



NATIONAL PETROCHEMICAL COMPANY
STANDARDS

ENGINEERING STANDARD
FOR
FLARE STACK

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41 7	NOZZLES, COUPLINGS AND FLANGES
5	<u>MATERIAL OF CONSTRUCTION</u>
6	<u>CORROSION ALLOWANCE</u>
7	<u>JOINT EFFICIENCY</u>
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9	<u>STRESS RELIEF, WINTERIZING AND CONTROL</u>
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SCOPE

- .1 This standard covers the requirements for design and materials of fusion welded selfsupported/guyed/derrick flare stacks (hereafter called stacks), and is intended to supplement the applicable codes.
- .2 This standard does not cover the requirements for fabrication inspection and testing of fusion welded stacks; nevertheless, as far as the fabrication, inspection and testing requirements do pertain to the design of stacks, they have been mentioned.
- .3 The compliance with this standard does not relieve the designer from his own responsibilities and guarantees for the safe mechanical design of stacks.
- .4 This standard when accompanied by the particular stack description, stack drawings, typical details and material standard for flare stack, NPCS-MS-PV-05, constitute a complete set of standards outlining acceptable construction of stack.

STANDARDS AND CODES (Latest edition and addenda)

- ASME Boiler and Pressure Vessel Code Sec. VIII, Div.1 and/or 2 & Sec.11 & Sec.V.
- BS 4076 Specification for Steel Chimneys.
- All codes referred to, in the above mentioned codes such as ANSI B16.5, API 605, etc.
- API 941 Steel for Hydrogen Service at Elevated Temperature and Pressure.
- ANSI A58.1 Standard for Wind and Seismic Load.
- NPCS-ES-ST-01 Engineering Standard for Concrete.
- NPCS-ES-ST-06 Engineering Standard for Anchor Bolts.

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3 OVERVIEW OF FLARING

3.1 TYPES OF FLARES

There are basically two types of flare systems, namely, elevated flares and ground flares. In an elevated flare system, combustion reactions are carried out at the top of a pipe or stack where the burner and igniter are located. A ground flare is similarly equipped except that the combustion takes place at or near ground level. Three types of ground flares are in general use:

- a) The type that uses a water spray to disperse the combustion gases.
- b) The Venturi type that depends on the kinetic energy available in the waste gases to inspirate and mix the proper amount of air with the gases.
- c) Multijet ground flares where the flow of the waste gas is distributed through many small burners.

3.1.1 The principal components in a ground flare system, are a knock-out drum, multijet burners, a refractory lined rectangular flare box and a seal drum. The flare flame is returned to the inside of the flare chamber.

3.1.2 In an elevated flare system, relieving gases are sent through an elevated stack from a closed collection system and burned off at the top. The flame generated is open in this case.

3.1.3 Flares are not intended to operate continuously under normal process conditions. However, during plant startups there may be continuous flaring for six or seven consecutive days.

3.2 FLARE SYSTEM COMPONENTS

3.2.1 A typical flare system is comprised of the following components:

- a) Relief, safety, and depressuring valves.
- b) Pressure-relieving header(s) that convey discharges from safety and pressure-control valves in the process unit to the flare.
- c) Knock-out drum located before the flare stack in order to separate any condensate or liquid from the relieving vapors (It is hazardous to burn liquid droplets).

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- d) Flare stack consisting of the riser structure, molecular seal, and burner tip.

3.2.2

A Brief Description of the Major Components Follows

Riser structure

This normally consists of two or more sections. The flare header enters at the bottom section, which serves as a flare stack knock-out drum where any condensate carried over from the knock-out drum is collected.

Molecular seal

This is welded to the riser section. It provides a seal against entrance of air into the flare stack and minimizes the possibility of an explosive mixture forming in the flare system. Briefly, it resembles a bubble cap' and creates a seal by using the buoyancy of the purge gas to create a zone where the pressure is greater than atmospheric pressure.

Flare burner Lip

The burner tip is a complete assembly sealed to the molecular seal outlet. Accessories on the burner tips include about three or four gas pilots, a similar number of pilot gas/air mixture assemblies, and steam supply nozzles for steam injection.

3.2.3

The relieving gases from safety-relief valves are collected in a horizontal or vertical knock-out drum through a flare main header. Any condensate carried over along with the gases is knocked down here. A constant liquid level is maintained in the boot. The liquid is pumped to a slop tank or reused in oil recovery facilities. Steam is used for winterizing to prevent freezing. The gas from the knock-out drum is then sent to an elevated flare stack. At the bottom of the stack a liquid seal is maintained. Alternately another seal may be located between the knock-out drum and the flare stack. A positive water seal is maintained by controlling the level. It is also provided with steam for winterizing.

The stack is comprised of a riser section, molecular seal, and burner tip. At the top of the burner tip, pilot burners, which are automatically lighted from a remote place through the igniter line, are positioned. The steam connection is also provided for smokeless flares and a purge gas connection is provided for maintaining an air-free system and to prevent flashback by maintaining pressure at the molecular seal higher than atmospheric pressure. This arrangement prevents air from reentering the stack from the ambient surroundings,

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SMOKELESS FLARES

A flame is referred to as being luminous when incandescent Carbon particles are present in it. When these particles cool, they form smoke. It has been observed that smoke formation mainly occurs in fuel-rich systems where a low Hydrogen-atom concentration suppresses the smoke. Prevention of smoke in flares is normally accomplished in three different ways:

- a) By the addition of steam.
- b) By making a pre-mix of fuel and air before combustion so as to provide sufficient Oxygen for efficient combustion (which is always done in fired boilers and furnaces).
- c) By distribution of the flow of raw gases through a number of small burners.

Among these methods, the addition of steam is most commonly used to produce a smokeless flare for economy and superior performance. In steam addition, the raw gas is preheated before it enters the combustion zone of the flame. If the temperature is high enough, cracking of the hydrocarbons may occur. This produces free Hydrogen and Carbon. When the cracked hydrocarbons travel to the combustion zone, Hydrogen reacts much faster than Carbon. Unless the Carbon particles are burned away, they cool down and form smoke. Consequently, in order to prevent smoke, either the Hydrogen atom concentration must be decreased to ensure uniform burning of both Hydrogen and Carbon or enough Oxygen must be provided for complete combustion.

There are several theories as to the chemistry of smokeless flares using steam. One of them assumes that the steam separates the hydrocarbon molecules, thereby minimizing polymerization reactions, and forms Oxygen compounds that burn at a reduced rate and temperatures so as to prevent cracking.

I. 4

MULTIJET FLARE

The multijet flare developed by Esso Research and Engineering Company burns with no smoke, noise or visible flame. It costs about twice as much as a flare with no steam but half as much as an elevated flare with steam if off-site steam facilities are included.



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The flare uses two burners. A small burner handles normal leakage and small blows, while both burners operate at higher flaring rates. This staging is controlled by two water-seal drums set to release at different pressure levels. A third emergency release is provided in the center of the stack, bypassing the multijet burners. The water seal to this release will blow at flaring rates higher than the design capacity of the flare. When the overcapacity seal has been blown, the flare is both luminous and smoky. But the unit is usually sized so that an overcapacity blow would be a rare occurrence. The overcapacity line may also discharge to an elevated flare rather than to the center of the multijet stack. The staging system is balanced by adjusting the hand-controlled butterfly valve leading to the first stage drum. After its initial setting, this valve is locked into position.

4

DESIGNING THE FLARE STACK AND ACCESSORIES

4.1

GENERAL

4.1.1

The stack designer shall be responsible for the accuracy of all mathematical manipulations, calculations and computer programs used for the stress, deflection, buckling and other design criteria of the stack.

4.1.2

The thickness specified shall be regarded as minimum thickness acceptable.

4.1.3

Stacks shall be designed taking into account the most severe coincident conditions of design temperature and design pressure.

4.1.4

The design of a flare system first requires a detailed analysis of the possible situations that can cause discharge from pressure-relief valves, thus establishing the maximum loading for emergency operations. The maximum load of a system is comprised of the individual loads contributed by the entire process. That is, a conservative design is one that assumes all contributors for the process are relieving simultaneously under any emergency condition.



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From a practical standpoint, it is preferable that relieving of overpressures to the flare systems via the pressure-relief valves should be kept to a minimum, since after popping, the pressure-relief valves often do not reseal. This results in leakage, and consequently reduces the recovery of valuable products. For minor operational upsets, and especially at startup, where flaring for periods of time is often necessary, the use of pressure-relief valves is undesirable. Therefore, overriding pressure-control valves strategically located on some equipment are often used in addition to the pressure-relief valves. Examples of such locations are the suction sides of compressors, overhead product lines of fractionating columns, at the beginning or at the end of a series of high pressure reactors, etc.

1.2 KNOCK-OUT DRUM SIZING

1.2.1 The hydrocarbon relief streams are mainly vapors, but they may carry some liquids that condense in the collecting line. Therefore, material entering the knock-out drum (also called a blow-down drum) will be a mixture of vapor and liquid. A particle that is 150 microns or less can be burned in the flare without hazard. Larger particles must be removed in the knock-out drum. This liquid is pumped out from the bottom of the knock-out drum either for reuse or for disposal in a slop tank. In some process plants, e.g., ethylene plants or coal gasification plants, hot vapors containing water are collected in a separate flare header (called a wet flare header). The liquid collected in the knock-out drum for the wet flare contains water and liquid hydrocarbons. In the same manner, cold and dry hydrocarbon vapors are collected in a dry flare header. The hydrocarbon liquid collected in the knock-out drum of the dry flare is usually vaporized below the knock-out drum and sent back to the flare.

1.2.2 Knock-out drums are either horizontal or vertical. They are also available in a variety of configurations and arrangements that include:

- a) A horizontal drum with the vapor entering at one end of the vessel and exiting at the top of the opposite end (no internal baffling).
- b) A horizontal drum with the vapor entering at each end on the horizontal axis and a center outlet.
- c) A horizontal drum with the vapor entering in the center and exiting at the two ends on the horizontal axis.



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d) A vertical drum with the vapor entering at the top on a certain diameter and provided with a baffle so the flow is directed downward. The outlet nozzle is located at the top of the vertical axis.

e) A vertical drum with a tangential nozzle

4.2.3

Selection of the drum arrangement depends on economics. When large liquid volume storage is required and the vapor flow is high, normally a horizontal drum is more economical. A split entry or exit reduces the size of the drum for large flows. As a rule of thumb, when the drum diameter exceeds 3.66 m (12 ft), the split flow arrangement is normally economical. Knock-out drums are usually sized by a trial and error method. Liquid particles drop-out when the vapor velocity traveling through the drum is sufficiently low. In other words, the drum must be of sufficient diameter to effect the desired liquid-vapor separation. Tan gives the following formula for sizing horizontal drums:

$$W = 4.98 D^2 \cdot \sqrt{[(P_L - P_G) MP/T]}$$

Valid for particle size of 400 microns.

where:

W = kg/s of vapor
 P_L = liquid density Kg/m³
 P_G = gas density Kg/m³
M = mol. wt. of the vapor
T = temperature of the vapor in °K
P = pressure, Kpa
D = drum diameter, m

Similar expressions are available for vertical knock-out drums. A practical formula for the vapor velocity is:

$$V = 0.1219 \sqrt{[(P_L - P_G) / P_G]} , \quad \text{m/s}$$