliability is dependent on only one utility (i.e. fuel gas) since the air is self-inspired.
- b. The pre-mix type design affords greater stability and reliability relative to raw gas or diffusion flame type burners.

In some cases, compressed-air pre-mix pilots have been used instead of the inspiring type. In addition to the fuel gas supply, compressed air pilots are dependent on the reliability of the compressed air system. To safely utilize compressed air pilots, an effort should be made to ensure that installation is done via one of the following conditions:

- a. The compressed air system has sufficient reliability. The probability of pilot failure due to air supply failure is acceptably low.
- b. The flare can be immediately taken out of service if the compressed air system fails
- c. The pilot's function will automatically revert to inspiring if the compressed-air supply fails
- d. An independent set of inspiring pilots is installed as backup.

In some cases direct spark ignition of the flare or of a slip-stream of the flare gas has been used in lieu of a continuous pilot. Such designs are not considered to be a suitable alternative to a continuous pilot because, without an independent fuel supply, it is impossible to ensure that a flammable mixture will always exist at the location of the spark.

In order to ensure stable operation and ignition of the flare gas, the recommended minimum pilot heat release is 13.2 MW (45,000 BTU/hr) (LHV) when flaring hydrocarbon gases with a lower heating value of 11175 kJ/Nm³ (300 BTU/scf) or greater. Pilot heat release in common practices ranges

from this minimum up to 102.5 MW (350,000 BTU/hr). The pilot should remain lit and continue to ignite the flare at wind speeds up to 160.9 km/hr (100 mph) under dry conditions and 136.7 km/hr (85 mph) when combined with 2 in. of rainfall per hour.

The number of pilots required is a function of the flare burner diameter. For very small flares, a single 13.2MW (45,000 BTU/hr) pilot will reliably light the flare gas. However, it should be noted that if only a single pilot is used, a single pilot failure would represent a complete failure of the ignition system.

As the flare burner diameter increases, the number of pilots required to reliably light the flare, regardless of wind direction, increases. The minimum number of pilots recommended for most flare burners is given in Table 2 as a function of tip diameter (actual connection size, not hydraulic diameter) when flaring hydrocarbon gases with a lower heating value of 11175 kJ/Nm³ (300 BTU/scf) or greater.

While the recommended minimum number of pilots for flare burners of 200 mm (8 in.) or less is only one, greater reliability can be achieved if at least two pilots are installed on every flare. Pilots in excess of those shown are often added to further reduce the risk of an unburned release.

For non-hydrocarbon gases or hydrocarbon/inert mixtures with heating values less than 11175 kJ/Nm³ (300 BTU/scf), additional pilots, higher heat release pilots, or some other form of fuel gas addition may be required.

5.2.3 Mechanical Details

The continuous pilots listed above can be broken into two groups depending on the means of achieving the fuel/air pre-mix: self-inspiring and compressed air. Both self-inspiring and compressed air pilots generally consist of the following components: a fuel orifice that meters the fuel, a mixer in which the air and fuel are blended, piping which connects the mixer and pilot tip, and a pilot tip where the flame is stabilized.

Table 2—Minimum Number of Pilots Recommended for Most Flare Burners

Min. Number of Pilots Recommended	Flare burner Diameter (mm)	Flare burner Diameter (in.)
1	Up to 200	Up to 8
2	Up to 600	Up to 24
3	Up to 1050	Up to 42
4	Up to 1500	Up to 60

The most significant difference between self-inspiring and compressed air pilots is the design of the mixer. In a self-

inspired pilot the mixer is an eductor and the fuel orifice is not only used for fuel metering, but is also the means by which a fuel jet is created which inspirates air into the eductor. The components of a typical self-inspiring pilot are shown in Figure 9.

In a compressed air pilot the mixer is designed to meter and blend two pressurized gas streams. Two orifices are required in this case, one for the fuel gas and one for the air.

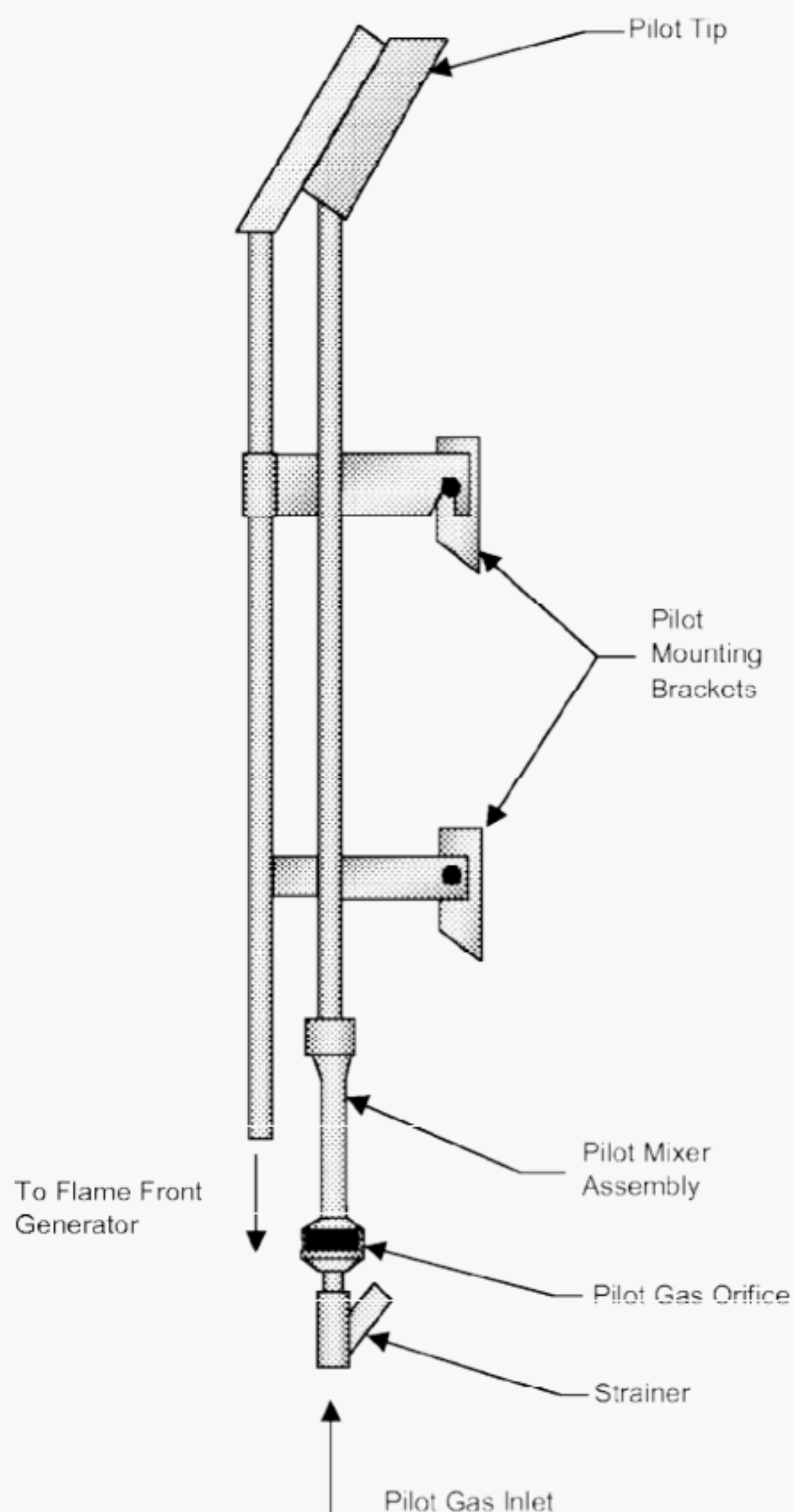


Figure 9—Flare Pilot Assembly

The pilot should be long enough that the mixer is not exposed to the flare flame. The mixer must never become enveloped in burned or unburned flare gas. The pilot mixer should be a distance of at least 1.8 m (6 ft) or 125% of the actual tip diameter (whichever is greater) from the top of the tip. Cast iron, ductile iron, and carbon steel are adequate materials for construction for the pilot mixer, pilot gas orifice and strainer. Stainless steel is sometimes used for the mixer in order to avoid deterioration due to rust. Rust could affect pilot reliability by blocking the mixer thereby affecting the pilot's air to fuel mixture ratio.

Pilots are available with mixers located at much greater distances from the flare burner, and in some cases even at grade. Inspiring pilots of extended length are often made from larger piping. They have few bends in order to minimize pressure drop.

Because of the increased piping pressure drop, less pressure drop is available at the pilot tip. Consequently, these designs often have a more restricted range of gas pressure and composition over which they can operate. Issues arising from increased pressure drop in extended length pilots are not as problematic in compressed air pilots. Compressed air pilots can operate at higher pressures.

The pilot tip is continuously exposed to the pilot flame and may routinely be exposed to the flare flame. The pilot tip should be constructed of a heat resistant material, such as 309SS, 310SS, CK 20, or a nickel-based alloy such as 800H. If the flare or pilot gases are expected to contain H_2S , the nickel-based alloys should be avoided, or some protective material should be installed to prevent high temperature corrosion in this environment.

The piping between the pilot tip and mixer may occasionally experience exposure to the flare flame. For this portion of the pilot, an austenitic stainless steel, such as 304SS or 316 SS is adequate.

In order to minimize the chance of pilot failure due to orifice plugging, a strainer or a settling chamber should be installed just prior to the fuel orifice. The strainer should contain a screen or wire mesh with openings that are 25% or less than the diameter of the fuel orifice.

A settling chamber should be sized to remove similarly sized particles. The strainer or settling chamber should be accessible from grade or from a platform below the flare burner. Occasionally, pilot designs are employed which are completely retractable. In the case of a retractable pilot, not only the strainer, but also the entire pilot can be serviced at grade.

With a typical length pilot, the strainer or settling chamber, located just upstream of the fuel orifice, will be very near the flare burner. It will only be accessible when the flare is shut down. In some instances this strainer has been removed since it cannot be routinely serviced. A strainer will collect many particles before it plugs, while the pilot

orifice only requires one particle to plug. Strainer removal is not recommended.

In order to prevent the strainer at the pilot from plugging, an additional strainer should be mounted at grade. The strainer at grade should allow routine on-line cleaning. The strainer mounted at grade should be equipped with a screen or wire mesh that has the same size or smaller openings as the screen installed in the strainer at the pilot.

In addition to the strainers mounted at grade, a knockout pot is recommended if there is any possibility for condensate to form in the pilot fuel line. The pilot fuel supply should also be equipped with its own regulator to prevent other intermittent gas uses to cause a significant change in pilot gas pressure. The regulator should be installed downstream of the strainer and knockout pot. A pressure gauge downstream of the regulator is needed to properly set the regulator. A flow meter in the pilot fuel gas lines is not a requirement, but can be an extremely helpful troubleshooting tool when pilot troubles occur.

In order to accommodate pilot removals for maintenance or replacement during shutdowns, provisions should be included in the fuel supply for either a double-block-and-bleed valve arrangement or the insertion of a blind flange.

If the strainers and knockout pot installed at grade function correctly, the remaining major source of debris that may plug the strainer upstream of the pilot are corrosion products from the fuel line piping. The most common pilot fuel piping is 12.5, 19, or 25 mm ($1/2$, $3/4$ or 1-inch) carbon steel piping. This piping is structurally sound and inexpensive. Unfortunately, carbon steel is subject to corrosion.

In order to avoid corrosion, stainless steel piping or tubing can be used. Stainless steel piping is the best alternative, but it is expensive. Stainless steel tubing offers superior corrosion resistance, but has limited durability if not properly supported. The choice of piping material is left to the user. However, if carbon steel is to be used with corrosive plant fuel gas, separate fuel lines to each pilot should be considered. Fuel lines in older installations should be inspected periodically to determine the condition of the fuel lines.

5.2.4 Operation

In order to maximize pilot reliability, the most consistent and reliable fuel source should be used. Where possible, natural gas should be used. Its availability and composition are generally more consistent than that of plant gas. The likelihood of corrosion associated with impurities is much lower. If plant gas is used, due consideration must be given to the range of fuels to be handled. Some level of stability under adverse conditions will be sacrificed as the range of fuel compositions to be handled is increased.

Prior to operation, the pilot fuel lines should be blown clear. The pilots should not be attached to avoid blowing debris into the pilots' strainer or mixing orifice. The composi-

tion of gas within the flare system should be confirmed to be outside the explosive range prior to pilot ignition. Typically this is achieved by purging with several system volumes of inert gas prior to pilot ignition. See API RP 521 for more information on flare purge requirements prior to start-up.

Once the lines have been blown clear and the flare system has been confirmed to be outside the explosive range, the pilots can be ignited. Operation of the ignition equipment is covered in Section 5.3. Once ignited, the pilots should be monitored to confirm that each pilot has a flame. Flame detection is covered in Section 5.4. If the pilots are extinguished they should be re-ignited immediately. The pilots should remain lit as long as the flare is in service.

5.2.5 Maintenance

Routine maintenance of the pilots should be performed while the flare is in service. This consists of monitoring the supply pressure and cleaning the fuel strainers, knockout pots and drains that are accessible from grade.

When the flare is taken out of service, the strainer upstream of the orifice should be cleaned and the orifice should be inspected. In addition, the pilot tip should be inspected. If the pilot tip shows signs of deterioration, it should be replaced.

5.2.6 Troubleshooting

Determination if a pilot flame has failed is covered in Section 5.4, Flame Detection Equipment. If a pilot is known to have failed and will not re-ignite, the explanations in Table 3, Troubleshooting Pilots, are possible.

Table 3—Troubleshooting Pilots

Problem	Possible Cause	Corrective Action
Ignition system failure		See Section 5.3, Ignition Equipment before attempting to troubleshoot the pilots themselves.
Plugged pilot tip or eductor	This may occur at start-up due to debris left behind during manufacture. Plugging will cause the mixture at the pilot to be fuel rich. If the flame does ignite, it is likely to be orange and lazy. If the plugging is severe, most of the gas may exit the mixer. Severe plugging may result in a flame exiting from the vicinity of the mixer.	Remove debris either manually or via high pressure blowing.
Plugged pilot tip or eductor	Debris accumulation while out of service, such as a wasp nest.	Remove debris either manually or via high pressure blowing.
Plugged pilot tip or eductor	Unsaturated fuel hydrocarbons	Remove debris either manually or via high pressure blowing. Return to design fuel gas
Damaged pilot tip	If the pilot tip opening(s) have increased in size, the pressure drop in the pilot will have decreased. The air/fuel mixture at the pilot will become more fuel lean. Pilot may not stay lit or flashback may occur. Pilot may be difficult to light.	Replace pilot tip
Plugged strainer, plugged nozzle or plugged orifice	This can be detected by turning the fuel gas on and then off. If the fuel line is not plugged, the fuel pressure should fall very rapidly. If the fuel pressure does not fall, or falls slowly, then the fuel line is probably plugged. The flare vendor may advise the time expected for the pressure to fall.	Clean strainer, nozzle or orifice as required.
Incorrect fuel.	This can be determined by a fuel sample analysis. If the hydrogen concentration has increased significantly, flashbacks may be audible and flames may be visible at the mixer.	Return to design fuel gas or modify pilot to match the new fuel composition. Pilot modifications may include: a. Replace pilot orifice. b. Adjust air door (if any) c. Replace pilot entirely

5.3 IGNITION EQUIPMENT

5.3.1 Purpose

Ignition equipment must reliably ignite the pilot.

5.3.2 General Description

There are four types of ignition systems that are commonly employed to light flare pilots:

- Spark ignition at pilot tip
- Spark ignition of a portion of the pilot gas/air mixture prior to the pilot tip
- Compressed air flame front generator
- Inspiring flame front generator

Spark ignition at pilot tip: Spark ignition of a flare pilot at the pilot tip is simple and is easy to automate. With this system the spark generation must be located somewhere near the pilot tip where it will be exposed to the flammable mixture that exits the tip. In some cases, the life of the sparking device may be shortened due to continuous exposure to the pilot or flare flame once ignition is established. Unlike pilots used in boilers or process heaters, the flare pilot or sparking device cannot be replaced while the flare is in operation. Consequently, spark ignition at the pilot tip is generally not recommended as the only means of pilot ignition.

Spark ignition of a portion of the pilot gas/air mixture prior to the pilot tip: In order to limit the sparking device's flame exposure, the sparking device can be used to ignite a portion of the pilot's gas/air mixture prior to the flame exiting the tip. Downstream of the sparking device, the ignited portion of the gas/air mixture is reintroduced to the pilot tip. Such a system has to be carefully designed to prevent flashback or stable burning between the ignition source and the pilot tip. As with spark ignition at the pilot tip, this type of system is relatively easy to automate. However, the sparking device is still located at the pilot and cannot be serviced while the flare is in operation. Consequently, spark ignition prior to the pilot tip is generally not recommended as the only means of pilot ignition.

Compressed air flame front generator: The most prevalent flare pilot ignition system is the compressed air flame front generator. With this system, compressed air and fuel are metered through orifices into a mixing chamber located at grade. Downstream of the mixing chamber there is a sparking device and piping which connects the mixing chamber and sparking device to the pilot tip. See Figures 10 and 11. During operation the flow of combustible gas is established and then ignited. This sends a flame front through the connecting piping to the pilot tip. The flame front ignites the pilot. The principal advantage of the compressed air flame front generator is

that the flow controls and the sparking device are at grade and can be serviced while the flare is in operation. The principal disadvantage of the flame front generator is its propensity to form moisture within the piping leading to the pilot. The moisture can cause corrosion and, if not drained prior to use, can extinguish the flame front. In cold environments, the moisture problem often results in the requirement for heat tracing and insulation in order to avoid freezing. Flushing each ignition line after use can reduce the moisture problem.

Self-inspiring flame front generator: This approach is similar to that of the compressed air flame front generator, but instead of compressed air, fuel pressure is used to inspire the combustion air. The obvious advantage is that compressed air is not required. The disadvantage is that self-inspired devices can generate only limited pressure; consequently, they can only be applied to limited distances and piping configurations.

Based on the above discussion, no single ignition system is preferred in all circumstances. For improved reliability, multiple ignition systems can be installed. Spark ignition at the pilot is often preferred as the primary means of ignition because it is easily automated. A manual compressed air flame front generator is commonly installed as backup system because of its ultimate reliability and serviceability.

5.3.3 Mechanical Details

5.3.3.1 Spark Ignition at Pilot Tip

Generally, these systems require that an electrode capable of a capacitive high-energy or high-voltage discharge be located close to the pilot tip discharge. The electrode may be routed down the interior of the pilot or along the outside of the pilot. Electrode supports and/or penetrations into the pilot must be constructed such that they electrically isolate the electrode from the pilot.

In some cases the electrode in this location will serve the dual role of igniter and flame ionization detector. See Section 5.4 for more on flame ionization for pilot flame detection.

The distance between the electrode and a high voltage power supply is often limited to approximately 7.5 m (25 ft). This limitation requires that the power supply be mounted on the flare stack. This distance is great enough that the power supply is usually not subject to damage from the flame, but small enough that the power supply cannot be accessed while the flare is in service.

Low voltage, high-energy igniters utilize a solid-state spark plug that produces a spark, generally of one joule or greater energy. The high energy is produced from a capacitor discharge system. These systems use a semi-conductor spark plug from the aircraft industry in place of an air gap, spark device. The semiconductor acts as an insulator that breaks down at a voltage generally less than 600V and produces a

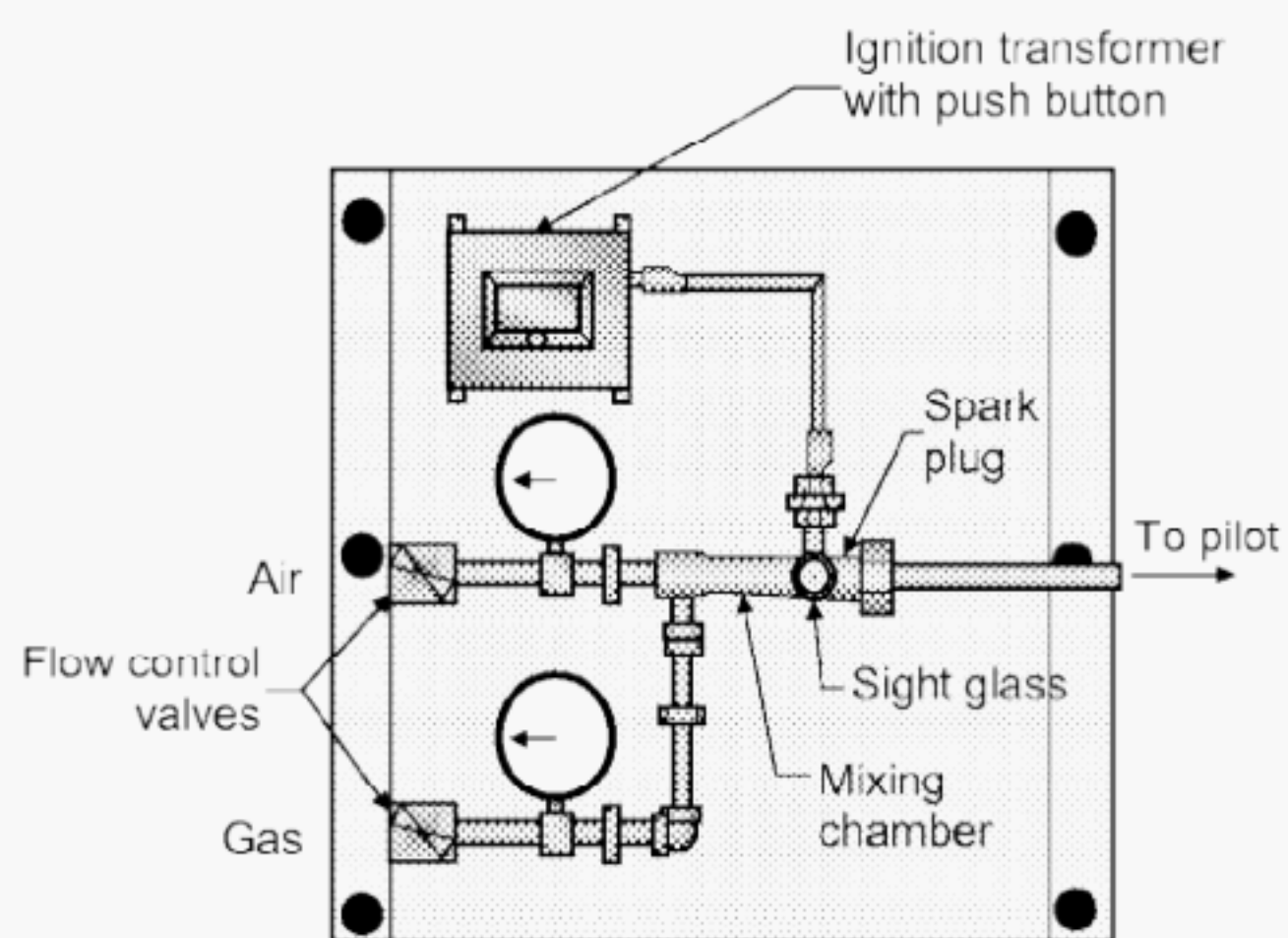


Figure 10—Flame Front Generator Panel Arrangement

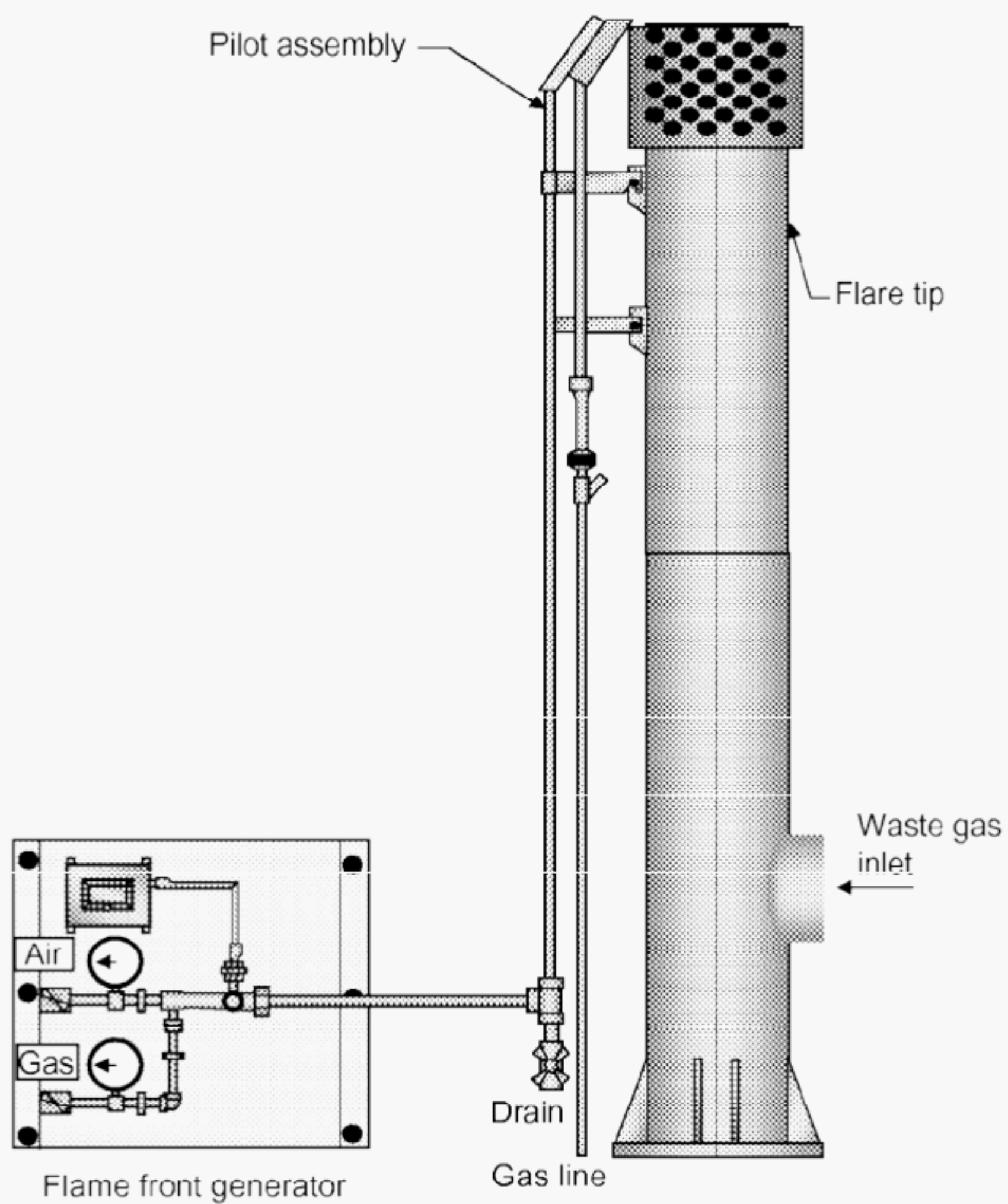


Figure 11—Flare/Pilot/FFG Panel Arrangement

high-energy spark. This voltage is significantly less than the several thousand volts of a standard air gap, high voltage spark igniter. Low voltage, high-energy igniters can be located more than a thousand ft from the energy source.

These igniters offer several advantages over traditional spark igniters. The lower voltage means that the wiring between the exciter and spark device can be 600V wiring suitable for anticipated temperature. The igniter can be located several hundred ft away from the electronics package. This feature allows mounting of the electronics package for the igniter at grade, where it can be maintained and can be protected from the radiant heat of the flare. In addition the semiconductor surface is not as likely to foul as a traditional air gap spark system. The lower voltage is not as susceptible to grounding through insulators. The system is less affected by rain and or carbons build up. The system is less dependent upon ceramic insulators that are prone to cracking in a flare application.

The high energy of the igniter will successfully ignite a wider range of air-fuel mixtures than a traditional spark igniter. The igniter can be located inside the pilot's air-fuel gas stream away from the normal pilot tip and its flame. The ignition of the pilot is almost instantaneous making it well suited for automatic ignition systems. It is well suited for wet gas or harsh environments where a greater energy is required to provide ignition.

5.3.3.2 Spark Ignition of a Portion of the Pilot Gas/Air Mixture Prior to the Pilot Tip

These systems generally require that an electrode capable of a high-energy capacitive discharge be located in the piping upstream of the flare burner or in a bypass line between the piping and the flare burner discharge. As with the spark ignition system described above, electrode supports and/or penetrations into the pilot must be constructed such that they electrically isolate the electrode from the pilot.

The electrode in this system is not located in close proximity to the flame. This lack of continuous flame exposure is often claimed to extend service life. The lack of flame exposure precludes use of the electrode for flame detection.

5.3.3.3 Compressed Air Flame Front Generator

Compressed air flame front generator systems are usually built with a control panel. The control panel includes the valves and orifices as well as the mixing tee, spark generator, and sight glass. The spark generator is typically either a spark plug or a piezoelectric igniter. It is generally more convenient for cleaning and part replacement if the piping at the control panel is threaded. Either orifice unions or machined orifices may be used. The fuel and air pressure gauges should either be liquid filled or installed with a snubber to prevent damage to the gauge due to pressure pulses. All valves downstream of the point where the fuel and air are mixed should be full port.

The sight port at the spark generator should be designed for at least the same pressure as the piping. The system must be designed to prevent back-flow of one utility system into another.

The piping downstream of the control panel is usually constructed from welded DN25 (1-inch) schedule 40, carbon steel pipe. However, stainless steel pipe and/or threaded fittings can be used. Larger pipe sizes are more likely to have the flame front transition to a detonation. Smaller pipe sizes are more likely to have the flame front quenched before it reaches the pilot. Piping with equivalent lengths in excess of 1.6 km (one mile) has been successfully employed in flame front generator service.

In order for a flame front to propagate down the flame front generator line, the line must be dry. Consequently, it is essential that all the flame front generator lines be sloped to drains that can be accessed, opened, and drained prior to use. In cold environments the flame front lines are often heat traced and insulated to prevent plugging due to freezing.

One flame front generator can be used to light multiple pilots. This can be done one of two ways. The flame front generator can be connected to a manifold of valved lines, each of which ignites a single pilot. In this case each pilot is ignited individually. A flame front generator can also be designed to light all pilots simultaneously with a single branching flame front line. If this is done, care must be taken to ensure that the flow to each line is balanced adequately to light all pilots, regardless of the wind condition. The design with a single line that branches and lights all pilots simultaneously is less expensive. However, this design has the disadvantage that the pulse from the flame front generator may fail to light all pilots. Then, a re-ignition attempt is required again to light all pilots rather than the single failed pilot. The flame front generator pulse during this reignition attempt may possibly extinguish a working pilot.

5.3.3.4 Self-Inspiring Flame Front Generator

A self-inspiring flame front generator has a pressure loss limitation because the fuel/air mixture is created with an eductor. This pressure loss limitation has a significant impact on the mechanical design. First, branching lines and valve manifolds are generally not feasible; consequently, each self-inspiring flame front generator is dedicated to a single pilot. Second, the piping is usually limited to 90 m (300 ft) in length with very few turns. Because of the pressure drop limitations the eductor and spark generator are usually mounted in the vertical near the base of the stack. Assuming there are no horizontal sections and the eductor is open to the atmosphere, no drains are required.

5.3.4 Operation

During start-up the operator should ensure that the flare system is free of oxygen prior to igniting the pilots.

5.3.4.1 Direct Spark Igniter

Systems that involve spark ignition at the pilot are either controlled by a sequencing central system such as a Programmable Logic Controller (PLC) or have a push button on a control panel located at grade. Operation of these systems is summarized as follows:

- a. Turn on the fuel to the pilot that is to be ignited and set at manufacturer's recommended pressure. Allow adequate time for the fuel to reach the pilot tip.
- b. Press and release the button to initiate the spark.
- c. Monitor the flame detection system for confirmation of pilot ignition.

If the pilot flame is not detected, repeat Steps (a) and (b). If a pilot flame is not detected after several attempts, refer to the troubleshooting Section 5.3.6.

5.3.4.2 Compressed-Air Flame Front Generators

These ignition systems are the most complex to operate. Operation of these systems is summarized as follows:

- a. Drain condensate from fuel and compressed air supply lines to avoid entraining condensate into the flame front generator.
- b. Confirm that the fuel inlet valve is closed. Confirm that at least one pilot ignition line is open.
- c. Open the air inlet and flush the flame front generator line(s) with air.
- d. Close the air inlet.
- e. Open all condensate drains in the flame front generator line(s). Clean the drains as necessary to ensure that all liquid is removed. Close the drains.
- f. If valves attach the flame front generator to several separate pilots, open the valve to the pilot to be ignited and close all others.
- g. While observing the sight glass, test the spark generator to confirm that a spark is generated. Alternatively, try to detect R.F. interference from a spark on an open channel of a radio, but this is directionally less reliable than sight observation.
- h. Turn on the fuel to the pilot that is to be ignited; set at manufacturer's recommended pressure. Allow adequate time for the fuel to reach the pilot tip.
- i. Turn on the air to the flame front generator and set at the manufacturer's recommended pressure.
- j. Turn on the fuel to the flame front generator and set at the manufacturer's recommended pressure. Allow adequate time to develop a sufficient quantity of premixed fuel and air in the ignition line.

k. Press and release the button to initiate the spark. Observe the sight glass and/or the pressure gauges at the time of the spark. If the mixture ignites, a flame should be visible in the sight port and a pulse should be seen in the pressure gauges. Do not hold down the button that initiates the spark. The intent is to ignite the mixture once, and then to allow the flame front to travel down the pipe to the pilot. Holding the button down does not continue to generate a flame front and may stabilize a flame at the spark generator. A stabilized flame at the spark generator will eventually overheat the equipment in the vicinity of the spark generator. If such a stabilized flame occurs, immediately close the fuel block valve, maintain airflow, and allow equipment to cool. Restart the ignition sequence from step j.

l. If no flame is observed in the sight glass and no pulse seen in the pressure gauges when the spark is generated, refer to the operations manual or contact the manufacturer. In most cases, an incorrect fuel/air mixture is the cause and that typically requires field adjustment. See section 5.3.6 on troubleshooting.

m. Once ignition is observed at the control panel, wait for the flame front to reach the pilot. Allow an appropriate amount of time for the flame front to reach the pilot. About one to three seconds for each 30 m (100 ft) of piping is typical. Consult the operations manual or manufacturer for your system specifics. Monitor the flame detection system for confirmation of pilot ignition.

n. When awaiting a successfully detected pilot ignition, some delay may occur with thermocouple detectors. Do not quickly repeat FFG ignition attempts.

o. If the pilot flame is not detected, repeat Steps (k) (l), (m), and (n). If a pilot flame is not detected after several attempts, refer to the troubleshooting Section 5.3.6.

p. Once the pilot is ignited, flush the line with air only to remove corrosive combustion products. After the line is flushed, close the valve leading to the ignited pilot and open the valve to the next pilot to be ignited. Repeat Steps (j), (k) (l), (m), and (n) for all pilots to be lit.

q. Once all pilots are lit, shut off the fuel to the flame front generator, purge with air for several minutes to remove all fuel and combustion products, then shut off the air.

5.3.4.3 Self Inspiring Flame Front Generator

Operation of this ignition system is generally simpler than that of the compressed air type. The differences between the two types of systems are summarized below:

- a. There is no compressed air. If mixture adjustment is required it must be accomplished through fuel orifice changes or eductor adjustments.

- b. The system is not enclosed. If the flame front line is plugged, a combustible mixture could back flow out the mixer. If this is the case, do not initiate the spark. Never look into the mixer when igniting.
- c. These systems seldom service more than one pilot; hence there are rarely valves downstream of the mixer.
- d. These systems are usually installed vertically with very little horizontal piping. Consequently, these systems usually have no drains.
- e. When the fuel supply is stopped, flashback may occur in the mixture tube. The user should decide whether special measures are required to mitigate this flashback.

5.3.4.4 Operator Training

A plan for periodic training of operators in the use of pilot ignition equipment should be implemented. The training should prepare the operator to properly operate the ignition equipment under adverse or urgent conditions.

5.3.5 Maintenance

Routine maintenance of systems that provide a spark at the pilot is limited due to their location. Generally, these systems can only be accessed when the flare is out of service. When the flare is taken out of service, these systems should be cleaned, inspected, and replaced, if necessary.

Routine maintenance of flame front generator systems is focused on keeping the system dry and clear as well as maintaining the valves, gauges, and spark generator.

The system should be installed with drain(s) at all low spots. The drains should be left closed when not in use, but should be opened and cleaned regularly. The reason for leaving the drains closed when not in use is twofold:

- a. If the drains are left open, exhaust gas from the pilot may circulate down through the flame front generator, promoting water condensation, corrosion and accumulation of moisture.
- b. If the drains are left open and accidentally not closed prior to use, a vapor cloud explosion could be generated in the vicinity of the drain.

The pilot ignition system should be treated as an important safety control system and should be inspected and maintained on the schedule the plant has established for such safety systems. The fuel and air orifices as well as the valves may occasionally require cleaning. The pressure gauges may occasionally require replacement or recalibration. The spark generator may also require some routine service, such as adjusting the spark gap. Periodic functional checkout should be part of the normal maintenance procedure and can be combined with an ongoing training regimen for the operators.

5.3.6 Troubleshooting

Determination if a pilot flame has failed is covered in Section 5.4 on flame detection. If a pilot is known to have failed

and will not re-ignite, it is important to first understand the whether the problem is the pilot or the ignition system. Pilot problems can result from the wrong pilot fuel, no pilot fuel, improper fuel air mixture, or loss of stability. The causes of these problems are discussed in Section 5.2.6. The ignition system troubleshooting should be performed first because it can be done to a large extent without requiring a plant shut-down. See Table 4 for ignition system troubleshooting.

5.4 FLAME DETECTION EQUIPMENT

5.4.1 Purpose

The flame detection system confirms that the pilots are lit. This is often confused with simple confirmation that a flame exists. While these two statements are usually synonymous, there is an important difference. If the pilots are lit and a volume of inert gas is released, the flare flame will be extinguished only while the inert gas is being discharged. If the pilots are not lit, but the flare is, and a volume of inert gas is released, the flare flame will remain extinguished after the inert gas release and until a pilot can be ignited. If the pilots are not lit because they have failed, the flare may remain unlit for an extended period of time. Consequently, it is important to confirm both the presence of a flame and also the presence of a pilot flame.

5.4.2 General Description

A pilot flame detection system utilizes the heat, ionized gas, light or sound generated by a pilot flame to verify that a pilot is burning. An example of the use of each of these energy sources for flame detection is described below.

5.4.2.1 Thermocouples

The most common flare pilot flame detector is a thermocouple. Thermocouples have the advantage that they detect the pilot flame only and are not directly exposed to the flare flame. Relative to other types of detectors, thermocouples have the disadvantage of a relatively slow response time and an often-limited service life. The limited service life is a significant problem, since in most cases the thermocouples cannot be replaced while the flare is in operation.

5.4.2.2 Flame Ionization

A flame generates ionized gases within the flame envelope. Flame ionization detectors function based on a change of resistance between two electrodes. Flame ionization detectors have the advantage that they respond rapidly and that they detect the pilot flame only. The disadvantage of flame ionization detectors is that they must be exposed directly to the flame. Similar to a thermocouple, the flame ionization detector is mounted on the pilot; hence, if it fails it cannot be serviced while the flare is in operation.

Table 4—Troubleshooting Ignition Systems

Problem	Possible Cause	Corrective Action
Pilots with spark ignition at pilot tip		
No ignition.	Failed electrode. This could occur due to extended flame exposure or exposure to corrosive gases.	Replace electrode
No ignition.	Liquid accumulation. Depending on location, this may or may not be possible. If the igniter is located someplace where liquids can collect, this may isolate the spark from the gas/air mixture.	Check piping arrangement to remove low spots. Check knockout drum operation.
No ignition.	Failed power supply	Replace power supply
No ignition.	Short. This could result from a failure of the cable between the electrode and the power supply or a failure of the insulation between the electrode and pilot.	Replace cable
Pilots with spark ignition of a portion of the pilot gas/air mixture prior to the pilot tip		
No ignition	Failed electrode. See above. Liquid accumulation. See above Failed power supply. See above Short. See above	See above
No ignition	Improper pilot fuel. In this system the spark lights a portion of the fuel air mixture supplied to the pilot tip. Improper pilot fuel may cause flashback or stabilization of a flame upstream of the pilot tip.	Return to design fuel gas or modify pilot to match the new fuel composition. Pilot modifications may include: a. Replace pilot orifice b. Adjust air door (if any) c. Replace pilot entirely
Pilots with a compressed air flame front generator		
Failure to spark	Failed Spark Generator e.g., transformer Faulty ignition lead wire Damage to Spark plug Fouling or improper spark plug gap are possible causes of spark failure	Replace failed component
No fuel to flame front generator	Valves being closed or the fuel-metering orifice being plugged could cause this	Check valve position and/or orifice cleanliness.
No air to flame front generator	Valves being closed or the air-metering orifice being plugged could cause this	Check valve position and/or orifice cleanliness.
No flame present.	Fuel composition and pressure to flame front generator. Air pressure to flame front generator. Improper fuel characteristics can cause no flame or a detonation. Improper fuel/air mixture. An improper mixture will not support a flame front. An improper mixture can result from incorrect fuel or air pressure setting, incorrect fuel or air orifice sizing, or improper fuel composition.	Return to design fuel gas. Restore original pressure settings. Replace FFG fuel orifice to match the new fuel composition. Refer to manufacturer's instructions.

Table 4—Troubleshooting Ignition Systems (Continued)

Problem	Possible Cause	Corrective Action
No flame	Plugged piping to flare. Ice formation and debris are two examples. Pressurizing the air supply only while simultaneously observing the air and fuel pressure gauges can identify plugging.	High pressure blowing to remove debris. Inject deicing chemicals to melt ice plug.
No flame	Moisture in piping to flare. This is one of the most common problems in flame front generators. A small amount of moisture can quench the flame front. A symptom of this problem is a seemingly strong ignition, but no evidence of a flame front reaching the pilot.	Purge flame front generator and ignition pipe with dry air prior to attempting ignition. Drain any low points in ignition piping.
No flame	Drain open in piping to flare. In an effort to eliminate moisture in the piping, drain valves or plugs have been accidentally left open. This can result in the same symptoms observed with moisture, but is far more dangerous as combustible gas and/or a flame front may be discharged at an unexpected location.	Check drain valve position or reinstall drain plugs.
Pilots with a self-inspiring flame front generator		
No ignition or flame	Failed spark generator. See above. No fuel to flame front generator. See above. Improper fuel to flame front generator. See above. Improper fuel/air mixture. See above. Plugged piping to flare. See above. Moisture in piping to flare. See above.	See above.

5.4.2.3 Optical Systems

There are two types of optical sensors: ultraviolet (UV) and infrared (IR). Both types have the advantage of being located at grade where they can be serviced while the flare is in operation. Both types can indicate false flame failures caused by obscuration due to clouds or precipitation. The most significant disadvantage concerning existing designs of these detectors is their inability to detect the pilot flame separately from the main flame. Given this disadvantage, these detectors are not recommended for use as the sole means of pilot flame detection.

Infrared imagers are being developed which may overcome this disadvantage.

5.4.2.4 Acoustic Systems

A flare pilot flame generates a characteristic sound when it is burning. If the pilot flame is extinguished, the sound changes. The pilot sound is conveyed to grade where an acoustic pilot flame detector monitors the pilot sound and signals the pilot operating condition. The acoustic detector differentiates the monitored sound from the other sounds in the neighborhood of the pilot. An acoustic pilot flame detector can be installed and serviced while the flare is in operation.

5.4.3 Mechanical Details

5.4.3.1 Thermocouples

Typically, Type K thermocouples in 310SS or Inconel sheaths are used. The sheathing should extend throughout the zone that could see flame impingement, typically at least 1.8 m (6 ft) or 125% of the actual flare burner diameter. In order to improve the service life, thermocouples are sometimes located in a thermowell that is incorporated into the pilot design. In addition, some designs today are available with multiple thermocouples such that if one fails, the second can be put into service. There are also systems that are now offered with retractable thermocouples that can be replaced while the flare is in service.

Retractable thermocouple systems usually consist of a smoothbore conduit with a limited number of bends and that extends from grade to the pilot. A coiled flexible thermocouple is inserted from grade through the conduit. These systems add expense to the flare system, but improve reliability when properly installed by allowing thermocouple replacement while the flare is in service.

5.4.3.2 Flame Ionization

Two electrodes are required for a flame ionization system. In practice, the pilot tip is usually used as the ground electrode. A conductor of much smaller area is positioned in the flame envelope and functions as the other electrode. An alternating voltage is applied across the electrodes; direct current flow is monitored as a means of flame detection.

5.4.3.3 Optical Systems

Systems are mounted at grade and must be directed at the flare. All optical systems have some means of aiming the detector, either sighting directly through the detector optics or through a scope mounted to the detector. The detectors should be mounted on an easily accessible, vibration-free platform which is located one to three stack heights from the flare burner. Most optical systems have a maximum range of 150 to 300 m (500 to 1000 ft), which is adequate for most flares. Infrared detectors should be located such that at no time during the day will the detector see direct sunlight. In the Northern Hemisphere this would mean that the detector should be mounted on the south side of the stack.

The electronics associated with optical detectors are usually mounted close to the detector. Local status lights and alarm strobes are available from some manufacturers.

5.4.3.4 Acoustic Systems

An acoustic pilot detection system consists of a sensor unit and a signal-processing unit. Wiring interconnects the units. The pilot sound is normally conveyed to grade via the piping connecting the pilot to the flame front generator. The sensor unit is attached to the pilot's flame front generator pipe near the base of the flare stack. The signal-processing unit may be placed in a location up to 365 m (1200 ft) distant from the sensor unit.

5.4.4 Operation

5.4.4.1 Thermocouples

A temperature greater than some minimum set by the pilot manufacturer indicates the presence of a pilot flame. Some manufacturers have speeded flame detection by looking at the rate of temperature change as well as its magnitude.

5.4.4.2 Flame Ionization

The presence of a flame between the electrodes creates a current flow between electrodes. The difference in electrode areas is such that the resulting current is rectified (flows preferentially in one direction). A short in the system will create current flow, but it will not be rectified. Hence, the rectified current is indicative of a flame.

5.4.4.3 Optical Systems

As mentioned above, both IR and UV systems are available. Because of the significant background levels of IR radi-

ation in the atmosphere, an infrared detector must look for more than simply the magnitude of the IR radiation within a certain waveband. Infrared detectors make use of the fact that flames emit IR radiation at relatively discrete frequencies. By observing the IR radiation in two bands, one characteristic of flame emission and one not, the ratio of the two signals is indicative of a flame.

There is substantially less background UV radiation and flames emit UV at very discrete wavelengths. Consequently, UV systems simply look at the magnitude of UV radiation in a particular waveband (usually that associated with emissions from OH radicals). UV is absorbed by regular glass so the optics in an UV system is generally constructed from quartz. The sun also emits UV radiation. Application of UV based detectors must avoid interference from sun generated UV.

5.4.4.4 Acoustic Systems

Pilot sound is continuously monitored by the system. A change in pilot status is detected and indicated via the local status lights and the dry contacts. Factory signal processor settings can be field adjusted to account for site conditions such as the complexity of the piping from the pilot to the sensor.

5.4.5 Maintenance

5.4.5.1 Thermocouples

Unless a retractable thermocouple system is installed, there is very little maintenance that can be performed on a thermocouple, other than monitoring its performance to ensure that it has not failed. If it fails and more than one thermocouple is installed, the spare thermocouple can be put into service. If it fails and is retractable, obviously it can be replaced.

5.4.5.2 Flame Ionization

There is virtually no maintenance that can be performed on a flame ionization system, unless the pilot is taken out of service. Only maintenance on the controls "at grade" is possible during operation of the flare.

5.4.5.3 Optical Systems

The aim of optical systems should be checked regularly to ensure that the flare burner remains in the field of view. The optics should be periodically cleaned.

5.4.5.4 Acoustic Systems

The sensor and signal processing units are located at grade and are accessible during flare operation. The drains in the sound conveying piping should be checked on a regular schedule.

5.4.6 Troubleshooting

See Table 5, Troubleshooting Flame Detection Systems.

Table 5—Troubleshooting Flame Detection Systems

Problem	Possible Cause	Corrective Action
Pilot detector is suspected of being in error	Pilot and its ignition system are believed to be functioning correctly, check corrective action steps to confirm pilot ignition	Inspect with binoculars or telescope Inspect at night Use the FFG to supply additional fuel to make the pilot flame more visible
Pilot detection system is determined to be showing a false loss or false confirmation of flame	Check electrical supply and fuses.	Perform a functional check based on the manufacturers' instructions.
	Thermocouple failure	Will show no flame when one is present. Check for open circuit.
	Thermocouple sensing flare flame rather than pilot flame	Check winds direction and flame position relative to pilot in question.
	Flame ionization electrode failure.	Will show no flame when one is present. This can be caused by movement or distortion of flame rod or problems with the wiring.
	Flame ionization electrode shorting.	The signal processor should recognize this as an unrectified signal.
	Flame ionization electrodes sensing flare flame rather than pilot flame	Check winds direction and flame position relative to pilot in question.
	Improperly aimed optical system	Will show no flame when one is present. Check aim
	Optical system obscured by clouds or fog.	Will show no flame when one is present. Check line of sight
	Optical system obscured by dirty optics	Will show no flame when one is present. Inspect optics and clean as required
	Optical system sensing flare flame rather than pilot flame	This is a given with the optical systems presently available
	The acoustic system sound-conveying path may be blocked	Check drains. Check for displaced or damaged piping. Confirm that the path is clear.
	Suspected false confirmation of flame by acoustic system	Checked by first disconnecting the sensor unit from the sound conveying piping; and second, covering the sensor inlet. The system should then indicate the pilot is out.
Pilot detector is suspected of being in error	Interconnecting wiring and its terminals may be compromised or faulty.	Replace or repair wiring
Pilot detector is suspected of being in error	The "control" units may be faulty or be suffering from the effects of a malign environment.	Replace components

5.5 PURGE GAS CONSERVATION SEALS

5.5.1 Purpose

All flare systems are susceptible to flashback and explosion if not properly purged to keep air (oxygen) from entering the flare stack downward through the flare burner. To prevent air from entering the system during normal operation, a continuous purge is required. A purge conservation device may be installed in (or immediately below) the flare burner in order to reduce the amount of purge gas consumption.

5.5.2 General Description

Purge conservation devices are mechanical stationary designs. They reduce the use of purge gas while preventing some (but not all) air from entering downward into the flare stack. Several names are used to describe these seals, but some commonly used names are diffusion seals, velocity seals, venturi seals, and buoyancy seals.

5.5.3 Mechanical Details

Refer to API Recommended Practice 521, *Guide for Pressure Relieving and Depressuring Systems* for examples of these seals.

5.5.4 Maintenance

Diffusion or buoyancy type purge seals have several flow reversals. These act to separate the liquids from the flare gas. These liquids can accumulate in the bottom of the seal and cause several concerns including blockage of the seal, corrosion and additional structural loads. Seals are equipped with a drain connection and separate drain line to allow removal of these liquids and elimination of these problems.

The seal should be equipped with an inspection opening to allow cleaning of the drain during shutdowns. The drain should be designed in a manner to mitigate plugging. The drain must be sealed to prevent the entry of air. This is often accomplished by the use of a liquid-filled, loop seal sized for least two times the sum of the calculated seal and flare burner pressure drop at the maximum flow rate.

This seal leg should have level indication and alarm. These drains must be of an adequate size to prevent plugging and must be maintained. The drain line should allow for routine back blowing with a purge gas containing no oxygen. The drain line must be protected against freezing. A pressure gauge should be used to insure the line is open and free.

Velocity or venturi type seals do not normally require maintenance except for inspection and cleanout at shutdowns.

5.5.5 Troubleshooting

See Table 6, Troubleshooting Purge Gas Conservation Seals.

5.6 ELEVATED FLARE EQUIPMENT COMPONENTS SUPPORT STRUCTURE

5.6.1 Piping

5.6.1.1 Typical piping requirements on the support structure include piping for steam, pilot gas, assist gas, buoyancy seal drain, pilot ignition, electrical conduit, and instrumentation conduit.

5.6.1.2 Design criteria of the pipe should be per applicable codes such as ANSI B31.3. Material of the piping should be selected on the basis of the fluids being transported in the piping, temperature and pressure of the fluids, and potential ambient temperature impact.

5.6.1.3 Flanges should be kept to a minimum since they can be a source of leakage. Maintenance or inspection of the flanges is difficult even during periods that the flare system is shut down due to accessibility. Flanges are not accessible during operation due to safety constraints for personnel.

5.6.1.4 Piping should be evaluated for expansion due to the difference in temperature between the piping and the support structure. If necessary, expansion loops should be used in the piping on the stack. Expansion joints are not acceptable due to their tendency to leak and the difficulty to be maintained. Movement of the piping interface point should be specified by the flare system designer and accommodated in the inlet piping.

5.6.1.5 All piping must be considered in the structural analysis of the wind and earthquake loads, including any insulation that is installed on the pipe or may be installed in the field.

5.6.1.6 Piping should be designed for all operating and test loads including water filled steam piping.

5.6.2 Aircraft Warning Lighting

5.6.2.1 Lighting of the support structure shall be in accordance with the latest edition of the appropriate code as defined by the local aviation authority. Typically, this code is either per the U.S. Department of Transportation and the Federal Aviation Administration Advisory Circular 70/7460, Obstruction Marking and Lighting, or the ICAO Aerodromes Annex 14 guidelines as published in Montreal, Canada. The local aviation authority may supersede either of these general guideline documents.

5.6.2.2 Warning lights supported by the structure may be fixed or retractable, and shielded from radiation as necessary.

5.6.3 Platforms and Ladders

5.6.3.1 An elevated flare can meet its purpose as stated in Section 4.1 without being equipped with platforms or ladders. However, it is recommended that, as a minimum, a 360° plat-

Table 6—Troubleshooting Purge Gas Conservation Seals

Problem	Possible Cause	Corrective Action
Burning through seal (hole in top or sidewall) Hole in side of flare tip	Internal burning	Check drain loop seal. Restore liquid level if needed. Temporary—switch to nitrogen or inert purge. Repair or replace soonest. Divert to backup or rental flare.
Burning through seal (hole in top or side wall) Hole in side of flare tip	Corrosion from steam condensate from smokeless flare	Temporary—switch to nitrogen or inert purge. Repair or replace soonest. Divert to backup or rental flare.
Excessive pressure drop	Purge gas conservation device is plugged	Clean drain or replace device
Excessive pressure drop	Freezing due to steam condensate from smokeless flare or rain accumulation	Blow drain (if equipped) with high pressure hot glycol or alcohol mixture—check heat tracing is operational if installed Divert to backup or rental flare.
Excessive pressure drop	Carbon build up due to internal burning	Blow drain (if equipped) with high-pressure gas to clear. Use pipe-cleaning service if possible. Repair or replace soonest. Divert to backup or rental flare.
Excessive pressure drop	Refractory cracking and spalling—plugging drain and bottom of seal	Blow drain (if equipped) with high-pressure gas to clear. Repair or replace soonest. Divert to backup or rental flare.
Excessive sway at top of flare	Purge gas conservation device is plugged and full of liquid or debris	Clean drain
Leakage from base of seal	Corrosion due to plugged or fouled drain	Clean drain with high-pressure steam or gas. Temporary—switch to nitrogen or inert purge. Repair or replace soonest. Divert to backup or rental flare.
Liquid carry over (burning rain)	Hydrocarbon condensate build up and accumulation—carried out through the seal and tip by large gas flows. Excessive liquid build up is normally also seen as excessive pressure drop. Small amounts of HC liquid will not cause noticeable pressure drop but are easily swept up and out of the flare by large flaring rates.	Check knockout drum liquid level. Drain liquid if level is too high. Clean drain. Blow drain with high pressure steam or hot nitrogen—start blow down procedure slowly and watch for burning rain—gradually increase blow rate—check heat tracing is operational if installed Divert to backup or rental flare.
Noise	Purge gas conservation device is too small or partial plugging from carbon, ice or refractory	Clean drain or replace device with larger diameter. See above for excessive pressure drop recommendations.

form be provided near the top of elevated flares more than 15 m (50 ft) height. This elevation may be increased depending on site specific capabilities and maintenance practices. This platform should be located below the flare burner mounting flange or connecting weld and be positioned so that it can be used during inspections, maintenance and flare burner replacement. An access ladder is preferred but not mandatory. Alternative access can be achieved via a crane basket or heli-

copter. This platform will also allow access to the velocity type air seal if present.

5.6.3.2 If the flare is equipped with a buoyancy-type air seal, a platform can be provided for access to the inspection and clean out nozzles. A 120-degree platform is commonly preferred for this application.

5.6.3.3 An access platform(s) may be desirable for inspection and maintenance of aircraft warning lights of the type located above grade and attached or supported by the flare stack. The location and size of such platforms will depend on the aircraft warning light design and location. Access to warning light maintenance platforms is normally via a ladder.

5.6.3.4 Additional access platforms may be located at other locations as necessary. For example, the erection plan for the flare stack may make a full 360-degree or partial platform desirable at each stack assembly joint.

5.6.3.5 If any platforms are at an elevation greater than about 9 m (30 ft) or if ladder access is used, intermediate landing platforms may be required by regulation, e.g. OSHA, or company policy.

5.6.3.6 If the flare system is equipped with a knockout drum and/or a liquid seal, platforms may be provided for access to man-ways, level instruments and the like. Access to such platforms is normally via ladder.

5.6.3.7 In general, the flare burner maintenance platform should have a minimum 0.9 m (3 ft) clear width from the flare burner and its appurtenances. In some cases, placement of the platform, and the flare burner/stack connection, at a somewhat lower elevation may allow the use of a smaller diameter platform.

5.6.3.8 Ladders attached to or accessing the top of the flare burner itself are discouraged. If present, such ladders should not be utilized after the flare has been in operation.

5.6.3.9 Platform decking shall be at least 6 mm ($\frac{1}{4}$ in.) checker plate or 25 mm by 5 mm (1 in. by $\frac{3}{16}$ in.) open grating.

5.6.3.10 Normally, platforms and ladders shall be fabricated from carbon steel and protected from corrosion by hot dip galvanizing.

5.6.3.11 Design of the ladders and platforms should comply with the requirements set forth by the United States Occupational Health and Safety Act (OSHA) or equivalent national requirements or more restrictive local rules and regulations.

5.6.4 Structural Design

5.6.4.1 General

General descriptions of several methods that can be used to support a vertical flare are found in section 4.2.1. Guidelines for the design of vertical flare support structures are set forth below. In general the structural design should be based on ASME/ANSI STS-1 *Steel Stacks* and/or AISI/ASD *Manual of Steel Construction*. The information regarding the purchaser's design requirements is contained in the Flare Data Sheets.

5.6.4.2 Design Loads

The design of a support structure for a vertical elevated flare shall consider, as a minimum, the design loads given below. The designer shall review the intended application and eliminate those loads that are not applicable.

a. Wind Loads. Wind loadings shall take into account the riser and all of its appurtenances such as but not limited to piping (including insulation, if any), access platforms, and ladders. When appropriate the wind loading on supporting derrick structures must be included. Wind loads should be based on ASCE 7, *Minimum Design Loads for Buildings and other Structures*.

b. Earthquake Loads. Earthquake induced loads shall be based on UBC *Uniform Building Code* or ASCE 7 *Minimum Design Loads for Buildings and other Structures*. Structural design shall be based on wind loads and earthquake loads occurring separately.

c. Wind-Induced Vibration Loads. The structural design shall include an analysis of the loads imposed by wind-induced vibration and a determination of the critical wind velocity for the first and second modes of vibration for the new and corroded conditions. The critical wind velocity of the first and/or second vibration mode shall fall within an acceptable range as set forth in either ASME / ANSI STS-1 *Steel Stacks* or API Standard 560, *Fired Process Heaters for General Refinery Services*. If the critical wind velocity of the first and/or second mode falls outside the acceptable range the design of the structure must be modified in order to change the natural frequency of the structure. Means to modify the natural frequency include, but are not limited to:

- Changes in riser diameter or length
- Use of multiple diameters,
- Changes to the wall thickness,
- Changes in the mass of the riser,
- Use of a tuned mass damper,
- Use of strakes or the like,
- Changes in foundation design.

Wind loads of modified structures should be reviewed and revised if necessary.

d. Internal Pressure. Flare stacks are generally operated at near atmospheric pressure and are not specifically designed as a pressure vessel. In some cases the bottom portion of the stack incorporates a Knockout drum or liquid seal or both. When specified in the Flare Data Sheets the stack portion containing the Knock-out drum or liquid seal may be designed as a pressure vessel including, if specified, hydrostatic testing and code stamping. In such cases, the design of

the pressure vessel portion shall be in accordance with ASME *Boiler and Pressure Vessel Code*, Section VIII, Division I and shall be based on the design pressure and temperature stated in the Flare Data Sheets or a minimum of 105 kPa (15 psig). It is common practice for the riser portion of the stack to be designed for structural loads and the anticipated maximum operating pressure when the base section of the stack is designed as a pressure vessel. For design purposes the riser section is deemed to start at the pressure vessel outlet. The design of a stack base section, that is a pressure vessel, shall include provision for internal pressure loads and for simultaneous wind loads based on 70 percent of the design wind velocity. The design pressure (Maximum Allowable Working Pressure) of a stack base section that is a pressure vessel shall not be increased due to any material thickness that is in excess of that thickness required to meet the design pressure.

e. **Sudden Internal Pressure.** An alternate structural design may consider an internal pressure component that allows for a sudden internal pressure rise resulting from a flashback within the flare stack riser.

f. **Nozzle Loads.** The nozzle loads imposed upon the stack by the flare header to stack connection can have a major influence on the design and cost of the flare stack. This influence becomes greater as the elevation of the flare header increases. In general the flare stack itself should not be used as a major fixed point for the flare header piping. If possible, the purchaser shall note the preliminary flare header imposed nozzle loads on the Flare Data Sheets furnished to the vendor with the request for quotation. The purchaser shall provide final flare header imposed nozzle loads during the design phase. The purchaser should minimize the nozzle loads imposed on the stack by other service connections. If the purchaser does not furnish nozzle load information either at the quotation stage or the order stage the flare supplier shall base the nozzle design on Section 5 of API Standard 560, *Fired Heaters for General Refinery Services*.

g. **Thermal Loads.** Some of the relief gas cases described in the Flare Data Sheets may have a gas temperature that is different than ambient. The flare stack designer shall provide for thermal expansion (+ or -) that can be caused by specified gas temperature or temperature differences caused by wind or rain. Thermal loads are of greatest concern on guyed stacks and derricks. The freedom of movement of a self-supported stack reduces the thermal load concerns providing that the thermally induced deflections does not exceed 450 mm per 30 m (18 in. per 100 ft). The designer shall also provide for thermally induced differential changes in length between the stack and the piping attached to the stack.

h. **Erection and/or Maintenance Loads.** The flare stack designer shall be informed of erection techniques the purchaser will employ. If the stack is to be erected in a single lift the designer shall also be informed as to the degree of pre-

erection attachment of piping, ladders and platforms, etc. Unless otherwise noted in the Flare Data Sheets lifting trunnions shall be designed for one time use. As noted in section 4.2.1.3 some derrick supported flares are designed to allow the flare riser to be lowered (either as a single section or multiple sections) to allow grade level access to the flare burner for maintenance. The designer shall provide for the loads imposed on the flare riser and derrick by the intended plan of operation. In some cases a davit, located near the top of the flare stack, is used to lower the flare burner to grade. The designer shall determine and provide for the davit imposed loads based on the intended plan for operation.

i. **Special Loads.** The purchaser shall note any additional loads that will be imposed on the flare stack / support structure on the Flare Data Sheets. Examples of special loads are 1) hydrostatic testing of the stack or the attached piping after the flare is erected, or 2) loads from ice build up, or 3) acceleration loads due to FPSO or platform movement, or 4) loads imposed during transport to the job site. Hydraulic liquid load is not generally considered for design.

5.6.4.3 Design Details

The following design details shall be incorporated into the support structure design.

a. Wind load or earthquake caused stack deflection shall not exceed the following guidelines:

Derrick supported structures	150 mm per 30 m (6 in. per 100 ft)
Self-supported structures	225 mm per 30 m (9 in. per 100 ft)
Guyed structures	300 mm per 30 m (12 in. per 100 ft)

b. Stack sections in the form of a frustum of a cone shall be designed in accordance with API RP 2A, *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms*.

c. Field assembly of gas riser or stack sections shall be by welding unless otherwise specified on the Flare Data Sheets. Flanged assembly may be used on multiple section demountable risers.

d. A minimum corrosion allowance of 1.6 mm (0.0625 in.) is recommended and shall be added to the minimum metal thickness necessary to meet the requirements of Section 5.6.4.2. No corrosion allowance is required on alloy steel portions of the stack unless specifically noted on the Flare Data Sheets. Non-alloy steel internal parts of liquid seal or knock-out drums that are normally wetted shall have the 1.6 mm (0.0625 in.) corrosion allowance applied to each side. No cor-

rosion allowance is required for derrick structures and other metal objects that do not normally come into contact with the relief gas stream.

e. The following guidelines shall be incorporated when the support structure design includes the use of guy wires:

1. Guy wire slope and initial tension should take into account: the elevation of the guy connections to the riser (there may be more than one connection elevation); the available guy wire anchor radius; the range of riser temperatures both ambient and process; wind loads; and mass distribution.
2. Guy wires 16 mm (0.625 in.) diameter or less should conform to ASTM A475, Class A. The use of a non-metallic core is not allowed.
3. Guy wires greater than 16 mm (0.625 in.) diameter should conform to ASTM A586, Class A.
4. End fittings, turnbuckles and pins should have a load capacity suitable for the maximum guy wire tension expected during service.
5. The initial guy wire tension should not be less than 2% or greater than 12.5% of the maximum guy wire tension expected during service.
6. Turnbuckles should be located at the anchor end of the guy wire immediately above the anchorage.

5.6.4.4 Materials of Construction

Materials of construction shall be as specified in the Flare Data Sheets. If a material is not specified, any portion of the flare stack that is normally exposed to the relief gases shall be of a material that is compatible with the gas composition as stated in the Flare Data Sheets. In addition the materials normally exposed to the relief gases must be compatible with the most extreme maximum and minimum temperatures imposed by the relief gases, the ambient temperatures or the design temperature(s) specified in the Flare Data Sheets. Portions of the flare stack or support structure that would not normally be exposed to the relief gases may be of a material suitable for their purpose. Welded attachments to the portions of the stack that carry the relief gases shall be of a material that is compatible with the material of the respective gas-containing portion.

Derrick structures may be designed for fabrication from members that are structural shapes, pipe or plate or any combination thereof. Guy wires, as set forth in 5.6.4.3 (e), shall be all metallic, galvanized or stainless steel wire rope or bridge strand. End fittings and turnbuckles should be galvanized or stainless steel.

Materials used for portions of the support structure that are designated as being designed to the ASME Boiler and Pres-

sure Vessel Code shall be in accordance with Section II of that Code.

5.6.4.5 Welding

Relief gas containing portions of the support structure shall be fabricated in accordance with the welding requirements of AWS or ASME. If the bottom portion of the stack is to be designed in accordance with the ASME *Boiler and Pressure Vessel Code* then the fabrication of that portion shall be governed by the requirements of Section IX of that Code. Non-gas containing portions of the support structure shall be fabricated in accordance with the welding requirements of AWS or ASME Section IX.

5.6.4.6 Inspection

Relief gas containing portions of the support structure shall be inspected in accordance with the requirements set forth below:

- a. The American Welding Society Structural Welding Code ANSI/AWS or ASME Section IX shall be used for non-destructive testing and inspection procedures, techniques, standards for acceptance, inspector qualification and inspections.
- b. All welds should be visually inspected during the welding operation and again after the work is completed to determine satisfactory penetration of weld metal fusion and satisfactory operator performance. After the welding is complete, welds shall be cleaned before the inspector performs the final weld inspection. The inspector shall pay particular attention to surface cracking, surface porosity, surface slag inclusion, undercut, overlap, gas pockets, and size of weld. Defective welding shall be corrected according to the applicable code requirements.
- c. Radiographic weld inspection shall be performed on all full penetration structural butt welds to the extent specified in the following requirements: A minimum of one radiograph per each three shop circumferential seams on the relief gas containing structural shell, at the vertical weld intersection. The developed radiographic film should show at least 150 mm (6 in.) of weld seam.
- d. Other types of non-destructive testing may be utilized if specified on the Flare Data Sheets.
- e. Hydrostatic testing is not required unless specified on the Flare Data Sheets.

If the bottom portion of the stack is to be designed and fabricated in accordance with the ASME *Boiler and Pressure Vessel Code*, Section VIII, then the bottom portion shall be inspected in accordance with that Code. In the case where the bottom portion is a Code vessel, the upper (non-Code) portion shall be inspected as set forth in (a) through (e) above.

Hydrostatic testing is not required unless specified by the Flare Data Sheets or a code stamp is specified.

Non-gas containing portions of the support structure shall be inspected visually using the procedure set forth under item (b) of this section.

5.6.4.7 Surface Preparation and Protection

Unless otherwise specified on the Flare Data Sheets, carbon steel external surfaces of stack and piping that can be directly exposed to weather shall be cleaned in accordance with Structural Steel Painting Council SP-6 Commercial Blast Cleaning. The cleaned surfaces shall then be painted with inorganic zinc primer per the primer manufacturers' instructions.

Unless otherwise specified on the Flare Data Sheets, components of derricks, ladders, platforms and the like shall be prepared for and galvanized in accordance with ASTM A-123, *Zinc (Hot-dip Galvanized) Coatings on Iron and Steel Products*.

Alloy steel components do not require surface preparation or protection.

5.7 KNOCK-OUT DRUMS AND LIQUID SEALS

5.7.1 Knock-Out Drum

5.7.1.1 A flare knockout drum separates liquid from gas in flare system and holds a specified amount of liquid that can be relieved during an emergency situation.

5.7.1.2 Knockout drums are typically located on the main flare line upstream of the flare stack or any liquid seal. When there are particular pieces of equipment or process units within a plant which provide major sources of liquid to the flare, it is desirable to have knock-out drums inside the battery limits for these sources. This will reduce the sizing requirements for the main flare knockout drum as well as facilitate product recovery.

5.7.1.3 There are three basic types of knockout drum designs that can be incorporated into a flare system: a horizontal settling drum, a vertical settling drum and a vertical centrifugal separator.

5.7.1.4 API Recommended Practice 521, *Guide for Pressure Relieving and Depressuring Systems* describes flare knock-out drums orientation, design criteria, instrumentation, mechanical details, operations, maintenance, and troubleshooting.

5.7.2 Liquid Seal

5.7.2.1 Flare liquid seal purposes include:

a. Prevent any flashback originating from the flare burner from propagating back through the flare system.

b. Maintain a slight system pressure to ensure no air leakage into the flare system and permit use of a flare gas recovery system.

c. Provide a method of flare staging between a smaller capacity smokeless flare and full size emergency flare.

d. Prevent ingress of air into the flare system during sudden temperature changes such as that following major release of flare gas or steaming to flare.

5.7.2.2 Liquid seals are located after the main knockout drum and before the flare itself. Elevated flares may provide a separate seal drum or incorporate the liquid seal into the base of the flare stack

5.7.2.3 Liquid seal and purge system should be designed to prevent the seal from being broken as a result of the vacuum formed in the flare header following a major release of flare gas or steaming as specified on General Data Sheet 5. See also the data sheet instructions for General Flare Data Sheet 5.

5.7.2.4 For facilities that flare cryogenic products, consideration should be given to the effect of the cold material on the seal medium. Water seals are not recommended where there is a risk of obstructing the flare system due to an ice plug. Alternate sealing fluids such as stove oil or glycol/water mixture may be considered. If a flammable seal fluid is used, consider that liquid carryover from a liquid seal can occur during a major flaring event.

5.7.2.5 API Recommended Practice 521, *Guide for Pressure Relieving and Depressuring Systems* describes additional information for liquid seals.

5.8 BLOWERS AND DRIVERS

5.8.1 Purpose

A blower (fan) is used to provide air and turbulence to the combustion process to make a flare smokeless. The circumstances when this should be considered are addressed in section 5.1.5. This section describes some design and practical considerations associated with such devices.

5.8.2 General Description

In general, three types of blowers have been used for this duty:

1. **Centrifugal:** Commonly backward-curved bladed fans are used with electric motor drives. Internal combustion engine or steam turbine drives have been used under special circumstances. See Figure 12.

2. **Vaneaxial axial flow fans with fixed or adjustable pitched blades:** Commonly used with close-coupled electric motor drives up to 260 kW (350 HP). See Figure 13.

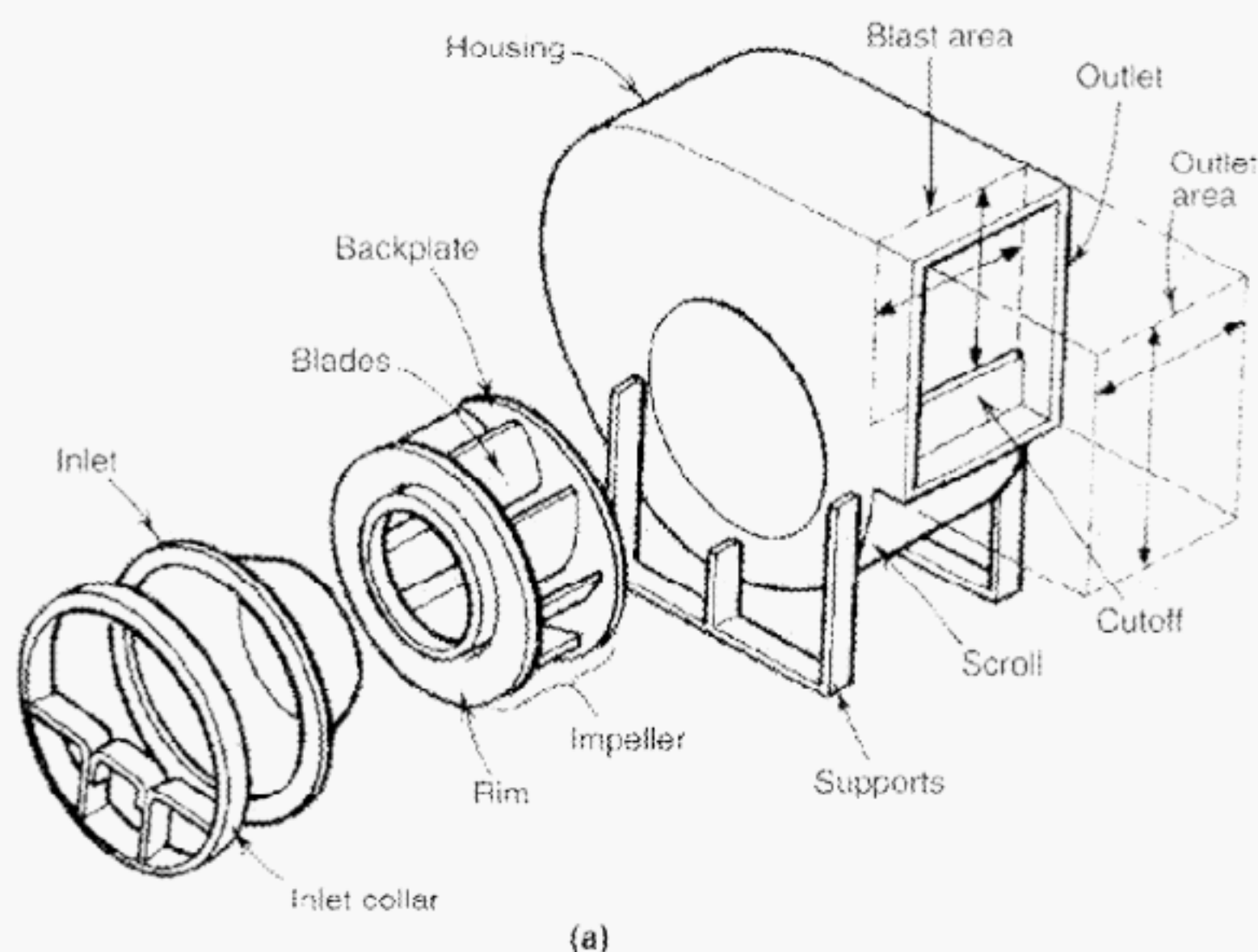


Figure 12—Centrifugal Fan

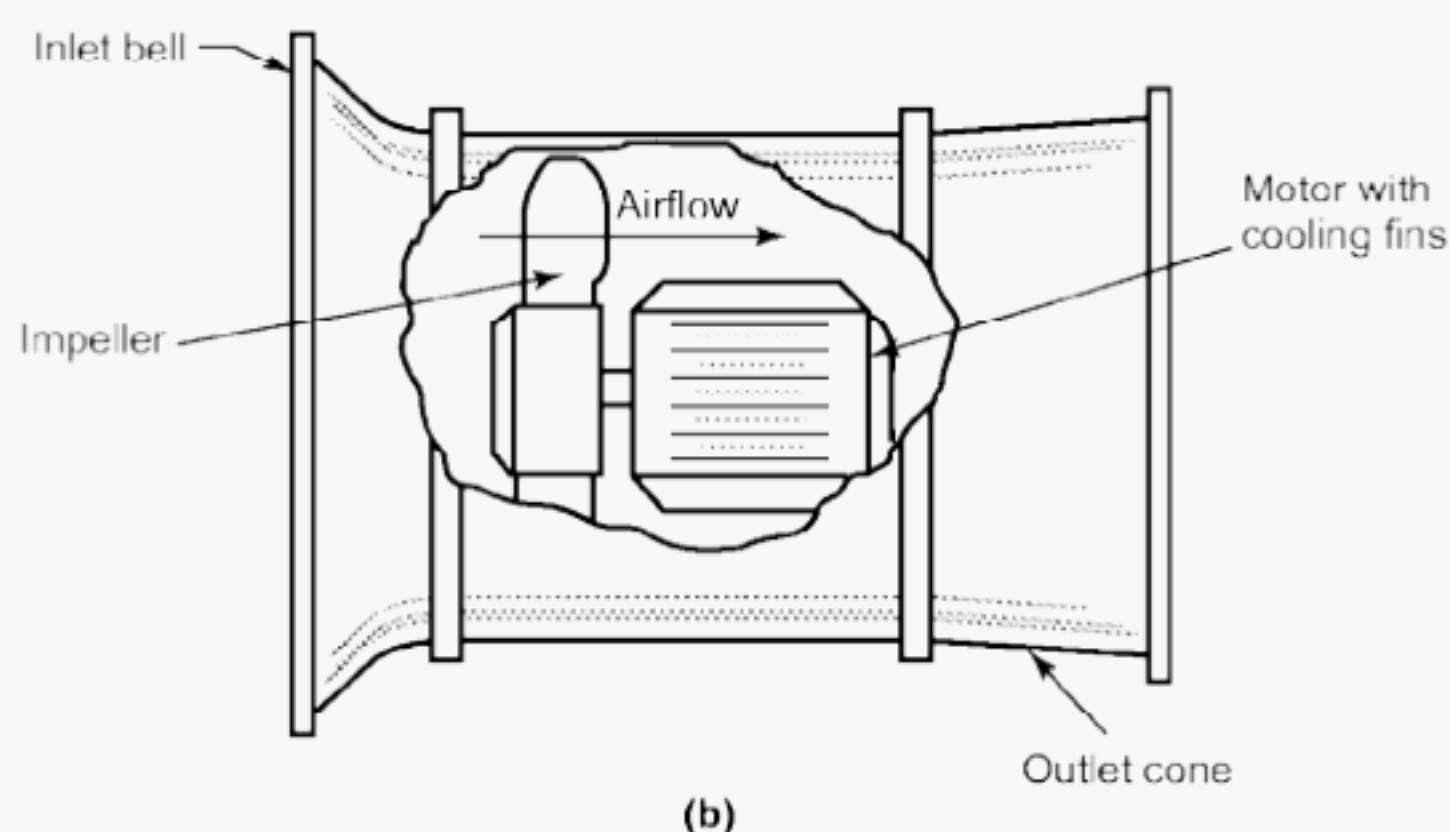


Figure 13—Vaneaxial Fan

3. **High pressure blowers:** Commonly multi-stage centrifugal blowers with a wide variety of impeller configurations are used with discharge pressures typically up to 103 kPa (15 psig) or more.

Blowers can be used singly, in multiples allowing stand-by, or in multiples allowing added capacity (see later, Design Considerations). The drives can be single, double or variable speed, and with or without other flow control devices.

5.8.3 Mechanical Details

The following mechanical details should be considered.

1. If multiple blowers are provided, attention should be paid to the potential of air from the active blower passing

through the inactive (idle) blower. Back-draft dampers or “anti-sail” pawls on the blower drive should be provided to forestall problems. There are two principal effects of this air loss:

- The escape of air through this route will lower smokeless capacity.
- The passage of air will cause the blades of the idle blower to rotate in the opposite direction to that of the driven condition. Thus, when the blower has to start, the motor has to stop spinning in the reverse direction. This extends the period of low speed operation. It is common that electric motor starters may trip on thermal overload during this extended period of low induc-

tance. In extreme cases, it is possible to break the driveshaft under these conditions.

2. The blower selection, installation and operation are an essential part of the performance of the flare. It is recommended that the flare manufacturer be given design and supply responsibility to reduce operational problems.

3. Care should be taken when applying purchaser standards to this blower. The specifications for a blower for smokeless burning with an air assisted flare burner may not conform to the specifications for blowers applied to process plant requirements. Those purchaser fan specifications typically reflect the use of much larger fans under much different service conditions (API Standard 560, *Fired Process Heaters for General Refinery Services*). The blower on an air-assisted flare will be rated for a peak duty to generate a maximum smokeless burning capacity. This blower will rarely operate at this high load condition. Normal air assisted smokeless flare blower operations should be at a reduced operating condition. It is not typical to rate a smoke suppression blower with the over rating on air-flow and/or pressure that is typical for a process blower requirement where the blower is fully loaded and critical to plant operations.

4. The driver for a blower for an air assisted smokeless flare operation differs from those applied to process blowers. As noted above, the horsepower rating need not reflect the over-rating for additional airflow and/or pressure drop. The driver rating may also be engineered with regard to the typical load cycle of a smoke suppression blower where high flow rates and pressures are atypical of daily operating conditions. The specifications for an electric driver needs to reflect the flare operating area requirements and the type of blower applied. Typically, totally enclosed motors are applied to meet electrical area classifications.

5. For centrifugal blowers, the motor will be TEFC (Total Enclosed Fan Cooled). For direct drive axial blowers, a TEAO (Totally Enclosed Air Over) motor is typically applied. A TEAO motor is essentially a TEFC without the cooling fan. The TEAO motor uses the blower airflow for cooling and is more efficient and may have higher power availability than does a TEFC motor. Normal electric motor specifications can cause problems when improperly applied; e.g. most sites require all motors to be TEFC but the vaneaxial design in AMCA arr.4 uses a TEAO motor design.

6. The blowers used for air assisted smokeless flares can contribute to the plant noise levels. For overall noise management, mufflers and noise enclosures are sometimes used. Local noise levels at the blower should consider the flare location and the worker exposure time to the blower

noise. If the blower is operating at a high rate, there will be significant flaring and it may be atypical for service personnel to be at the blower location and exposed to the local blower noise for extended time periods. The application of blower mufflers and enclosures needs to consider their impact on the blower performance and power requirements.

7. Winter operation will cause the motors to draw more current than summer conditions. Selection of winter thermal overload settings and breaker settings must account for this increase. In a TEAO configuration, the additional cooling from blowing very cold air over the motor prevents the motor from overheating.

8. Blower control options are available that provide enhanced flow control and substantial energy savings. These options include inlet vane dampers, controllable pitch vaneaxial fans, multiple blower combinations and variable speed drives.

9. The attachment of the blower and/or its ducting to a flare stack needs to consider the relative movement and structural loads of the attachment. For instance, if a fixed blower foundation is used, the ducting between the blower attachment and the flare stack needs to consider the flare stack movement at the point of attachment. If an axial blower is directly attached to a flare stack, the flare stack structural design needs to consider the loads due to the blower.

5.8.4 Operations

Operation of a blower fitted to an air assisted flare should recognize the following concerns:

1. Over-aeration can cause the following problems:
 - Flame blowout.
 - Excessive noise (low frequency).
 - Lower combustion or destruction efficiency.
 - Shorter tip life.
2. Most large motors have limits on the number of cold and hot starts per hour. System shall be designed and operated to avoid excessive restarts.
3. The blower should be operating (at least at low airflow) at all times for cooling and if there is the potential that there will be a backflow of flare gas (especially high molecular weight) within the air riser. At least one blower should be operating at all times in a multi-blower system.

5.8.5 Maintenance

Unlike many components of a flare system, blowers are generally in a position where they can be maintained. Motor and blower vendors should provide maintenance schedules

for their equipment showing recommended frequency for actions such as:

1. Motor bearing and impeller lubrication as required.
2. Free operation of back-draft dampers or anti-sail devices.
3. Operation of flow control devices, together with associated controls and actuators.
4. Check of motor speed control devices and starters (as appropriate).
5. Out-of-balance or unusual vibration conditions.
6. Ensure open passage to air entry (e.g., silencers, screens).
7. Replacement of any wearing parts such as rotating unions for controllable pitch fans.

Blowers are normally located at the base of the flare. Consideration needs to be given to the degree of radiation to which both equipment and personnel are exposed. Such considerations include taller flare stack and radiation shielding.

5.8.6 Troubleshooting

Possible problems with blowers that are specific to their use in a flare system are ultimately related to the production of unexpected smoke in a flare flame; such smoke need not necessarily be caused by the blower system. Table 7 provides a number of potential problems and possible causes that can generally be checked without shutting down the flare system. The flare vendor and/or the blower vendor should be contacted to determine if there are any other possible problems/causes that are application-specific.

Table 7—Troubleshooting Blower Systems

Problem	Possible Cause	Corrective Action
Blower not moving	Tripped overload or breaker	Check for short circuits in power wiring to blower motor. Reset overload or breaker.
Blower not moving	Incorrect power	Check feed voltage and current draw on each phase leg. Correct any wiring problems revealed by this check. Provide correct voltage to the blower.
Insufficient airflow	Local blockage at blower inlet	Inspect blower inlet. Remove any debris or obstructions
Insufficient airflow	Incorrect fan speed	Confirm fan speed.
Incorrect airflow	Incorrect blade pitch	Stop blower. Record actual blade settings on each fan blade. Compare average blade setting to design setting. Adjust as required to match design setting.
Incorrect airflow	Improper fan selection	Measure fan outlet pressure. Compare to fan selection basis. Adjust fan blades (if possible) to obtain proper airflow.
Incorrect airflow control	Incorrect control signals to flow control (e.g., inlet vane damper, blade pitch, or speed control)	Review conditions of waste gas flow and/or pressure governing the control logic. Repair or replace any malfunctioning instruments.
Incorrect airflow control	Malfunction of flow control (e.g. inlet vane damper, blade pitch, or speed control)	Verify proper operation of any flow control systems associated with the blower.
Reverse airflow	Reversed power wiring	Confirm proper wiring. Confirm correct direction of rotation of fan by shutting off power to the fan and observing rotation as the fan slows down.
Reverse airflow	Blockage at blower outlet	Confirm position of outlet damper.
Reverse airflow when blower should be off	Backflow from another blower	Confirm position of outlet damper.

5.9 BLOWER STAGING AND CONTROL EQUIPMENT

5.9.1 Purpose

In an air-assisted flare system, the objective is to achieve satisfactory performance, i.e., smokeless operation over the design range without undue waste of power or noise, possibly over a wide range of flow and gas composition. An auxiliary control system may be needed to determine what combination of blowers and operation of controls is required to achieve such performance.

5.9.2 General Description

The equipment falls into three categories:

1. **Detection:** The condition of the flare system is continuously monitored and the system is operated in response to the parameters of this monitoring. This detection can be as simple as monitoring the flare gas pressure (by pressure switch or transmitter). However, if the temperature or gas composition may change substantially, such control can become more complex, possibly with flare and airflow measurements and/or smoke or infrared detection with added modification from such controls. See Section 5.11. Feedback control on blower output may also possibly be required.
2. **Logic:** The signal(s) from the detection phase are required to be processed to give appropriate control action. This can be done by local dedicated control systems (e.g., PLCs) or the logic can be passed to a central control system (e.g., DCS).
3. **Flow control:** The control system from (2) is arranged to provide the appropriate signals to provide control. This can be as simple as arranging for an increase in motor speed or the starting of another blower motor. However, the control may have to be as complicated as a sophisticated logic system that uses all or some of these techniques: step-wise speed control, continuous motor speed control, additional capacity addition, continuous flow control (by damper). In all control schemes, readily available manual over-ride control should be fitted.

5.9.3 Mechanical Details

The selection of blower and blower control equipment for an air assisted smokeless flare is a function of:

- The smokeless burning requirements,
- The flare design, and
- Environmental parameters.

The quantity of forced draft air that must be supplied for smokeless burning is the most common design question.

Often this is some fraction of the stoichiometric combustion air requirement. The air quantity alone, though, does not determine the smokeless burning performance. The air quantity plus its velocity at the mixing point with relief gas are the important factors. This is the air energy at the flare tip. The stoichiometric air fraction used for smokeless burning can be significantly altered by the velocity employed at the flare tip and by the flare tip design.

Blower energy expended to deliver the air to the flare tip does not effectively contribute to the smokeless burning. Care must be taken in the design of the air delivery piping/stack and connection of the blower(s) to the flare. Obstructions in the air delivery system, like flanges on an internal gas riser, can significantly contribute to blower energy losses.

The blower airflow is designed for a maximum smokeless burning rate with maximum design airflow. The flare system must operate at reduced smokeless burning capacities without excessive use of energy and without the generation of unstable and noisy flames. The number of blowers and the type of airflow control employed are functions of the size, type and burning requirements of the flare system. On some systems, a single blower is sufficient. Reduced smokeless flaring, on such a system, can be achieved with the use of a multiple speed blower motor, a variable speed blower motor or the use of blower inlet or outlet dampers. The least operating power will be realized with the use of the multiple speed or variable speed motor. An inlet damper will also reduce operating power. Outlet dampers do not lower the operating horsepower.

In the simplest control system, a multiple speed blower motor is advanced to high speed or returned to low speed operation on a flow or pressure signal from the flare relief header. It is recommended that the advancement to high speed and the return to low speed incorporate some signal hysteresis. If a single switch point is used, the blower may cycle between speeds excessively due to flow/pressure variations in the flare header. Attention should be paid to the practicality of pressure detection if there is a wide flow range (the gas pressure will vary directly with the square root of the flow over the relevant range). Special care should be paid to setting of the "deadband" to avoid frequent blower stopping and starting at a particular range of flare flow.

Air assisted smokeless flare design should assure that the blower speed selections supply sufficient energy to produce smokeless burning at the maximum rate while offering sufficiently low air energy at reduced rates to stably burn minimum flow rates.

If a variable speed motor or inlet damper is used for proportional control of smoke suppression airflow to relief gas flow, then reliable instrumentation to monitor the flow of flare vapors in the header is required. This flow measurement will need to consider the full operating range of the flare system design. Air assisted smokeless flares are often designed for large relief rates where smoke is acceptable while offering

smokeless burning at much lower flow rates. For such systems, measuring low speed, low-pressure flows in a flare header can be difficult. Please refer to Section 5.11, Flow and Pressure Sensing Equipment.

Continuously variable airflow control over the design range is possible by continuous motor speed control (e.g., steam turbine, or internal combustion engine) or by a conventional damper control. To control such a system requires suitable detection devices, e.g., a pressure transmitter, a flare gas flow metering control or smoke control (e.g., infrared detector). Care must be given to ensure that the airflow response is rapid enough to avoid troublesome emissions of smoke during flow change operations. It may be necessary to modify the control action to reduce the effects of control loop lag.

The use of multiple blowers adds additional concerns for the air assisted smokeless flare design. First, the full operation of all blowers must be engineered from their start up sequencing through their maximum flow operation. Multiple blowers can be equipped with multiple speed motors, variable speed motors and/or dampers. The integration of these devices must consider how airflow is to be regulated from a minimum to a maximum. Anytime an additional blower is required, its start up needs to consider the operating condition in the flare air delivery system. A second or third blower will start up against a static pressure in the flare system. Such start-ups can cause blower surging and instability. Any blower surging and airflow instability can be amplified by the combustion at the flare tip to create unstable, noisy flare flames. Likewise, a blower engaged on a low speed motor operation may not have sufficient static pressure capability to add airflow to an air assisted flare that has airflow already established by a blower operating on a high speed motor. The lower speed fan will be discharging against a "dead head" and the fan will not contribute to the common flow until its discharge pressure is sufficiently high to cause flow. With two identical blowers, both must operate at the same speed to cause significantly more flow than one blower alone. The control scheme must be arranged with this in mind.

The entire airflow system needs to be engineered to assure that proper airflow to hydrocarbon gas relief rates can be achieved over the full range of flaring conditions with any multiple blower system. This engineering needs to consider the starting and stopping of blowers as well as the airflows that they produce. Large horsepower motors can only be started a limited number of times per hour. The system design must address how to avoid excessive cycling blower operations with transient flow conditions to the flare header. Most important, the multiple blower operations must address manual operator inputs to adjust airflow for smokeless, low noise operations.

Multiple blowers system must be designed with isolation dampers for any blower that is out of service. This is to prevent airflow from discharging out the idle blower. The opening and closing of these isolation dampers must be considered

in the design of the control logic of an air assisted smokeless flare system with multiple blowers.

Control systems for multiple blowers can be by pressure/flow switch operation or can be by proportional control to the flare relief flow.

Variable speed drivers can include electric, steam or internal combustion power. A hybrid system that uses a steam driven blower motor can incorporate a steam assist for smokeless burning, using the exhaust steam from the turbine drive.

The connection of air-assisted blower to a flare stack should consider the loads due to blower operations and the movements due to stack deflections.

5.9.4 Operations

Operation of air assisted smokeless flare system should start with an initial check out of the blower operations. Each blower should be checked for proper rotation and speed. The motor amperage should be confirmed for all operating points with multiple blowers. It should be noted that many of the axial type blowers used for air assisted flare applications have blade pitch adjustments that can affect the air delivery. The blower blade pitch should be set to the maximum allowed by the motor or as otherwise recommended by flare equipment manufacturer. The blower initial check out should confirm the operation of damper, isolation or flow control. The blowers/motors should be checked for vibration limits.

Blower controls should be checked for proper blower speed and multiple blowers sequencing. Operator indication of operating blowers, blower speeds and damper positions should be provided. Maintenance items for the blowers, motors and controls should be located to be accessible while the flare remains in service. Some items exposed to radiant flare flame loads may require shielding.

Smokeless flaring operations should cover the range of flare relief gas compositions and flow rates specified for the flare operation. At times operator intervention into blower operations may be required to adjust airflow to achieve smokeless burning and/or to reduce flare noise. Excessive airflow rates can lead to excessive flare noise.

While electrical blower motors have a limited number of starts/stops per hours, leaving a blower on after a flare smokeless relief load has subsided can create excessive noise.

Air assisted flare operations should consider operation of the flare system if a blower power failure occurs. Lack of forced air will allow the flare to smoke. Other considerations such as migration of relief gas flows in to the air delivery system should be considered for flare operations and design. Likewise the radiation from a non-assisted flame on an air assisted smokeless flare may be significantly different from the radiation from the forced draft air assisted flame. The highest radiation load, blower-on or blower-off, should be used for safety.

Air assisted flare design should mitigate any possible leakage from the pressurized air delivery system into the flare relief gas riser. For instance at low relief gas flow rates, the air pressure can exceed the gas pressure in the flare header. If an opening such as a tear in the gas riser or a loose gas riser flange is encountered, forced air can flow into the gas header. This can create an explosion hazard in the flare relief gas header.

5.9.5 Maintenance

Much blower staging and control equipment is located where local conditions allow maintenance, provided that access and isolation are permitted. The recommendations of the manufacturers of all equipment in the system should provide good guidance. Such advice might include such items as:

1. The forced draft blower and its driver should be maintained per the manufacturer's recommendations. This may require lubrication service.
2. Any dampers should be regularly inspected for operation and adjustment. Damper linkages can vibrate and wear and become loose. This can upset airflow and smokeless flare operations.

3. Controls for airflow operations should be calibrated and maintained per the instruments manufactures recommendations.

4. Any expansion joints used to connect blowers and blower ductwork to the flare stacks should regularly be inspected for wear and leakage.

5. The air assisted flare tip should be observed at night-time for hot spots that can occur due to internal burning.

6. Flare pilots and ignition systems should be maintained as detailed in sections 5.2 and 5.3.

7. Ensure electrical parts are not subjected to high heat or vibration.

8. Ensure electrical and physical integrity of control boxes are not compromised.

5.9.6 Troubleshooting (Blower Staging and Control)

See Table 8, Troubleshooting Blower Staging and Control Equipment.

Table 8—Troubleshooting Blower Staging and Control Equipment

Problem	Possible Cause	Corrective Action
Smokeless burning is not being achieved	Insufficient air flow	Confirm that blowers and dampers are operating correctly
		Confirm that blower adjustments are set to use the available power
		Confirm that there is no significant air leakage from the flare or air delivery system
		Confirm that relief gas flow rates and compositions are within design specifications.
		Confirm that there is no liquid carryover in the flare relief gas.
Excessive flare noise levels	Excessive airflow	Confirm that the blower, dampers and controls are operating properly.
	Tip damage	Confirm that the flare flame is stable. If the flame is not stable, then evaluate airflow, gas flow, and loss of flame holding devices as potential causes.
	Incorrect waste gas composition or flow	Confirm that the relief gas flow rates and compositions are within design specifications and that transient flow conditions between differing relief gas scenarios is not occurring.
	Blower surging or flame instability	Reduce airflow rates to see if the excessive noise subsides. If it does, it may be possible to advance the airflow back to a higher flow rate to achieve smokeless burning. Once an unstable flame is started, it is very difficult to mitigate without either reduction of the gas flow or the airflow.

5.10 PRESSURE STAGING EQUIPMENT

5.10.1 Purpose

In some flare arrangements, the flare flow is arranged to go to a number of burning locations (stages) to achieve the specific object of the arrangement (often smokeless operation). See Section 5.1 for further information. Maintaining sufficient tip pressure during turndown conditions may be critical and often requires that a staging system be employed to proportionately control the number of flare burners in service with relationship to the gas flowing. This section addresses itself to the auxiliary equipment necessary to operate this kind of flare.

5.10.2 General Description

The equipment falls into three categories:

1. **Detection:** The condition of the flare system is continuously monitored and the system is operated in response to the parameters of this monitoring. This detection can be as simple as monitoring the flare gas pressure (by pressure switch or transmitter), but can become more complex with

associating flare and steam flow measurements with or without added modification from smoke or infrared detection. (See Section 5.11 for more).

2. **Logic:** The signal(s) from the detection phase are required to be processed to give appropriate control action. This can be done by local dedicated control systems (e.g., PLCs) or the logic can be passed to a central control system (e.g., DCS). It is also common to have a local control indication of pilot and stage condition.

3. **Flow control:** The control system from (2) is arranged to provide the appropriate signals to operate devices (usually control valves with on-off or continuous operation).

Figure 14 is a simplified P&I drawing showing a staged system containing three stages such as the system discussed in Paragraph 4.2.4.2. The design and safety requirements of each application may impact the instrumentation selection and arrangement.

Note: On some systems, the operative purpose of the above equipment can be achieved with a suitably designed liquid seal. Such a device and operation is described in Section 5.7.

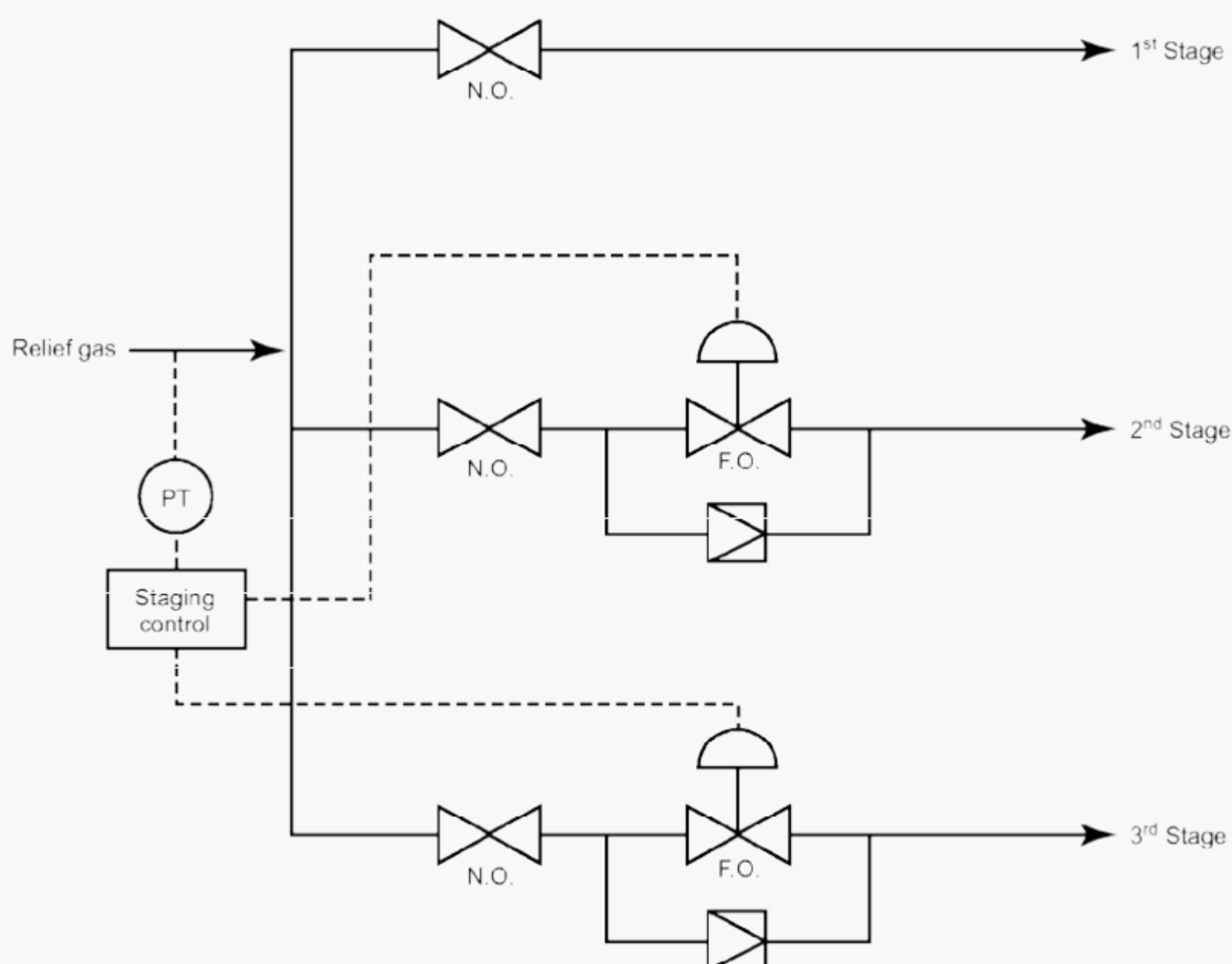


Figure 14—Simplified P&I Diagram for a Three-Stage Flare System

5.10.3 Mechanical Details

The actual selection and co-ordination of this type of equipment is very much an integral part of the proprietary knowledge of the system supplier. The following are only general comments that may help in acquiring such a system:

1. Reliability of the detection devices is of paramount importance; ease of maintenance is also of major concern. Some users address these concerns by utilizing redundant control elements such as pressure transmitters in staging systems. Some operators prefer triple redundant instrumentation for these critical control elements.
2. Particular attention should be paid to control logic, with the greatest importance being given to the *safe* operation of the system to act as a complete flare system.
3. The greatest concern with control valves used in this duty is that the safety of the flare system is not compromised by valve failure. To this end it is common to install bypasses on such valves and these bypasses are fitted with devices that will be guaranteed to operate if the upstream pressure reaches an unsafe level; such devices are rupture disks or similar fail-safe devices. Care should also be taken that the access and isolation of the valve systems will permit maintenance.
4. An operational note concerning rupture disks: when a valve closes to turn off a stage, there is a possibility that there will be a flashback in the pipework immediately after the valve. It is possible that a pressure wave associated with this flashback can burst rupture disks from the downstream side, thus creating serious operational problems. It is strongly urged that an after purge with an inert material (e.g., nitrogen or carbon dioxide) be immediately introduced into the piping downstream of the valve to clear the pipe of any material that might form a burnable mixture in the pipe. This purge need not be continuous but its application has to be at the same time, or closely following, the closing of the staging valve.

5.10.4 Operations

As with many flare system components, a staging system should be designed to operate automatically without any human intervention. After commissioning, no "operations" procedure should be required (other than Maintenance and Troubleshooting, see later). However, any such procedure that may be required by the system supplier, or which has been developed by site engineers after due consideration, should be suitably promulgated and observed.

5.10.5 Maintenance

Much equipment of a staging system is in a position where local conditions allow maintenance, provided that access and isolation are permitted. The recommendations of the manufacturers of all equipment in the system should provide good guidance. Such advice might include such items as:

1. API Recommended Practice 521, *Guide for Pressure Relieving and Depressurizing Systems*, describes flare knockout drum maintenance, and troubleshooting. Adequate knock out drums should be installed immediately prior to the flare for any application that contains gas that can go to dew point. Liquid will result in smoking flames and a significant growth in flame length that can produce severe damage to the surrounding equipment.
2. Stroke all staging valves fully open and then rapidly close on a routine basis. A common practice is every 2 to 3 months. This testing insures the valves function and prevent seizure of the seating surfaces and actuators.
3. Check bypass device or the staging valve for leakage. One method commonly used for this confirmation is to install a block valve ahead of the device and a small connection for the introduction of nitrogen. The operator confirms that pressure produced via the introduced nitrogen is maintained for a set period of time indicating that the system is gas tight.
4. If pin actuated devices are installed, flex the pin moving the piston on a routine basis sufficiently to prevent seizure of the o-rings to the valve body.
5. The instruments associated with the staging and pilot systems should be treated as critical safety controls and inspected and calibrated on the schedule the plant has established for such critical control elements.
6. Refer to sections 5.2.5, 5.3.5, and 5.4.5 for maintenance of pilots and pilot detection systems.
7. Ensure scaffolding, debris, etc. does not impair the operation of all valves and similar parts.
8. Ensure electrical parts are not subjected to high heat or vibration.
9. Lubricate actuators, as appropriate.
10. Ensure electrical and physical integrity of control boxes are not compromised.
11. Replace burned-out indicator bulbs promptly.

5.10.6 Troubleshooting

See Table 9, Troubleshooting Pressure Staging Equipment.

Table 9—Troubleshooting Pressure Staging Equipment

Problem	Possible Cause	Corrective Action
Smoking or flames on a stage that should be closed.	Relief device has blown and the flow reduced to a low level. Smoke will occur on the stage that is now no longer under the control of the staging system, i.e., the relief device is an open pipe to the affected stage.	Restore relief device to closed condition. Arrange control scheme to indicate opening of relief device (possibly using limit switches to indicate correct operation).
Smoking or flames on a stage that should be closed.	Leaking valves or bypass devices	Repair valve or bypass device.
Smoking or flames on a stage that has just closed.	Normal behavior for short time while residual gas downstream of staging valve bleeds off.	If condition does not correct itself in a few minutes, check for blown relief device (possibly using limit switches to indicate correct operation). Use post-purge system to flush residual gas out of affected stage more rapidly.
Smoking on a stage that should be open.	Incorrect waste gas composition	Route sources of this composition to another flare system or stand-by-emergency flare. Replace burners with equipment designed to handle this gas composition.
Smoking Stage valve does not close at the time expected.	Insufficient air pressure to valve actuator.	Check for obstructions in instrument air line such as closed block valve, kinks in tubing, failed pressure regulator, etc. (possibly using limit switches to indicate correct operation).
Pulsing flames	Staging system can enter a mode of frequent opening and closing ("fluttering") at certain flare loads	Modification of the software controlling the valve action by adjusting response rates, modifying timing delays, etc.

5.11 FLOW AND PRESSURE SENSING EQUIPMENT

5.11.1 Purpose

A flare system may be fitted with a flow and/or pressure measuring system for a number of reasons:

1. To act as an input element into a smoke control system
2. To provide record-keeping for total flow going to flare for operational or legal reasons.

5.11.2 General Description

The selection of equipment for this duty is dependent on its primary purpose. Although multiple parameters may be measured by such instrumentation, there are generally two types of system:

1. **Pressure:** It is common to measure the pressure in the type of flare that uses the pressure of the gas to provide the energy necessary to give smokeless performance. This pressure input provides the indication of flare system condition to operate the pressure staging system described in Section 5.9. The measuring element can be a pressure switch but pressure transducers are being increasingly used.

2. **Flow:** A flow meter is an alternate and more direct way to determine flow. However, the measurement of volume alone does take into account any variation in molecular weight. Certain installations may require a mass flow meter to achieve the desired objectives. (Note: A system that may have flows of compositions with varying degrees of saturation may require more than just a measure of mass flow as an input for smoke control.)

5.11.3 Mechanical Description

The mechanical details of equipment covered by this section are very much dictated by the requirements of the instrument supplier. There are, however, some generalized notes that should be observed:

1. Inasmuch as the flare system, in general, should be available at all times, the application of plant-wide installation specifications may not be applicable. As an example, whereas an instrumentation specification might demand that isolating valves be fitted on all pressure sensing devices (for service purposes), it should be recognized that a flare system may depend upon the assumption that a pressure sensing switch or transmitter is always live to the process and it can not be turned off except under controlled circumstances.
2. The potential flow range in a flare system is extremely wide. Care must be taken that equipment designed for a normal relatively small flow rate is not damaged or upset by occasional high flow (and pressure) excursions.
3. Flare streams are notoriously unpredictable in composition. This affects the interpretation of flow information (e.g., for smoke control, a flow meter may not be able to differentiate propane from propylene). Unpredictability may also affect the physical operational condition of a system (e.g., it is common to have gummy liquids and solids existing in flare lines that may render flow detection elements inaccurate or inoperative).
4. Equipment reliability should be carefully assessed in reference to the importance of the function of the equipment.

5.11.4 Operations

Under normal circumstances, this equipment should operate automatically.

5.11.5 Maintenance

The manufacturer's recommendations should be used as a guide for maintenance. The opportunities for maintenance may be restricted, however, and this should be assessed at original installation (see 5.11.3 [1]).

5.11.6 Troubleshooting

The manufacturer's recommendations should be used as a guide for troubleshooting.

6 Multi-Burner, Staged Flare Equipment Components

6.1 BURNERS

A multi-point flare has multiple burners to distribute flared gases across several burning points. The multiple burning points may be arranged in arrays located near grade or at an elevated position. See Figure 15 for one example.

Multi-burner, staged flares are fed from a manifold. The manifold distributes the flow of flare gas to individual branches containing one or more burner tips. Control valves direct the flow of flare gas to each branch. The control valve feeding each stage opens or closes depending upon the upstream pressure.

A burner ejects the flare gas to entrain surrounding air at sufficient velocities to induce proper mixing for ignition and stable combustion. An individual burner has multiple orifices and some means of flame stabilization. The burner can be constructed of cast or wrought materials.

Typical burner metallurgy is high grade, austenitic stainless steel. The burners are normally welded to the flare gas risers. In some cases they are threaded, then back-welded.

Burner riser material shall be of suitable grade to withstand operating flare and flare gas temperatures. Flare gas temperatures include situations if and when releases go cryogenic. Typical material for the riser is Type 304 stainless steel in the upper portion (about 1.8 m [6 ft]). The lower portion of the risers can be of carbon steel. It should be properly insulated and jacketed if required.

The burner performance is dependent upon burner spacing and elevation and row spacing and length. These factors influence air supply to the burners. Proper burner spacing is critical for reliable cross lighting between burners of a given stage.

6.2 PILOTS

6.2.1 Flare pilots must reliably ignite the individual flare stages. Cross lighting ignition from adjacent stages is not recommended. If an individual stage pilot fails to operate in correct stage sequence, unburned hydrocarbons and/or toxic gases could be released to the atmosphere, potentially resulting in a vapor cloud explosion, odor problems or adverse health effects. Should a flare pilot fail to ignite a particular

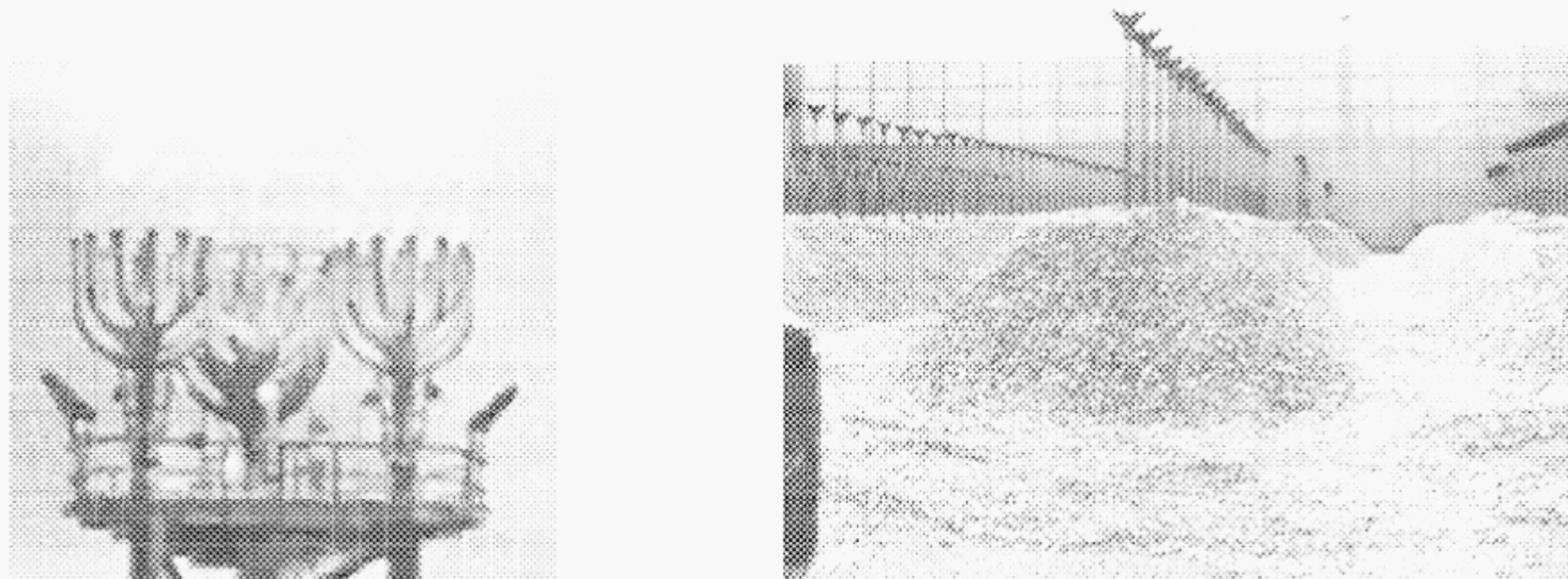


Figure 15—Multi-Burner Staged Flares

stage in proper sequence, subsequent stages may be prevented from operating. In most Multi-burner flare applications, the pilot cannot be accessed for service or replaced while the flare is in operation. Consequently, the pilot system must be reliable enough to operate for years without maintenance.

6.2.2 Pilot designs are similar to elevated pilot designs. The majority can be described as fixed heat release, self-inspiring, pre-mix burners.

6.2.3 See Section 5.2 for additional details.

6.3 IGNITION EQUIPMENT

6.3.1 The purpose of the ignition equipment is to reliably ignite the pilot.

6.3.2 There are four types of ignition systems that are commonly employed to light flare pilots:

- Spark ignition at pilot tip,
- Spark ignition of a portion of the pilot gas/air mixture prior to the pilot tip,
- Compressed air flame front generator,
- Self-inspiring flame front generator.

6.3.3 No single ignition system is preferred in all circumstances. For improved reliability, multiple ignition systems are often installed.

6.3.4 See Section 5.3 for additional details.

6.4 FLAME DETECTION EQUIPMENT

6.4.1 The purpose of the flame detection system is to confirm that the pilots are lit.

6.4.2 There are several types of flame detection such as thermocouples, flame ionization detectors, optical systems, and acoustic systems.

6.4.3 See Section 5.4 for additional details.

6.5 BUOYANCY AND VELOCITY SEALS

Buoyancy and velocity seals are typically not applicable to multi-burner, staged flares.

6.6 MANIFOLDS

A common manifold distributes the flow of flare gas to individual manifolds that contain multiple burner tips. The manifold materials shall be of suitable grade to withstand operating flare and flare gas temperatures. These individual manifolds may be externally insulated or covered by earth and stone as appropriate.

Open/close valves supply flare gas to individual manifolds. Figure 7 shows the effect of opening additional stages as the flow increases. Should the open/close valve fail to operate as needed to prevent overpressurization, a valve bypass piping system may be utilized.

After closure of each stage, the piping downstream of the staging valve may be purged. An inert gas may be used to purge the line of any combustible gases.

6.7 SUPPORT STRUCTURE

6.7.1 Elevated, Multi-burner, Staged Flares

The support structure for the piping, lighting and platforms and ladders shall be as described in Section 5.6. Consideration shall be given for the additional staged piping required.

6.7.2 Radiation Shielding

All piping subject to thermal radiation, upstream of the individual burner risers, shall be adequately protected. Such piping is typically covered with loose gravel or metallic shielding. The covered piping shall be suitably protected from environmental effects and corrosion.

6.8 OPERATIONS

A staging system should be designed to operate automatically without any human intervention. After commissioning, no "operations" procedure is required (other than that described in Maintenance and Troubleshooting, see later), but the system supplier's advice should be followed.

6.9 MAINTENANCE

Much equipment of a staging system is in a position where local conditions will permit maintenance provided that access and isolation will permit. There is nothing about the use of any such equipment that is specific to flare systems and thus the recommendations of the manufacturers of all equipment in the system should provide good guidance.

Maintenance items for a multi-burner staged flare system are primarily those associated with the staging system. Refer to Section 5.10.5 for a list of maintenance items.

6.10 TROUBLESHOOTING

Troubleshooting of multi-burner staged flare systems most often involves troubleshooting the staging system. Refer to Section 5.10.6 for this troubleshooting guide.

7 Enclosed Flame Flares

7.1 PURPOSE

There are circumstances when it is desirable that all or part of a flare load be disposed of in a way that causes the minimum of disturbance to the immediate locality.

1. To eliminate or reduce radiant heat to nearby equipment or work areas.
2. To reduce noise in the immediate vicinity.
3. To make the flare flame less obvious for community relations.
4. To potentially achieve improved emissions.

7.2 GENERAL DESCRIPTION

Enclosed flame flares burn the flare gas from a burner or burners placed as near the ground as is practicable to ensure good operation. The resulting flames are hidden from sight by a surrounding wall or chamber. The top of the chamber is

open to the atmosphere and allowance is made in the bottom of the chamber to permit the ingress of combustion air. It is common for the chamber to be surrounded by a wind fence to modify the effect of crosswinds on the combustion process and to prevent unauthorized access.

An enclosed flame flare system has a number of key components. These include:

- Combustion chamber.
- Burners,
- Piping systems,
- Wind fence,
- Operational and safety controls.

An enclosed flame flare is more complex than simply installing a pipe flare inside a combustion chamber. This flare design requires an engineered combustion process, with considerations for airflow into the combustion chamber and flue gas flow from the chamber. Burner designs have been specially developed to meet the combustion requirements of enclosed flame flares.

Enclosed flame flares are typically rated for normally occurring flare relief conditions. There is considerable expense in providing enclosure for larger relief capacities that rarely occur. For selected applications, an enclosed flame flare will be the first stage of a flare system that includes another flare for the combustion of larger, emergency flare relief flows. See Figure 16.

7.2.1 Combustion Chamber Size and Shape

Since the combustion chamber encloses the flare flame, consideration needs to be given to the size of the flame. The flame size is a function of the burner design, the airside pressure drop, the gas discharge energy and the fuel and air conditions. Smaller flames can be produced with the use of higher air and gas energies.

Combustion chamber design typically results in a volumetric heat release about 1.12M kJ/Nm³ (30,000 BTU/Hr/Ft³). The design volumetric heat release is a function of the burner size and design, combustion chamber geometry, relief gas composition, and other factors. The largest enclosed flame flares now operating are rated at capacities above 90,000 kg per hour (200,000 pounds per hour). The smallest enclosed flame flares are rated at only a few hundred pounds per hour of relief gas flow.

The combustion chamber can be configured in several shapes including vertical cylindrical, rectangular, and multi-sided. The choice of shape includes a number of process, safety, structural and economic concerns. Site fabrication and economical factors often are paramount in the selection of the shape of an enclosed flame flare. The top of the combustion chamber is typically open for flue gas discharge. None of the

combustion chamber shapes have an inherent advantage in the mitigation of combustion noise. See Figure 17.

7.2.2 Burners

The burners and burner control systems for enclosed flame flares are engineered for the specified gas flow rates and compositions. Burners can be unassisted, steam assisted, air assisted or pressure energized to produce smokeless burning and to assist in control of the flame volume. Burners can be fuel gas enriched to achieve desirable combustion efficiency for low heating value and hard to combust relief gases.

All enclosed flame flares, except the very smallest in size, use multiple burners. For larger capacity enclosed flame flares, the multiple burners typically operate in staged systems as is described in Section 6 of this document.

The burners typically combust a variety of gas compositions and flow rates. Staged and unstaged burner systems necessitate different design considerations. With a staged burner system, only the first stage turns down to purge flow rates. Furthermore, the burner staging provides control on the gas discharge energy of the burners to assure proper mixing of fuel and air and thus control of the flame volume. Large gas flow rates, at low-pressure discharge, will produce softer, larger flames unless supplemented by energy from the combustion airflow. Such flames can be difficult to contain in the combustion chamber and have a propensity to produce smoke and poor combustion. If an unstaged burner system is used, then all of its burners require turndown to the minimum purge rate.

The design of burners for enclosed flame flares is proprietary to the manufacturers.

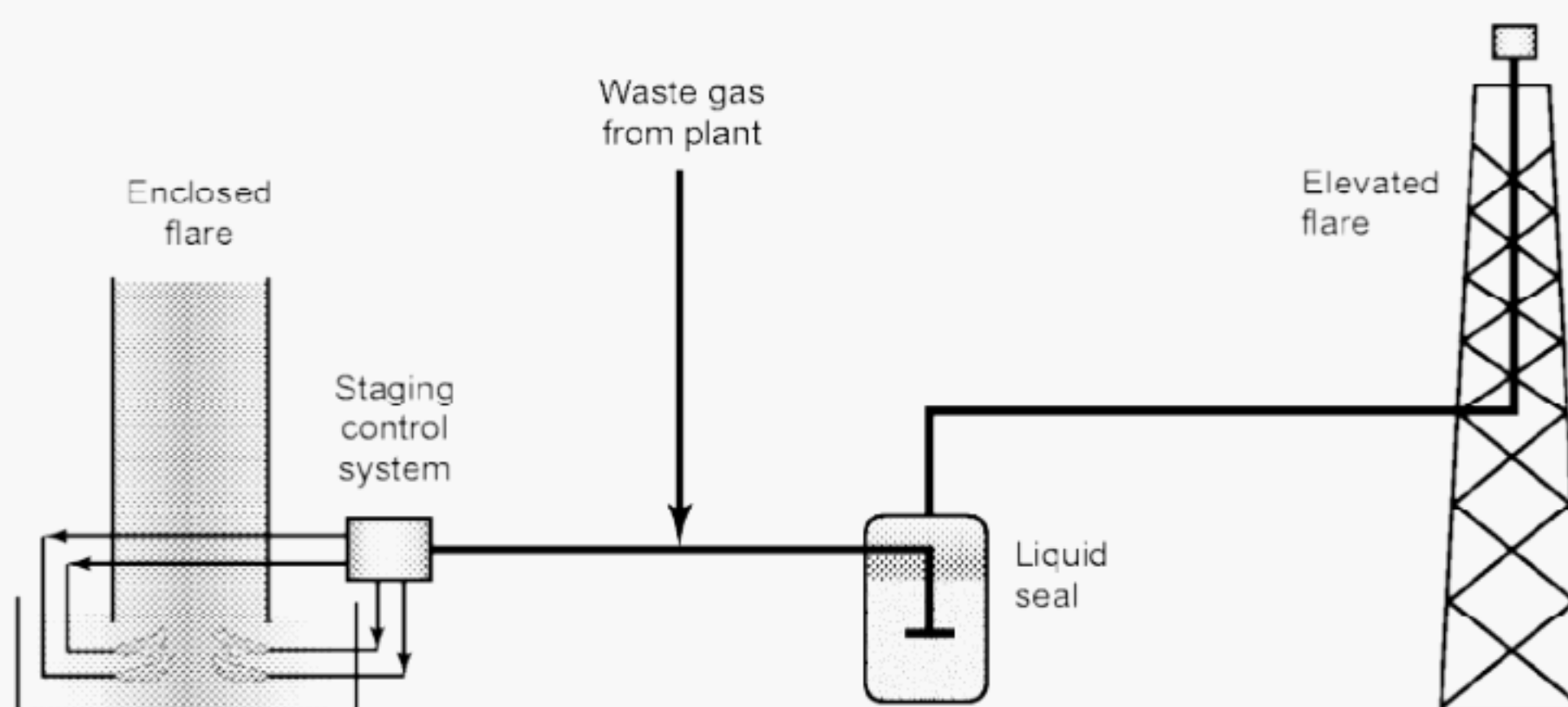


Figure 16—Typical Enclosed Flare Staged to Elevated Flare

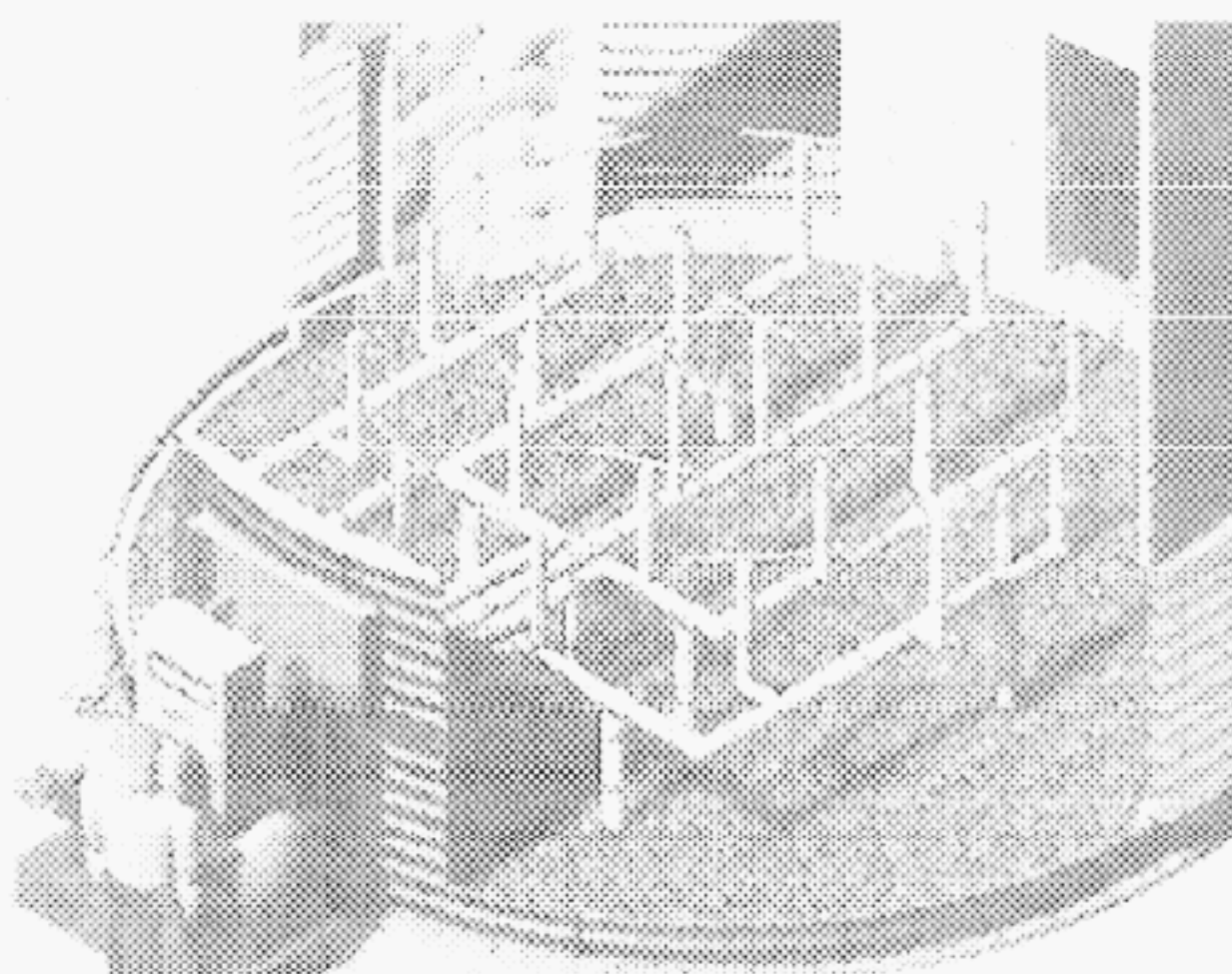


Figure 17—Enclosed Flare

The burner design must:

- Be engineered for the relief gas flow rates and compositions, the possible pressure and temperature ranges of the gases.
- Consider the utilities (or lack thereof) that are available for burner operation.
- Consider known likely operating conditions.
- Operate at all airflow rates and velocities within the design range.
- Achieve the desired level of combustion emissions with flame volumes that are contained within the combustion chamber.
- Produce stable flames for all relief gas flow conditions and compositions.
- Not induce any combustion rumble that can trigger excessive noise and resonance from the combustion chamber.

Experience with a burner design operating as part of a complete design of an enclosed flame flare is recommended.

Airflow design into the combustion chamber establishes the distribution and velocity with which the air mixes with the fuel discharge. A pilot flame initially ignites these fuel-air mixtures. Once a main burner flame is established, the burner should be stable and maintain continuous flame ignition on its own. Flame stability of a main burner should never have to rely totally on the pilot flame. Burner flame stability is produced by flare manufacturer proprietary means. Mechanisms include mechanical elements of the burner design in conjunction with air and gas flow dynamics.

7.2.3 Air and Flue Gas Flows

An enclosed flame flare design must provide for the airflow into the combustion chamber and for the flow of hot flue gases out of the combustion chamber. The heat produced in the combustion process is absorbed by large quantities of excess air so that the resulting flue gas temperature is low enough to allow the use of common refractory materials. The airflow into the combustion chamber can be by natural draft or forced draft. Natural draft is most often employed on large size enclosed flame flares. The natural draft level produced at any flaring rate is a function of:

- Gas flow rate, composition, and heat release.
- Airflow dynamics into the combustion chamber.
- Frictional and combustion pressure losses as the flame propagates.
- Flow throughout the combustion chamber.

- Pressure loss of the flue gases exiting the combustion chamber.
- Combustion chamber dimensions.

These factors can be engineered for performance of the ground flare from minimum flow rates to maximum flow rates. The combustion chamber maximum operating temperature is set by such engineering. For natural draft enclosed flame flares, the combustion chamber temperature at any flow rate less than maximum will be lower and its operating excess air will be higher. Even with cooler flue gas exit temperatures and higher overall excess air levels, high combustion efficiencies are achieved from the flames alone, as is the case for most open air elevated flares.

The enclosed flame flare can achieve higher combustion and destruction efficiencies with the flare flame contained in the combustion chamber. Natural draft airflow can also be controlled by the use of dampers or other means to control the airflow into the combustion chamber. Control of the airflow can allow for control of the combustion chamber operating temperature over variations of relief gas flow rate and composition. Controlled combustion temperature can achieve higher hydrocarbon destruction efficiencies.

Forced draft air movement can be used for multiple purposes in enclosed flame flares.

1. Some air assisted designs use forced air to supplement the flame energies to produce smokeless flames of reduced flame volume.
2. Designs for 100% forced draft air volumes are controllable, and thereby control the enclosed flame flare combustion chamber temperature.

Excessive forced draft use can contribute to enclosed flame flare noise, resonance and vibration concerns. The use of forced draft fan and its driver impacts reliability and availability of the overall system and should be evaluated.

Flue gas flows from the enclosed flare occur at the temperature of combustion chamber for the given operating condition. Typically, the temperature factor dominates for the dispersion of combustion products. If the flame volume is contained within the combustion chamber, there is very little, if any, measurable thermal radiation from the plume. However, the hot plume from the ground flare can impinge upon structures and components that are close by and above the elevation of the combustion chamber discharge.

The flow of gas through the burner, the flow of air into the combustion chamber, and the flow of flue gases out of the combustion chamber all must be engineered for a successful enclosed flame flare.

7.2.4 Wind Fence

Enclosed natural draft flame flares use wind fences or other designs to mitigate the potential of the wind to upset air and

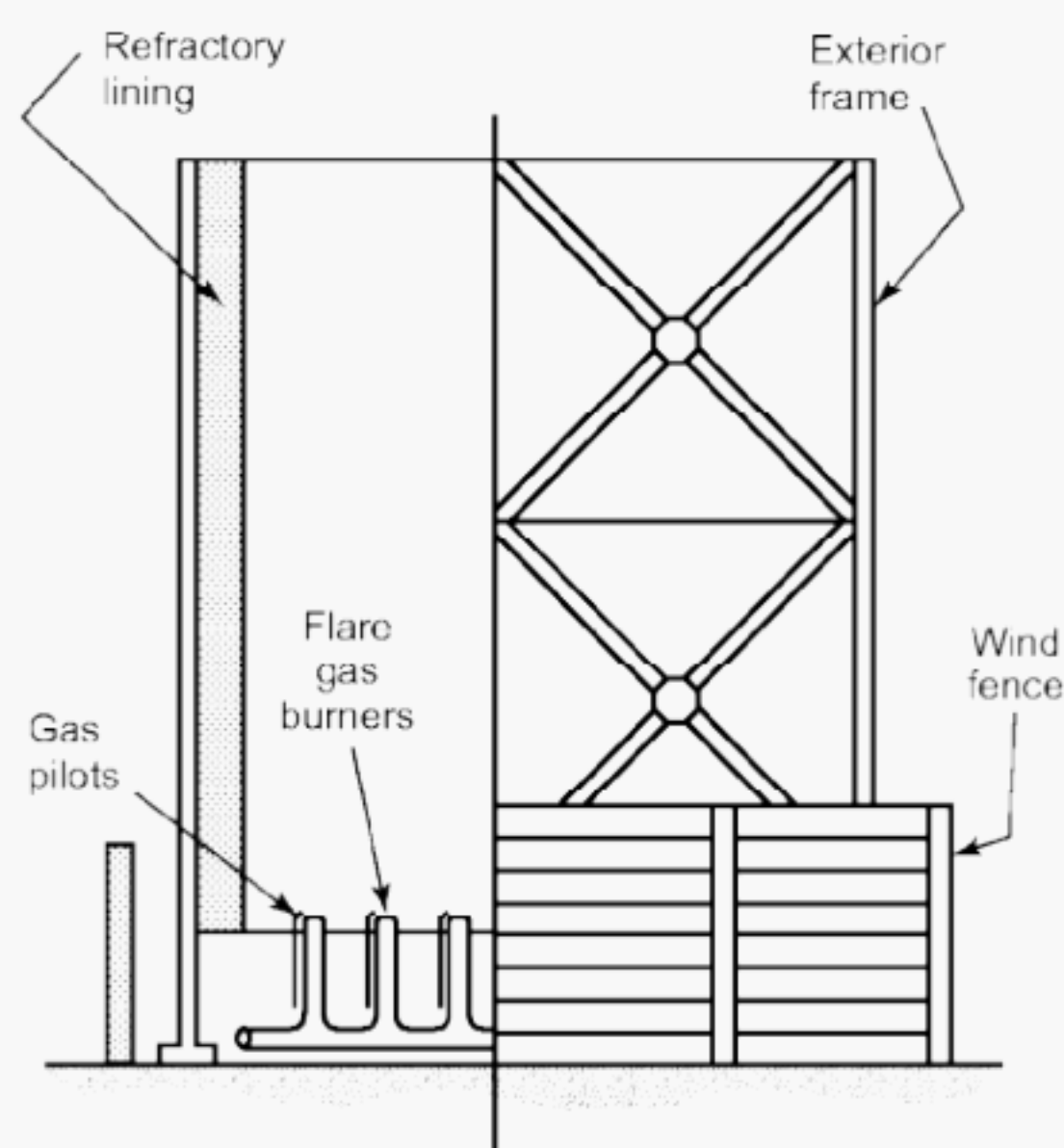


Figure 18—Windfence of Enclosed Flare

flue gas flows. Uniform airflow to all sides of all burners is important to achieving controlled combustion. Wind fences surround the burner air inlets and are designed to allow airflow to distribute to the burners. Without a wind fence, the wind can upset the natural draft of the combustion chamber. This may result in flames exiting the base of an enclosed flare. Without a wind fence, the wind can flow in the upwind burner openings and out the downwind ones. Wind fence design needs to consider the enclosed flame flare operating draft levels and must not restrict airflow to the burner openings. See Figure 18.

Wind fence designs acoustically dampen the noise. See Section 7.4.2.

Wind fences also offer safety protection for personnel from the radiation of the flare flames and from the external surfaces of the combustion chamber. The inside surface of the wind fence and all components of the enclosed flame flare inside the wind fence must be engineered for the temperatures that will be experienced from the thermal radiation of the flames visible there. Personnel access inside the wind fence of an operating enclosed flame flare is restricted.

The wind fence also isolates the air intake for the enclosed flame flare from the adjacent ground level environment. Elevating the air intake can mitigate the possible ignition of combustible ground level hydrocarbon vapor clouds. This is an important factor where the enclosed flame flare is located in close proximity to hydrocarbon storage or processing equipment.

7.2.5 Operational and Safety Controls

Enclosed flame flares require a number of operational and safety controls. As for any flare, the relief gas should never be ignited without the assurance that safe operating conditions exist. The flare system may need to be purged and all flare operating systems must be operational.

Some flare burners in a stage utilize pilots and pilot ignition systems. Flame front generator or direct electric ignition of the pilots is often employed. Flame detection devices monitor pilot flames. Automatic pilot re-ignition is often incorporated into the system design. Operating pilots are a necessary permissive to allow flare burner staging.

Burner staging system, as is described for the burners above and in Section 6, is used on larger capacity enclosed flame flares.

The combustion chamber of an enclosed flame flare can be over heated if the gas heat release is too high and/or if the airflow is not sufficient. The gas heat release can be too high due to excessive gas flow or due to changes in gas composition. The airflow demand can exceed the design or can become restricted. A high temperature alarm and/or shutdown is often supplied to protect the combustion chamber. The possible shutdown of an enclosed flame flare must not be allowed to restrict safe discharge and disposal of relief gases. The high temperature control action can disengage a burner stage and will effect a diversion of the relief gases to other systems, such as an elevated flare.

The enclosed flame flare system may require a purge or sweep gas. As is typical for staged burner systems, only the first stage may require a purge gas flow. Some smaller

enclosed flame flares eliminate purge gas flows by opening and closing the first stage burners to maintain a minimum pressure in the flare header. For relief gas compositions with a wide ratio of upper to lower flammability limit, an inert gas post purge of a burner stage as it turns off is recommended. The post purge will sweep the reactive gas out of the burners and burner piping, and will mitigate flashback and combustion in the flare system piping. Gases of concern include hydrogen, ethylene, acetylene and others as defined by a high ratio of upper to lower flammability limits.

Enclosed flame flares can be tested for combustion performance. Flue gas can be sampled in the combustion chamber or an extractive sample can be drawn out of the combustion chamber. The emission factors for an enclosed flame flare can thus be measured. Ability to measure can be significantly influenced by the physical flare configuration.

Relief gas compositions that are difficult to ignite and combust can be aided by the use of fuel enrichment. Flare gas analyzers combined with control systems can be implemented for the fuel gas enrichment. With temperature control in an enclosed flame flare, less enrichment gas will be required to achieve higher combustion/destruction efficiencies than would be typical for an elevated flare.

For enclosed flare flames that are located in a area where gas vapors might be present, Lower Explosive Limit (LEL) meters can be located adjacent to the flare to alarm. Alternate choices are shut the flare down and/or divert the flare gases.

7.2.6 Enclosed Flame Flare Applications

Enclosed flame flare applications include:

- Flares for normally occurring relief rates for hydrocarbon processing and production facilities such as start up/shutdown flows and normal process venting.
- Petroleum terminal vapor control.
- Biogas disposal. The products of anaerobic digestion (e.g., from landfills, industrial digestion processes or sewage processing) are fed at a fairly steady and predictable rate.
- Flare applications where combustion chamber temperature control must assure a high hydrocarbon destruction efficiency.
- Flare applications where the assist fuel gas quantity can be reduced by use of an enclosed flame.
- In refining or petrochemical applications where the flare acts as a lower stage to the complete relief system, designed to handle "day-to-day" loads. See Figure 16.
- Onboard Floating Production Storage and Off-loading (FPSO) vessels, where the bulk of flaring events are to be handled in a safe way in the confined space available.

7.3 MECHANICAL DETAILS

7.3.1 Combustion Chamber

Mechanically the combustion chamber is a self-supported stack. The stack design should conform to an acceptable code such as ANSI/ASCE 7.98 using the site parameters for wind speed, rain, exposure factor, seismic factor, etc. The stack design and material must accommodate the thermal requirements of the enclosed flame. Internally, the combustion chamber temperature is established by the flow of relief gases through the burners and how combustion and quench air are supplied to the flames. Most enclosed flame flares are designed to operate with a maximum internal temperature of about 980 to 1090°C (1800 to 2000°F). Flue gas temperature in excess of 980°C (1800°F) can produce visible emissions, not flames, due to ionization.

The combustion chamber requires an internal refractory lining. The refractory system selection and design must consider:

- The peak operating temperature (with a safety factor).
- Exterior shell temperature limits for materials and coating.
- Thermal cycling with rapid increase and decrease of combustion chamber operating temperature with changes in relief gas flows to the flare.
- The velocity of the airflow into the combustion chamber and the flue gas velocity out of the combustion chamber.
- Environmental exposure to rain, wind, etc.
- Refractory weight, friability, expansion/contraction factors, durability, maintainability, and service life.
- Refractory curing schedules and start-up plans.
- Refractory insulation for thermal heat loss is not a factor in the design. All of the heat of the enclosed flame flare is lost to the atmosphere.

The shape and size of the combustion chamber impacts the degree to which the flare can be pre-assembled to meet field erection requirements. The external shell of the combustion chamber is typically fabricated of carbon steel. Internal surfaces can be lined or painted to mitigate dew point corrosion as required by the enclosed flame flare design and operating conditions. Any coating material must be compatible with the design metal temperatures for the flare and its refractory lining. Exterior metal temperatures may exceed 205°C (400°F), which would require protective coatings and applications/curing different than typical.

Ladders and service platforms, for access to enclosed flame flare instruments and for stack emissions sampling, can impact the structural design of the combustion chamber. Per-

sonnel protection may be required adjacent to combustion chamber. See Sections 5.6.3 and 5.6.4.1.

7.3.2 Burners

There are distinct designs from several manufacturers that are available with many variables. Mechanically the burner design controls the fuel and air for combustion, its state of mixing and the ignition and completeness of combustion. Heat affected areas are typically fabricated of heat resistant stainless steel. Enclosed flame flares can have the burners firing in a vertical upward direction or the burners may be horizontally fired into the combustion chamber. The choice of burner firing direction is a function of size and manufacturer's experiences.

Flare burner assemblies are typically connected to burner piping by welding, flanges or screwed fittings. The connection type needs to consider the composition and temperature of the relief gas. The connection type needs to consider its exposure to high thermal loads from its proximity to the flames and combustion chamber temperatures. These temperature effects can loosen some screwed and flanged connections.

Burner steam, air or other auxiliary connections likewise need to be engineered compatible for their location. Steam, air or other auxiliary connections can be welded, flanged or screwed.

7.3.3 Burner Piping

Burner piping should conform to ASME B31.3 as a minimum. The piping must be engineered to have the flexibility to accommodate thermal growths of the combustion chamber and the piping. The piping design needs to consider the requirements to maintain an engineered burner position in the air inlet to the combustion chamber.

Piping located inside the combustion chamber enclosure needs to be engineered for high temperature exposure. Piping internal to the combustion chamber can be subjected to flame impingement resulting from poor air or gas distribution. Flame impingement can also result from liquid pool fires that can form if condensation and liquid drainage into the combustion chamber occurs. Piping external to the combustion chamber but within the wind fence may need to be protected from radiant heat loads by radiation shields.

If liquid carryover and/or gas condensation can occur, the piping design should accommodate drainage. If liquid hydrocarbons are maintained in the piping, they can form blockages.

Piping material selection must be compatible with the relief gas composition and temperature requirements as well as those set by the enclosed flame flare design.

7.3.4 Pilots

Each stage should be equipped with at least one pilot. The first stage may require more than one pilot; that decision should be made during the design phase. However, not every burner of every stage of an enclosed flame flare requires a pilot. Depending on the burner design and the arrangement of the burners, a single pilot can light one main burner and cross ignition to other burners can be achieved. The number of pilots depends on the number of burners, the design of the burners, the burner arrangement, and the operating status of the enclosed flame flare. At higher gas relief capacity, a substantial flame and temperature exists in the combustion chamber. This can ignite the relief gas flow from the subsequent stages.

Pilot fuel and supply systems should be the cleanest, most reliable fuel source in the plant. Pilots typically are a single firing rate, premix burner. The pilot gas orifice is generally quite small. Potential plugging of this orifice should be mitigated by good piping design and by the use of strainer located immediately upstream of the pilot gas orifice.

Pilots for enclosed flame flares can be engineered to facilitate inspection and maintenance while the flare remains in service. This is accomplished by locating key components external to the wind fence and/or by making the pilot assemblies easily removable from outside the wind fence.

Many of the pilot and pilot ignition details covered in Section 5.2 are applicable to enclosed flame flares. Enclosed flame flares allow the use of flame scanners as the flames are enclosed in the combustion chamber. Pilots for burners in enclosed flame flare are more protected from the weather than those typical of open air elevated flares. With a properly designed enclosed flame flare and with an effective wind fence design, the airflow across the pilot and burner is unidirectional as opposed to open air elevated flare pilots that are affected by wind from varying directions.

7.3.5 Wind Fence

Wind fence designs follow the structural requirements as noted for the combustion chamber. The wind fence design should withstand heat, and mitigate wind effects, limit access, and provide acoustical dampening. Wind fence enclosures of steel and concrete are typically utilized. Wind fence designs can also control reflected light from the combustion chamber.

Wind fence design should limit access to the space inside the wind fence and to any hot metal surfaces. The wind fence material selection should provide for an external surface temperature acceptable for worker exposure. Doors or manways should be provided to limit access to the inside of the wind fence. This access is for inspection, maintenance and repairs. Wind fences may also be equipped with viewing ports for observations while the flare is in service. The number of doors and view ports are selected based on inspection and

access requirements, and limitations to view and movement inside the wind fence.

7.4 ENCLOSED FLAME FLARE OPERATING CONCERNS

7.4.1 Visible Flames

The purpose of the enclosed flame flare is to hide the flame. Visible flame can be caused by:

- Exceeding design heat release capacity.
- Undersized combustion chamber.
- Burner performance or operation related to:
 - Control of smoke suppression medium.
 - Burner arrangement/position.
 - Burner plugging or damage.
 - Liquid carry over to the burner.
- Air distribution to the burners and combustion chamber.
- Wind effects.
- Poor temperature control for units operating with a temperature controlled combustion chamber.

In some cases, reported flame visibility is simply reflected light from the combustion chamber on a foggy or low cloud night. High combustion chamber temperatures can produce a visible ionized gas glow of the flue products exiting the combustion chamber that may appear to be visible flames.

During normal flare operation up to the maximum capacity of the units, the flame length should be contained within the enclosure and will not be directly visible from the outside. For the majority of specified operating cases, combustion will be smokeless.

The flare may be designed to mechanically withstand certain overload cases for short duration. These cases will cause a greater or lesser amount of flame to come out of the top of the enclosure and might be visible to a remote observer. Generally, operating in an overload condition is discouraged.

7.4.2 Noise and Vibration

As some heat release energy in an enclosed flame flare is converted to acoustical energy, high noise levels can be encountered. Burner design and burner stability are key elements to controlling enclosed flame flare noise.

1. Burners of moderate gas/air mixing intensity avoid creating excessive noise concerns with typical volumetric heat release.
2. If burners of greater flame intensity are utilized, the ground flare will have an increased tendency to produce excessive combustion driven noise.

3. If burners of less intensity are used, the enclosed flare might be quieter since the combustion chamber is proportionally physically larger in size.

The combustion chamber may amplify any noise level produced by unstable burners or unstable gas or airflow. Excessive low frequency noise and vibrations can be encountered if a resonance is set up in the combustion chamber. Typically combustion chamber prime resonant frequencies are sub-audible. These low frequency noise levels can travel significant distances without attenuation that may induce vibrations in structures remote from the enclosed flame flare. Resonance problems are best avoided by empirical experience. If a problem does occur, the most readily available remedy is modification of the burners and burner operating systems and/or a reduction in operating capacity.

Noise levels from an operating enclosed flame flare are a function of heat release and equipment design. Noise levels are affected by several design factors listed above including the number of stages that are operating. Wind fence designs may serve to acoustically isolate the combustion chamber noise. Some flares can achieve an 85 dBA noise level or less at a 3-ft distance from the wind fence.

7.4.3 Refractory Failures

Refractory failures may result in hot spots on the shell of the combustion chamber. How the refractory fails, the nature and extent of its failure, and its consequences and repair are a function of the type of lining used.

For ceramic fiber linings, shell hot spots often initially develop at the seam of the blanket lining where high temperature contraction has opened a gap. This is avoided by proper design of the refractory lining that considers such shrinkage. Ceramic fiber shrinkage rates can increase when subject to cyclic service and proximity to flames in enclosed flame flares. Ceramic fiber lining can also fail due to over temperature and/or excessive velocity operations. For high velocity failures, particles of the high temperature lining can be discharged from the top of the combustion chamber. High temperature, high velocity failures are avoided by proper material selection, proper anchoring design, good installation, and by good operating and maintenance practices. When using rigidizers to improve the velocity rating of ceramic fiber linings, consider the cyclic temperature operation of enclosed flame flares and thermal expansion difference of the rigidized material and the base material. Ceramic fiber linings should be avoided on horizontal surfaces where liquid hydrocarbons can collect. If a pool fire develops on a flat horizontal surface, the fiber materials insulating capabilities may be significantly reduced.

For castable or other hard material linings, hot spots on the combustor shell typically occur first at expansion joint or seam locations. These are avoided or mitigated by eliminating expansion joints where practical and/or proper expansion

joint design and maintenance. Castable type refractory materials are also subject to failure by reason of improper initial curing. Castable refractory should be cured per manufacturers' recommendations. Cosmetic cracks produced during curing/initial operation can be expected and would generally not affect long-term performance. Larger cracks which are 3 mm ($\frac{1}{8}$ in.) or greater in width and penetrate more than 50% of the castable thickness shall be repaired. See Standard 560 regarding repair technique. Some phosphate based castable refractories do not require a high temperature cure out. Castable refractory strength and durability can be enhanced by the addition of metal needles. Polypropylene fibers have been successfully used to enhance the thermal cycling and cure out for castable refractories.

Any hard refractory system needs to include a proper anchoring means. Repairs to hard refractory systems should be made in accordance with manufacturer's recommendations.

The use of high temperature alarms and shutdowns can mitigate some refractory failures.

7.4.4 Pre-Commissioning

Pipe work associated with the flare should be tested if required prior to the installation of the flare burners and pilots.

1. All flare lines must be free from debris and obstruction. All lines should be blown down prior to installing flare burners, pilots, and the steam nozzles (if fitted). All lines should be blown down with a velocity greater than will be encountered during normal operation. Typically, such velocity exceeds 90 mps (300 fps).
2. Ensure that the pilot orifices are not blocked.

7.4.5 Commissioning

When initially commissioning the flare header or following any shutdown where the flare header is gas-free and positively isolated, the following procedure is applicable.

1. All scaffolding, supports, tools, etc. are to be removed from within the perimeter of the windfence or other barrier that indicates restricted access.
2. The flare line downstream of main header blind should be purged with inert gas to reduce the oxygen levels to safe proportions. The header should be purged with at least 10 times the free volume of the header with a non-condensable inert gas. As a result of this purge, a maximum oxygen concentration of less than 6% vol. is recommended unless process conditions indicate a more conservative level should be reached. The use of inert gas as the purge medium prior to pilot ignition will preclude the possibility of a gas/air mixture forming within the flare enclosure that could be ignited

explosively when the pilots are lit. After the pilots are lit a hydrocarbon gas purge can be used.

3. In consideration of the inert gas purge, normal safety precautions should be taken within the flare area.

When bringing the system on-line, the following procedure is applicable:

1. Remove blinds from the steam line, if appropriate. Slowly admit steam to distribution pipework to avoid excessive condensation and water hammer. Check functioning of steam traps and any flexible hoses.
2. Prior to pilot ignition, ensure that the oxygen content of the flare header has been maintained less than 6% vol.
3. Ignite pilots in accordance with manufacturer's instructions.
4. Verify pilot ignition.
5. Remove blinds from the main headers

The system can now be considered on-line.

7.4.6 Normal Operations

7.4.6.1 Multiple Flare Operations

For large plant applications, an enclosed flame flare is typically designed for flow rates at normally occurring plant operations. In some plants, multiple enclosed flame flares are utilized upstream of the emergency flare. Emergency flaring still requires a larger capacity open-air flare. How the multiple flares operate, e.g., in series or in parallel, needs engineered equipment and controls to meet the plant requirements. Further, the staging of flares can maximize the use of the capacity of the enclosed flame flare. Finally if an emergency flare relief occurs, all flare gas flow can be directed to the emergency flare.

Safe multiple flare operations will require providing a means to prevent very low relief gas flows going unimpeded to multiple flare locations. If low relief gas flows have more than one possible exit point, it is quite likely that all of the gas flow will proceed to one flare and air will ingress through the other flare(s). Such flare cross flows are prevented by the use of flare staging devices, including liquid seal and valve operated staging system and flare purge systems.

One advantage of having a primary enclosed flame flare is that it will mitigate the internal burning and external flame impingement on a large flare sized for emergency flaring loads when lower level flaring occurs. The service life of the emergency flare is greatly extended. Should the primary enclosed flame flare require maintenance, this can be accomplished by diverting all flows to the emergency flare. The primary flare thus does not require a plant shutdown for maintenance. By reducing potential damage to the emergency

flare during lower level flaring conditions, the likelihood of incurring expensive cranes for its maintenance is reduced.

Effective operations on an enclosed flame flare will greatly reduce the visibility of flaring occurrence, thereby improving plant community relations.

7.4.6.2 Hydrocarbon Purge

The hydrocarbon purge gas flowing from the burners will normally ignite from the pilots. If at any time the flame is visible or is excessively long then the purge rate should be checked and adjusted.

Combustible purges may produce internal burning, which will be indicated by smoke exiting the burners. This problem must be corrected by adjusting the purge rate. This problem can also be caused by a failure of a staging device.

7.4.6.3 Inert Gas Purge

Using inert gas for the purge medium is highly preferable for start-up and optional for normal operations. It has the advantages of causing no detriment to the burners and not affecting pilot operation.

7.4.6.4 Normal Flare Operation

Any flare gas that passes to the Enclosed Flame Flare will be distributed to flare burners, often through a valving system that responds to demand.

During normal flare operation up to the maximum capacity of the units, the flame length should be contained within the enclosure and will not be directly visible from the outside. For the majority of specified operating cases, combustion will be smokeless.

The flare may be designed to mechanically withstand certain overload cases for short duration. These cases will cause a greater or lesser amount of flame to come out of the top of the enclosure and might be visible to a remote observer.

7.4.6.5 Normal Shutdown Procedure

The normal shutdown operation is:

1. Allow flare gas flow to decline to zero.
2. Shut off pilot gas.
3. Shut off purge gas.
4. Install line blinds as appropriate before commencing maintenance.

7.5 MAINTENANCE

Depending on the design of the flare and its ancillaries, some maintenance work may be possible during the operation

of the flare. Any valve staging equipment is likely accessible as well as instruments and devices mounted on the outside shell of the flare enclosure. Normal inspection and maintenance procedures as specified by the manufacturer or which is normal good practice should be followed.

General inspections of all aspects of the flare should be undertaken at every convenient shut down. In particular, the following conditions should be assessed:

1. General Burner Condition:
 - i. Distortion/damage.
 - ii. Condition of feeder piping.
2. Carbon Deposits:
 - i. Remove any excessive deposits.
3. Port Blockage:
 - i. Blow clear, as appropriate
4. Pilot Burners:
 - i. Nozzles should be cleaned.
 - ii. Orifices should be cleaned
5. Refractory Lining:
 - i. Internal lining should be examined visually and an assessment made on the level of damage at every suitable opportunity when the flare is shutdown. See 7.4.3 regarding expansion joint condition and cracking considerations.
 - ii. Temporary patching should be considered to avoid further damage.
 - iii. Visually inspect for hot spot distortion during an outage.
 - iv. Inspect for hot spots while operating either visually or via infrared means.
6. Structure & Manifolding:
 - i. The flare structures and burner manifolding should be examined using normal maintenance procedures and action taken as appropriate.
7. Staging and Block Valves:
 - i. Valves should be regularly stroked to ensure continued operation. Actual valve position should be compared versus the intended position from control signal. Valves should be maintained in accordance with the manufacturer's instructions.

7.6 TROUBLESHOOTING

See Table 10, Troubleshooting Enclosed Flame Flare Systems.

Table 10—Troubleshooting Enclosed Flame Flare Systems

Problem	Cause	Action
Pilot Failure	Several	See section 5.3.6 for general guidance
High frequency noise	Most likely associated with steam injection.	Check steam quantity and properties.
Combustion roar (low frequency)	Intense combustion	a) Check flare gas pressure b) Check steam quantity
Backfire	Flashback in stage manifold	Check after-purge system is operative
Smoke	1. Air starvation 2. Low gas pressure 3. Steam/support air shortage	a) Check for windfence blockage b) Is the wind condition unusual? a) Check bypass relief devices (e.g. rupture disks) b) Check staging valve and system operation a) Check steam supply and/or blowers
Visible flame	Excessive flow	Check diverting water seal or valve

APPENDIX A—EQUIPMENT DATA SHEETS AND INSTRUCTIONS FOR USE

This appendix includes data sheets for Elevated and Enclosed Flares and instructions for completing API RP 537 Flare Data Sheets

Data Sheets (SI units first and US Customary Units following) are provided.

1. General Data Sheets (7 sheets)
 - a. Site specifics
 - b. Utilities
 - c. Flare Gases
 - d. Pilots
 - e. Ignition System
 - f. Liquid Seal
 - g. Knockout Drum
2. Elevated Flare Data Sheets (5 sheets)
3. Enclosed Flare Data Sheets (5 sheets)

Instructions for Flare Data Sheets

Introduction

These data sheets are designed to provide a concise but thorough definition of the flare system and its performance. The data sheets should evolve throughout the course of a project. The level of detail reflected in the data sheets should be consistent with the current stage of the project. Early in a project the sheets may contain less detail than later revisions. Some of the fields on these sheets may remain blank if the information is not known or not relevant to the particular application. Users of these data sheets are encouraged to apply reasonable judgement in determining which fields apply.

It is intended that these data sheets become the controlling document in specifying flare equipment. Accordingly, all parties involved with the flare including vendors, engineering contractors, purchasers and end users, must share a clear understanding of the meaning of each field. While many of the fields are self-explanatory, some require clarification beyond the wording of the field labels. These instructions describe in more detail fields whose labels may be inadequate to fully define their purpose. In addition, to support the goal of defining the flare system, it is often appropriate to append a P&I diagram to the data sheets at the start of a flare project.

Data sheets are divided into groups to facilitate use. Data sheets designated as Form Gen-1 to 7 set forth general information regarding a project and may be used for any type of flare, elevated, enclosed, etc. Information specific to an elevated flare can be noted on data sheets that are designated as Form Elev-1 to 5. Enclosed flare data belongs on sheets designated as Form Encl-1 to 5. Thus a combination of Gen and Elev forms can be used to specify an elevated flare system.

These data sheets cover both mechanical and process aspects of flare design. Those using the data sheets are referred to API RP 521 Guide for Pressure-Relieving and Depressuring Systems for process information. The combination of API RP-521 and this Standard provide a broad source of information for those interested in flares.

All forms have a line in the header at the top that contains Page ____ of _____. This page numbering system is an integral part of the General Notes system. The preparer of this form is strongly encouraged to include both page numbers and total pages on all forms. In the event that subsequent revisions result in additional pages (such as additional gas stream

or notes pages), it is recommended to modify the page numbers by using 3A, 3B, etc. for gas stream pages, as an example. This avoids having to renumber all pages and note references on Form(s) Gen-7 and prevents the confusion that can result from renumbering errors. Changes to the total page count at the top of each page are necessary whenever pages are added to the package.

All forms have a column labeled "Note" which is intended to refer to additional notes on one or more copies of Form Gen-7: General Notes. Numbering of notes should start with one (1) on each new page. The liberal use of explanatory notes is strongly encouraged to ensure a clear communication of all job requirements.

Example: A system using a Form Gen-3 to define the flow conditions may be more clearly described by placing a numeral "1" in the N column on line 1 or 2 even though previous pages already contain notes. On a copy of Form Gen-7 the user would place a note referring, perhaps, to Page 3, Note 1. The note may define normal flow rates, frequency and duration for various streams on that Form Gen-3 as opposed to maximum hydraulic flow or smokeless capacity required. Such a note would help both the designer and the operator understand how the equipment would actually be used.

It is to be expected that revisions will occur to the data sheets during the course of a project. All forms include one or more columns labeled "REV" where a revision can be marked. In addition, the heading section of each form contains a Revision Number field. When a set of changes is made to a set of data sheets, this set of changes is referred to as a revision and is assigned the next revision number. The original issue should be noted as revision zero (0). All changes made in a revision will be marked with the same revision number. As a matter of reference, a copy of Form Gen-7 should be included which contains the revision history. Each revision note should contain as a minimum: the revision number, the revision date, and some description of the revision such as "Revised per Vendor Quote" or "Revised for Purchase." Additional information such as a list of affected forms/lines may be useful for tracking purposes. Each revision should be issued as a complete set of pages, not as individual pages. This ensures that all recipients have a complete, current set of data sheets.

General Information Forms—Instructions

Form General 1		
Line 9	Jobsite Climate	Indicate type of climate such as dusty desert, arctic tundra, or tropical jungle. Can indicate need for dust filters, freeze protection, special radiation considerations, instrument packaging, etc.
Line 16	Local Codes	State or local codes may affect electrical equipment, mechanical design, process performance, shipping or other aspects of a major construction project such as a flare system. Any such regulations that may affect the design, fabrication, delivery, construction or operation of the system should be identified as early in the project as possible.
Line 19	Ambient Conditions (Design / Normal).	Each of the conditions listed has design values and normal values. Design values may be necessary for proper selection of metallurgy or piping growth. Normal values can provide a better idea of conditions that will normally prevail and may allow for certain operational efficiencies most of the time. Provide minimum and maximum temperatures as they influence items such as blower design, structural materials, thermal growth/shrinkage.
Line 22	Relative Humidity	Some radiation models allow a credit for atmospheric attenuation at large distances. Atmospheric humidity can affect smokeless performance, electrical circuit design, etc.
Line 24	Predominant Wind Direction	If the jobsite has a very predominant wind direction, it is sometimes possible to design the system to take this into consideration. A wind rose can be provided if it is available. Suitable orientation of pilots, for example, may allow longer equipment life by avoiding the predominant flame pull down area.
Lines 25, 26	Solar Radiation	Refer to API RP-521 for a discussion of solar radiation allowances.
Line 27	Jobsite Elevation	Altitude of jobsite affects local atmospheric pressure, which affects pressure drop calculations, fan sizing, etc.

Form General 2		
Line 1	Minimum Flare Height	Nearby structures, electrical classification issues, independent dispersion calculations or company standards may impose a minimum flare height requirement.
Line 2	Anticipated Flare Header Diameter	Fields in Lines 2,3,4 allow the designer to estimate the flare header volume, surface area, pressure drop, etc. These factors can affect purge system design, peak waste gas flow rate or actual gas temperature arriving at the flare, and other important design issues. It is sometimes possible to anticipate transient behaviors in the flare system that can affect overall performance. Flare header volume includes all piping and drums that may be pressurized by a flare event regardless of whether the relief actually passes through that section of the flare header system.
Line 3	Approx. Flare Header Length	
Line 4	Flare Header Volume	
Line 5	Plot Space Available	This can affect selection of the support method, size of component parts, guy wire radius, etc.

Line 11	Special Erection Requirements	Plans to construct a system using gin poles in lieu of a crane, single point lifting requirements, limited laydown areas for construction or preference for bolted construction are examples of special requirements that need to be defined early in a flare project.
Line 23	Utilities Available (Design / Normal)	Each of the conditions listed has design values and normal values. Design values may be necessary for proper selection of metallurgy or piping growth, for example. Normal values can provide a better idea of conditions that will normally prevail and may allow for certain operational efficiencies most of the time.
Line 26	Location of Steam Conditions	Steam temperature and pressure vary from one point in the steam system to another due to heat losses and pressure drops. The designer must know whether the indicated pressure is available at the flare tip, at the base of the stack, at a point outside a sterile radius, or at a boiler somewhere. The designer must also know whether the pressure and temperature are downstream or upstream of the control valve.
Lines 27, 28	Electrical Power	It is important to know whether the local power supply is 50 Hz or 60 Hz as this has a profound effect on blower motor performance. Voltage must be known before vendors can select appropriate control equipment.
Line 33	Fuel Gas	One of the compositions that should be defined on a copy of Form Gen-3 is that of the fuel gas to be used for pilots, flame front generator, enrichment gas, etc. As a minimum, the designer needs to know the MW and LHV of the fuel gas. If the fuel gas will contain more than 10% of hydrogen, unsaturated hydrocarbons, hydrogen sulfide or inerts, then the composition must be identified.
Line 34	Purge Gas	Purge gas composition should be defined on a copy of Form Gen-3.
Line 38	Nearby Structures (Distance, Height)	Flares are usually sized to meet a specified radiation criterion at grade. Radiation on nearby structures, especially heat sensitive structures such as cooling towers, can be accounted for only if such structures are identified and located.
Lines 39-42	Other Active Flares	If there are other flares in the vicinity of the specified flare that are expected to be flaring simultaneously with the specified flare, these should be accounted for in the design of the specified flare. In order to account for such flares properly, some clear definition of the other flare's radiation information is necessary. Heat release and radiant fraction as a minimum enable only a rough accounting. Direct information e.g., isopleths from the other flare's vendor is preferred. It should be included by reference with a note and any attachments as may be useful. Consideration could be given to be doing maintenance work on one flare while any nearby flare is operating.

Form General 3		
Line 2	Smokeless Capacity, Opacity	Smokeless capacity is defined on the data sheets in kg/hr (lb/hr), rather than some percentage of design flow. The smokeless capacity requirement should be established by thoughtful review of actual relief scenarios. Conditions that are expected to occur often enough to require smokeless operation, either by regulation or company standards, should set the smokeless requirement. Indicate the opacity or Ringleman number that is allowable at the smokeless flow rate.

60	60	<p>Static pressure, in this context, is the pressure exerted by the gas on the walls of the flare header. This pressure determines gas density. A conventional pressure gauge mounted on the side of a pipe measures static pressure. An additional component of pressure at the flare inlet is the velocity pressure</p> <p>The sum of these two components is called total pressure, also known as stagnation pressure. The total pressure is a good measure of the energy available in the flowing fluid. A properly positioned pitot tube measures the total pressure on the port facing the flow stream. Due to the tendency for plugging, pitot tubes are not often used for common pressure measurements.</p> <p>Velocity pressure can be calculated for given flow stream if the static pressure and pipe diameters are known. This approach allows the use of conventional pressure gauges to check performance. This is the reason for requiring declaration of both static pressure and diameter at the flare inlet. If the purchaser does not define the flare inlet diameter, then the specified pressure should be indicated as total pressure.</p> <p>Pressure is based on relieving conditions as identified by different operations specified on these data sheets.</p>
Line 6	V eq	<p>This parameter is the volumetric flow rate of air at standard temperature (60°F) that produces the same velocity pressure as the specified flow stream at local atmospheric pressure and the defined stream temperature. It is proportional to the waste gas flow rate and is independent of the pipe diameter used to evaluate velocity pressure. The formulae for <i>Ve_q</i> are defined below:</p> $Ve_q = 3.091 \times (lb/hr) \times \sqrt{\frac{T_{gas}(R)}{MW_{gas}}}$ $Ve_q = SCFH \times \sqrt{\frac{MW_{gas}}{29} \times \frac{T_{gas}(R)}{520}}$ <p>It should be noted that <i>Ve_q</i> is intended as a means to compare hydraulic performance or requirements among flowing conditions at a fixed jobsite. If comparisons to other jobsites at other altitudes are required, then a correction must be made for atmospheric pressure variations.</p>
Line 8	Duration at Max. Rate	Duration of the relief can affect allowable radiation levels, noise levels, smokeless requirements, and other aspects of the design.
Line 9	Relief Source	Some indication of the relief source and its cause is useful to the designer. A label such as Power Failure or Demethanizer Overheads can help both for communication about cases and for understanding the character of the relief.
Line 10	Controlling Case For ...	Indicate whether this relief case is the controlling case for pressure drop (DP), radiation (RAD), noise (NOI), smokeless performance (SMK), etc.
Line 11	Gas Composition	Designer needs to know whether the specified composition is on mass or mole basis to properly evaluate stream properties. Either circle one of the options (if that option applies to all streams) or define the basis explicitly for each stream.

Lines 12-40	Compounds	Several blank lines have been left at the end of the list to allow for inclusion of compounds not found on the preprinted list. If necessary, one or more of the unused compounds in the preprinted list can be struck through and replaced with additional unlisted compounds.
Line 41	Total	Ideally gas composition should total 100%. Compositions are sometimes provided in the form of flow rates of each component, in which case the total of flow rates should match the design flow condition.

Form General 4		
Line 8	Flame Monitors	Indicate number of flame monitors required and whether this count is per pilot or per flare.
Line 9	Flame Monitor Type	Indicate Type K (or other) thermocouples, optical, ionization, acoustic detectors or as appropriate.
Line 14	Retractable Pilots	Used primarily for enclosed flares. Indicate whether pilots should be removable while the flare is in service.
Line 15	Retractable Thermocouples	Indicate whether pilot thermocouples should be removable while the flare is in service.
Line 21	Distance from Stack	Indicate the distance in terms of piping length from the ignition panel to the flare stack. This may be substantially longer than simple radial distance if the piping runs along a pipe rack.

Form General 5		
Line 4	Integral/Separate from stack	Indicate whether this vessel is required to be integral with the stack or separate from the stack. It is often more economical to build the vessel into the base of an elevated structure. However, high corrosion rates or a need to bypass and isolate the vessel while the flare is in service may require a separate vessel.
Line 10	Seal Depth	Seal depth determines the inlet pressure at which the first bubble of gas flows through the vessel. Design seal depth will vary depending on the purpose of the liquid seal. Simple maintenance of positive upstream header pressure may require only a few cm (in.) of depth. Flare gas recovery systems often require 500-750 mm (20-30 in.) of seal depth to ensure adequate suction pressure for the compressor. Liquid seals used for staging between multiple flares may have seal depths of 2.5 meters (100 in.) or more.

Line 11	Max Vacuum	Flare gas recovery systems or hot gas thermal contraction and/or condensation can result in substantial vacuums in the flare header. A vertical section of piping in the liquid seal inlet line can allow seal fluid to be drawn up by the vacuum without drawing air in through the flare tip. This protects the plant against a potentially dangerous situation. To achieve this level of protection it is necessary to design the vessel with sufficient liquid volume in the normal seal depth area to fill the vertical section of piping. Safe design of this liquid volume should take no credit for addition of supplemental liquid. Operationally, it is necessary to maintain the proper liquid level in the liquid seal and to restore that level promptly after any hot relief and before the vacuum forms. The maximum vacuum protection achievable may be limited by piping or vessel elevations.
Lines 13, 17-28	Various Connections	Each of these lines asks for a description of a vessel connection including the type of connection (flanged, threaded, and welded), the size in mm (in.) and the number of these connections.

Form General 6		
Line 5	Integral/Separate from stack	Indicate whether this vessel is required to be integral with the stack or separate from the stack. It is often more economical to build the vessel into the base of an elevated structure. However, high corrosion rates or a need to bypass and isolate the vessel while the flare is in service may require a separate vessel.
Line 6	Design Code	The Purchaser shall specify.
Line 11	Max Liquid Level	Maximum liquid level may be defined either as a distance above bottom tangent or as an absolute elevation. The Vendor may define this value to prevent re-entrainment of accumulated liquid in the waste gas stream.
Line 12	Liquid Holdup Volume	The Purchaser based on anticipated liquid volumes that may be sent to the flare system may define liquid holdup volume. Sufficient volume should be provided to prevent overfilling of the knockout drum which could lead to liquid carryover to the flare tip, smoke, flaming rain and other hazardous conditions.
Lines 14, 18-29	Various Connections	Each of these lines asks for a description of a vessel connection including the type of connection (flanged, threaded, and welded), the size in mm (in.) and the number of these connections.

Form General 7

The Page No. and Note No. columns are intended to allow all notes associated with all pages to be collected on a single set of pages appended to the back of the data sheet package. Page and Note numbers should precede each note to indicate

the location in the data sheet package to which the note refers. Notes can be several lines long and require the Page and Note references only on the first line.

Elevated Flare Forms—Instructions

Form Elev-1		
Radiation and Noise Performance is often specified in terms of the maximum flaring rate. Similarly, Smokeless Performance specifications require smokeless operation up to some specified flow rate. In practice, it is often the performance of the flare at rates substantially below maximum and below peak smokeless capacities that actually determines whether the flare is acceptable to the user or the community. Some representation of these turndown conditions can be provided as an additional gas stream on Form Gen-3. Performance expectations for these conditions can be specified either by using one of the blank lines on Form Elev-1 or through the use of General Notes.		
Line 13	SPL at Flare Base	Unless otherwise specified, noise at the base of the flare is defined at a point 1.5m (5 ft) above grade and 10% of the flare stack height distance from the flare stack centerline. Nearby noise sources such as blowers or steam control valves should be identified and a General Note should indicate whether these nearby sources are to be included in the noise prediction or not
Lines 14, 15	SPL at Distance	Noise at a distance is measured at 1.5m (5 ft) above grade and the specified distance from the flare stack centerline. If typical background noise levels in the target area are known, they should be indicated with a General Note
Line 27	Smokeless Definition	Environmental regulations usually specify that a flare may not exceed some opacity level for more than a certain amount of time. That opacity level defines the smokeless criteria. An opacity level of 20% corresponds to Ringelman 1, 40% to Ringelman 2. Zero opacity is Ringelman 0

Form Elev-2		
In some cases it may be necessary to add a General Notes page to include any clarifications in the areas of Predicted System Performance.		
Line 2	Static Inlet Pressure	Normally, this should be based on the specified flare inlet diameter (Form Gen-3, Line 5). If the vendor is proposing a different flare inlet diameter, the proposed diameter should be clearly defined on this line such as "20kPa @ 600 mm" ("3 PSIG @ 24 in. inlet").
Line 11	(blank)	Some vendors provide radiation information in the form of graphical outputs. Such outputs should be appended to the data sheets and may be referred to here by filling in "Radiation Plot" as the description and "See Attached" as the value.
Lines 13-17	Noise Performance	Some vendors provide noise information in the form of tables showing octave band breakdowns. These can be appended or included as General Notes.
Line 27	S/HC Ratio	Steam consumption has often been characterized in terms of mass ratios of steam to hydrocarbon required for smokeless performance. The value provided on this form will be based on operation at or near the smokeless capacity. The purchaser is cautioned that the ratio necessary for waste gas flows in the turndown range may exceed the ratio near the smokeless capacity.
Lines 32, 33	Air Capacity and Pressure	Vendor should clearly indicate whether the pressure basis is static or total pressure at the blower outlet. If static pressure is used, the outlet area of the fan must be indicated.

Form Elev-4		
Line 8	Loop Seal Depth	Some purge conservation devices, such as buoyancy seals, include a drain to continuously remove rainfall, steam condensate or other liquids that may enter the seal. A loop seal, similar to that used for an API knockout drum or liquid seal skimmer, should be used to prevent flare gas from migrating into the drainage system. Refer to API RP-521 for further information on determining this depth. The required depth of this loop seal should be defined on this line.
Line 12	Stack Design Pressure	Purchaser is cautioned against excessively high design pressures as the combination of stack loadings from wind, earthquake and internal pressure may result in much thicker walls than are actually needed.
Line 13	Stack Design Temperature	When gas temperatures differ substantially from ambient temperature, a significant heat transfer rate can exist between the waste gas and ambient air. This heat transfer can affect stack design temperatures in two ways. First, heat transfer to or from the waste gas while it is flowing from the plant to the flare stack generally causes the waste gas temperature to move closer to ambient temperature. Second, the steel temperature will fall somewhere between the waste gas temperature arriving at the flare stack and the ambient temperature. Both of these effects should be considered when establishing the stack design temperature to avoid overspecification. The vendor and purchaser can work together to specify this temperature if so noted on the data sheet.

Form Elev-5		
Line 10	Max Motor Current – Winter	As discussed in Section 5.8.3, flare fans deliver a certain maximum volumetric flow of ambient air to the flare tip. At minimum ambient temperatures, the density of this air is the highest. As a result, the motor horsepower required is highest in winter. The electrical current required to drive the motor under these conditions usually dominates the design requirements for the switchgear and substation that delivers this power to the fan motor.

Enclosed Flare Forms - Instructions

Form Encl-1		
Line 1	Enclosed Capacity	Indicate the maximum continuous flow rate that the enclosed flare must handle without visible flame, excessive temperature or noise.
Line 7	SPL at Windfence	Noise at the windfence is measured 1.5m (5 ft) above grade and 0.9m (3 ft) from the major bounding surface at the base of the flare. This is usually the windfence. Nearby noise sources such as blowers or steam control valves should be identified and a General Note should indicate whether these nearby sources are to be included in the noise prediction or not.

Lines 8, 9	SPL at Distance	Noise at a distance is measured at 1.5m (5 ft) above grade and the specified distance from the flare stack centerline. If typical background noise levels in the target area are known, they should be indicated with a General Note.
Lines 27, 28	Purge Gas	Staging is often used in enclosed flares to improve turndown performance. A continuous purge is recommended to keep the flare header swept clear and prevent air ingress through the first stage of burners. In many cases, a brief, relatively high purge flow is injected downstream of each staging valve to flush out residual waste gases after that staging valve is closed. If there are purge gas capacity limitations, these should be specified by the Purchaser.

Form Encl-2		
Line 1	Enclosed Capacity	Vendor should indicate maximum enclosed capacity for the specified composition from Encl-1. If there are multiple flow streams, vendor should indicate maximum enclosed capacity for each stream as a General Note. Any discussion relating to the interpretation of enclosed flaring should be included as a General Note.
Lines 7-11	Noise Performance	Some vendors provide noise information in the form of tables showing octave band breakdowns. These can be appended or included as General Notes.
Line 12	Smokeless Capacity	Vendor should indicate smokeless capacity for the specified composition from Encl-1. If there are multiple flow streams, vendor should indicate smokeless capacity for each stream as a General Note.
Line 19	S/HC Ratio	Steam consumption has often been characterized in terms of mass ratios of steam to hydrocarbon required for smokeless performance. The value provided on this form will be based on operation at or near the smokeless capacity. The purchaser is cautioned that the ratio necessary for waste gas flows in the turndown range may exceed the ratio near the smokeless capacity.
Line 27,28	Purge Gas	Vendor should indicate both the continuous purge requirement and the maximum intermittent purge flow requirement during staging operations.
Line 33	Supplemental Gas	If supplemental fuel gas is to be used to maintain a minimum temperature in the firebox, the vendor should indicate the flow rate necessary in cold weather.

Form Encl-3		
Lines 21-29	Firebox and Wind-fence Dimensions	Most enclosed flares fall into one of the following shape categories: rectangular, round or polygonal. Purchaser should indicate any preferences regarding shape. Vendor should indicate selected shape and associated dimensions.
Line 30	Refractory Material	Purchaser should indicate any requirements or limitations on refractory material.
Line 32	Max. Service Temperature	Vendor should indicate service temperature of the proposed refractory.

Line 33	Max. Shell Temperature	Vendor should indicate expected shell temperature for ambient conditions of 27°C (80°F) and still air. This calculated temperature is used to select paint system for outside of firebox. Purchaser should indicate hot face temperature basis for calculation as either: max. allowable temperature for the refractory or calculated operating temperature at the enclosed flaring capacity. Significant cost savings may accrue to the use of a lower hot face temperature basis.
Line 35	Max. Expected Flue Gas Temperature	Vendor should indicate expected flue gas temperature for ambient conditions of 27°C (80°F) and still air.
Line 39	Max. Personnel Exposure Temperature	Vendor should indicate maximum temperature on any surface where personnel exposure may occur. This is often limited to the outer windfence surface when access to the upper stack platforms is not necessary during maximum operation.

Form Encl-4		
Line 4	Heat Shielding	Any material or equipment with a view of the burner windows may be exposed to high heat radiation. Heat shielding is often used to reduce metallurgical requirements and piping stresses.
Lines 19, 25, 31, 37	Air Valve	If air assisted burners are to be used, Purchaser should indicate any preferences for large single blower w/ distribution by manifolds and valves vs. individual blowers for various stages or sections of burners. Vendor should indicate proposed / actual method for distributing air. Use General Notes if necessary to clarify the issue.

Form Encl-5		
Line 5	Damper Control Required	Vendor should indicate whether any air dampers/valves will be modulated (based on temperature or flow), automatically opened/closed or manually set
Line 11	Supplemental Requirements	Purchaser should indicate whether any special requirements such as explosion proof motors or inlet filters exist for the air blowers.

American Petroleum Institute		Job Number		
		Item Number		
General Flare Data Sheet No. 1 SI Units		Specification		
		Purchase Order		
		Revision Number	Revision Date	
		Page ____ of ____	By	
Purchaser Supplied - General Information				
		Note		REV
1	Purchaser			
2	Reference Number			
3	Plant Owner / Operator			
4	Reference Number			
5	Vendor			
6	Reference Number			
7				
8	Jobsite Location			
9	Jobsite Climate			
10	Unit Tag			
11	Equipment Number			
12	Service			
13	Quantity Required			
14	Is Smokeless Required? (Y/N)			
15	Preferred Smokeless Method			
16	Local Codes			
17	Is P&ID Attached? (Y/N)			
18				
19	Ambient Conditions (Design / Normal)			
20	Minimum Temperature, deg C			
21	Maximum Temperature, deg C			
22	Relative Humidity, %			
23	Maximum Wind Speed, mph			
24	Predominant Wind, (Y/N) / Direction			
25	Peak Solar Radiation, W/m ²			
26	Include Solar w/ Flare Radiation (Y/N)			
27	Jobsite Elevation, meters above sea level			
28	Seismic Zone			
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				
44				
45				
46				

American Petroleum Institute		Job Number		
		Item Number		
General Flare Data Sheet No. 2 SI Units		Specification		
		Purchase Order		
		Revision Number	Revision Date	
		Page ____ of ____	By	
Purchaser Supplied - General Information				
		Note		REV
1	Minimum Flare Height, meter			
2	Anticipated Flare Header Diameter, mm			
3	Approx. Flare Header Length, meter			
4	Flare Header Network Volume, cu meter			
5	Plot Space Available, Length/Width, meter			
6	Aircraft Warning Lights Required? (Y/N)			
7				
8	Welding Code			
9	Peak Radiation at Grade, W/m ²			
10	Surface Prep. & Paint Requirements			
11	Special Erection Requirements			
12				
13	Nozzle Loads on Flare Inlet			
14	Fx, Fy, Fz (kg)			
15	Mx, My, Mz (meter-kg)			
16	Special Piping Treatment			
17	Fireproofing			
18	Insulation			
19	Supports			
20	Covering			
21	Heat Tracing (Elec., Steam)			
22				
23	Utilities Available (Design / Normal)			
24	Steam Pressure, kPa (ga)			
25	Steam Temperature, deg C			
26	Location of Steam Conditions			
27	Blower Power, Volts / Phase / Freq			
28	Instr. Power, Volts / Phase / Freq			
29	Electrical Classification, Cl / Gp / Div			
30	Instrument Air, kPa (ga)			
31	Plant Air, kPa (ga)			
32	Nitrogen, kPa (ga)			
33	Fuel Gas, kPa (ga) / Case #			
34	Purge Gas, kPa (ga) / Case #			
35	Utility Costs			
36				
37	Nearby Structures (Distance, Height), meter			
38	Other Active Flares			
39	Direction from Current Flare			
40	Heat Release, W			
41	Radiant Fraction			
42	Other Inactive Flares			
43	Cooling Towers			
44	Electrical Substations			
45	Property Line			
46				

American Petroleum Institute		Job Number						
		Item Number						
General Flare Data Sheet No. 3 SI Units		Specification						
		Purchase Order						
		Revision Number		Rev. Date				
		Page ____ of ____		By				
PROCESS DESIGN CONDITIONS - PURCHASER								
		Note	CASE 1	Rev	CASE 2	Rev	CASE 3	Rev
1	Design Flare Capacity, kg/hr							
2	Smokeless Capacity, kg/hr / opacity							
3	Gas Temperature, deg C							
4	Static Pressure at Flare Inlet, kPa (ga)							
5	Flare Inlet Diameter, mm							
6	Veq, SCFH air equivalent							
7	Heat Release, MW							
8	Duration @ Max. Rate, min.							
9	Peak Radiation at Grade, W/m ²							
10	Controlling Case For . . .							
11	GAS COMPOSITION (Mole% / Mass%)							
12	Methane							
13	Ethane							
14	Propane							
15	Isobutane							
16	n Butane							
17	Isopentane							
18	n Pentane							
19	Hexane							
20	Heptane							
21	Octane							
22	Ethylene							
23	Propylene							
24	Butylene							
25	Acetylene							
26	Butadiene							
27	Benzene							
28	Toluene							
29	Xylene							
30	Hydrogen							
31	Carbon Monoxide							
32	Hydrogen Sulfide							
33	Ammonia							
34	Water Vapor							
35	Nitrogen							
37	Carbon Dioxide							
38								
39								
40	TOTAL (should be 100%)							
41	Molecular Weight							
42	Lower Heating Value, kJ/Nm ³							
43	Ratio of Specific Heats, Cp/Cv							
44	Viscosity, mPa s							
45	UEL, % in air							
46	LEL, % in air							

American Petroleum Institute General Flare Data Sheet No. 4 SI Units		Job Number:				
		Item Number:				
		Specification:				
		Purchase Order:				
		Revision Number:		Revision Date:		
		Page ____ of ____	By			
MECHANICAL DESIGN DATA (PILOTS / IGNITION SYSTEM)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	PILOTS					
1	Quantity					
2	Rating - Each, kW					
3	Gas Pressure					
4	Inspirator Type					
5	Inspirator Material					
6	Gas Orifice Size, mm					
7	Strainer (Y/N)					
8	Peak Radiation at Grade, W/m ²					
9	Flame Monitor Type					
10	Pilot Fuel Connection Type / Size, mm					
11	Fuel Gas Manifold (Y/N)					
12	Manifold Connection Type / Size, mm					
13	Ignition Connection Type / Size, mm					
14	Retractable Pilots (Y/N)					
15	Retractable Thermocouples (Y/N)					
16						
17						
18						
19						
	IGNITION SYSTEM					
20	Type (FFG / Electronic / Other)					
21	Distance from Stack, meter					
22	Automatic / Manual Ignition					
23	Elec. Class., Cl / Gp / Div					
24	Remote Alarm Contacts - Quantity					
25	Remote Ignition Contact (Y/N)					
26	Pressure Regulators - Quantity					
27	Pressure Gauges - Quantity					
28	Pilot Selector Valves - Type / Quantity					
29	Pilot Indicator Lights (Y/N)					
30						
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						

American Petroleum Institute		Job Number				
General Flare Data Sheet No. 5 SI Units		Item Number				
		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page ____ of ____		By		
MECHANICAL DESIGN DATA (LIQUID SEAL)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	LIQUID SEAL					
1	Vessel Diameter, meter					
2	Height / Length (T/T), meter					
3	Material / Thickness, mm					
4	Integral / Separate from stack					
5	Design Code					
6	Code Stamp (Y/N)					
7	Design Pressure, kPa (ga)					
8	Peak Radiation at Grade, W/m²					
9	Corrosion Allowance, mm					
10	Seal Depth, mm					
11	Max. Vacuum w/o adding liquid, mm WC					
12	Freeze Protection Type					
13	Connection Type / Size, mm / #					
14	Instrument / Valve Requirements					
15	Special Requirements					
16	Vessel Connections					
17	Flare Gas Inlet Type / Size, mm / #					
18	Flare Gas Outlet Type / Size, mm					
19	Fill Nozzle Type / Size, mm / #					
20	Drain Type / Size, mm / #					
21	Level Gauge Type / Size, mm / #					
22	Level Switch Type / Size, mm / #					
23	Temperature Type / Size, mm / #					
24	Pressure Type / Size, mm / #					
25	Skimmer/Overflow Type / Size, mm / #					
26	Manway Type / Size, mm / #					
27	Skirt Access (Y/N) / Type / Size, mm / #					
28	Skirt Vents (Y/N) / Type / Size, mm / #					
29						
30						
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						
41						
42						
43						
44						

American Petroleum Institute		Job Number				
		Item Number				
General Flare Data Sheet No. 6 SI Units		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page _____ of _____		By _____		
MECHANICAL DESIGN DATA (KNOCKOUT DRUM)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	KNOCKOUT DRUM					
1	Type (Horiz / Vert / Cyclone, ref. RP-521)					
2	Vessel Diameter, meter					
3	Height / Length (T/T), meter					
4	Material / Thickness, mm					
5	Integral / Separate from stack					
6	Design Code					
7	Code Stamp (Y/N)					
8	Peak Radiation at Grade, W/m ²					
9	Design Temperature, deg C					
10	Corrosion Allowance, mm					
11	Max. Liquid Level, meter					
12	Liquid Holdup Volume, cu meter					
13	Freeze Protection Type					
14	Connection Type / Size, mm / #					
15	Instrument / Valve Requirements					
16	Special Requirements					
17	Vessel Connections					
18	Flare Gas Inlet Type / Size, mm / #					
19	Flare Gas Outlet Type / Size, mm					
20	Fill Nozzle Type / Size, mm / #					
21	Drain Type / Size, mm / #					
22	Level Gauge Type / Size, mm / #					
23	Level Switch Type / Size, mm / #					
24	Temperature Type / Size, mm / #					
25	Pressure Type / Size, mm / #					
26	Skimmer/Overflow Type / Size, mm / #					
27	Manway Type / Size, mm / #					
28	Skirt Access (Y/N) / Type / Size, mm / #					
29	Skirt Vents (Y/N) / Type / Size, mm / #					
30						
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						
41						
42						
43						
44						

American Petroleum Institute			Job Number		
General Flare Data Sheet No. 7 SI Units			Item Number		
			Specification		
			Purchase Order		
			Revision Number		
			Revision Date		
			Page _____ of _____	By	
GENERAL NOTES					
	PAGE NO.	NOTE NO.	REV NO.		
1					
2					
3					
4					
5					
6					
7					
8	Peak Radiation				
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					

American Petroleum Institute Elevated Flare Data Sheet No. 1 SI Units		Job Number			
		Item Number			
		Specification			
		Purchase Order			
		Revision Number		Rev. Date	
		Page _____ of _____	By		
REQUIRED SYSTEM PERFORMANCE - PURCHASER					
	Note	Specified	REV	Based on Case / Flow	REV
FLOW PERFORMANCE					
1	Hydraulic Capacity, kg/hr				
2	Static Inlet Pressure, kPa (ga)				
3	Peak Exit Velocity, meter/s				
4	Peak Mach Number				
5					
6					
RADIATION PERFORMANCE					
7	Peak Radiation at Grade, W/m ²				
8	Distance to Peak Radiation, meter				
9	Distance to _____ W/m ² , m				
10	Distance to _____ W/m ² , m				
11					
12					
NOISE PERFORMANCE					
13	SPL at Flare Base, dBA				
14	SPL at _____ meter from base, dBA				
15	SPL at _____ meter from base, dBA				
16					
17					
SMOKELESS PERFORMANCE					
18	Smokeless Capacity, kg/hr				
19	Smokeless Definition (R0 / R1 / R2)				
20					
SMOKELESS STEAM CONSUMPTION					
21	Primary Steam, kg/hr				
22	Secondary Steam, kg/hr				
23	Tertiary Steam, kg/hr				
24					
25	Max. Total Steam, kg/hr				
26	Continuous Steam, kg/hr				
27	S/HC ratio @ Design Smokeless Rate				
SMOKELESS AIR REQUIREMENTS					
28	Continuous (Min), kW				
29	Second Stage, kW				
30	Third Stage, kW				
31	Max. Total Power, kW				
32	Design Air Capacity, m ³ /min				
33	Design Blower Pressure, in w. c.				
UTILITY CONSUMPTION					
34	Purge Gas, Nm ³ /HR				
35	Pilot Gas, Nm ³ /HR				
36	Ignition Gas, Nm ³ /HR (Intermittent)				
37	Ignition Air, Nm ³ /HR (Intermittent)				
38	Assist Gas, Nm ³ /HR / lb/hr waste				
39	Supplemental Gas, Nm ³ /HR				

API RP-537 Form Elev-1

Copyright por American Petroleum Institute
Mon Mar 01 16:57:53 2004

American Petroleum Institute Elevated Flare Data Sheet No. 3 SI Units		Job Number				
		Item Number				
		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page ____ of ____	By			
MECHANICAL DESIGN DATA (FLARE BURNER)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
FLARE BURNER BODY						
1	Tip Type / Model					
2	Quantity of Burners					
3	Smokeless Method					
4	Overall Length, meter					
5	Upper Section Length, meter					
6	Material / Diam. / Thickness, mm					
7	Lower Section Length, meter					
8	Peak Radiation at Grade, W/m ²					
9	Connection Type / Size, mm					
10	Lining, Length, meter					
11	Material / Thickness					
12	Muffler, Length / Diameter, mm					
13	Windshield, Type / Material					
14	Flame Retention, (Y/N) / Material					
15						
16						
17						
18						
STEAM ASSIST EQUIPMENT						
19	Primary Steam, Material					
20	Connection Type / Size, mm					
21						
22	Secondary Steam, Material					
23	Connection Type / Size, mm					
24						
25	Tertiary Steam, Material					
26	Connection Type / Size, mm					
27						
28						
29						
30						
AIR ASSIST EQUIPMENT						
31	Air Plenum Length, meter					
32	Air Plenum Diameter, mm					
33	Connection Type / Size, mm					
34						
35						
36						
37						
38						
39						
40						
41						

American Petroleum Institute		Job Number				
		Item Number				
Elevated Flare Data Sheet No. 4 SI Units		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page ____ of ____		By		
MECHANICAL DESIGN DATA (PURGE DEVICE / STACK)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	PURGE CONSERVATION DEVICE					
1	Type (Buoyancy / Velocity / None)					
2	Outside Diameter, mm					
3	Overall Length, meter					
4	Material / Thickness					
5	Inlet Type / Size, mm					
6	Outlet Type / Size, mm					
7	Drain Type / Size, mm					
8	Peak Radiation at Grade, W/m ²					
9						
	STACK					
10	Overall Height, meter					
11	Support Method					
12	Design Pressure, kPa (ga)					
13	Design Temperature, deg C					
14	Riser Material					
15	Upper Section Length, meter					
16	Material / Diam. / Thickness, mm					
17	Middle Section Length, meter					
18	Material / Diam. / Thickness, mm					
19	Lower Section Length, meter					
20	Material / Diam. / Thickness, mm					
21	Inlet Type / Size, mm					
22	Drain Type / Size, mm					
23	Derrick Base Shape / Size, meter					
24	Guy Wire Dead Man Radius, meter					
25						
26						
27						
	PIPING ON STACK					
28	Pilot Gas Lines - Quantity					
29	Material / Size (mm) / Schedule					
30	Ignition Lines - Quantity					
31	Material / Size (mm) / Schedule					
32	Primary Steam - Mat'l / Size / Sched					
33	Secondary Steam - Mat'l / Size / Sched					
34	Tertiary Steam - Mat'l / Size / Sched					
35						
36	Drain Line - Mat'l / Size / Sched					
37	Assist Gas Line - Mat'l / Size / Sched					
38	T/C Conduit - Mat'l / Size, mm					
39	Ignition / Power Conduit - Mat'l / Size, mm					
40	ACWL Power Conduit - Mat'l / Size, mm					
41						
42						
43						
44						

American Petroleum Institute		Job Number				
		Item Number				
Elevated Flare Data Sheet No. 5 SI Units		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page ____ of ____		By		
MECHANICAL DESIGN DATA (ANCILLARIES)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
AIR ASSIST BLOWER SYSTEM						
1	Fan Quantity					
2	Fan Type / Material					
3	Fan Location					
4	Damper Quantity					
5	Damper Control Required / Included					
6	Motor Type / Speed					
7	Motor Enclosure					
8	Peak Radiation at Grade, W/m ²					
9	Motor / Fan - Lubrication					
10	Max. Motor Current - Winter, amps					
11	Supplemental Requirements					
12						
13						
14						
LADDERS & PLATFORMS						
15	Top Platform, Deg. / Size, meter					
16	Step-off Platforms, Quantity					
17	Buoyancy Seal Access (Y/N)					
18	Instrument Access, Quantity					
19	Ladders Type					
20	Material / Finish					
21	L&P Specification					
22						
AIRCRAFT WARNING SYSTEM						
23	Quantity					
24	Location					
25	Color / Type (Strobe / Beacon / Paint)					
26	Retractable (Y/N)					
27	Painting Specification					
28						
EST. EQUIPMENT WEIGHTS, LB						
29	Flare Tip					
30	Purge Reduction Device					
31	Gas/Air Risers + Piping					
32	Support System					
33	Ladders & Platforms					
34	Liquid Seal					
35	Knockout Drum					
36	Control Panels					
37						
38	SMOKE SUPPRESSION CONTROL					
39	Flare Gas Flow Detector					
40	Smoke Detector					
41	Control Strategy (Auto / Manual)					
42						

American Petroleum Institute		Job Number				
		Item Number				
Enclosed Flare Data Sheet No. 1 SI Units		Specification				
		Purchase Order				
		Revision Number		Rev. Date		
		Page _____ of _____		By _____		
REQUIRED SYSTEM PERFORMANCE - PURCHASER						
		Note	Specified	REV	Based on Case / Flow	REV
	FLOW PERFORMANCE					
1	Enclosed Capacity, kg/hr					
2	Static Inlet Pressure, kPa (ga)					
3	Peak Burner Exit Velocity, meter/s					
4	Peak Mach Number					
5						
6						
	NOISE PERFORMANCE					
7	Peak Radiation at Grade, W/m ²					
8	SPL at _____ ft from base, dBA					
9	SPL at _____ ft from base, dBA					
10						
11						
	SMOKELESS PERFORMANCE					
12	Total Smokeless Capacity, kg/hr					
13	Smokeless Definition (R0 / R1 / R2)					
14						
15						
16						
	SMOKELESS STEAM CONSUMPTION					
17	Max. Total Steam, kg/hr					
18	Continuous Steam, kg/hr					
19	S/HC ratio @ Design Smokeless Rate					
20						
21						
	SMOKELESS AIR REQUIREMENTS					
22	Design Air Capacity, CFM					
23	Design Blower Pressure, mm w.c.					
24	Max. Motor Power, kW					
25						
26						
	UTILITY CONSUMPTION					
27	Purge Gas, Nm ³ /HR (Continuous)					
28	Purge Gas, Nm ³ /HR (Intermittent)					
29	Pilot Gas, Nm ³ /HR					
30	Ignition Gas, Nm ³ /HR (Intermittent)					
31	Ignition Air, Nm ³ /HR (Intermittent)					
32	Assist Gas, Nm ³ /HR / kg/hr waste					
33	Supplemental Gas, Nm ³ /HR					
34						
35						
36						
37						
38						
39						
40						

Copyright por American Petroleum Institute
Mon Mar 01 16:57:55 2004

Copyright por American Petroleum Institute
Mon Mar 01 16:57:56 2004

American Petroleum Institute		Job Number				
		Item Number				
Enclosed Flare Data Sheet No. 4 SI Units		Specification				
		Purchase Order				
		Revision Number	Revision Date			
		Page ____ of ____	By			
MECHANICAL DESIGN DATA (PIPING)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	PIPING TO BURNERS					
1	Waste Gas Piping - Material					
2	Steam Piping - Material					
3	Air Piping - Material					
4	Heat Shielding - Material					
5						
6						
7	Pilot Gas Lines - Quantity					
8	Peak Radiation at Grade, W/m ²					
9	Ignition Lines - Quantity					
10	Material / Size (mm) / Schedule					
11	Assist Gas Line - Mat'l / Size / Sched					
12	T/C Conduit - Mat'l / Size, mm					
13	Ignition/Power Conduit - Mat'l / Size, mm					
14						
15						
16	Stage 1 - Burner Count					
17	Waste Gas Valve Size, mm / Type					
18	Steam Valve Size, mm / Type					
19	Air Valve Size, mm / Type					
20						
21						
22	Stage 2 - Burner Count					
23	Waste Gas Valve Size, mm / Type					
24	Steam Valve Size, mm / Type					
25	Air Valve Size, mm / Type					
26						
27						
28	Stage 3 - Burner Count					
29	Waste Gas Valve Size, mm / Type					
30	Steam Valve Size, mm / Type					
31	Air Valve Size, mm / Type					
32						
33						
34	Stage 4 - Burner Count					
35	Waste Gas Valve Size, mm / Type					
36	Steam Valve Size, mm / Type					
37	Air Valve Size, mm / Type					
38						
39						
40						
41						
42						
43						
44						
45						
46						

American Petroleum Institute		Job Number			
		Item Number			
Enclosed Flare Data Sheet No. 5 SI Units		Specification			
		Purchase Order			
		Revision Number		Revision Date	
		Page _____ of _____	By		
MECHANICAL DESIGN DATA (ANCILLARIES)					
	Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	AIR ASSIST BLOWER SYSTEM				
1	Fan Quantity				
2	Fan Type / Material				
3	Fan Location				
4	Damper Quantity				
5	Damper Control Required / Included				
6	Motor Type / Speed				
7	Motor Enclosure				
8	Peak Radiation at Grade, W/m ²				
9	Motor / Fan - Lubrication				
10	Max. Motor Current - Winter, amps				
11	Supplemental Requirements				
12					
13					
14					
	LADDERS & PLATFORMS				
15	Top Platform, Deg. / Size, meter				
16	Step-off Platforms, Quantity				
17	Instrument Access, Quantity				
18	Ladders Type				
19	Material / Finish				
20	L&P Specification				
21					
22					
23					
	EST. EQUIPMENT WEIGHTS, LB				
24	Firebox				
25	Flare Burners				
26	Piping				
27	Control Valves				
28	Windfence				
29	Ladders & Platforms				
30	Liquid Seal				
31	Knockout Drum				
32	Control Panels				
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					

American Petroleum Institute		Job Number		
		Item Number		
General Flare Data Sheet No. 1 US Customary Units		Specification		
		Purchase Order		
		Revision Number	Revision Date	
		Page ____ of ____	By	
Purchaser Supplied - General Information				
		Note		REV
1	Purchaser			
2	Reference Number			
3	Plant Owner / Operator			
4	Reference Number			
5	Vendor			
6	Reference Number			
7				
8	Jobsite Location			
9	Jobsite Climate			
10	Unit Tag			
11	Equipment Number			
12	Service			
13	Quantity Required			
14	Is Smokeless Required? (Y/N)			
15	Preferred Smokeless Method			
16	Local Codes			
17	Is P&ID Attached? (Y/N)			
18				
19	Ambient Conditions (Design / Normal)			
20	Minimum Temperature, deg F			
21	Maximum Temperature, deg F			
22	Relative Humidity, %			
23	Maximum Wind Speed, mph			
24	Predominant Wind, (Y/N) / Direction			
25	Peak Solar Radiation, BTU/hr-sq.ft.			
26	Include Solar w/ Flare Radiation (Y/N)			
27	Jobsite Elevation, ft above sea level			
28	Seismic Zone			
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				
44				
45				
46				

American Petroleum Institute		Job Number		
		Item Number		
General Flare Data Sheet No. 2 US Customary Units		Specification		
		Purchase Order		
		Revision Number	Revision Date	
		Page ____ of ____	By	
Purchaser Supplied - General Information				
		Note		REV
1	Minimum Flare Height, ft			
2	Anticipated Flare Header Diameter, in			
3	Approx Flare Header Length, ft			
4	Flare Header Network Volume, cu ft			
5	Plot Space Available, Length/Width, ft			
6	Aircraft Warning Lights Required? (Y/N)			
7				
8	Welding Code			
9	Weld Inspection			
10	Surface Prep. & Paint Requirements			
11	Special Erection Requirements			
12				
13	Nozzle Loads on Flare Inlet			
14	Fx, Fy, Fz (kips)			
15	Mx, My, Mz (ft-kips)			
16	Special Piping Treatment			
17	Fireproofing			
18	Insulation			
19	Supports			
20	Covering			
21	Heat Tracing (Elec., Steam)			
22				
23	Utilities Available (Design / Normal)			
24	Steam Pressure, psig			
25	Steam Temperature, deg F			
26	Location of Steam Conditions			
27	Blower Power, Volts / Phase / Freq			
28	Instr. Power, Volts / Phase / Freq			
29	Electrical Classification, Cl / Gp / Div			
30	Instrument Air, psig			
31	Plant Air, psig			
32	Nitrogen, psig			
33	Fuel Gas, psig / Case #			
34	Purge Gas, psig / Case #			
35	Utility Costs			
36				
37	Nearby Structures (Distance, Height), ft			
38	Other Active Flares			
39	Direction from Current Flare			
40	Heat Release, BTU/hr			
41	Radiant Fraction			
42	Other Inactive Flares			
43	Cooling Towers			
44	Electrical Substations			
45	Property Line			
46				

American Petroleum Institute		Job Number					
		Item Number					
General Flare Data Sheet No. 3 US Customary Units		Specification					
		Purchase Order					
		Revision Number		Rev. Date			
		Page ____ of ____	By				
PROCESS DESIGN CONDITIONS - PURCHASER							
	Note	CASE 1	Rev	CASE 2	Rev	CASE 3	Rev
1	Design Flare Capacity, lb/hr						
2	Smokeless Capacity, lb/hr / opacity						
3	Gas Temperature, deg F						
4	Static Pressure at Flare Inlet, psig						
5	Flare Inlet Diameter, inches						
6	Veq, SCFH air equivalent						
7	Heat Release, MMBTU/hr						
8	Duration @ Max. Rate, min.						
9	Relief Source						
10	Controlling Case For . . .						
11	GAS COMPOSITION (Mole% / Mass%)						
12	Methane						
13	Ethane						
14	Propane						
15	Isobutane						
16	n-Butane						
17	Isopentane						
18	n-Pentane						
19	Hexane						
20	Heptane						
21	Octane						
22	Ethylene						
23	Propylene						
24	Butylene						
25	Acetylene						
26	Butadiene						
27	Benzene						
28	Toluene						
29	Xylene						
30	Hydrogen						
31	Carbon Monoxide						
32	Hydrogen Sulfide						
33	Ammonia						
34	Water Vapor						
35	Nitrogen						
37	Carbon Dioxide						
38							
39							
40	TOTAL (should be 100%)						
41	Molecular Weight						
42	Lower Heating Value, BTU/scf						
43	Ratio of Specific Heats, Cp/Cv						
44	Viscosity, cp						
45	UEL, % in air						
46	LEL, % in air						

American Petroleum Institute General Flare Data Sheet No. 4 US Customary Units		Job Number			
		Item Number			
		Specification			
		Purchase Order			
		Revision Number		Revision Date	
		Page ____ of ____	By		
MECHANICAL DESIGN DATA (PILOTS / IGNITION SYSTEM)					
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual
	PILOTS				
1	Quantity				
2	Rating - Each, BTU/hr				
3	Gas Pressure				
4	Inspirator Type				
5	Inspirator Material				
6	Gas Orifice Size, in.				
7	Strainer (Y/N)				
8	Flame Monitors (per pilot / per flare)				
9	Flame Monitor Type				
10	Pilot Fuel Connection Type / Size, in.				
11	Fuel Gas Manifold (Y/N)				
12	Manifold Connection Type / Size, in.				
13	Ignition Connection Type / Size, in.				
14	Retractable Pilots (Y/N)				
15	Retractable Thermocouples (Y/N)				
16					
17					
18					
19					
	IGNITION SYSTEM				
20	Type (FFG / Electronic / Other)				
21	Distance from Stack, ft				
22	Automatic / Manual Ignition				
23	Elec. Class., CI / Gp / Div				
24	Remote Alarm Contacts - Quantity				
25	Remote Ignition Contact (Y/N)				
26	Pressure Regulators - Quantity				
27	Pressure Gauges - Quantity				
28	Pilot Selector Valves - Type / Quantity				
29	Pilot Indicator Lights (Y/N)				
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					

American Petroleum Institute		Job Number				
		Item Number				
General Flare Data Sheet No. 5 US Customary Units		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page ____ of ____		By		
MECHANICAL DESIGN DATA (LIQUID SEAL)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	LIQUID SEAL					
1	Vessel Diameter, ft					
2	Height / Length (T/T), ft					
3	Material / Thickness, in.					
4	Integral / Separate from stack					
5	Design Code					
6	Code Stamp (Y/N)					
7	Design Pressure, psig					
8	Design Temperature, deg F					
9	Corrosion Allowance, in.					
10	Seal Depth, in.					
11	Max. Vacuum w/o adding liquid, in. WC					
12	Freeze Protection Type					
13	Connection Type / Size, in. / #					
14	Instrument / Valve Requirements					
15	Special Requirements					
16	Vessel Connections					
17	Flare Gas Inlet Type / Size, in. / #					
18	Flare Gas Outlet Type / Size, in.					
19	Fill Nozzle Type / Size, in. / #					
20	Drain Type / Size, in. / #					
21	Level Gauge Type / Size, in. / #					
22	Level Switch Type / Size, in. / #					
23	Temperature Type / Size, in. / #					
24	Pressure Type / Size, in. / #					
25	Skimmer/Overflow Type / Size, in. / #					
26	Manway Type / Size, in. / #					
27	Skirt Access (Y/N) / Type / Size, in. / #					
28	Skirt Vents (Y/N) / Type / Size, in. / #					
29						
30						
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						
41						
42						
43						
44						

American Petroleum Institute		Job Number			
		Item Number			
General Flare Data Sheet No. 6 US Customary Units		Specification			
		Purchase Order			
		Revision Number		Revision Date	
		Page ____ of ____	By		
MECHANICAL DESIGN DATA (KNOCKOUT DRUM)					
	Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	KNOCKOUT DRUM				
1	Type (Horiz / Vert. / Cyclone, ref. RP-521)				
2	Vessel Diameter, ft				
3	Height / Length (T/T), ft				
4	Material / Thickness, in.				
5	Integral / Separate from stack				
6	Design Code				
7	Code Stamp (Y/N)				
8	Design Pressure, psig				
9	Design Temperature, deg. F				
10	Corrosion Allowance, in.				
11	Max. Liquid Level, ft.				
12	Liquid Holdup Volume, cu ft.				
13	Freeze Protection Type				
14	Connection Type / Size, in. / #				
15	Instrument / Valve Requirements				
16	Special Requirements				
17	Vessel Connections				
18	Flare Gas Inlet Type / Size, in. / #				
19	Flare Gas Outlet Type / Size, in.				
20	Fill Nozzle Type / Size, in. / #				
21	Drain Type / Size, in. / #				
22	Level Gauge Type / Size, in. / #				
23	Level Switch Type / Size, in. / #				
24	Temperature Type / Size, in. / #				
25	Pressure Type / Size, in. / #				
26	Skimmer/Overflow Type / Size, in. / #				
27	Manway Type / Size, in. / #				
28	Skirt Access (Y/N) / Type / Size, in. / #				
29	Skirt Vents (Y/N) / Type / Size, in. / #				
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					

American Petroleum Institute		Job Number		
		Item Number		
General Flare Data Sheet No. 7 US Customary Units		Specification		
		Purchase Order		
		Revision Number	Revision Date	
		Page ____ of ____	By	
GENERAL NOTES				
	PAGE NO.	NOTE NO.		REV NO.
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				
44				

Copyright por American Petroleum Institute
Mon Mar 01 16:58:01 2004

Copyright por American Petroleum Institute
Mon Mar 01 16:58:02 2004

American Petroleum Institute		Job Number				
		Item Number				
Elevated Flare Data Sheet No. 3 US Customary Units		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page ____ of ____	By			
MECHANICAL DESIGN DATA (FLARE BURNER)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	FLARE BURNER BODY					
1	Tip Type / Model					
2	Quantity of Burners					
3	Smokeless Method					
4	Overall Length, ft					
5	Upper Section Length, ft					
6	Material / Diam. / Thickness, in					
7	Lower Section Length, ft					
8	Material / Diam. / Thickness, in					
9	Connection Type / Size, in					
10	Lining, Length, ft					
11	Material / Thickness					
12	Muffler, Length / Diameter, ft					
13	Windshield, Type / Material					
14	Flame Retention, (Y/N) / Material					
15						
16						
17						
18						
	STEAM ASSIST EQUIPMENT					
19	Primary Steam, Material					
20	Connection Type / Size, in					
21						
22	Secondary Steam, Material					
23	Connection Type / Size, in					
24						
25	Tertiary Steam, Material					
26	Connection Type / Size, in					
27						
28						
29						
30						
	AIR ASSIST EQUIPMENT					
31	Air Plenum Length, ft					
32	Air Plenum Diameter, in					
33	Connection Type / Size, in					
34						
35						
36						
37						
38						
39						
40						
41						

Copyright por American Petroleum Institute
Mon Mar 01 16:58:03 2004

American Petroleum Institute		Job Number				
		Item Number				
Elevated Flare Data Sheet No. 5 US Customary Units		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page ____ of ____	By			
MECHANICAL DESIGN DATA (ANCILLARIES)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	AIR ASSIST BLOWER SYSTEM					
1	Fan Quantity					
2	Fan Type / Material					
3	Fan Location					
4	Damper Quantity					
5	Damper Control Required / Included					
6	Motor Type / Speed					
7	Motor Enclosure					
8	Motor Nameplate HP					
9	Motor / Fan - Lubrication					
10	Max. Motor Current - Winter, amps					
11	Supplemental Requirements					
12						
13						
14						
	LADDERS & PLATFORMS					
15	Top Platform, Deg. / Size, ft					
16	Step-off Platforms, Quantity					
17	Buoyancy Seal Access (Y/N)					
18	Instrument Access, Quantity					
19	Ladders Type					
20	Material / Finish					
21	L&P Specification					
22						
	AIRCRAFT WARNING SYSTEM					
23	Quantity					
24	Location					
25	Color / Type (Strobe / Beacon / Paint)					
26	Retractable (Y/N)					
27	Painting Specification					
28						
	EST. EQUIPMENT WEIGHTS, LB					
29	Flare Tip					
30	Purge Reduction Device					
31	Gas/Air Risers + Piping					
32	Support System					
33	Ladders & Platforms					
34	Liquid Seal					
35	Knockout Drum					
36	Control Panels					
37						
38	SMOKE SUPPRESSION CONTROL					
39	Flare Gas Flow Detector					
40	Smoke Detector					
41	Control Strategy (Auto / Manual)					
42						

American Petroleum Institute		Job Number				
		Item Number				
Enclosed Flare Data Sheet No. 1 US Customary Units		Specification				
		Purchase Order				
		Revision Number		Rev. Date		
		Page _____ of _____		By _____		
REQUIRED SYSTEM PERFORMANCE - PURCHASER						
		Note	Specified	REV	Based on Case / Flow	REV
FLOW PERFORMANCE						
1	Enclosed Capacity, lb/hr					
2	Static Inlet Pressure, psig					
3	Peak Burner Exit Velocity, ft/s					
4	Peak Mach Number					
5						
6						
NOISE PERFORMANCE						
7	SPL at Windfence, dBA					
8	SPL at _____ ft from base, dBA					
9	SPL at _____ ft from base, dBA					
10						
11						
SMOKELESS PERFORMANCE						
12	Total Smokeless Capacity, lb/hr					
13	Smokeless Definition (R0 / R1 / R2)					
14						
15						
16						
SMOKELESS STEAM CONSUMPTION						
17	Max. Total Steam, lb/hr					
18	Continuous Steam, lb/hr					
19	S/HC ratio @ Design Smokeless Rate					
20						
21						
SMOKELESS AIR REQUIREMENTS						
22	Design Air Capacity, CFM					
23	Design Blower Pressure, in. w.c.					
24	Max. Motor Power, HP					
25						
26						
UTILITY CONSUMPTION						
27	Purge Gas, SCFH (Continuous)					
28	Purge Gas, SCFH (Intermittent)					
29	Pilot Gas, SCFH					
30	Ignition Gas, SCFH (Intermittent)					
31	Ignition Air, SCFH (Intermittent)					
32	Assist Gas, SCFH / lb/hr waste					
33	Supplemental Gas, SCFH					
34						
35						
36						
37						
38						
39						
40						

Copyright por American Petroleum Institute
Mon Mar 01 16:58:04 2004

American Petroleum Institute		Job Number:				
		Item Number:				
Enclosed Flare Data Sheet No. 3 US Customary Units		Specification:				
		Purchase Order:				
		Revision Number:		Revision Date:		
		Page ____ of ____		By:		
MECHANICAL DESIGN DATA (COMBUSTION EQUIPMENT)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	FLARE BURNER BODY					
1	Tip Type / Model					
2	Quantity of Burners					
3	Smokeless Method					
4	Overall Length, ft					
5	Tip Material					
6	Exit Section Length, ft					
7	Material / Size, in. / Sched.					
8	Inlet Section Length, ft					
9	Material / Size, in. / Sched.					
10	Connection Type / Size, in.					
11	Flame Retention, (Y/N) / Material					
12						
	STEAM ASSIST EQUIPMENT					
13	Steam Injector, Material					
14	Connection Mat l / Type / Size, in.					
15						
	AIR ASSIST EQUIPMENT					
16	Air Plenum Length, ft					
17	Air Plenum Diameter, in					
18	Connection Type / Size, in.					
19						
20						
	FIREBOX EQUIPMENT					
21	Overall Height, ft					
22	Firebox Outside Dimensions, ft					
23	Rectangular - Length / Width					
24	Round - Diameter					
25	Polygonal - No. Sides / Width					
26	Windfence Outside Dimensions, ft					
27	Rectangular - Length / Width					
28	Round - Diameter					
29	Polygonal - No. Sides / Width					
30	Refractory Material					
31	Thickness, in.					
32	Max. Allowable Oper. Temp., F					
33	Max. Shell Temperature, F					
34	Anchor Type / Material					
35	Max. Flue Gas Temperature, F					
36	Stack T/C (Y/N)					
37	Stack Sample Conn. (Y/N)					
38	Connection Type / Size, in.					
39	Max. Personnel Exposure Temp., F					
40						
41						
42						
43						

American Petroleum Institute		Job Number				
Enclosed Flare Data Sheet No. 4 US Customary Units		Item Number				
		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page _____ of _____		By _____		
MECHANICAL DESIGN DATA (PIPING)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
	PIPING TO BURNERS					
1	Waste Gas Piping - Material					
2	Steam Piping - Material					
3	Air Piping - Material					
4	Heat Shielding - Material					
5						
6						
7	Pilot Gas Lines - Quantity					
8	Material / Size (in) / Schedule					
9	Ignition Lines - Quantity					
10	Material / Size (in) / Schedule					
11	Assist Gas Line - Matl / Size / Sched					
12	T/C Conduit - Matl / Size, in					
13	Ignition/Power Conduit - Matl / Size, in.					
14						
15						
16	Stage 1 - Burner Count					
17	Waste Gas Valve Size, in. / Type					
18	Steam Valve Size, in. / Type					
19	Air Valve Size, in. / Type					
20						
21						
22	Stage 2 - Burner Count					
23	Waste Gas Valve Size, in. / Type					
24	Steam Valve Size, in. / Type					
25	Air Valve Size, in. / Type					
26						
27						
28	Stage 3 - Burner Count					
29	Waste Gas Valve Size, in. / Type					
30	Steam Valve Size, in. / Type					
31	Air Valve Size, in. / Type					
32						
33						
34	Stage 4 - Burner Count					
35	Waste Gas Valve Size, in. / Type					
36	Steam Valve Size, in. / Type					
37	Air Valve Size, in. / Type					
38						
39						
40						
41						
42						
43						
44						
45						
46						

American Petroleum Institute		Job Number				
		Item Number				
Enclosed Flare Data Sheet No. 5 US Customary Units		Specification				
		Purchase Order				
		Revision Number		Revision Date		
		Page ____ of ____	By			
MECHANICAL DESIGN DATA (ANCILLARIES)						
		Note	Purchaser - Specified	REV	Vendor - Proposed / Actual	REV
AIR ASSIST BLOWER SYSTEM						
1	Fan Quantity					
2	Fan Type / Material					
3	Fan Location					
4	Damper Quantity					
5	Damper Control Required / Included					
6	Motor Type / Speed					
7	Motor Enclosure					
8	Motor Nameplate HP					
9	Motor / Fan - Lubrication					
10	Max. Motor Current - Winter, amps					
11	Supplemental Requirements					
12						
13						
14						
LADDERS & PLATFORMS						
15	Top Platform, Deg. / Size, ft					
16	Step-off Platforms, Quantity					
17	Instrument Access, Quantity					
18	Ladders Type					
19	Material / Finish					
20	L&P Specification					
21						
22						
23						
EST. EQUIPMENT WEIGHTS, LB						
24	Firebox					
25	Flare Burners					
26	Piping					
27	Control Valves					
28	Windfence					
29	Ladders & Platforms					
30	Liquid Seal					
31	Knockout Drum					
32	Control Panels					
33						
34						
35						
36						
37						
38						
39						
40						
41						
42						
43						

APPENDIX B—BIBLIOGRAPHY

1. General Information on Flares and Flare Systems

- C. E. Baukal, Jr., Editor and R. E. Schwartz Associate Editor, *The John Zink Combustion Handbook*, CRC Press, Boca Raton, FL, 2001, ISBN 0-8439-2337-1.
- K. Banerjee, N.P. Cheremisinoff and P.N. Cheremisinoff, *Flare Gas Systems Pocket Handbook*, Gulf Publishing Company, Houston, Texas, 1985, ISBN 0-87201-310-3.
- R.D. Reed, *Furnace Operations*, 3rd Edition, Gulf Publishing Company, Houston, Texas, 1981, ISBN 0-87201-301-4.
- W.C. Bluhm, "Safe Operation of Refinery Flare Systems", *API Proceedings*, Vol. 41, 1961, American Petroleum Institute, Washington, D.C.
- J.F. Straitz, III, "Improved Flare Design", *Hydrocarbon Processing*, Oct. 1994.
- R.E. Schwartz and S.G. Kang, "Effective Design of Emergency Flaring Systems", *Hydrocarbon Engineering*, Feb. 1998.
- H.W. Husa, "How to Compute Safe Purge Rates", *Hydrocarbon Processing and Petroleum Refiner*, Vol. 43, No. 5, May 1964.
- S.H. Kwon, et al, "Improve Flare Management", *Hydrocarbon Processing*, July 1994.

2. Mechanical and Structural

- G.B. Moody, "Mechanical Design of A Tall Stack", *Hydrocarbon Processing*, Sept. 1969, p 173–178.
- A.A. Brown, "How to design Pile-supported Foundations for Flare Stacks", *Hydrocarbon Processing*, Dec. 1969, p 139–146.
- M. Aslam, "How to find.... Minimum Length of Process Piping", *Hydrocarbon Processing*, Nov. 1970, p 203–208.
- R.G. Blick, "How to Calculate Wind-Caused Sway on Slender Columns", *Petroleum Refiner*, Vol. 37, No. 11, Nov. 1958, p 237–240.
- J.F. Kuong, "Find Wind-Caused Bending Moment on Tall Vessels by Nomograph", *Hydrocarbon Processing*, June 1969, p 192–195.
- A. Youness, "New Approach to Tower Deflection", *Hydrocarbon Processing*, June 1969, p 121–126.

- C.E. Freese, "Vibration of Vertical Pressure Vessels", ASME Paper 58-15, ASME Petroleum Mechanical Engineering Conference, Sept. 21–24, 1958.
- E.D. Bergman, "The Design of Vertical Pressure Vessels Subjected to Applied Forces", ASME Paper 54-A-104, *Transactions of the ASME*, August 1955, p 863–866.
- P.P. Bijlaard, "Stresses from Radial Loads and External Moments in Cylindrical Pressure Vessels", *The Welding Journal*.
- W.R. Wichmann, A.G. Hopper and J.L. Mershon, "Local Stresses in Spherical and Cylindrical Shells due to External Loadings", Welding Research Council.

3. Emissions

- "British Standard Ringelmann Chart", BS 2742C, British Standards Institution, London.
- "Miniature Smoke Chart", BS 2742M, British Standards Institution, London.
- "Notes on the use of the Ringelmann and Miniature Smoke Charts", BS 2742: 1969, British Standards Institution, London.
- Anonymous, "Ringelmann Smoke Chart", (Revision of IC 7718), U.S. Department of the Interior, Bureau of Mines, Information Circular 8333, 1967.
- Chemical Manufacturers Association, "A Report on a Flare Efficiency Study", Washington, D.C., March 1983.
- M.R. Keller and R.K. Noble, "RACT for VOC—A Burning Issue", *Pollution Engineering*, July 1983.
- R.R. Romano, "Control Emissions with Flare Efficiency", *Hydrocarbon Processing*, Oct. 1983.
- R. E. Schwartz and M.R. Keller, "Environmental Factors Versus Flare Applications", Paper No. 13d, presented at the Symposium on Loss Prevention in the Chemical Industry, 83rd National Meeting of the American Institute of Chemical Engineers, Houston, Texas, March 22, 1977.
- U.S. EPA, "Compilation of Air Pollutant Emissions Factors, Vol. 1, Stationary Point and Area Sources", AP-42, 4th Edition, 1985 and supplement F: Section 11.5, 9/91, "Industrial Flares".
- J.H. Pohl, "Combustion Efficiency of Flares", U.S. Environmental Protection Agency, Research Triangle Park, N.C., 1985.

- T.A. Brzustowski and E.C. Sommer, Jr., "Predicting Radiant Heating from Flares", *Proceedings-Division of Refining*, 1973, volume 53, American Petroleum Institute, Washington, D.C. p 865–893.
- J. Keller, R. Noble and M. Keller, "Determining Safe Levels of Thermal Radiation Exposure on Personnel", presented at the 34th Annual Loss Prevention Symposium, AIChE National Meeting, March 6–8, 2000.

- R.E. Schwartz and J. White, "Predict Radiation From Flares", *Chemical Engineering Process*, July 1997.

Additional Bibliography and References can be found in API Recommended Practice 521 "Guide for Pressure-Relieving and Depressuring Systems".

2003 Publications Order Form



American Petroleum Institute

Available through Global Engineering Documents.

Effective January 1, 2003.

Phone Orders: 1-800-854-7179 (Toll-free in the U.S. and Canada)
303-397-7956 (Local and International)

Fax Orders: 303-397-2740

Online Orders: www.global.lhs.com

Date: _____

☐ **API Member** (Check if Yes)

Invoice To (☐ Check here if same as "Ship To")

Name: _____

Title: _____

Company: _____

Department: _____

Address: _____

City: _____ State/Province: _____

Zip/Postal Code: _____ Country: _____

Telephone: _____

Fax: _____

E-Mail: _____

Ship To (UPS will not deliver to a P.O. Box)

Name: _____

Title: _____

Company: _____

Department: _____

Address: _____

City: _____ State/Province: _____

Zip/Postal Code: _____ Country: _____

Telephone: _____

Fax: _____

E-Mail: _____

Quantity	Product Number	Title	SO★	Unit Price	Total
	C53401	Publ 534, <i>Heat Recovery Steam Generators</i>		\$ 71.00	
	C53501	Publ 535, <i>Burners for Fired Heaters in General Refinery Services</i>		71.00	
	CX53005	Std 530, <i>Calculation of Heater Tube Thickness in Petroleum Refineries</i>		150.00	
	C53601	RP 536, <i>Post Combustion NO_x Control for Equipment in General Refinery Services</i>		71.00	
	C56003	Std 560, <i>Fired Heaters for General Refinery Services</i> (Includes Errata dated January 2002)		160.00	
	C57302	RP 573, <i>Inspection of Fired Boilers and Heaters</i> (ANSI/API Std 573-1992)		71.00	
	C57202	RP 572, <i>Inspection of Pressure Vessels (ANSI/API RP 572-2001)</i>		81.00	
	C57901	RP 579, <i>Fitness-For-Service</i>		613.00	

☐ **Payment Enclosed** ☐ **P.O. No.** (Enclose Copy) _____

Subtotal

☐ **Charge My Global Account No.** _____

Applicable Sales Tax (see below)

Rush Shipping Fee (see below)

Shipping and Handling (see below)

Total (in U.S. Dollars)

Credit Card No.: _____

Print Name (As It Appears on Card): _____

Expiration Date: _____

Signature: _____

★ To be placed on Standing Order for future editions of this publication, place a check mark in the SO column and sign here:

Pricing and availability subject to change without notice.

Mail Orders – Payment by check or money order in U.S. dollars is required except for established accounts. State and local taxes, \$10 processing fee*, and 5% shipping must be added. Send mail orders to: **API Publications, Global Engineering Documents, 15 Inverness Way East, M/S C303B, Englewood, CO 80112-5776, USA.**

Purchase Orders – Purchase orders are accepted from established accounts. Invoice will include actual freight cost, a \$10 processing fee*, plus state and local taxes.

Telephone Orders – If ordering by telephone, a \$10 processing fee* and actual freight costs will be added to the order.

Sales Tax – All U.S. purchases must include applicable state and local sales tax. Customers claiming tax-exempt status must provide Global with a copy of their exemption certificate.

Shipping (U.S. Orders) – Orders shipped within the U.S. are sent via traceable means. Most orders are shipped the same day. Subscription updates are sent by First-Class Mail. Other options, including next day service, air service, and fax transmission are available at additional cost. Call 1 800 854 7179 for more information.

Shipping (International Orders) – Standard international shipping is by air express courier service. Subscription updates are sent by World Mail. Normal delivery is 3-4 days from shipping date.

Rush Shipping Fee – Next Day Delivery orders charge is \$20 in addition to the carrier charges. Next Day Delivery orders must be placed by 2:00 p.m. MST to ensure overnight delivery.

Returns – All returns must be pre-approved by calling Global's Customer Service Department at 1-800-624-3974 for information and assistance. There may be a 15% restocking fee. Special order items, electronic documents, and age-dated materials are non-returnable.

***Minimum Order** – There is a \$50 minimum for all orders containing hardcopy documents. The \$50 minimum applies to the order subtotal including the \$10 processing fee, excluding any applicable taxes and freight charges. If the total cost of the documents on the order plus the \$10 processing fee is less than \$50, the processing fee will be increased to bring the order amount up to the \$50 minimum. This processing fee will be applied before any applicable deposit account, quantity or member discounts have been applied. There is no minimum for orders containing only electronically delivered documents.

There's more where this came from.

The American Petroleum Institute provides additional resources and programs to the oil and natural gas industry which are based on API® Standards. For more information, contact:

- | | |
|---|--|
| • API Monogram® Licensing Program | Phone: 202-962-4791
Fax: 202-682-8070 |
| • American Petroleum Institute Quality Registrar (APIQR®) | Phone: 202-962-4791
Fax: 202-682-8070 |
| • API Spec Q1® Registration | Phone: 202-962-4791
Fax: 202-682-8070 |
| • API Perforator Design Registration | Phone: 202-962-4791
Fax: 202-682-8070 |
| • API Training Provider Certification Program | Phone: 202-682-8490
Fax: 202-682-8070 |
| • Individual Certification Programs | Phone: 202-682-8161
Fax: 202-962-4739 |
| • Engine Oil Licensing and Certification System (EOLCS) | Phone: 202-682-8233
Fax: 202-962-4739 |
| • Training/Workshops | Phone: 202-682-8490
Fax: 202-682-8070 |

Check out the API Publications, Programs, and Services Catalog online at www.api.org.



American Petroleum Institute

Helping You Get The Job Done Right.®

Additional copies are available through Global Engineering Documents at (800) 854-7179 or (303) 397-7956

Information about API Publications, Programs and Services is available on the World Wide Web at: <http://www.api.org>



**American
Petroleum
Institute**

1220 L Street, Northwest
Washington, D.C. 20005-4070
202-682-8000

Product No. C53701