

ENGINEERING DESIGN SEMINAR

SEPTEMBER 6, 1994 – NOVEMBER 11, 1994

FLARE HEADERS

Nov. 4

By. Mr. Scott Wozniak

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PURPOSE OF FLARE

Disposal of Vapors and Liquids Discharged

Relief Valves

Rupture Discs

Pressure Control Valves

Types of Systems

Open System

Discharge Directly to Atmosphere

Closed System

Discharge to a Collection Header

Dispose to a Flare

Define Loadings to be Handled

Calculate Loadings for all Contingencies

Geographic Location of Each Source

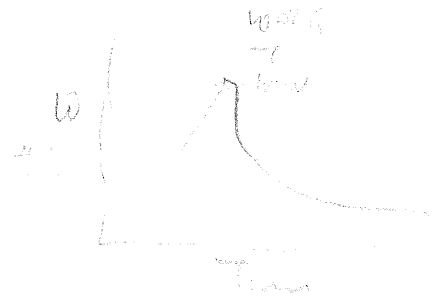
Calculate Maximum Load (Power Failure, Fire Case)

Fire Case Limited to a Ground Area of 230 - 460 Square Meters

(API 521) Fire zone

Calculate Maximum Allowable Back Pressure

Allowable Back Pressure is a Function of the Following



Type and Make of Pressure Relief Valve

Set Pressure of Relief Valve

Relieving Rate Required for Each Contingency

> 250 psia	Nonbalanced
< 250 psia	Balanced type.

$$S = 223 \sqrt{\frac{K T Z}{M W}}$$

$$\text{Sonic Velocity} = 223 \sqrt{\frac{K T Z}{M W}}$$

$$\% \text{ Mach} = \frac{\text{Actual Velocity}}{\text{Sonic Velocity}}$$

12.5 (1.33) Steam	1250	g/s
CR-12.5 (1.33)	1250	g/s
12.5 (1.33) GHg	340	g/s

MAJOR FACTORS INFLUENCING FLARE DESIGN

Gas Composition

Flow Rate

Gas Pressure Available

Initial Investment

Operating Costs

Gas Temperature

Energy Availability

Environmental Requirements 99% destruction factor

Safety Requirements

Social Requirements

Reduction in nitrogen oxides

500 ppm or less B/L

FLARE STACK

Final Disposal of Combustible Vapors by Burning

Provided with Pilot Burners and Ignition

Location

Downwind of Refinery

Safe Distance from Equipment and People

Height

Depends on Quantity and Nature of Vapors

Wind Velocity and Direction

Topography

Radiation Requirements

Concentration of Products of Combustion

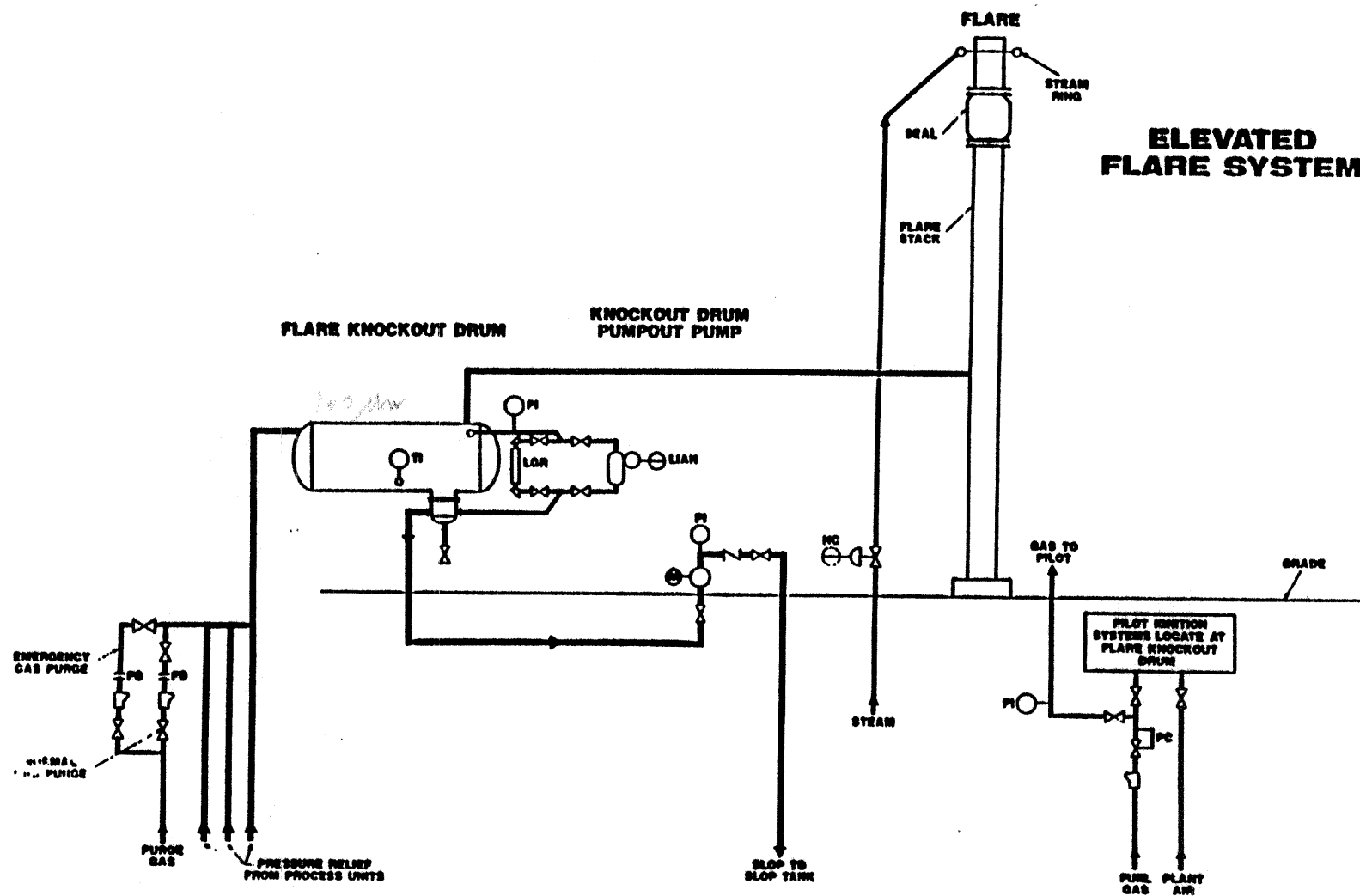
Usually Varies from 20 Feet to 300 Feet

Structure

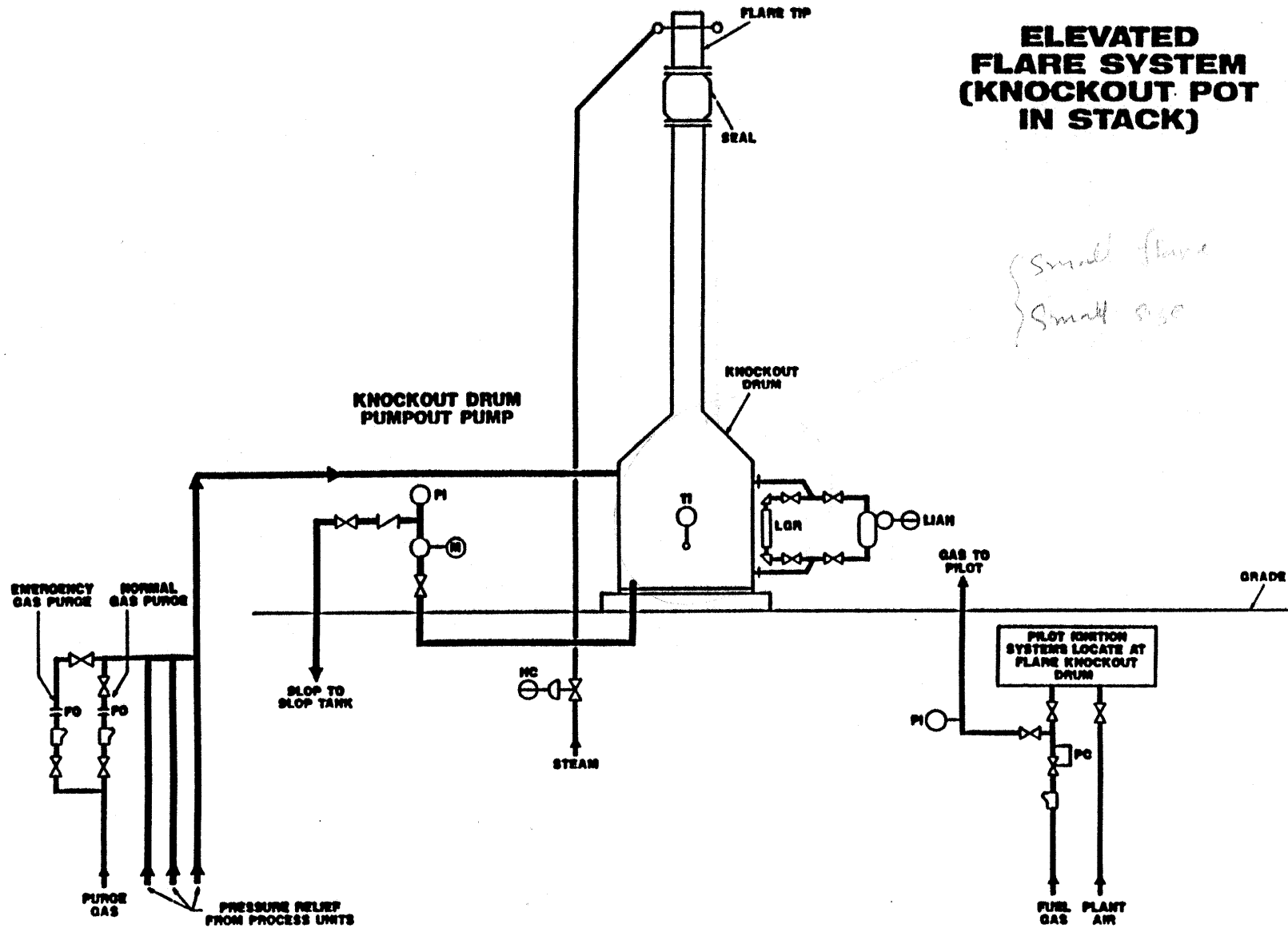
Self Supporting

Guy Supported

Derrick Type



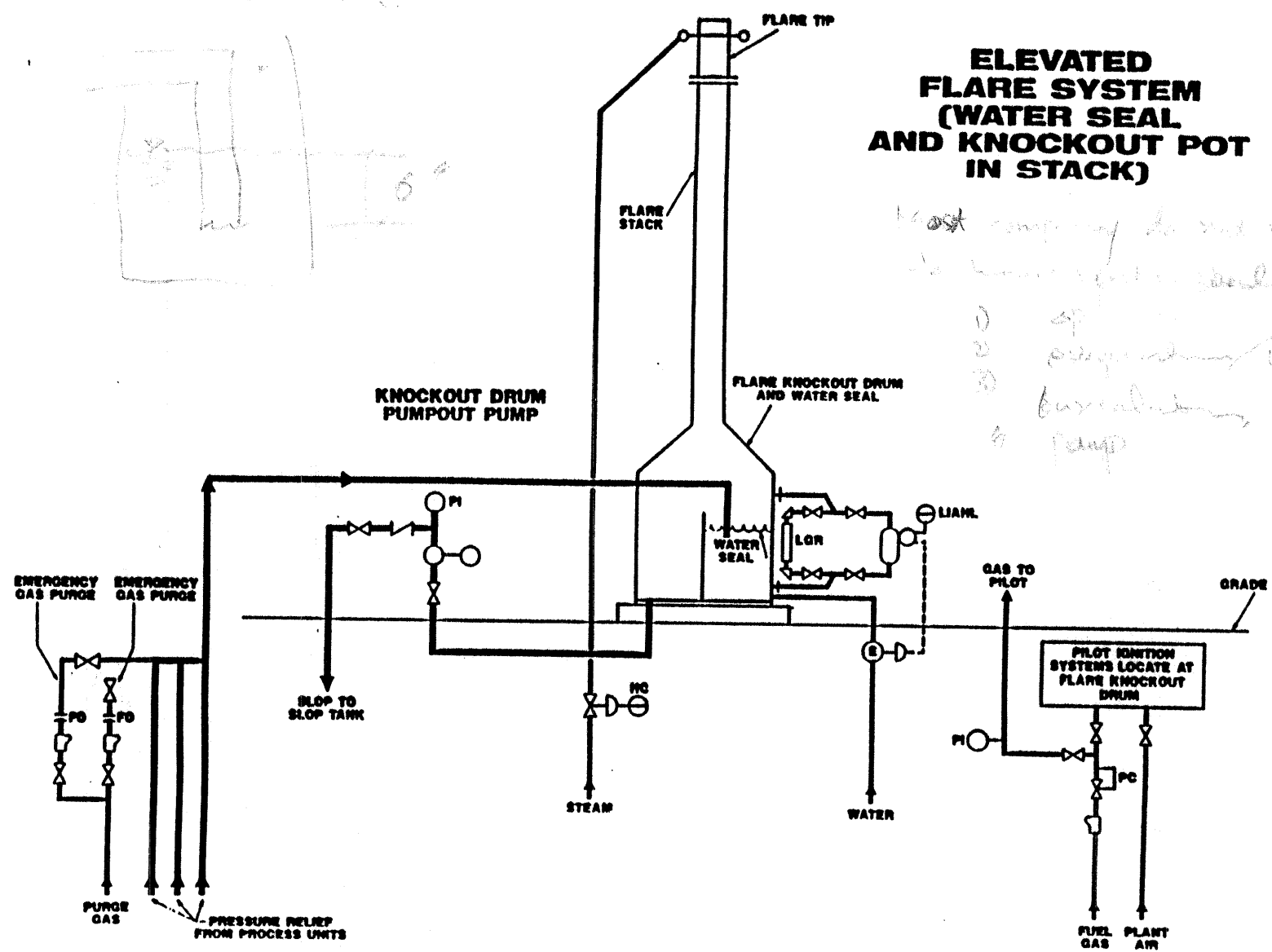
ELEVATED FLARE SYSTEM (KNOCKOUT POT IN STACK)



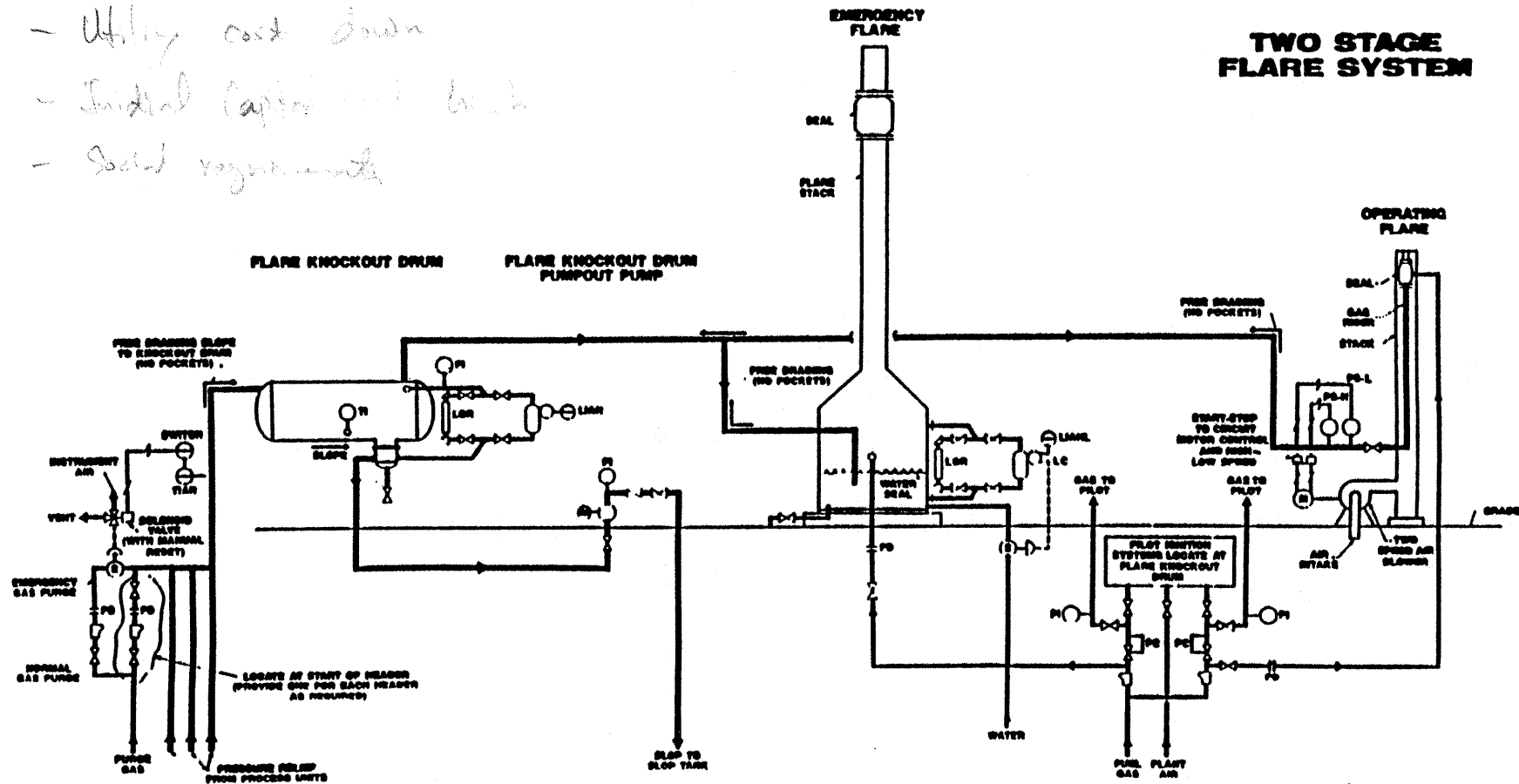
Water seal.

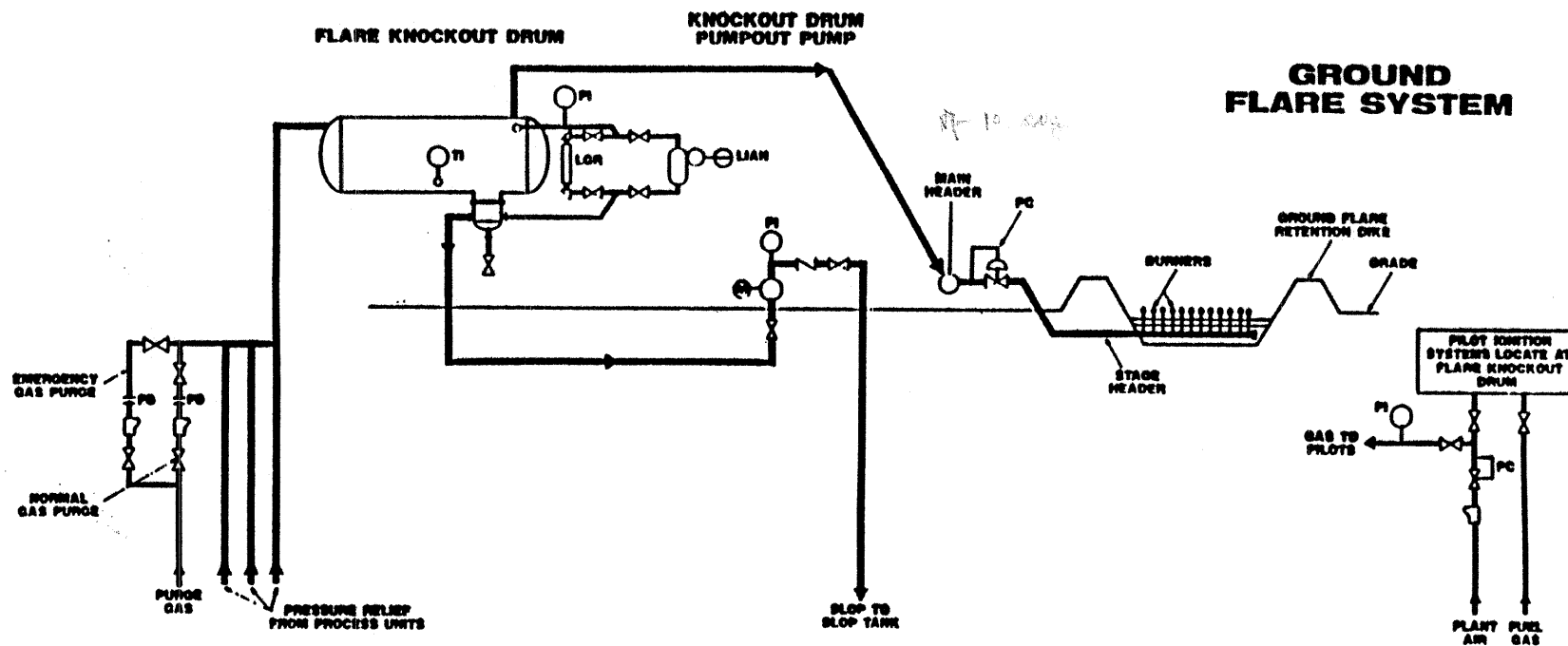
ELEVATED FLARE SYSTEM (WATER SEAL AND KNOCKOUT POT IN STACK)

Most companies do not recommend
to have water seal
1) up
2) depending on water
3) circulation
4) pump

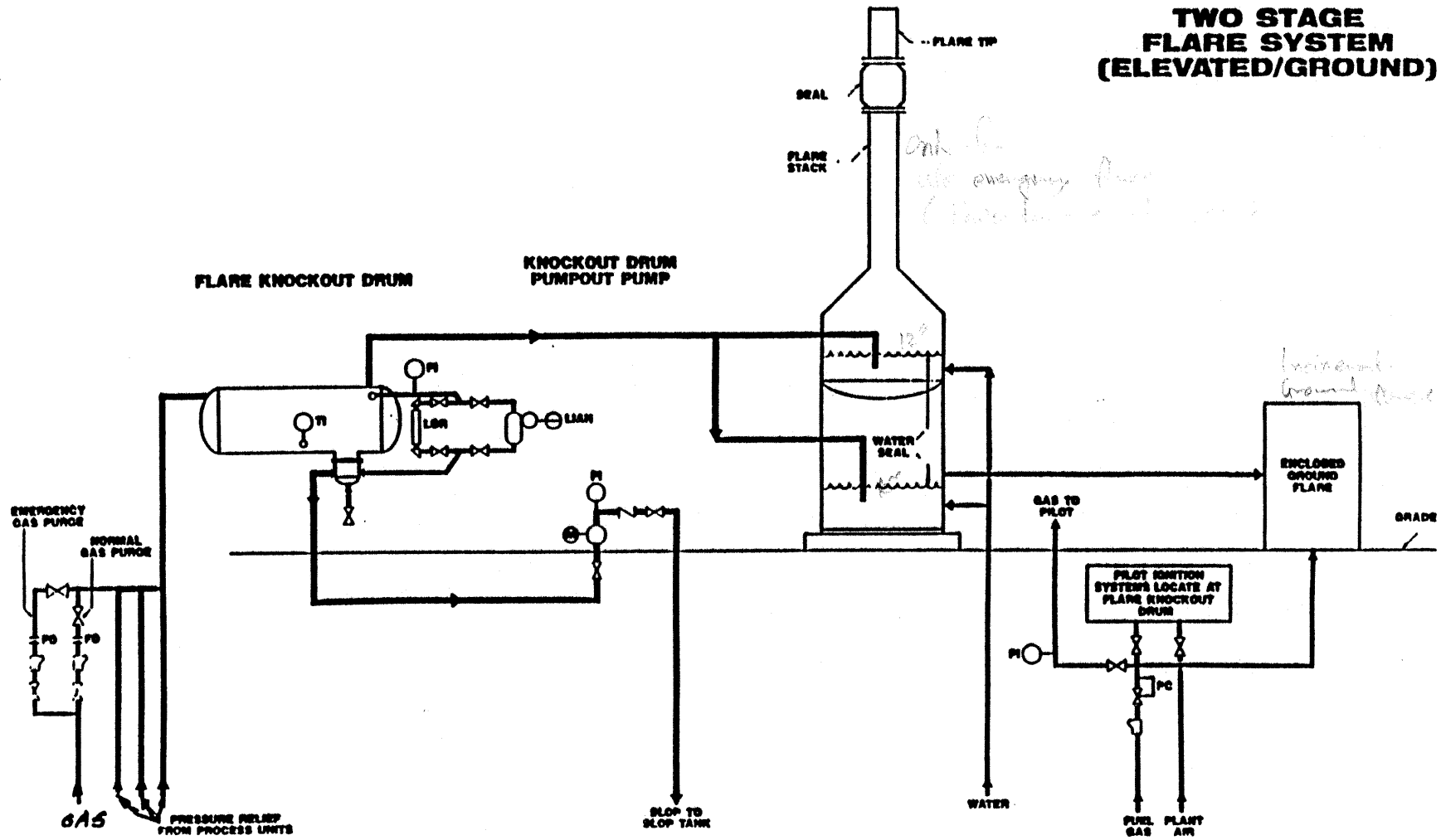


- more flexibility
- Purge gas down
- Utility cost down
- Initial Capital cost high
- Social requirements





TWO STAGE FLARE SYSTEM (ELEVATED/GROUND)



SUPPORT STRUCTURE

1993 \$

Self-Supported

$$\text{Cost}(\$) = (78.0 + 9.14D + 0.949L)^2$$

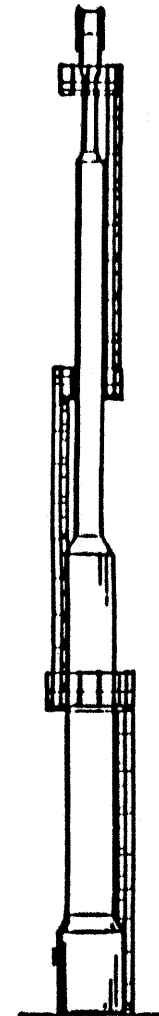
D: diameter ; in *average*

L; Height, ft

250'

36" Dia

353,180 \$



SUPPORT STRUCTURE

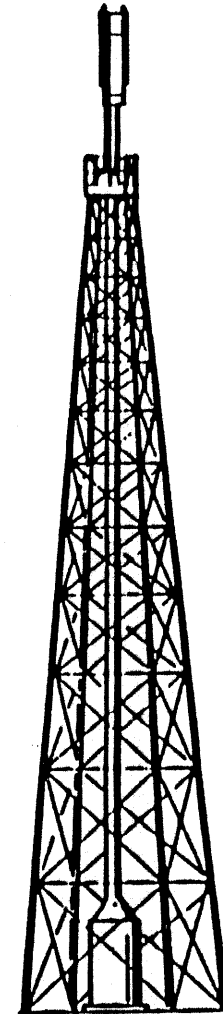
$$\text{Cost (\$)} = (96.4 + 2.72D + 1.64L)^2$$

250'

36" Dia

$$= 341,430 \$$$

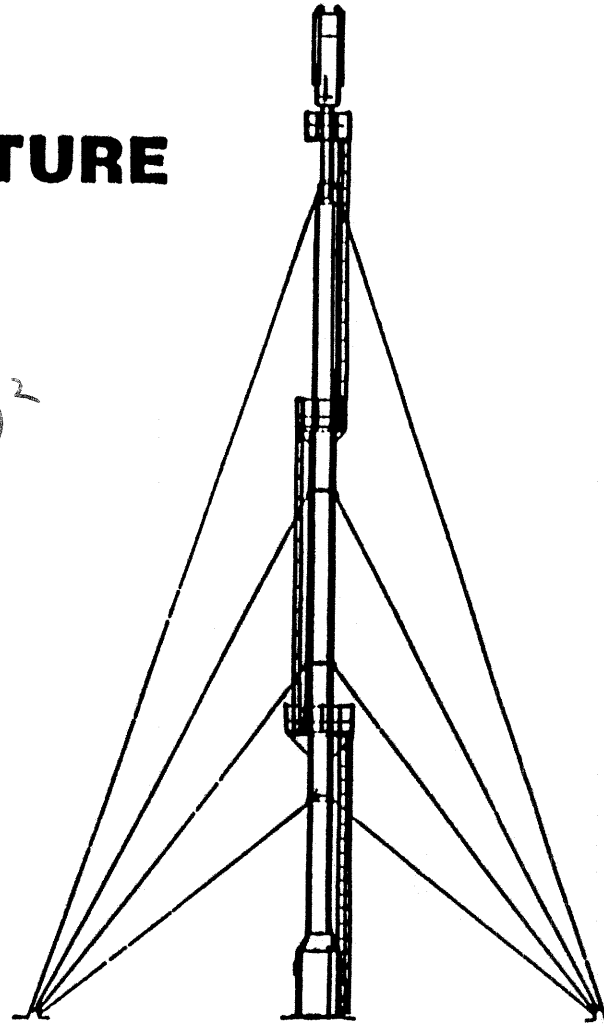
Derrick



SUPPORT STRUCTURE

$$\text{Cost}(\$) = (103 + 8.68D + .47L)^2$$

Guyed



STACK SUPPORTING SYSTEM

TYPE OF SUPPORT	DESCRIPTION	When to Use	When not to Use
Derrick	Used for structures from 150 to 550 feet tall. Relatively easy to erect and has superior strength when assembled.	● Plot space is tight ● Stacks over 250 feet ● Gas temperatures are over 450°F ● With Offshore systems	● Stacks less than 250 feet ● Cost sensitive applications
Guyed	Guy wire support flare stacks are typically the lowest material cost system, but they require the largest plot area. Used in systems from 100 to 700 feet tall.	● Stacks over 100 feet ● Radius equal to stack height available for guy wires ● Low capital cost is required ● Liquid carry over is unlikely	● Stacks less than 100 feet ● Tight plot area ● Liquid carry over likely
Self-Supporting	Self-supported flare stack is utilized for structures from 20 to 350 feet tall. Usually this design has the lowest installed cost and requires the smallest plot area.	● Stacks less than 100 feet ● Tight plot area ● Height less than 350 feet ● When liquid carry-over is likely ● When integral drum is specified	● Stacks taller than 350 feet ● Cost sensitive applications greater than 100 feet

COMBUSTION THEORY

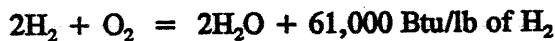
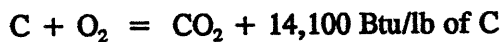
Three elements of combustion:

1. Fuel
2. Air
3. Source of Ignition

Combustion may be defined as the rapid chemical combination of oxygen with the combustible elements of fuel. There are just three combustible chemical elements of significance:

1. Carbon
2. Hydrogen
3. Sulfur

Sulfur is usually of minor significance as a source of heat, but it can be of major significance in corrosion and pollution problems. Carbon and hydrogen when burned to completion with oxygen unite according to the following:



The objective of good combustion is to release all this heat while minimizing losses from combustion imperfections and superfluous air. The combination of combustible elements and compounds of a fuel with all the oxygen requires temperature high enough to ignite the constituents, mixing or turbulence, and sufficient time for complete combustion. These factors are often referred to as the "three T's" of combustion.

MOLE

The mass of a substance in pounds equal to its molecular weight is called a pound-mole of the substance or simply a mole. For example, carbon (C) has a molecular weight of 12. Therefore a mole of carbon weighs 12 pounds. In the case of gases, the volume occupied by a mole is called the molar volume, and is a constant of 394 ft³ for "ideal" gases.

Fundamental Laws:

A. Conservation of matter

Matter is neither destroyed nor created. A+B lbs entering will always equal A+B lbs exiting.

COMBUSTION THEORY

B. Conservation of energy

Energy is neither destroyed nor created. The sum of energy entering must always equal the sum of energy exiting a process.

C. Ideal gas law

The volume of an ideal gas is directly proportional to its absolute temperature and inversely proportional to its absolute pressure.

$$V = RT/p$$

Where: V = volume, ft³/mole of gas
 p = absolute pressure, lb/sq. ft
 T = absolute temperature, Rankine
 R = universal gas constant, 1545 ft-lb/mole

D. Law of combining weights

All substances combine in accordance with simple definite weight relationship.

E. Avogadro's law

Equal volumes of different gases at the same pressure and temperature contain the same number of molecules. A pound-mole of any substance contains a mass equal in pounds to the molecular weight of the substance.

F. Dalton's law

The total pressure of a mixture of gases is the sum of the partial pressures which would be exerted by each of the constituents if each gas were to occupy alone the same volume as the mixture.

G. Amagat's law

The total volume occupied by a mixture of gases is equal to the sum of the volumes which would be occupied by each of the constituents when at the same pressure and temperature as the mixture.

Note that one mole of any gas at 60°F and atmospheric pressure, the volume is 379 ft³.

COMBUSTION THEORY

Heat content varies for combustible materials. One pound of carbon (C) completely burned to carbon dioxide (CO_2) gives off 14,100 Btu. One pound of methane (CH_4) completely burned to carbon dioxide (CO_2) and water (H_2O) gives off 21,500 Btu.

When combustion is complete, one pound of carbon releases 14,100 Btu. When carbon combines with oxygen to form carbon monoxide (CO), one pound of carbon releases only 4,000 Btu. Forming carbon monoxide instead of carbon dioxide releases only 28% as much heat.

Ignition Temperature

Ignition temperature is the temperature at which more heat is generated by combustion than is lost to the surroundings so that the combustion process becomes self-sustaining. Typical ignition temperatures of fuels in air are:

Sulfur	S	470°F
Charcoal	C	650°F
Fixed Carbon (Anthracite)	C	840-1115°F
Hydrogen	H	1070°F
Ethane	C_2H_6	900°F

Heating Values

Water vapor is one of the products of combustion for all fuels which contain hydrogen. The high heating value (HHV) based on that all water vapor formed during combustion is condensed to liquid. For the low heating value (LHV), it is assumed that all products of combustion remain in the gaseous state. The following equation can be used to determine LHV:

$$\text{LHV} = \text{HHV} - 1040 * (\text{lb water formed} / \text{lb fuel})$$

COMBUSTION THEORY

Combustion Air

Carbon, hydrogen and sulfur are normally the only combustible elements found in combustion for flares, the air (lb) theoretically required for the complete combustion of 1 lb of fuel is:

$$11.53C + 34.34(H_2 - O_2/8) + 4.29S$$

Where C, H₂, O₂ and S represent the fraction by weight (%/100) of carbon, hydrogen, oxygen and sulfur. With gaseous fuel, instead of breaking down the hydrocarbons into their constituent elements it can be condensed to the following theoretical air required for complete combustion (lb air / lb fuel):

$$2.47CO + 34.34H_2 + 17.27CH_4 + 13.30C_2H_2 + 14.81C_2H_4 + 16.12C_2H_6 + 6.10H_2S - 4.32O_2$$

The nitrogen component of air does not take part in the combustion reaction. It does, however, absorb some of the heat and thereby reduces the energy that is available for transfer to the process.

RADIATION THEORY

Investigation have been under taken to determine the effect of thermal radiation on human skin. In most cases 500 Btu/Hr-ft² has been determined to be a safe limit. Equipment normally can safely tolerate higher degrees of heat density than those defined for personnel.

The following equation by Hajek and Ludwig may be used to determine the minimum distance (L) required from the center of the flare flame and a point of exposure where thermal radiation must be limited:

$$L^2 \text{ (ft}^2\text{)} = (t)(f)(R)/(4\pi K)$$

$$L = [f t R / (4 \pi k)]^{1/2}$$

Where:

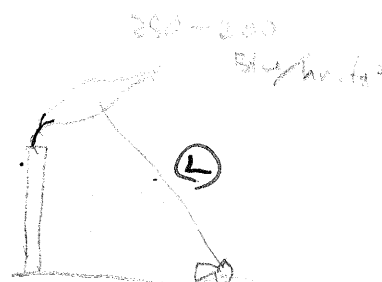
t = fraction of heat intensity transmitted

f = fraction of heat radiated

R = net heat release (Btu/hr)

K = allowable radiation (500 Btu/hr-ft²)

PI= 3.14159



Conservative design approach ignores wind effects and calculates the distance assuming the center of radiation is at the base of the flare (at the flare tip), not in the center. It is also assumed that the location where thermal radiation must be limited is at the base of the flare. Therefore, the distance (L) is equal to the required flare stack height. The (f) factor allows for the fact that not all the heat release in a flame propagated through the mechanisms: conduction, convection, and radiation. Thermal radiation may be either absorbed, reflected, or transmitted. Since the atmosphere is not a perfect vacuum, a fraction of the heat radiated is not transmitted due to atmospheric absorption (humidity, particulate matter). For estimating purposes, however, assume all of the heat radiated is transmitted (t=1). Below find a summary of heat radiated for various gaseous diffusion flames:

GAS	FLARE TIP DIAMETER (IN)	FRACTION OF HEAT RADIATED (f)
Hydrogen	< 1	.10
	1.6	.11
	3.3	.16
	8.0	.15
	16.0	.17
Butane	< 1	.29
	1.6	.29
	3.3	.29
	8.0	.28

GAS	FLARE TIP DIAMETER (IN)	FRACTION OF HEAT RADIATED (f)
	16.0	.30
Methane	< 1	.16
	1.6	.16
	> 3.3	.15
Natural gas	8.0	.19
	16.0	.23

In general, the fraction of heat radiated increases as the stack diameter increases. If stream-specific data are not available, a design basis of $f=0.2$ will give conservative results.

The heat release (R) is calculated from the flare gas flow rate (W) and the net heating value (B), as follows:

$$R \text{ (Btu/hr)} = W \text{ (lb/hr)} * B \text{ (Btu/lb)}$$

$$1000,000 \text{ lb/hr}$$

$$\text{NHV} : 18,000 \text{ Btu/lb}$$

$$f = 0.2$$

$$K = 1500 \text{ Btu/hr-ft}$$

$$x = 1.0$$

$$L = \sqrt{f * R / (4 \pi K)}$$

$$L = 439 \text{ ft}$$

RADIATION THEORY

EXPOSURE TIMES NECESSARY TO REACH THE PAIN THRESHOLD

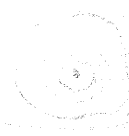
RADIATION INTENSITY

Btu/Hr-ft ² <i>500</i>	Kilowatts per M ²	Time to Pain Threshold (Seconds)
550	1.74	60
740	2.33	40
920	2.90	30
1500	4.73	16
2200	6.94	9
3000	9.46	6
3700	11.67	4
6300	19.87	2

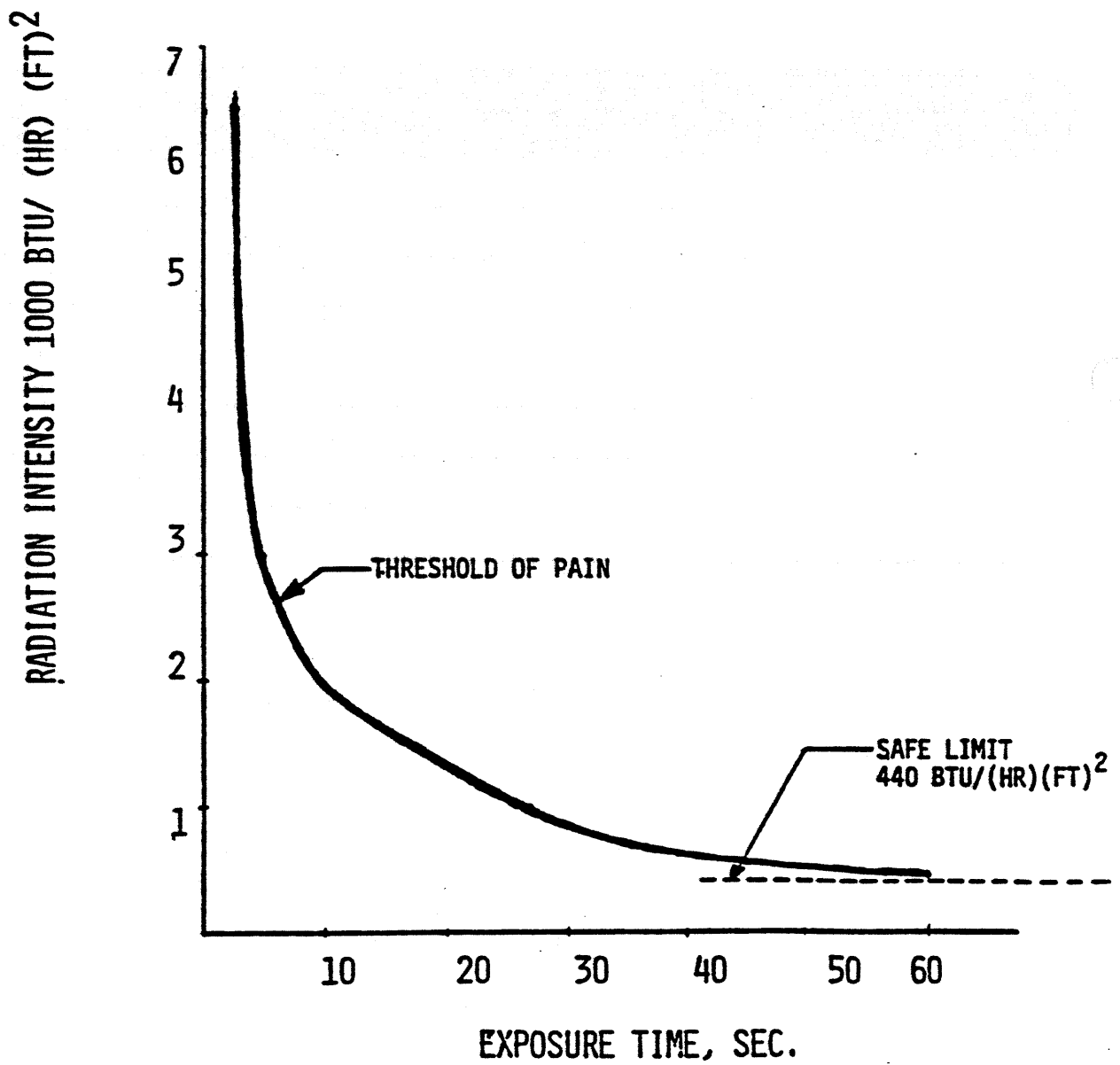
500 - Property limit value

1500 Btu/hr-ft² - Refinery, ~~zone~~ Petroleum zone.

3000 Btu/hr-ft² - Equipment



HEAT RADIATION INTENSITY VS. EXPOSURE TIME
FOR BARE SKIN AT THE THRESHOLD OF PAIN



REGULATORY COMPLIANCE

40 CFR 60.18

Flares shall be designed for and operated with no visible emissions except for periods not to exceed a total of five minutes during two consecutive hours. Flares shall be operated with a flame present at all times. Flares shall be used only with the net heating value of the gas being combusted being 11.2 MJ/scm (200 Btu/scf) or greater if the flare is non assisted.

Steam assisted and non assisted flares shall be designed for and operated with an exit velocity less than 18.3 m/s (60 ft/s). The presence of a flare pilot flame shall be monitored using a thermocouple or any other equivalent device to detect the presence of a flame.

PILOT BURNERS

Environmental regulations require that there be a presence of a continuous flame. Reliable ignition is obtained by continuous pilot burners designed for stability and positioned around the outer perimeter of the flare tip. The pilot burners are ignited by an ignition source system, which can be designed for either manual or automatic actuation.

Automatic systems may be activated by:

1. **Thermocouples**
2. **Infrared sensor**
3. **Ultraviolet sensor (ground flare application)**

STEAM JETS

A diffusion flame receives its combustion oxygen by diffusion of air into the flame from the surrounding atmosphere. Sometimes high volume of fuel flow into a flare system may require more combustion air than that from simple gas diffusion. Therefore, steam injection nozzles which are positioned around the tip increase gas turbulence and draw in more combustion air and improve combustion efficiency.

Three theories smoke formation:

1. Steam separates the hydrocarbon molecules, thereby minimizing polymerization, and forms oxygen compounds that burn at a reduced rate and temperature not conducive to cracking and polymerization.
2. Water vapor reacts with the carbon particles to form CO, CO₂, and H₂, thereby removing the carbon before it cools and forms smoke.
3. Reduce the temperature in the core of the flame and suppress thermal cracking.

Disadvantages of steam usage include noise and operating cost. Steam aggravates the flare noise problem by producing high-frequency jet noise. The jet noise can be reduced by the use of small multiple steam jets and by acoustical shrouding. To optimize steam usage, infrared sensors are available that sense flare flame characteristics and adjust the steam flowrate automatically.

GAS SEAL

Air may try to flow back into a flare stack due to wind or the thermal contraction of stack gases and create an explosion potential. To prevent this, a gas seal is typically installed in the flare stack as close as possible to the flare tip.

One type of gas seal is the molecular seal which is located below the flare tip to impede the flow of air back into the flare gas network. There are also "seals" which act as orifices in the top of the stack to reduce the purge gas volume for a given velocity and also interfere with the passage of air down the stack from the upper rim. These are known by the names "fluidic seal, and arrestor seal." These seals are usually proprietary in design and their presence reduces the operating purge gas requirements.

LIQUID SEAL

Process vent streams are usually passed through a liquid seal before going to the flare stack. The liquid seal is normally downstream of the knockout drum or sometimes incorporated into the knockout drum. This prevent possible flame flashbacks, caused when air is inadvertently introduced into the flare system and the flame front pulls down into the stack. The liquid seal also serves to maintain a positive pressure on the upstream system and acts as a mechanical damper on any explosive shock wave in the flare stack. Purge gas also helps to prevent flashback in the flare stack caused by low vent gas flow.

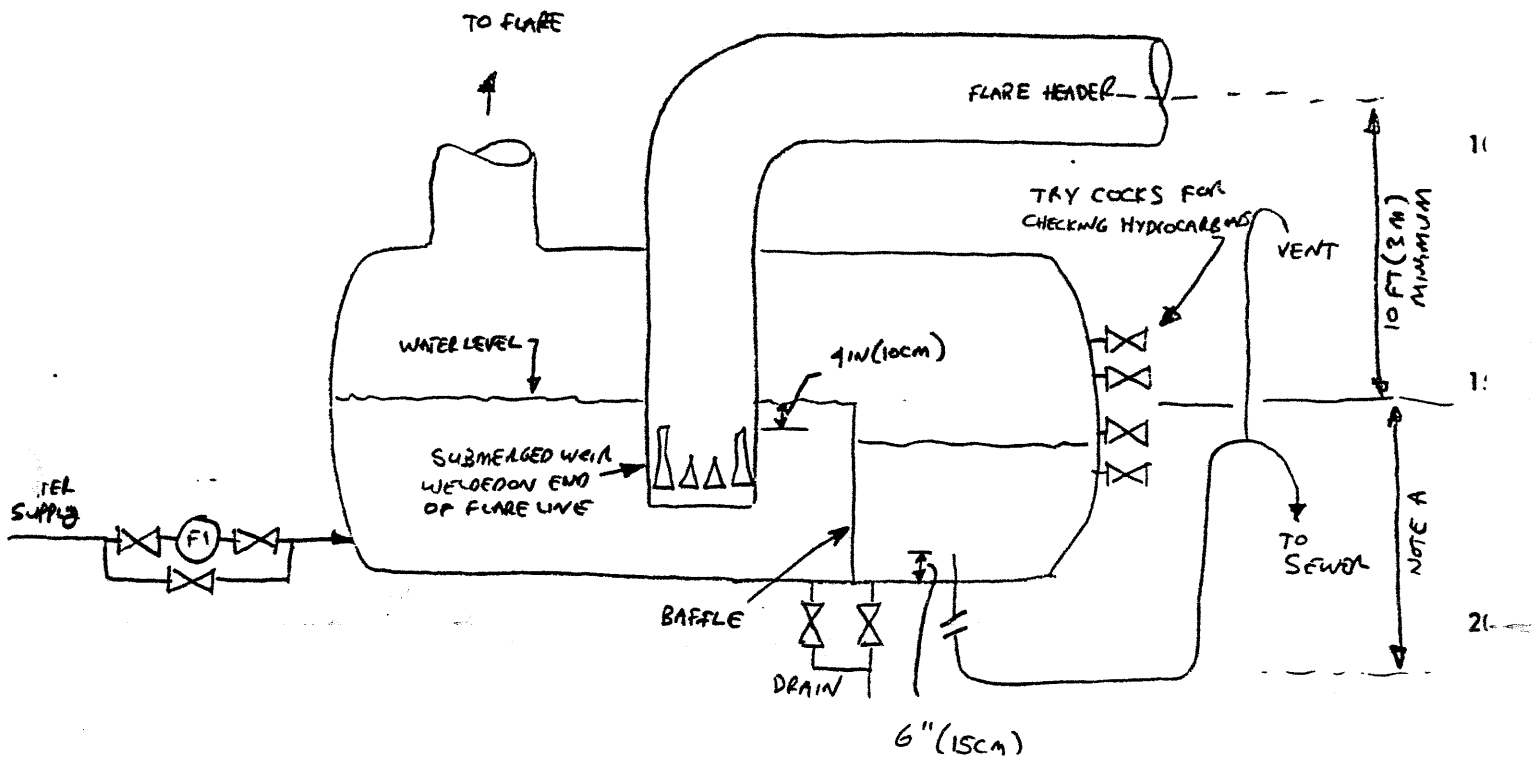
One problem in liquid seal drums is surges. Surging in seal drums can be minimized by the use of slots or V notches on the end of the dip pipe so that increasing flow area is provided as the gas flow increases, utilizing a principle similar to that involved in the design of a bubble cap.

The desired sealing level may be maintained by means of an automatic controller operating on the liquid supply line. Low and high level alarms are sometimes used for warning in case the liquid is not maintained within the desired levels.

CUSTOMER _____
 SUBJECT _____

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 DATE _____
 PROJECT _____
 BY _____

FLARE WATER SEAL



- ① SEWER SEAL SHOULD BE DESIGNED FOR A MINIMUM OF 175% OF DRUM'S MAXIMUM OPERATING PRESSURE

CONTROLS

Flare system control are normally automated. Components which are normally controlled include the following:

1. Auxiliary gas

Fuel gas consumption can be minimized by continuously measuring the vent gas flow rate and heat content (Btu/scf) and automatically adjusting the amount of fuel to maintain 300 Btu/scf.

2. Steam consumption

Steam consumption can be minimized by controlling flow based on vent gas flowrate or visual smoke monitors.

3. Ignition system

Automatic ignition panels sense the presence of a flame with either visual or thermal sensors and reignite the pilots when flameouts occur.

$$10\% \frac{\text{Maximum / Design Steam Consumption}}{\text{Emergency flow}}$$

PILOT AND IGNITION SYSTEMS

- FLAME SYSTEMS ARE PROVIDED WITH CONTINUOUSLY BURNING PILOTS WHICH ARE EQUIPPED WITH A REMOTELY ACTUATED IGNITION SYSTEM.
- FLAME FRONT GENERATOR
 - FUEL GAS AND AIR ADMITTED TO THE IGNITION PIPE IN A COMBUSTIBLE RATIO.
 - GAS IS IGNITED BY AN ELECTRIC SPARK.
 - FLAME TRAVELS THROUGH THE PIPE.
- FLARE TIPS
 - EQUIPPED WITH MULTIPLE PILOT BURNERS
 - SURROUNDING WINDSHIELD
 - ✓ ENSURES THAT PILOT FLAME WILL NOT BE EXTINGUISHED BY HIGH WINDS

FLAME FRONT GENERATOR IGNITION SYSTEM

GENERAL INSTRUCTIONS

If no spark is observed, check the electrical circuit and the spark gap.

If a blue flash cannot be observed at the sight glass, check for gas and air delivery.

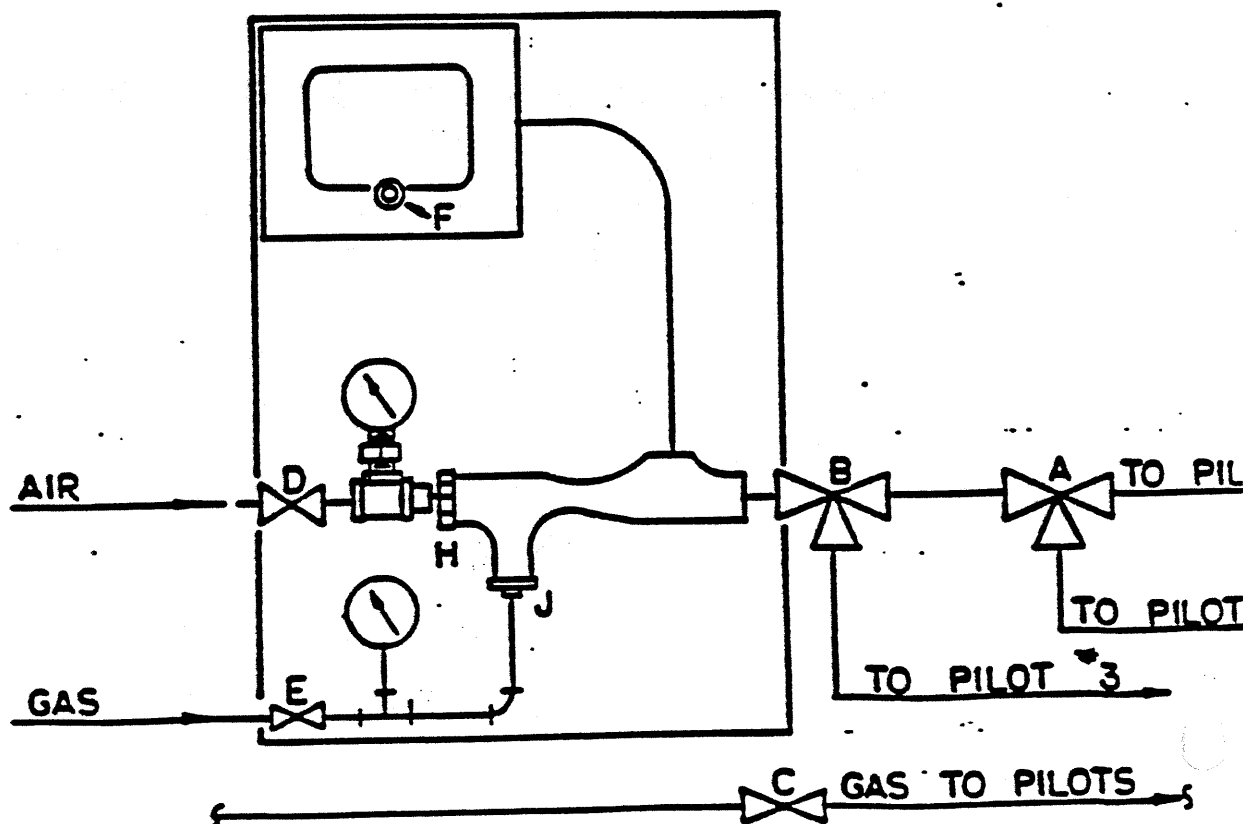
Disconnect spark lead and remove sight glass and check for air delivery and gas delivery individually.

If a noticeable hiss does not occur, break the piping union and clean ignition chamber at "H" and "J".

A drain should be installed in the flame front lines between the flame front generator and pilots.

The drains may be plugged and the lines may be filled with condensate.

Orifices "H" and "J" are sized for gas having a specific gravity of .8. To find the proper pressure for fuel having a specific gravity other than .8, set the air at 10W and with the push button "F" pressed, decreasing and/or increasing the fuel gas pressure until burning is observed through the sight glass. This will give you the fuel pressure required for the different specific gravities.



ENTRY OF PURGE GASES

TEMPERATURE CHANGES MUST BE TAKEN INTO ACCOUNT

- Changing absolute temperature ratios causes an added indraft of air.

- EXAMPLE:

24 INCH LINE, 1000 FEET LONG
VOLUME = 3140 CUBIC FEET
WITH GASES AT 400° F

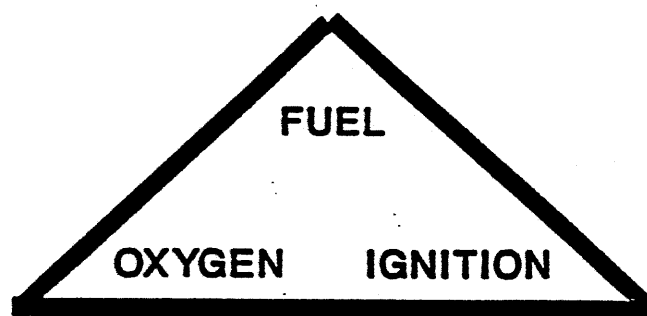
IF THE GASES COOL TO 60° F THEN THE VOLUME IS:

$$\begin{aligned}\text{VOLUME} &= (3140) * ((60+460)/(400+460)) = \\ \text{VOLUME} &= 1900 \text{ CUBIC FEET}\end{aligned}$$

Therefore, purge gas must make up the difference to prevent a vacuum situation. At least $(3140 - 1900) = 1240$ cubic feet must be made up by purge gases.

PURGING

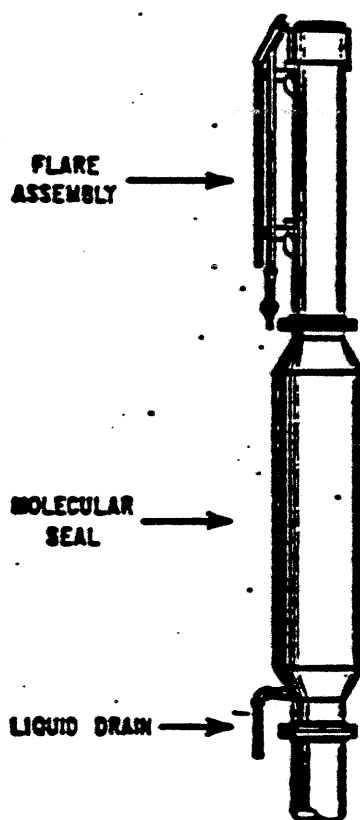
- **FLARE PURGE GAS**
ANY GAS WHICH CANNOT GO TO DEW POINT UNDER ANY CONDITION OF OPERATION.
 - FUEL GAS
 - INERT GAS
 - NITROGEN
- **PURGE RATE**
 - **FLARE STACK**
 - LINEAR VELOCITY 1FPS TO 5FPS.
 - **FLARE STACK WITH MOLECULAR SEAL**
 - 0.10 FPS TO 0.20 FPS.
- **SAFETY ASPECT**
 - TWO OF THE THREE ELEMENTS FOR EXPLOSION ARE ALWAYS PRESENT IN A FLARE SYSTEM.



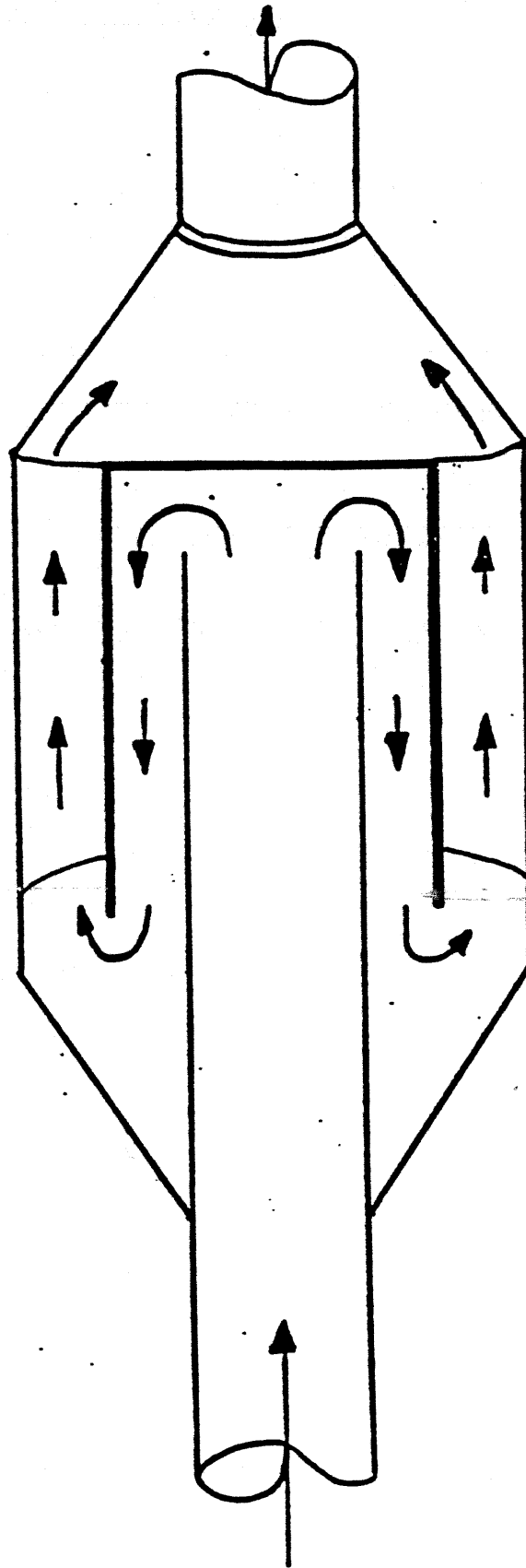
MOLECULAR SEAL

PRINCIPLE FEATURES

- A. PREVENTS EXPLOSIONS IN THE FLARE SYSTEM.
- B. PREVENTS ENTRY OF AIR TO THE FLARE SYSTEM.
- C. REDUCES PURGE OR "SWEEP" GAS REQUIREMENT.
- D. NO OBSTRUCTION TO THE FLOW OF FLARED GASES.
- E. PERFORMS SILENTLY, SAFELY AND WITHOUT ATTENTION.
- F. VERY SMALL PRESSURE-DROP.
- G. TRAPS LIQUID HYDROCARBON FOR RETURN TO GRADE AND RECOVERY.
- H. REDUCES DEMAND FOR PURGE GAS TO APPROXIMATELY 10% OF VOLUME REQUIRED IF SEAL IS NOT USED.



MOLECULAR SEAL



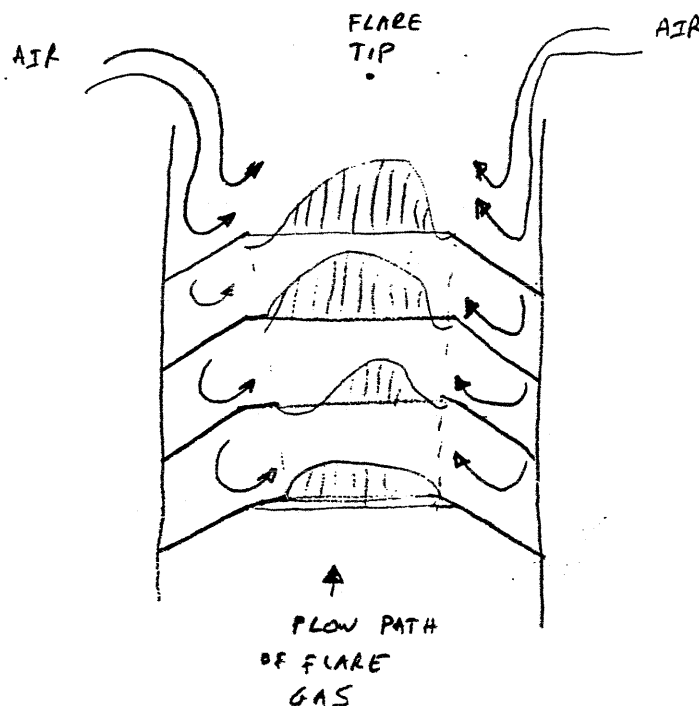
FLUIDIC SEAL

PRINCIPLE: ENABLES FLUID FLOW IN ONE DIRECTION WITH LITTLE RESISTANCE WHILE A REVERSAL OF FLOW DIRECTION RESULTS IN VERY HIGH RESISTANCE.

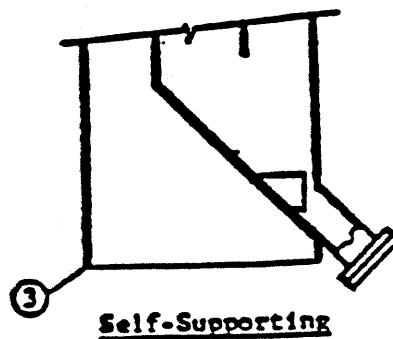
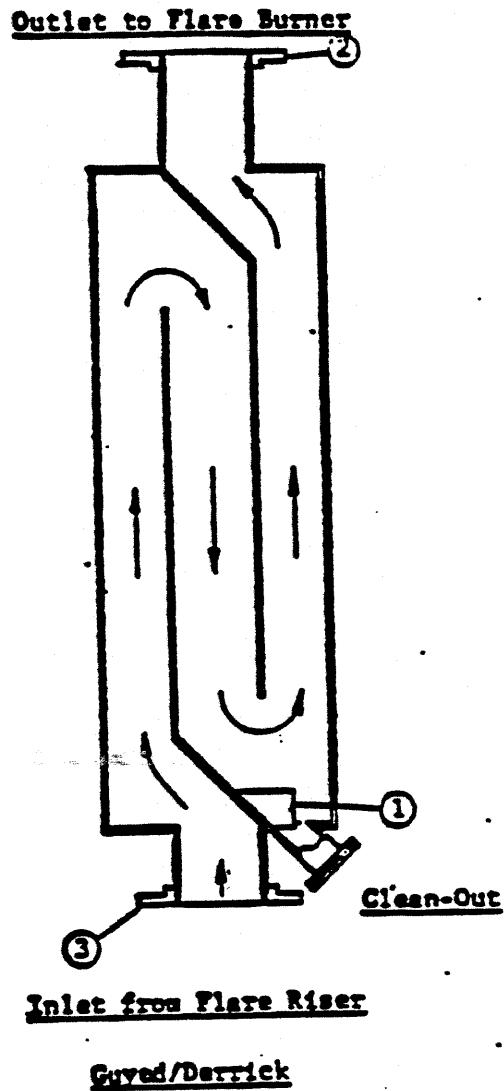
- **CONSISTS OF A SERIES OF FIXED BAFFLES, SHAPED LIKE OPEN-ENDED CONES WITHIN A FLARE TIP.**
- **BACK FLOW OF AIR IS ABOUT 5:1.**

ADVANTAGE OVER MOLECULAR SEAL

- **LESS PURGE GAS IS NECESSARY**
- **CAPITAL COST IS LESS**
- **WEIGHT IS LESS**
- **MINIMUM MAINTENANCE**



DOUBLE SEAL



<u>NO.</u>	<u>DESCRIPTION</u>
1	Internal Drain
2	Upper Connection
3	Lower Connection

PILOT GAS REQUIREMENT

Number of pilots for a flare depends on flare size and possibly the flare gas composition and wind conditions. Pilot gas usage is a function of the number of pilot burners required to ensure positive ignition of the flared gas, of the design of the pilots, and the mode of operation. The average pilot gas consumption based on an energy-efficient model is 70 scf/hr. The annual pilot gas consumption (F_p) is calculated by:

$$F_p \text{ (Mscf/yr)} = (70 \text{ scf/hr}) * (N) * (8,760 \text{ hr/yr})$$

$$F_p \text{ (Mscf/yr)} = 613 * N$$

N can be calculated from the following table:

FLARE TIP DIAMETER (IN)	NUMBER OF PILOT BURNERS (N)
1-10	1
12-24	2
30-60	3
> 60	4

STEAM REQUIREMENTS

Steam requirements depends on the composition of the gas being flared, the steam velocity from the injection nozzle, and the flare tip diameter. Although some gases can be flared smokeless without steam, typically 0.01 to 0.6 pound of steam per pound of flare gas is required. The ratio is usually estimated from the molecular weight of the gas, the carbon-to-hydrogen ratio of the gas, or whether the gas is saturated or unsaturated.

If a proprietary smokeless flare is purchased, the manufacturer should be consulted about the minimum necessary steam rate. A small diameter flare tip of less than 24 inches can use steam more effectively than a large diameter tip to mix air into the flame and promote turbulence. For a typical refinery, the average steam requirement is typically 0.25 lb/lb, and in chemical plants the rate is typically 0.5 lb/lb.

In general, the following equation can be used:

$$W_{\text{steam}} (\text{lb/hr}) = W_{\text{hc}} (\text{lb/hr}) * [0.68 - (10.8/\text{MW})] \quad \text{Typical}$$

PARAFFIN

$$W_{\text{steam}} (\text{lb/hr}) = W_{\text{paraffin}} (\text{lb/hr}) * \left[0.49 - \frac{10.8}{\text{MW}} \right]$$

OLEFIN

$$W_{\text{steam}} (\text{lb/hr}) = W_{\text{olefin}} (\text{lb/hr}) * \left[0.79 - \frac{10.8}{\text{MW}} \right]$$

GAS	Steam/GAS Weight Ratio	GAS	Steam/GAS
Paraffins		Olefins	
C ₂	0.15	propadiene	0.70
C ₃	0.25	pentadiene	1.05
C ₄	0.3	Aromatics	
C ₅	0.35	BZ	0.8
C ₆	0.38	TOL	0.85
Olefins		XY	0.9
C ₂	0.4		
C ₃	}		
C ₄			
C ₅	0.65		

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FLARE SYSTEM

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SMOKELESS BURNING AND CHEMISTRIES

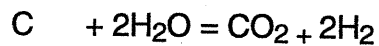
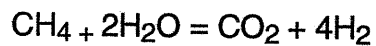
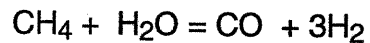
Major Factors for Smokeless Operation

Securing a combination of carbon with another element

Significantly upgrading the H/C ratio by weight

Chemistries

If carbon can be made to combine with oxygen as either CO or CO₂, the carbon cannot be seen and thus produces no smoke.



All reactions are endothermic

Smoke Suppression Methods

Steam Injection

High Pressure Gas Injection

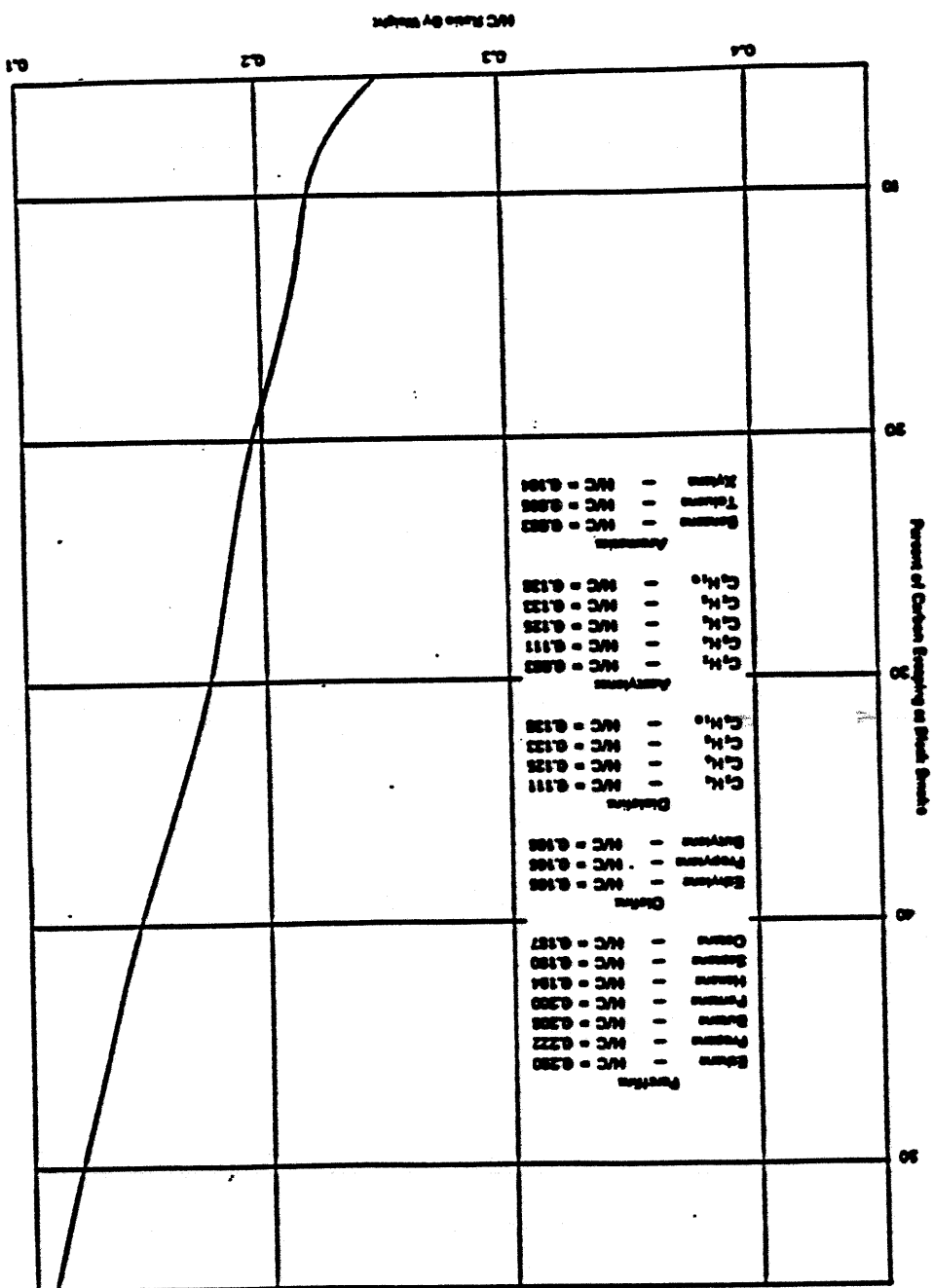
Low Pressure Air

Internal Energized Flare

Smokeless Rate

$$\text{Pounds Steam} = \text{Pounds Hydrocarbon} \left(0.68 - \frac{10.8}{mw} \right)$$

Flaring and Disposal



AUXILIARY FUEL REQUIREMENT

The flare tip diameter is a function of the vent gas flow rate plus the auxiliary fuel and purge gas flow rates. Some flare are provided with auxiliary fuel to combust hydrocarbon vapors when the lean flare gas stream falls below the flammability range or heating value necessary to sustain a stable flame. The amount of fuel required (F) is calculated based on maintaining the vent gas stream net heating value at the minimum of 300 Btu/scf required as described in the United States Federal Register:

$$(Q * B_v) + (F * B_f) = (Q + F) * (300 \text{ Btu/scf})$$

Where:

Q = vent stream flow rate, scfm

B_v = Btu/scf of the vent stream

B_f = Btu/scf of the fuel stream

Therefore,

$$F \text{ (scfm)} = Q * (300 - B_v) / (B_f - 300)$$

The annual auxiliary fuel requirement (F_a) is:

$$F_a \text{ (Mscfm/yr)} = (F \text{ scfm}) * (60 \text{ min/hr}) * (8760 \text{ hr/yr})$$

$$F_a \text{ (Mscfm/yr)} = 526 * F$$

FLARE TIP DIAMETER

Flare tip diameter is generally sized on a velocity basis, although pressure drop must also be checked. Flare tip sizing must also comply with the Federal Register (40 CFR 60.18) for the maximum velocity of steam-assisted, elevated flares:

NET HEATING VALUE OF VENT STREAM Bv (Btu/scf)	MAXIMUM VELOCITY Vmax (ft/sec)
< 300	60
300 - 1000	$\log_{10}(V_{max}) = (Bv + 1214)/852$
> 1000	400

It is standard practice to size the flare so that the design velocity of flow rate Q_{tot} is 80 percent of V_{max} :

$$D_{min} \text{ (in)} = 12 * [((4/PI)(Q_{tot}/60\text{sec/min})) / (0.8 * V_{max})]^{0.5}$$

$$D_{min} \text{ (in)} = 1.95 * (Q_{tot}/V_{max})^{0.5}$$

Where: $Q_{tot} = Q + F$ (measured at stream temperature and pressure) scfm

D_{min} should be rounded up to the next largest available commercially size.

A pressure drop calculation is required at this point to ensure that the vent stream has sufficient pressure to overcome the pressure drop occurring through the flare system at maximum flow conditions.

Propane : @ 100°F Sonic Velocity = 841 ft/sec
K = 1.12

$$\% \text{ Mach} = 400 / 841 = 0.48$$

KNOCKOUT DRUM

Knockout drums are used to remove any liquids that maybe in the vent stream. Horizontal and vertical type drums are normally used. The economics of vessel design influences the choice between a horizontal and vertical drum. When a large liquid storage vessel is required and the vapor flow is high, a horizontal drum is usually more economical. Flares designed to control continuous vent streams generally have vertical knockout drums, whereas emergency flares typically have horizontal vessels.

Liquid particles will separate when the residence time of the vapor or gas is equal to or greater then the time required to travel the available vertical height at the dropout velocity of the liquid particles and the vertical gas velocity is sufficiently low to permit the liquid dropout to fall. This vertical height is usually taken as the distance from the liquid surface. The vertical velocity of the vapor and gas should be low enough to prevent large slugs of liquid from entering the flare. Since the flare can handle small droplets, the allowable vertical velocity in the drum may be based on the necessary to separate droplets from 300 to 600 micrometers in diameter. The dropout velocity (U) of a particle in a stream or the maximum design vapor velocity is as follows:

$$U \text{ (ft/sec)} = G ((p_1 - p_v)/p_v)^{0.5}$$

Where: G = design vapor velocity factor
 p_1 and p_v = liquid and vapor densities, lb/ft³

$$((p_1 - p_v)/p_v) = \sim p_1/p_v$$

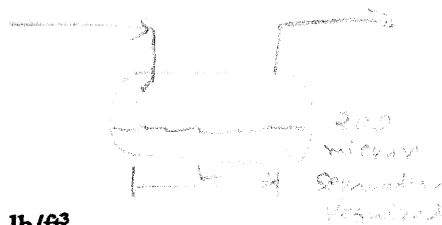
The design vapor velocity factor (G) ranges from 0.15 to 0.25 for vertical gravity separators at 85% of flooding. Once the design vapor velocity has been determined the minimum vessel cross-sectional area (A) can be calculated:

$$A \text{ (ft}^2\text{)} = Q_a \text{ (ft}^3\text{/min)} / [(60 \text{ sec/min}) * (U \text{ ft/sec})]$$

where Q_a is the vent stream flow in actual ft³/min or Q adjusted to the vent stream temperature and pressure. The vessel diameter (d_{min}) is calculated as follows:

$$d_{min} \text{ (in)} = (12 \text{ in/ft}) * [(4/\pi) * (A \text{ ft}^2)]^{0.5}$$

$$d_{min} \text{ (in)} = 13.5 (A)^{0.5}$$

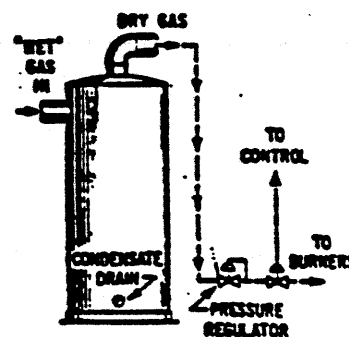
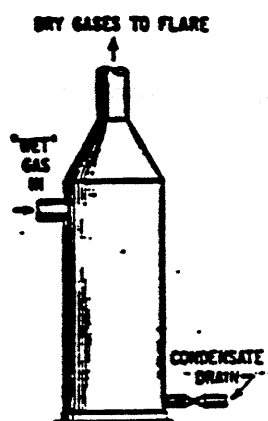


KNOCK-OUT DRUMS

PRINCIPLE FEATURES:

- A. COMPLETE REMOVAL OF EITHER SLUGS OR MISTS OF LIQUID.
- B. RECOVERS VALUABLE CONDENSED HYDROCARBONS.
- C. ENDS MAINTENANCE DIFFICULTY CAUSED BY "WET" GASES.
- D. USED AS THE BASE FOR THE FLARE RISER.
- E. ENDS "WET GAS" CONTROL PROBLEMS.

AT THE FLARE, LIQUID HYDROCARBONS CAN CREATE GREAT FIRE HAZARD DUE TO A SPRAY OF BURNING OIL; CAN CAUSE BLACK-SMOKE; CAN ADD TO FLARE MAINTENANCE AND RESULT IN UNNECESSARY LOSS OF HYDROCARBONS.



CONCENTRATION AT GRADE

AVERAGE TARGET CONCENTRATION AT GRADE,
DOWNWIND OF THE STACK, IS IN THE
ORDER OF 0.10 PPM.

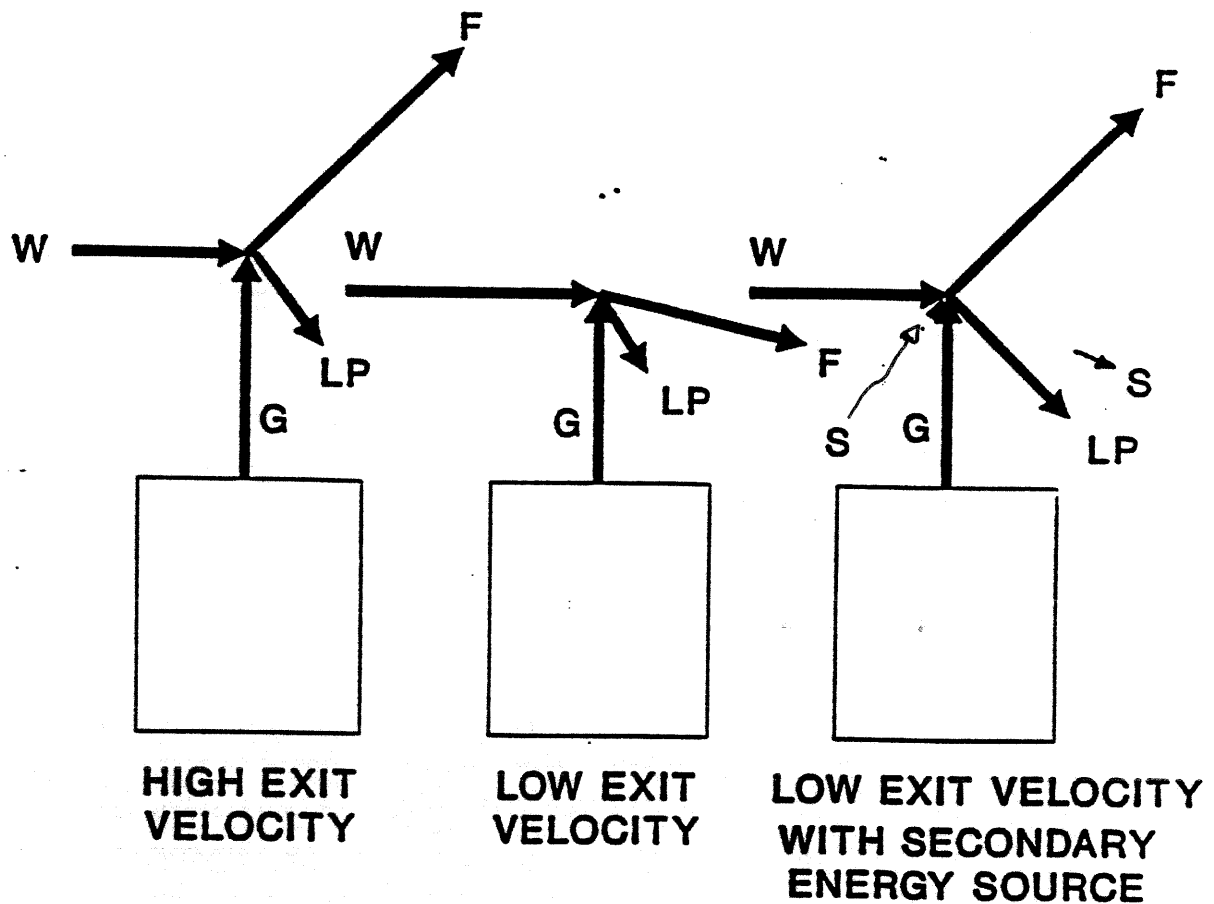
THE FOLLOWING SUBSTANCES WILL CAUSE ODOR
NUISANCE IN CONCENTRATIONS AS SHOWN:

ISOBUTYL	ALCOHOL	0.003 PPM
ISOAMYL	ALCOHOL	0.0026 PPM
METHYL	MERCAPTAN	0.041 PPM
ETHLY	MERCAPTAN	0.0028 PPM
n-PROPLY	MERCAPTAN	0.0016 PPM
n-BUTYL	MERCAPTAN	0.001 PPM
n THIOCRESOL		0.0027 PPM
ETHYL	SULFIDE	0.000056 PPM
PROPYC	SULFIDE	0.011 PPM

**FLASH-BACK PROBABILITY IN PREMIX BURNERS
WITH VARIOUS FUELS AS THEY COMPARE WITH
FLASH-BACK CHARACTERISTICS OF METHANE.**

FUEL	RATIO UPPER/LOWER EXPLOSIVE LIMITS	PROBABILITY OF FLASH-BACK
METHANE	3.00	1.00
PROPANE	5.25	1.75
ACETYLENE	32.00	INFINITE
CARBON DISULFIDE	40.00	INFINITE
ETHYLENE OXIDE	26.66	INFINITE
HYDROGEN	18.55	INFINITE
CARBON MONOXIDE	5.93	INFINITE

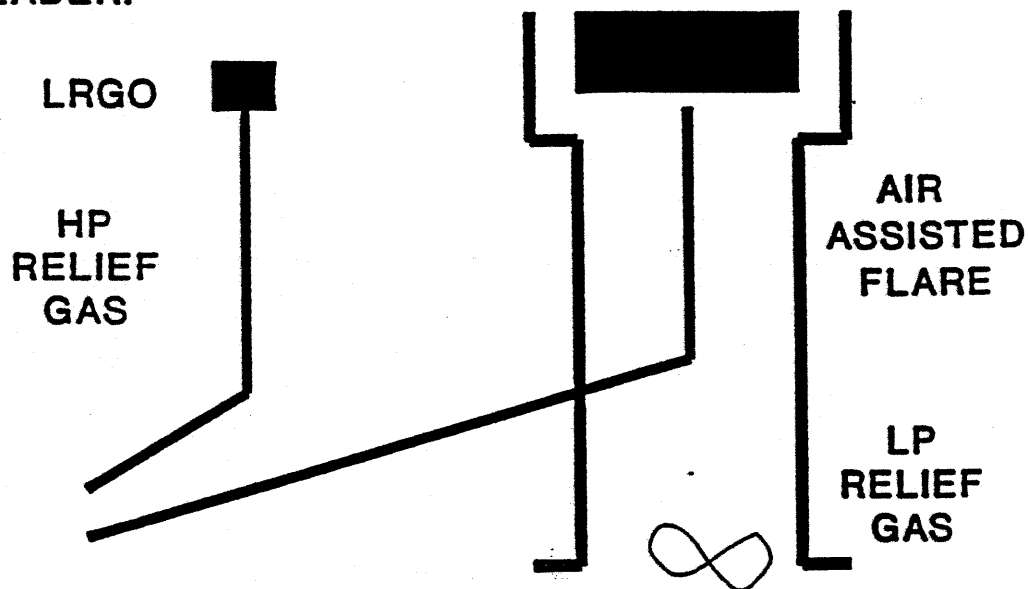
IMPROVE FLARE BURNER LIFE VECTOR DIAGRAMS



W = WIND
F = FLARE
LP = LP ZONE
G = GAS JET
S = SUPPLEMENTARY ENERGY

DUAL PRESSURE SYSTEM

SOME FLARE SYSTEMS HAVE TWO DISTINCT PRESSURE RELIEF LEVELS. IN THESE SITUATIONS, THERE WILL BE BOTH A LOW PRESSURE HEADER AND A HIGH PRESSURE HEADER.

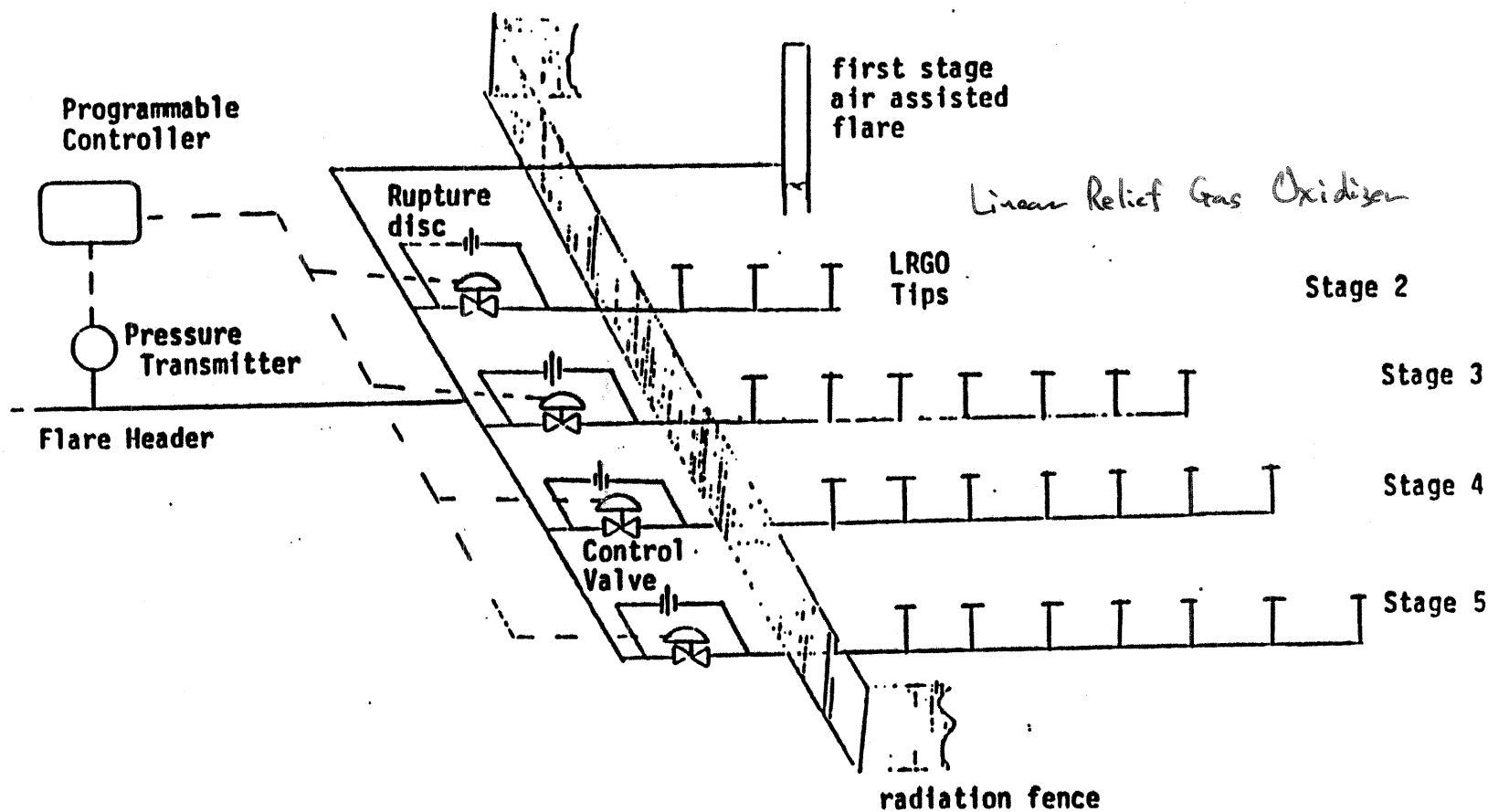


SINCE, SMOKELESS BURNING IS AN OBJECTIVE, AN LRGO CAN READILY BE USED FOR THE HIGH PRESSURE SYSTEM. SMOKELESS BURNING OF THE LOW PRESSURE GASES, HOWEVER, PRESENT AN INTERESTING DESIGN PROBLEM. SINCE, THE STREAM IS AT LOW PRESSURE THERE IS VERY LITTLE KINETIC ENERGY AVAILABLE AT THE COMBUSTION ZONE. THEREFORE, A SECONDARY SOURCE SHOULD BE USED TO ADD KINETIC ENERGY.

$$SV = \frac{(10.72)(T)(Z)}{(P)(MW)}$$

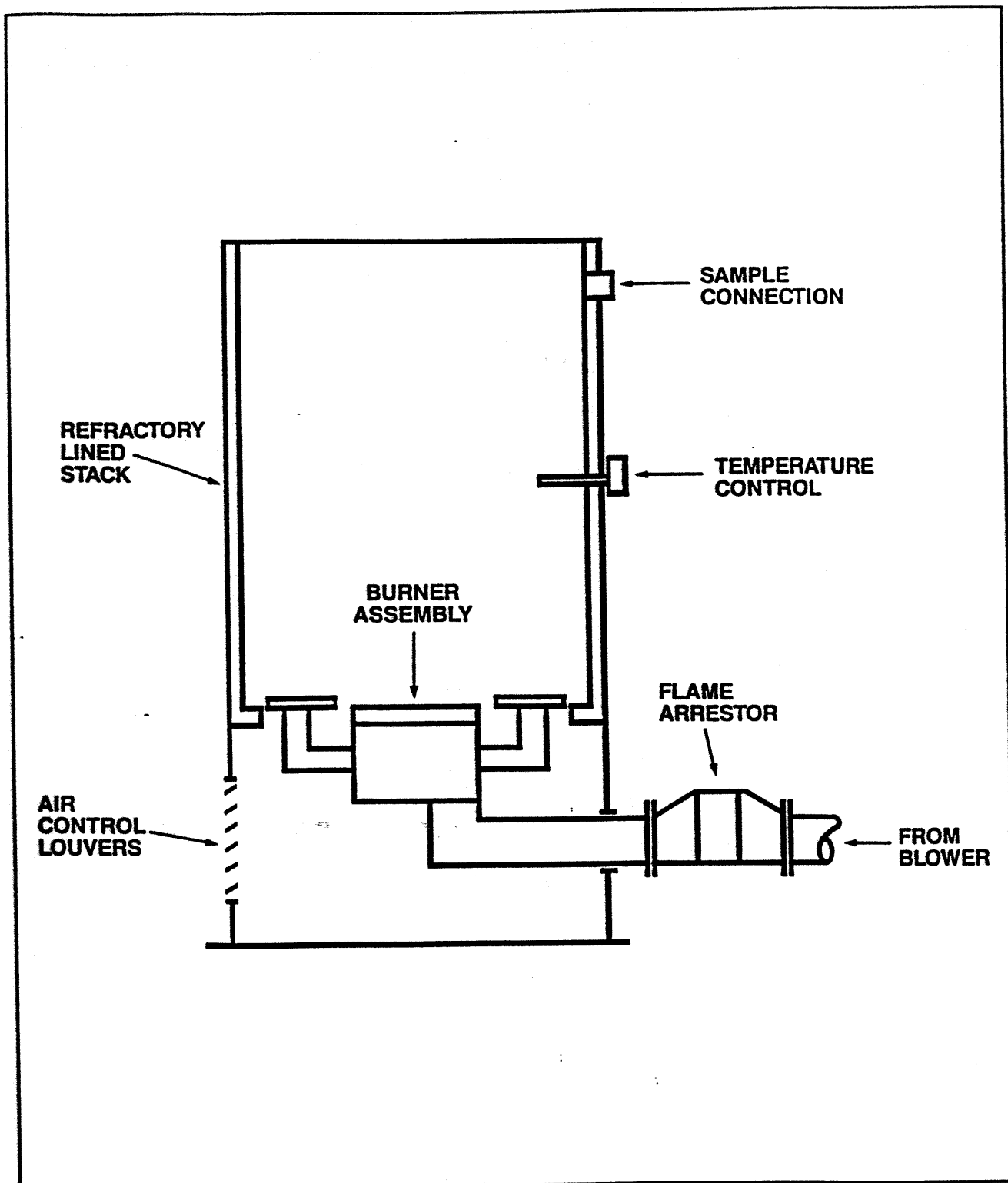


JOHN ZINK COMPANY

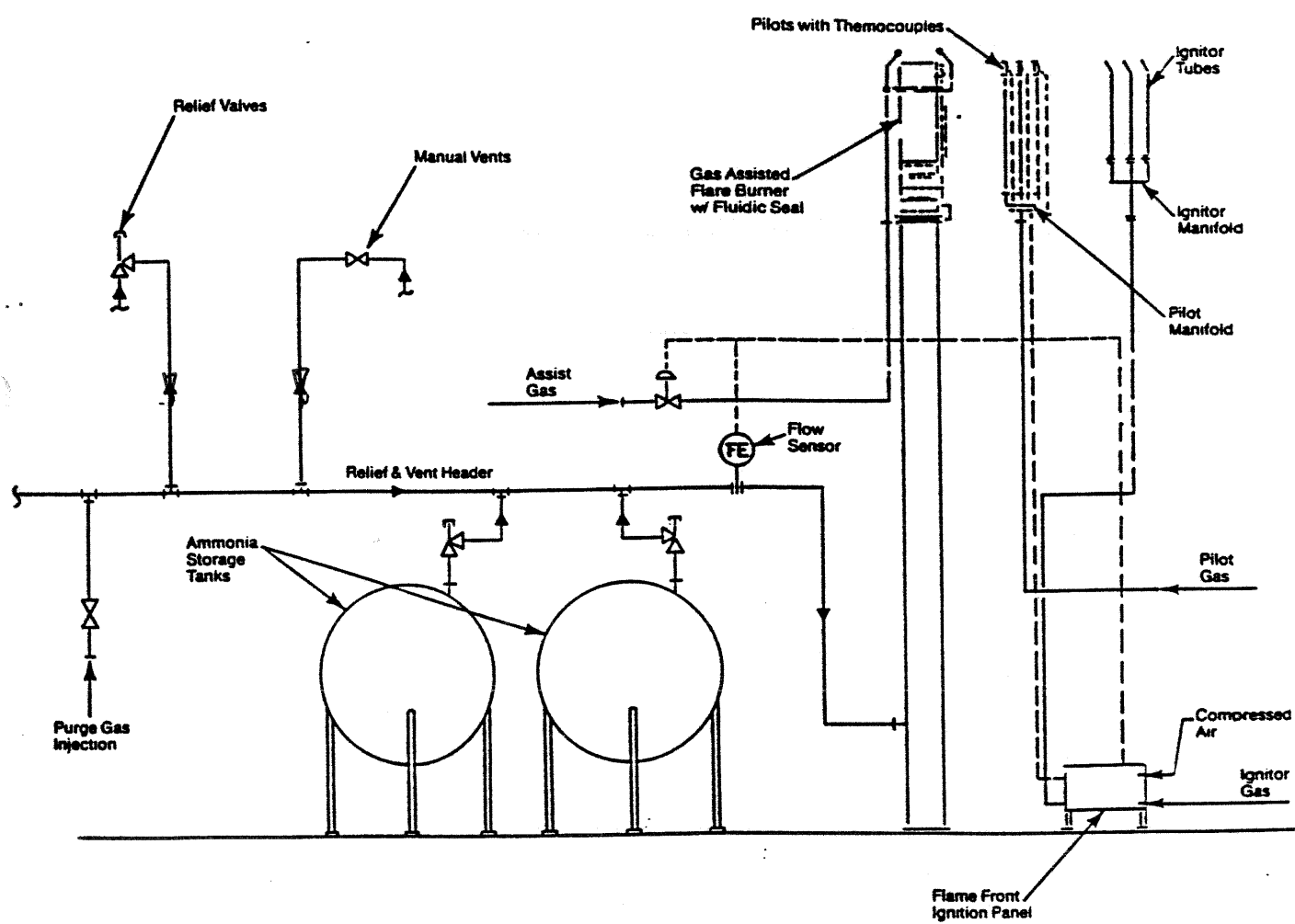


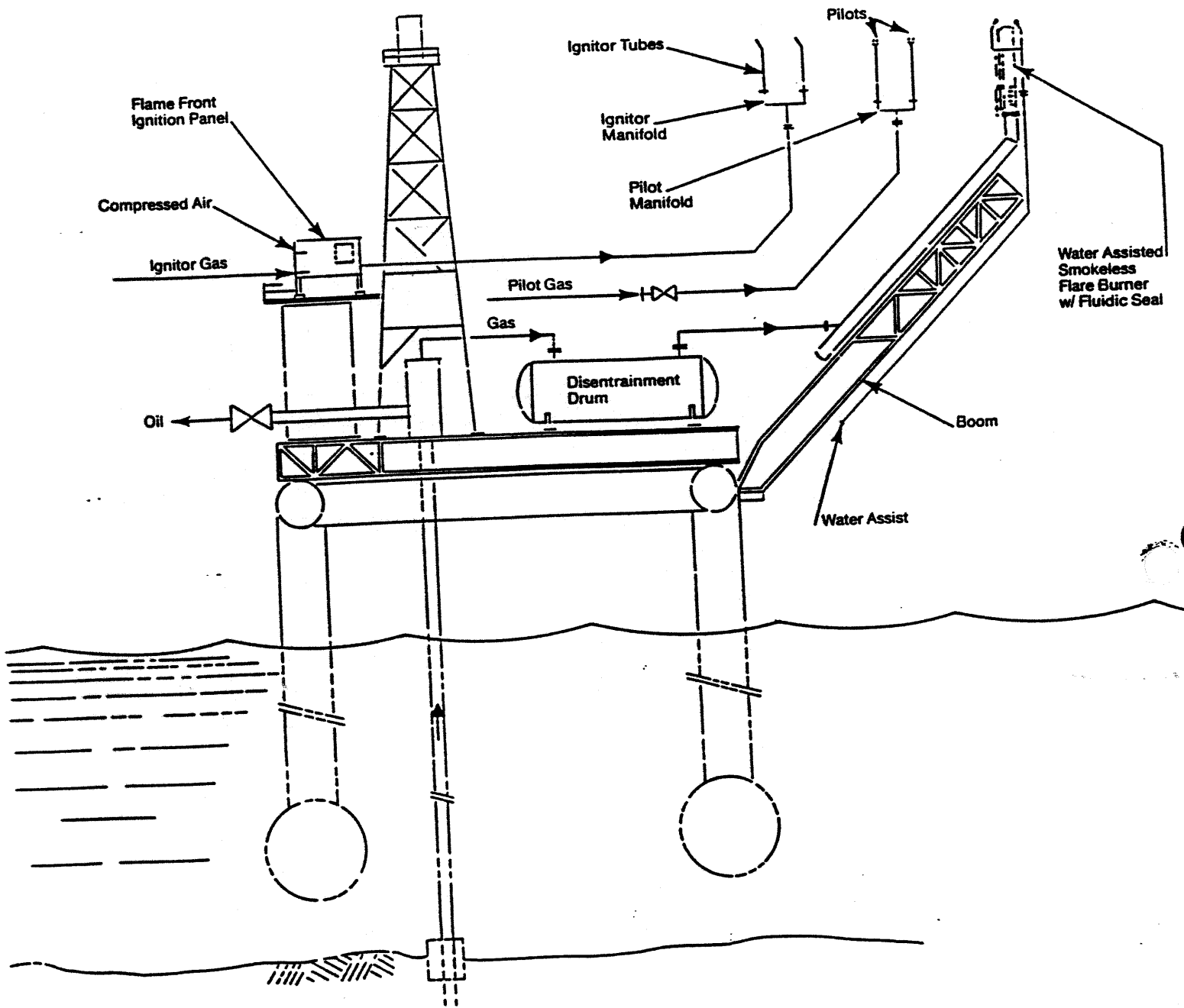
Illustrative LRGO Arrangement

JCC 5/85



TYPICAL ENCLOSED FLARE

NH₃ PLANT



OFFSHORE
PLATFORM

FLARE NOISE

At high flow rates and if steam or another medium is being used to make a flare smokeless normally causes a noise problem. There are special low-noise design, elevated or enclosed flare, can be purchased with acoustical treatment to reduce the noise. Noise is not a safety problem, except in applications such as offshore platforms where it may be impossible for operating personnel to hear warnings or other instructions.

Predicting flare combustion noise is important to ensure the flare is a certain distance from inhabited areas. Generally, it is not feasible to increase the stack height to lower the overall noise at a particular point. Depending on the spectrum, a lower power noise source may sound louder than a higher power source.

A sound source radiates power. The total power of the source is W_t watts. The sound power W watts is the fraction of the total power that is transmitted by the sound waves. The total power is given by the total thermal power:

$$W = eW_t, \text{ watts}$$

The ratio (e) of sound power to total thermal power of the source is also known as acoustical efficiency. Typical hydrocarbons have an e of between 10^{-7} to 10^{-9} .

The sound power level is defined as:

$$PwL = 10 \log W/W_o, \text{ dB}$$

W_o = reference sound power, watts, W = sound power, watts

The level is used to indicate a logarithm. In acoustics, the reference sound power is:

$$W_o = 10^{-12} \text{ watt}$$

The sound power is proportional to the square of sound pressure. The sound pressure level is defined by:

$$SPL = 10 \log (P/P_{ref})^2 = 20 \log P/P_{ref}, \text{ dB}$$

P = rms sound power, N/m^2

P_{ref} = reference rms sound pressure = $2(10^{-5}) N/m^2$

$$SPL = PwL - 20 \log R - 0.5, \text{ dB}$$

85 dBA

15

8 hours/day

INCINERATOR DESIGN

A. Function

The function of an incinerator is the destruction of organic and inorganic waste.

B. Mechanism: Oxidation reaction

Where endo-exothermic oxidation is the waste disposal process, the end products required are those of complete oxidation. Any waste containing elements which oxidize on exposure to adequate heat for a great enough time can be disposed of by oxidation whether they are in the liquid, solid or gaseous phase.

Requirements for such disposal methods must be based on the design temperature level, great enough residence at the design temperature level, a suitable condition of controlled turbulence and the presence of adequate amounts of oxygen.

Temp.
Time
Turbulence

C. Factors:

Factors time, temperature and turbulence which are classic for burning of fuels becomes factors in the disposal by oxidation. Autoignition temperature of disposal products are of small concern.

PRINCIPLES OF COMBUSTION

Burners

Ignite the Fuel and organic material

Chamber

Appropriate residence time for oxidation process

Three T's of Combustion

Temperature

Time

Turbulence

Not independent variables

RESIDENCE TIME OF GASES IN COMBUSTION CHAMBER

Calculated From:

$$t = V/Q$$

t = Residence Time (s)

V = Chamber Volume (ft³)

Q = Gas Volumetric Flow Rate at Combustion Conditions (ft³/s)

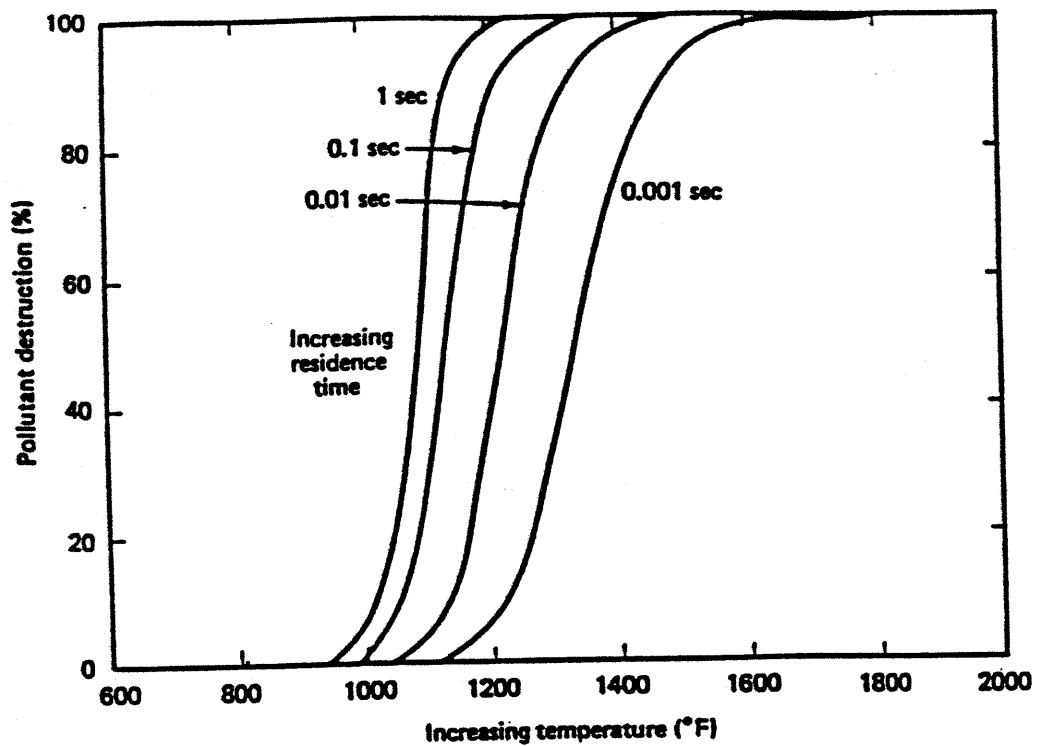


FIGURE 1. Coupled Effects of Temperature and Time on Rate of Pollutant Oxidation

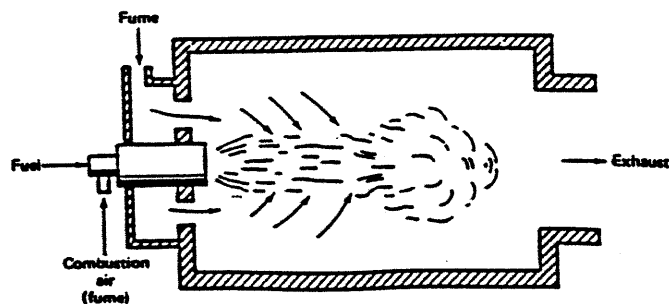


FIGURE 3. Schematic of a Thermal Incinerator

FLARE PRESSURE DROP

The total system pressure drop is a function of the available pressure of the vent stream, the design of the various system components, and the flare gas flow rate. The design pressure drop through the flare tip can range from 0.1 to 2 psi with the following approximate pressure drop relationships:

DESCRIPTION	PRESSURE DROP
Gas seal	1 to 3 times flare tip pressure drop
Stack	0.25 to 2 times flare tip pressure drop
Liquid seal and Knockout drum	1 to 1.5 times flare tip pressure drop plus pressure drop due to liquid depth in the seal, which is normally 0.2 to 1.5 psi
Gas collection system	Calculation based on diameter, length, and flow. System is sized by engineer to utilize the pressure drop available and still leave a pressure at the stack base of between 2 and 10 psi.
Total system	Typical total system pressure drop ranges from about 1 to 25 psi

~ 1 psi FLARE TIP
~ 2 psi GAS SEAL
1 psi LIQUID SEAL

PURGE GAS REQUIREMENTS

The total flow to the flame must be carefully controlled to prevent low flow flashback problems and to avoid flame instability. Purge gas is typically fuel gas, natural gas, or nitrogen. The purge is required to maintain a minimum flow so that the flare header can operate under positive pressure. If there is a possibility of air in the flare manifold, nitrogen or another inert gas must be used to prevent the formation of an explosive mixture in the flare system.

UOP's recommendation is to purge all subheaders at the farthest upstream point in the flare transport piping.

The minimum continuous purge gas required is determined by the design of the stack seal. Stack seal are normally designed by the flare manufacturers. Typical modern molecular seals or internal gas seals are stated to require a gas velocity of 0.001 to 0.04 ft/sec (at standard conditions). Normally 0.04 ft/sec is used and knowing the flare diameter (in) the annual purge gas volume (F) can be calculated:

$$F \text{ (Mscf/yr)} = (0.04 \text{ ft/sec}) * ((\pi * D^2 / 4) / (144 \text{ ft}^2)) * (3600 \text{ sec/hr}) * (8,760 \text{ hr/yr})$$

$$F \text{ (Mscf/yr)} = 6.88 * D^2$$

One must also consider the minimum flare tip velocity for operation without flashback or instability. This minimum velocity is dependent on both gas composition and diameter and can range to 0.5 ft/sec for large flares.

Purge gas is also required to clear the system of air before startup and to prevent a vacuum from pulling air back into the system after a hot discharge is flared.

TYPICAL WIND VELOCITY = 100 miles per hour

EQUIPMENT DESIGN

FLARE PROBLEM

Design and cost a complete flare system based on the following data:

DESCRIPTION	UNITS
Flow rate	63.4 acfm (399.3 lb/hr)
Heat Content	449 Btu/scf
System Pressure	10 psig @ source
System Pressure	1 psig @ flare tip
Temperature	90°F
Liquid Density	49.60 lb/ft ³
Vapor density	0.08446 lb/ft ³
Operating hours	8,760 hrs/yr
Natural gas	\$3.03/1000 scf
Steam	\$4.65/1000 lbs
Operating labor	\$15.64/hr
Maintenance labor	\$17.21/hr

EQUIPMENT DESIGN

1. Determine the appropriate flare tip diameter. Knowing the lower heating value of the vent stream the maximum allowed velocity can be calculated.

$$\log_{10} V_{\max} = (449 \text{ Btu/scf} + 1214)/852$$

$$1.95$$

$$V_{\max} = 89.5 \text{ ft/sec}$$

Because the stream is above 300 Btu/scf, no auxiliary fuel is required. Therefore, Q_{tot} equals the vent stream flow rate.

$$D_{\min} = 1.95 * (Q_{\text{tot}}/V_{\max})^{0.5}$$

$$D_{\min} = 1.95 * (63.4 \text{ acfm}/89.5 \text{ ft/sec})^{0.5}$$

$$D_{\min} = 1.64 \text{ in (use 2 inches)}$$

EQUIPMENT DESIGN

2. Determine the stack height.

Heat release from the flare is calculated by:

$$R \text{ (Btu/hr)} = (W \text{ lb/hr})(B_v \text{ Btu/lb})$$

$$B_v = 449 \text{ Btu/scf} / 0.08446 \text{ lb/scf} = 5316 \text{ Btu/lb}$$

$$R = (399.3 \text{ lb/hr})(5316 \text{ Btu/lb}) = 2,123,000 \text{ Btu/hr}$$

$$L_2 \text{ (ft}^2\text{)} = (t)(f)(R)/((4)(PI)(K))$$

$$L_2 = (1)(0.2)(2,123,000 \text{ btu/hr})/((4)(PI)(500 \text{ Btu/hr-ft}^2\text{)})$$

$$L_2 = 68 \text{ ft}^2$$

$$L = 8.2 \text{ ft (note the smallest available flare is 30 feet)}$$

3. Determine Knockout drum size.

Assuming a design vapor velocity factor (G) of 0.20:

$$U = G*((p_1 - p_v)/p_v)^{0.5} \text{ in ft/sec}$$

$$U = 0.20*((49.60 - 0.08446)/(0.08446))^{0.5}$$

$$U = 4.84 \text{ ft/sec}$$

Given a flare gas flow rate of 63.4 scfm, the minimum vessel cross-sectional diameter is calculated as follows:

$$A = (Q_a \text{ acfm})/((60 \text{ sec/min})(U \text{ ft/sec}))$$

$$A = 63.4/((60)(4.84))$$

$$A = 0.218 \text{ ft}^2$$

This results in a minimum vessel diameter of

$$d_{\min} = 13.5(A)^{0.5}$$

$$d_{\min} = 13.5(0.218)^{0.5}$$

$$d_{\min} = 6.3 \text{ inches}$$

The selected diameter (d) rounded to the next largest 6 inches is 12 inches. Use a 3:1

EQUIPMENT DESIGN

factor and the vessel should be 12 inches diameter X 36 inches high.

EQUIPMENT COST

4. Determine capital cost stack

Self Support Group

$$C_f(\$) = (78.0 + 9.14D + 0.749L)^2$$

Guy Support Group

$$C_f(\$) = (103 + 8.68D + 0.470L)^2$$

Derrick Support

$$C_f(\$) = (76.4 + 2.72D + 1.64L)^2$$

Since the stack height is 30 feet the stack will be self supporting.

$$C_f = (78.0 + 9.14(2) + 0.749(30))^2$$

$$C_f = \$14,100$$

5. Determine vessels thickness and capital cost of knockout drum

DIAMETER, d (inches)	VESSEL THICKNESS, T (inches)
$d < 36$	0.25
$36 \leq d < 72$	0.375
$72 \leq d < 108$	0.5
$108 \leq d < 144$	0.75
$d \geq 144$	1.0

$$\text{Capital Cost of knockout drum} = 14.2[dt(h+0.812d)]^{0.737}$$

$$\text{Capital Cost of knockout drum} = 14.2[(12)(0.25)(36+0.812(12))]^{0.737}$$

$$\text{Capital Cost of knockout drum} = \$530$$

EQUIPMENT DESIGN

The cost for vent stream piping (C_p) is a function of flare diameter (D):

$$C_p(\$) = 127D^{1.21} \text{ (where } 1" < D < 24")$$

$$C_p(\$) = 139D^{1.07} \text{ (where } 30" < D < 60")$$

the costs (C_p) include straight schedule 40 carbon steel pipe only and are based on 100 feet piping and are directly proportional to the distance required.

$$C_p(\$) = 127(2)^{1.21}$$

$$C_p = \$290$$

The total auxiliary equipment cost is the sum of the knockout drum and transport piping costs or \$530 + \$290 = \$820.

The total capital investment is calculated using the following table:

Cost item	Cost
Direct Costs (Purchased equipment costs)	
Flare (self supporting)	\$14,100
Knockout drum and transport piping	<u>820</u>
Sum = A	\$14,920
Instrumentation, 0.1A	1,490
Sales taxes, 0.03A	450
Freight, 0.05A	<u>750</u>
Purchased equipment cost, B	\$17,610
Direct installation costs	
Foundation and supports, 0.12B	2,110
Handling & erection, 0.40B	7,040
Electrical, 0.01B	180
Piping, 0.02B	350
Insulation, 0.01B	180
Painting, 0.01B	<u>180</u>

EQUIPMENT DESIGN

Cost item	Cost
Direct Installed Cost	\$10,040
Site preparation	-----
Facilities and Buildings	=====
Total Direct Cost	\$27,650
<u>Indirect Costs (Installation)</u>	
Engineering, 0.10B	1,760
Construction and field expenses, 0.10B	1,760
Contractor fees, 0.10B	1,760
Start-up, 0.10B	180
Performance test, 0.01B	180
Contingencies, 0.03B	<u>530</u>
Total Indirect Cost	<u>\$ 6,170</u>
Total Capital Investment (rounded)	\$33,800

The Total Capital Investment Costs for this flare system is \$33,800.

Total Annual cost for the flare system is as follows:

Cost item	Calculation	Cost
<u>Direct Annual costs, DC</u>		
Operating Labor		
Operator	630 hr/yr * \$15.64 <i>PA</i>	\$ 9,850
Supervisor	15% of operator = 0.15 * 9,850	1,480
Maintenance		
Labor	0.5hr/shift*shift/8hr*8,760hr/yr*\$17.21/h <i>FA6 F80</i>	9,420
Materials	100% of maintenance labor	9,420
Utilities:		
Electricity		-----
Purge gas	27.5 Mscf/yr * \$3.03/Mscf <i>FA7</i>	80

EQUIPMENT DESIGN

Cost item	Calculation	Cost
Pilot gas	613 Mscf/yr * \$3.03/Mscf	1,860
Steam	1,400 * 10 ³ lb/yr * \$4.65/10 ³ lb	<u>6,510</u>
Total DC		\$38,600
<u>Indirect Annual Cost, IC</u>		
Overhead	60% of total labor and material cost: = 0.6(9,850 + 1,480 + 9,420 + 9,420)	18,100
Administrative charges	2% of Total Capital Investment = 0.02(\$33,800)	680
Property tax	1% of Total Capital Investment = 0.01(\$33,000)	340
Insurance	1% of Total Capital Investment = 0.01(\$33,000)	340
Capital recovery (life)	0.1315 * \$33,800	<u>4,440</u>
Total IC		<u>\$23,900</u>
Total Annual Cost (rounded)		\$62,500

REGULATORY COMPLIANCE

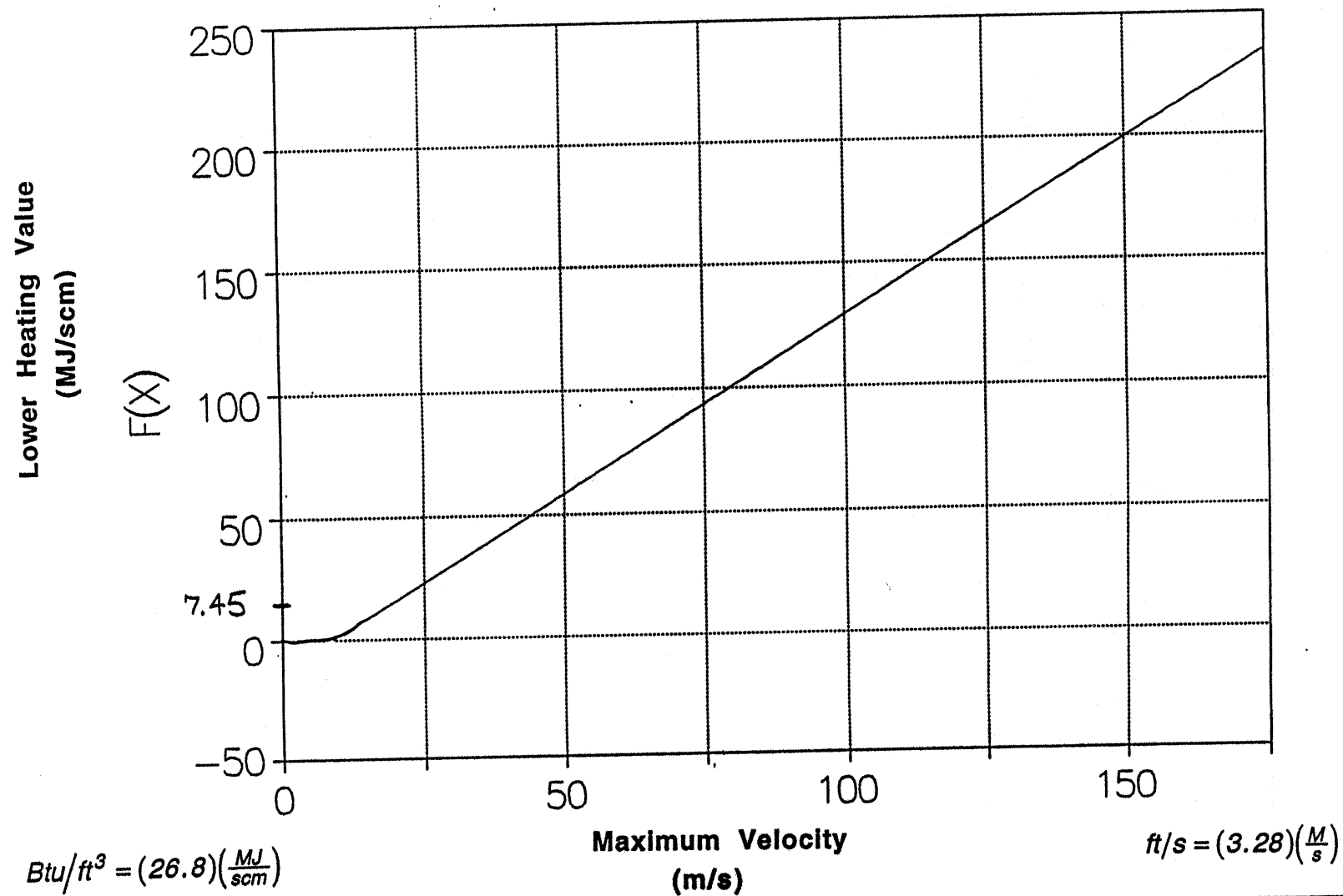
40 CFR 60.18

Flares shall be designed for and operated with no visible emissions except for periods not to exceed a total of five minutes during two consecutive hours. Flares shall be operated with a flame present at all times. Flares shall be used only with the net heating value of the gas being combusted being 11.2 MJ/scm (200 Btu/scf) or greater if the flare is non assisted.

Steam assisted and non assisted flares shall be designed for and operated with an exit velocity less than 18.3 m/s (60 ft/s). The presence of a flare pilot flame shall be monitored using a thermocouple or any other equivalent device to detect the presence of a flame.

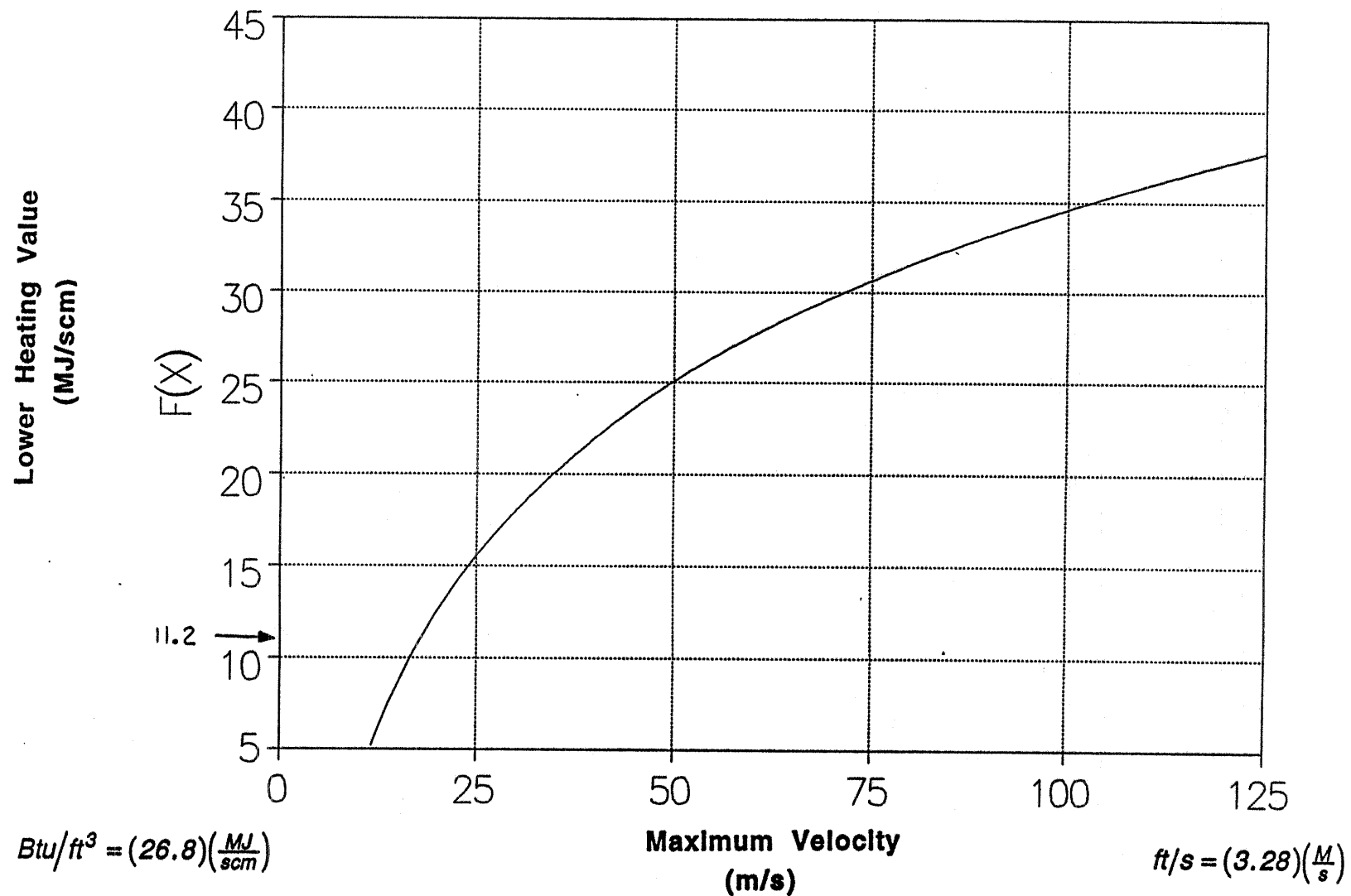
AIR ASSISTED FLARE

$Y=(X-8.706)/0.7084$
TableCurve View: Function(X)
Oct 14, 1994 11:11 AM



NON-ASSISTED FLARE
STEAM ASSISTED FLARE

$Y = 31.7 \cdot \text{LOG}(X) - 28.8$
TableCurve View Function(X)
Oct 14, 1994 10:59 AM



FLARE TIP

The flare tip is designed to give environmentally acceptable combustion of vent gas over the flare system's capacity range. The burner tips are normally proprietary in design. Consideration is given to flame stability, ignition reliability, and noise suppression.

The maximum and minimum capacity of a flare to burn a flared gas with a stable flame is a function of tip design. Flame stability can be enhanced by flame holder retention devices incorporated in the flare tip inner circumference.

Flare tips with modern flame holder designs can have a stable flame over a flare gas exit velocity range of 1 to 600 ft/sec. The actual maximum capacity of a flare tip is usually limited by the vent stream pressure available to overcome the system pressure drop. Elevated flares' diameters are normally sized to provide vapor velocity at maximum throughput of about 50% sonic velocity of the gas subject to the constraints of 40 CFR 60.18.

Failure of Tips

- Internal Burning (Low flow rate)
- Stress Division cracking.

- Inconel 625 } tip
- Incoloy 800 }

Type 321 stainless steel }
Type 347 stainless steel } wing

B
Deviation OVD Vapor line

- less flow - tube rupture
- Higher Temp.
- Lower Temp.

C: OVHD Receiver Deviation

- High press
- Low press
- Low level
- High level

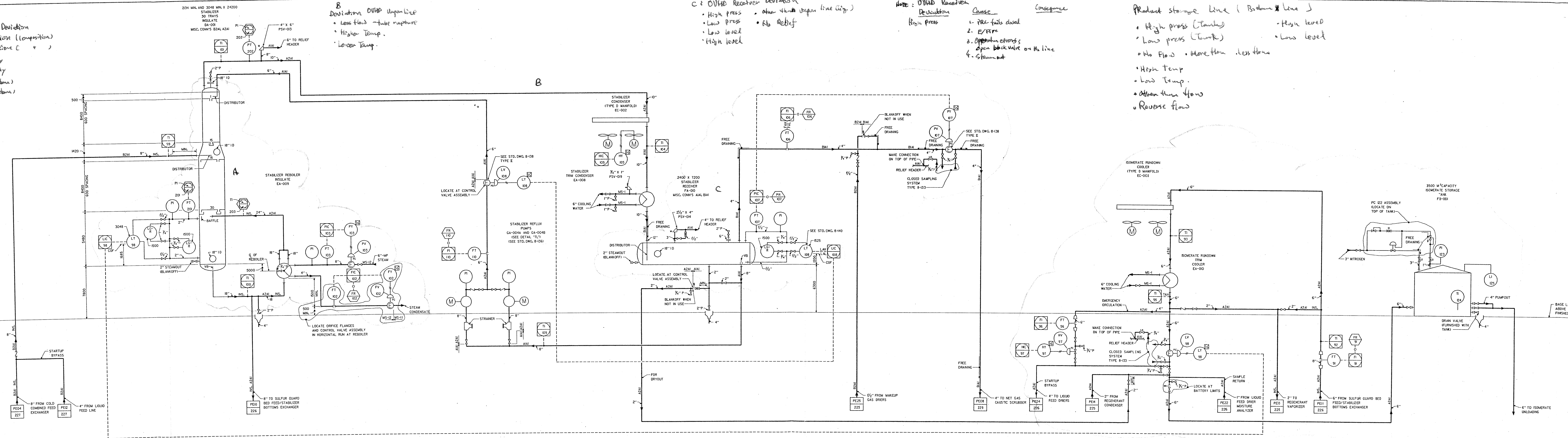
• other than vapor line cap.

• No Relief

Note: Other Reason

<u>Deviation</u>	<u>Cause</u>	<u>Consequence</u>
High Press	1. PRV fails closed 2. E/GRV 3. Operation errors Open back valve on H ₂ line 4. Steam out	

- Product storage line (Bottom line)
- High press (Tandem)
- Low press (Tank)
- No Flow
- More flow
- Less flows
- High Temp
- Low Temp.
- Other than flows
- Reverse flow
- High level
- Low level



THIS P & I DIAGRAM IS DIAGRAMMATIC ONLY. DESIGN OF PIPE LINES MUST BE INVESTIGATED FOR VENTING OF GAS AND VAPOR POCKETS IN PIPING AND EQUIPMENT, LOW POINTS IN PIPING, PUMPS AND EQUIPMENT FOR FREEZING AND DRAINING, AND ACCESSIBILITY OF ALL VALVES, FLANGES, INSTRUMENTS INCLUDING THERMOCOUPLES, ETC.

NOTE - THESE DATA ARE CONFIDENTIAL AND THE PROPERTY OF UOP AND SHALL NOT BE DISCLOSED TO OTHERS OR REPRODUCED IN ANY MANNER OR USED FOR ANY PURPOSE WHATSOEVER EXCEPT BY WRITTEN PERMISSION OR AS PROVIDED IN A SIGNED AGREEMENT WITH UOP RELATING TO SUCH DATA.

[illegible]

4. STEAM FLARE

TYPICAL SPECIFICATIONS

FLARE TIP REPLACEMENT

ITEM TAG _____

DATE _____

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1. PROJECT OBJECTIVES
2. SCOPE OF SUPPLY
3. PROPOSAL REQUIREMENTS
4. APPLICABLE SPECIFICATIONS AND STANDARDS
5. PROCESS DESIGN BASIS
6. UTILITIES
7. SITE DATA
8. GENERAL MECHANICAL REQUIREMENTS
9. FLARE TIP ASSEMBLY
10. FLARE TIP PIPING
11. PILOTS
12. MECHANICAL DATA SHEET
13. VENDOR DATA SUBMITTAL REQUIREMENTS
14. EQUIPMENT NOISE CONTROL DATA SHEET

1.0 PROJECT OBJECTIVES

The existing flare tips will be replaced during the _____ turnaround. Key objectives for the new flare tips are:

- Increased flare tip life (improved mechanical design).
- A high hydrocarbon destruction efficiency flare tip design.
- Low steam usage.
- Low noise flare design.
- Mechanically compatible with the existing stack/steam connections. Client does not want to field weld at high elevation if at all possible.

2.0 SCOPE OF SUPPLY

Design and supply two replacement flare tips in accordance with the attached specifications. Each Flare Tip (Item SP-_____ and Item SP-_____) shall include as a minimum:

- High efficiency flare tip made entirely of stainless steel with ____" flanged carbon steel connection.
- Four pilots. Each pilot shall include a thermocouple for pilot monitoring.
- Pilot gas manifold designed to match the appropriate riser on the flare stack.
- Steam piping designed to match the steam risers on the flare stack.
- 100% radiography of the stainless steel welds on the steam manifold and steam nozzle connections and 10% of the remaining stainless steel welds.

3.0 PROPOSAL REQUIREMENTS

3.1 Seller shall include the following data and drawings with his proposal:

- Sketch representing scope of supply
- Cross sections and general arrangements drawings
- Completed Flare Tip Data Sheet(s) - included in this requisition
- Utilities Requirements
- Performance Guarantees
- Pilots and Ignitors
- Steam Distribution System
- Piping and Supports to connect to existing lines where applicable
- Terminal Connections - Types and Locations, as required
- Materials of Construction
- Refractories and Supports (if required)
- Prefabrication and Shop Assembly - Description of extent, weights, etc.
- Noise Mufflers and Noise Data Sheet completed
- Overall Project Schedule

4.0 APPLICABLE SPECIFICATIONS & STANDARDS

4.1 Client Standards

_____ **Noise Control**
_____ **Equipment Noise Control**

4.2 National Standards

- ♦ ANSI B31.3 Code for Petroleum Refinery Piping
- ♦ Applicable OSHA Requirements
- ♦ API RP 521 Flare Design Guide
- ♦ CFR 40.60.18 Flare Design Requirements.
- ♦ Any other applicable National Code.

4.3 Reference Drawings (Attached)

4.4 Order of precedence between this specification and attachments is as follows:

- ♦ Requisition
- ♦ Data Sheets
- ♦ Standard Specifications
- ♦ Codes

5.0 PROCESS DESIGN BASIS

5.1 Maximum Flow

The flare tip shall handle the loads based on the process conditions in Cases I, II, III, and IV shown in the attached Table 1.

Vendor shall provide tip velocities, pressure drop and Mach number for the maximum flow condition.

Flare tip shall be designed to provide stable burning of all quantities of flared gases up to the maximum under all wind and atmospheric conditions without damage to parts.

5.2 Smokeless Flow

The flare tip shall smokelessly combust the flare gases as listed in Table 1 with minimum steam usage. Vendor shall provide test or field data to verify performance guarantee.

Vendor to also provide guaranteed steam flow for cooling steam.

5.3 Noise

Vendor shall submit expected and guaranteed noise levels (dBA at 1000 ft from the stack) based on zero wind conditions for the following conditions:

- ♦ Maximum design flow rate
- ♦ Maximum smokeless rate
- ♦ 10% of maximum smokeless rate

Vendor shall provide the basis for the noise levels calculations.

5.4 Flame Stability

The flame shall be stable and burn without pulsation or cyclical operation over the entire flow range (purge to maximum flow). The vendor shall identify conditions that would cause unstable flare operation.

5.5 Radiation

Vendor shall provide ground level radiation curves for Case III and Case IV flow rates based on a ____ ft high stack and a 20 mph wind speed.

Vendor shall detail the deviations between API RP 521 and the calculation method used to determine the expected radiation levels.

5.6 Flare Tip Life

Client routinely operates 5 years between turnarounds and would expect to obtain at least 10 years service from the new tips. The vendor shall discuss methods of maximizing the flare tip life. Specifically address the steam manifold and internal steam tube construction.

5.7 Thermal Degradation / Burnback

The flare will routinely burn methane, methanol, hydrogen and other light hydrocarbons which will not require steam for smokeless operation. Vendor shall discuss methods of preventing tip damage due to internal burning. Vendor shall also discuss methods used to prevent damage to external steam rings and injector tubes.

Vendor shall address method of preventing flame lick on the downwind side of the flare and method of preventing flame recirculation into the lower steam injectors.

5.9 Destruction Efficiency

Seller shall guarantee 99% destruction efficiency in writing and signed by officer of the company at time of accepting Client's purchase order. Vendor shall supply data and information to support the guarantee.

TABLE 1
Flare Gas Composition

Case I :
Case II :
Case III:
Case IV:

Flare Gas Composition	Case I (Vol %)	Case II (Vol %)	Case III (Vol%)	Case IV (Vol %)
Hydrogen				
Carbon Monoxide				
Methane				
Acetylene				
Ethylene				
Ethane				
Propylene				
Propane				
Butadienes/C4 Acetylenes				
Butylenes				
Butanes				
C5's				
C6-C8 Non Aromatic				
Benzene/Toluene/Xylene				
Styrene				
C9 - 400F BP				
Methanol				
Hydrogen Sulfide				
Carbon Dioxide				
Water (Steam)				
Total Vol %	100	100	100	100
Total Flow (lb/hr)				
Total Flow (mol/hr)				
MW				
Temp (F)				
Smokeless Capacity (lb/hr)				

6.0 UTILITIES

6.1 Fuel Gas Composition

Component	Normal Vol %	Startup Vol %
H2		
CO		
CH4		
C2H6		
N2		
Propane		
Butane		
MW		
LHV (BTU/Lb)		
HHV (BTU/SCF)		
Pressure (psig)		
Temperature (F)		

6.2 Steam

Available at ____ psig and approximately ____ F at the base of the stack.

The current tip uses steam in ____ stages with the following capacities:

Steam Line	Size	Max Flow (lb/hr)	Min Flow (lb/hr)
FV-1	__"		
FV-2	__"		
FV-3	__"		
TOTAL	---		

Vendor should indicate if differing quantities or distribution of steam is required. Vendor is to guarantee cooling steam requirement and steam flow for maximum smokeless operation.

7.0 SITE DATA

Geographic Location _____, Texas

Elevation _____ feet above M.S.L.

Ambient Temperature -20F to 120F

Humidity 100%, Salt Laden Air

Electrical Area Classification Class I, Group D, Div ____

Design Wind Speed _____ mph

Electric Power Available
at Flare Controls Skid 460V, 3 Phase, 60 HZ

Instrument Air 100F @ 90 psig, Dry

Plant Air 100F @ 90 psig

Nitrogen 90F @ 160 psig, Dry

Steam (at flare tip) _____ psig @ _____ oF

8.0 GENERAL MECHANICAL REQUIREMENTS

This specification covers the minimum requirements for the design, fabrication, testing/inspection and supply of two (2) complete flare tip assemblies including:

The Seller shall furnish the flare tip assembly completely assembled. As a minimum, the flare tip shall include the required flare tip section assembly with burners, pilots, headers, rings, manifolds, and required piping.

Client will furnish installation, and wiring between existing control panel and flare tip assembly.

Seller shall supply a flare tip assembly system of high efficiency design except as modified by this specification and attachments. Seller shall utilize to maximum extent the existing stack, existing piping to minimize downtime, the existing flame front generator and other items / components related to the existing flare system.

8.1 Shop Assembly

Shop fabrication of the flare tip assembly and associated equipment shall be maximized in order to minimize assembly and erection requirements in the field. The Seller shall guarantee that all flare tip and associated piping flanges will properly mate to the existing stack connections.

The Seller shall furnish a complete and detailed description of the extent of his shop assembly of parts and the additional field work required to complete the installations. LPC shall witness vendor verification of all assembly dimensions.

8.2 Materials of Construction

The Seller shall select materials suitable for the design temperatures and pressures. Materials shall conform to the applicable ASTM specifications. Minimum wall thickness shall be 1/4 inch. Material Test Reports (MTR) shall be supplied for all stainless steel components.

8.3 Corrosion Allowance

The flare tip assembly and other metal parts in contact with the flare gas or utility fluids shall be designed with a minimum corrosion allowance of 1/8 inch for carbon steel and 1/16 inch for stainless steel.

8.4 Welding Requirements

All welding shall be in accordance with the applicable codes and specifications of this requisition. The seller shall submit to Client for review and approval of the weld maps, weld descriptions, welding procedure specifications and applicable procedure qualification records.

8.5 Weld Inspection

All welds on the steam manifold, riser, steam tip and internal steam/air tubes shall receive 100% radiography. Unacceptable welds shall be repaired and x-rayed again. 10% of the remaining welds shall also be radiographed. Client inspectors shall have the authority to require additional radiography at Client's expense.

8.6 Painting

Surface preparation and painting (carbon steel only) shall consist of a SSPC-SP-6 "White metal" sandblast and a 3 mil inorganic zinc primer with 3 mil top coat of high temperature silicon aluminum paint.

8.7 Shipping and Handling

The flare tip assembly and auxiliary equipment shall be suitably packed and protected for shipment to the jobsite. Sufficient permanently attached lugs, braces, and struts shall be installed by the Seller to permit handling with conventional slings and hooks without damage to the equipment during shipment and at the construction site.

Shipping saddles shall be used to support the flare tip. The steam manifolds shall not be used to support the flare tip during shipment.

8.8 Tagging

Seller shall securely attach a stainless steel tag to each shipping piece showing item number, purchase order number, customer's name, and shipping address.

Seller shall bring any conflicts, errors or omissions in this specification, or the referenced documents immediately to the attention of the Client for resolution.

9.0 FLARE TIP ASSEMBLY

9.1 The seller shall furnish flare tip assembly complete with four pilots, pilot flame sensors, noise mufflers, steam manifolds and steam jets.

The flare tip shall also include all required pilot gas manifolds and steam distribution headers, rings, manifolds and runners for complete smokeless operations.

9.2 The upper 8 ft of the flare tip shall be 310 SS (minimum). The lower half shall be 304 SS (minimum).

Flame stabilizers shall be 310 SS. The noise muffler shall be refractory lined carbon steel. Vendor to supply optional price for a 304 SS noise muffler.

9.3 The main connecting flange between the new flare tip and existing stack is a ____" _____ flange. Flange dimensions are ____" O.D. with () ____" diameter holes on a ____" diameter bolt circle per Taylor Forge standard.

Seller shall provide studs, nuts and gaskets. All studs to be B16 high temperature grade with corresponding nuts.

9.4 If refractory lined tips are furnished, the seller shall specify in detail the lining and method of attachment to the flare tip. The refractory lining shall be shop installed and shall be of monolithic installation (without pour joints).

9.5 The flare tip shall include a "velocity type" purge reduction seal made of 304 stainless steel.

9.6 Lifting lugs shall be provided on the flare tip. Trunnion lift lugs are preferred to avoid removing lugs after installation.

9.7 An accurate flare tip weight must be provided with the proposal for the installation subcontractors erection plan.

10.0 FLARE TIP PIPING

10.1 Following are the existing flare tip's connections. Height dimensions start at the bottom of the flare tip flange. 0° orientation is top of page. Radial distance is measured from the flare tip centerline.

Nozzle	Service	Size	Type	Height	Orientation	Radial Dist.
N1	Flare Gas	___"			N/A	N/A
N2	Main Injector Steam	___"	150# RF	___'___"	___°	___'___"
N3	Upper Steam Manifold	___"	150# RF	___'___"	___°	___'___"
N4	Internal Steam	___"	150# RF	___'___"	___°	___'___" Horiz Connection
N6/7/8/9	Ignition Lines	___"	?	___'___"	___°	___'___"
N5	Pilot Gas	___"	?	___'___"	___°	___'___"
C9	Drain	___"	CPLG	___'___"	___°	___'___"

The above dimensions shall not be used for fabrication without vendor review and agreement. The successful vendor will receive drawings of the existing installation in order to confirm the above dimensions.

10.2 All flare tip piping shall be seamless including the steam and pilot gas lines.

10.3 All flare tip piping shall be stainless steel. Minimum stainless steel grades are:

Steam Riser:	304 SS
Steam Manifold / Tips	
- Upper	321 SS / 310 SS
- Lower	CS / 304 SS
Internal Steam Tubes	CS / 310 SS (seamless)
Pilot Gas:	309 / 310 SS
Ignition Gas:	309 / 310 SS

Vendor encourages vendors to submit alternate designs or material that will improve flare tip life.

The connecting steam flanges that mate to the stack piping shall be carbon steel (A105).

10.4 The flare tip shall include supports for the steam, pilot and ignition piping. The steam piping support shall be sufficient to support the entire steam line on the flare stack including expansion stresses.

Pipe supports shall be constructed of the highest quality stainless material as the pipe body or flare body.

Vendor shall specify the method of attaching supports to the flare body.

11.0 PILOTS

11.1 The pilots shall be designed for ignition of flared gases under all weather conditions. As a minimum, the pilots shall be able to remain lit in a 100 mph wind and ignite the flare in this wind. The existing flame front generator shall be reused.

11.2 Pilots shall be complete assemblies with wind shields for remote ignition. A pilot gas manifold and piping shall be connected to existing stack riser line (see attached drawings).

11.3 The pilot tip and shield shall be Inconel 601.

11.4 Pilots shall be accessible from top platforms. To facilitate pilot and tip removal, pilot gas and ignition lines shall be provided with flanges adjacent to the top platform.

12.0 MECHANICAL DATA SHEET

ITEM _____

Flare Tip	* (Data By Seller)
Manufacturer	*
Model	*
Quantity	Two
Max Capacity	*
Size x Length	*
Materials of Construction	* Seller to describe
Overall Weight	*
Refractory Insulation	*
No. of Pieces	* As shipped
Qty of Pilots	*
Pilot Material	*

Piping and Flanges	* Seller to describe
Size, Type & Rating	*
Steam	*
Flare Gas	*
Pilot	*
Ignition	*
Material of Construction	*

Steam Ring with Steam Jet Nozzles	
Capacity per Stage	*
Size and No. of Nozzles	*
Materials of Construction	*

Process Data

Max Flow Rate, lb/hr

Mach No.

Pressure Drop (psig)

Tip Velocity (FPS)

*
*
*

Smokeless Flow, lb/hr

Steam Composition

Steam Flow Rate (lb/hr) at

 Max Smokeless Rate

 Cooling Steam

 For Each Stage

0 to _____ (3-stage operation)
150 psig at 500°F

*
*
*

Utilities

Pilot & Purge Gas Type

Pilot Gas Flow Rate, CFH

Purge Gas Flow Rate, CFH

See Fuel Gas Table

* at * psig

*

13.0 VENDOR DATA SUBMITTAL REQUIREMENTS

Provide one full-size reproducible and _____ copies of all drawings and data indicated. Each drawing and data requirement has a priority indicated. Seller shall identify all data submitted by the purchase order number. Priority legend is as follows:

Priority A - Data needed for engineering. Must be submitted as soon as possible. Client approval required.

Priority B - Data must be reviewed by Client before start of fabrication. Client approval required.

Priority X - Data must be submitted prior to equipment delivery, but does not require urgency.

Drawings and Information

Priority	Drawings
A	General arrangements, plans and elevations.
A	Flare tip assembly
A	Auxiliary piping and supports
A	Pilots and ignitors
A	Control panel, controls and instrumentation (as required)
A	Refractory lining, if required
A	Noise control equipment
A	Flare tip data sheets
A	Codes and standards used for design
B	Bill of Material with exact stainless grade
B	Weld quality controls
B	Test pressures and testing procedures
B	Lining installation and dry-out procedures
B	Auxiliary equipment data sheets
X	Manufacturer's data reports as required by code
X	Mill test reports including chemical composition and mechanical tests
X	Certified shop test reports
X	Installation, operating, and maintenance instructions, ____ copies
X	Priced spare parts list recommended by Seller for on hand spares
X	Noise level data sheets

Seller's drawings must be applicable to the equipment furnished. Standard drawings not tailored for this requisition are not acceptable.

14.0 EQUIPMENT NOISE CONTROL DATA SHEET

Client to Attach