



RP 44-3

DESIGN GUIDELINES FOR RELIEF DISPOSAL SYSTEMS

November 1993

Copyright © The British Petroleum Company p.l.c.

All rights reserved. The information contained in this document is subject to the terms and conditions of the agreement or contract under which the document was supplied to the recipient's organisation. None of the information contained in this document shall be disclosed outside the recipient's own organisation without the prior written permission of Manager, Standards, BP International Limited, unless the terms of such agreement or contract expressly allow.

BP GROUP RECOMMENDED PRACTICES AND SPECIFICATIONS FOR ENGINEERING											
Doc. No. RP 44-3		Issue Date November 1993	Latest Amendment Date								
Document Title DESIGN GUIDELINES FOR RELIEF DISPOSAL SYSTEMS (Replaces BP Engineering CP 25)											
APPLICABILITY Regional Applicability: International											
SCOPE AND PURPOSE This document presents specific requirements for relief disposal (flare) systems from a relief device discharge flange up to and including flare(s), vents or any other ultimate disposal system for relieved materials. This includes piping, valving, knock out and seal drums and instrumentation. It is based on API RP 520 (5th Edition) and API RP 521 (3rd Edition). It is partnered by BP Group RP 44-1 Overpressure Protection Systems which specifies the requirements for relief devices and the calculation of the relief loads.											
AMENDMENTS <table border="0" style="width: 100%;"> <tr> <td style="width: 15%;">Amd</td> <td style="width: 25%;">Date</td> <td style="width: 25%;">Page(s)</td> <td style="width: 35%;">Description</td> </tr> <tr> <td colspan="4"> </td> </tr> </table>				Amd	Date	Page(s)	Description				
Amd	Date	Page(s)	Description								
CUSTODIAN (See Quarterly Status List for Contact) Plant Design											
Issued by:- Engineering Practices Group, BP International Limited, Research & Engineering Centre Chertsey Road, Sunbury-on-Thames, Middlesex, TW16 7LN, UNITED KINGDOM Tel: +44 1932 76 4067 Fax: +44 1932 76 4077 Telex: 296041											

CONTENTS

Section	Page
FOREWORD	iv
1. INTRODUCTION.....	1
1.1 Scope.....	1
1.2 Application of this Recommended Practice.....	1
1.3 <i>Quality Assurance</i>	2
2. CHOICE OF DISPOSAL SYSTEMS	2
3. ATMOSPHERIC VENTING	3
3.1 General Requirements	3
3.2 Non-hazardous Discharge	4
3.3 Flammable and Toxic Discharge	4
4. CLOSED SYSTEMS.....	6
4.1 General	6
4.2 Sizing.....	8
4.3 Special Relief Arrangements.....	9
4.3.1 Hydrogen Sulphide Relief	9
4.3.2 Corrosive Reliefs	9
4.3.3 Low-Temperature Relief.....	10
4.4 Winterisation.....	10
5. FLARE SYSTEMS	11
5.1 Component Parts of the Systems	11
5.2 Design Considerations.....	11
5.3 Engineering Line Diagrams	15
5.4 Flare Types	15
5.4.1 Flare Structure.....	15
5.4.2 Types of Combustion Device	17
5.4.3 Onshore Installations	19
5.4.4 Offshore Installations	19
5.5 Smokeless Flaring	21
5.6 Sizing of Flare Systems	23
5.7 Siting	24
5.7.1 General Principles	24
5.7.2 Height of Flares	25
5.7.3 Radiation Levels	26
5.7.4 Calculation Methods for Flare Radiation	28
5.7.5 Restricted Access Zone (Sterilisation Zone)	29
5.8 Elevated Flares.....	30
5.8.1 Construction	30
5.8.2 Flare tips.....	33
5.8.3 Platforms and Ladders	36
5.8.4 Derrick for Tip Removal.....	36
5.8.5 Guarantees.....	37



5.9 Ground Flares	37
5.9.1 Process Design	37
5.9.2 Construction	38
5.9.3 Burners	39
5.9.4 Materials	39
5.9.5 Purging	39
5.9.6 Noise	40
5.9.7 Instrumentation	40
5.9.8 Guarantees	40
5.10 Ignition Systems	41
5.10.1 General	41
5.10.2 Pilots	41
5.10.3 Igniters	41
5.10.4 Pilot Gas Supply	42
5.11 Flashback Prevention	42
5.12 Noise Levels	44
5.13 Auxiliary Flare Piping	44
5.14 Trace Heating	45
5.15 Flare Sparing Philosophy	45
6. LIQUID REMOVAL	46
6.1 On-site Knock-out Drum (Onshore)	46
6.2 Off-site Knock-out Drum (Onshore)	48
6.3 Cold Service	48
6.4 Liquid Removal (Offshore)	49
7. FLARE PURGING AND SEALING	49
7.1 Gas Purge	49
7.2 Liquid Seals	51
7.2.1 Uses of Seals	51
7.2.2 Types of Liquid Seals	52
7.2.3 Design (See Figure 1)	52
7.3 Gas Seals	54
7.4 Flame Arresters	54
7.5 Efflux Velocity Accelerators	55
8. FLARE LINES	55
8.1 Routing	55
8.2 Design and Construction	55
9. CONTROLS AND INSTRUMENTATION	57
9.1 General	57
9.2 Pilot Ignition (See Figure 1)	57
9.3 Pilot Flame Failure Detection (See Figure 1)	57
9.4 Automatic Smoke Control (See Figure 1)	58
9.5 Burn-back Detection	59
9.6 Purge Control	59
9.7 Oxygen Monitoring (See Figure 1)	59
9.8 Flow Measurement	60



9.9 Requirements for Instrumentation	61
10. SURFACE PROTECTION.....	62
11. WINTERISATION	63
12. TESTING	63
13. SPARES.....	63
FIGURE 1	65
TYPICAL ARRANGEMENT OF A FLARE SYSTEM	65
APPENDIX A.....	66
DEFINITIONS AND ABBREVIATIONS	66
APPENDIX B.....	69
LIST OF REFERENCED DOCUMENTS.....	69
APPENDIX C.....	72
H.W. HUSA'S CORRELATION FORMULAE.....	72



FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory Volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Recommended Practice

The International Industry Standards [API RP 520](#) and [RP 521](#) must of necessity provide more flexibility than is required by the BP Group and do not include specific BP Group experience. This Recommended Practice adds the requirements that the BP Group has found are necessary for safe and cost effective operation.

From the experience of the industry as a whole, the API RPs are a distillation of general experience. Individual companies have different cultures and operating procedures (again learnt from experience). The BP requirements given in this Recommended Practice fit with the operating and design philosophy used by BP. At least some of these requirements will not be appropriate to a different operating and design philosophy.

Application

Text in *italics* is Commentary. Commentary provides background information which supports the requirements of the Recommended Practice, and may discuss alternative options. It also gives guidance on the implementation of any 'Specification' or 'Approval' actions; specific actions are indicated by an asterisk (*) preceding a paragraph number.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Principal Changes from Previous Edition

There have been no changes to philosophy or requirements. The major change is in updating to the latest API editions and to the 'Way Forward' format.



Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP RPSE's, to assist in the process of their continuous improvement.

For feedback and further information, please contact Standards Group, BP International or the Custodian. See Quarterly Status List for contacts.



1. INTRODUCTION

1.1 Scope

1.1.1 This Recommended Practice specifies BP general requirements for relief disposal systems based on the engineering principles set out in [API RP 521](#) Guide for Pressure Relief and Depressuring Systems and [API RP 520](#) Design and Installation of Pressure Relieving Systems in Refineries. The whole disposal system is considered for fluids discharged from pressure relief valves, other pressure relief devices, control valves or manual valves into a closed system. This closed system terminates in one or more disposal systems such as flares when the fluids are to be combusted, cold vents or blowdown systems.

1.1.2 It should be used in conjunction with BP Group [RP 44-1](#), Overpressure Protection Systems.

Within a formal construction project, the Project Manager will need to delegate the authority to issue waivers as appropriate to the management structure. In smaller modification teams there will be a chain of command and this should be used alongside the site safety and environment checking procedure to authorise waivers where appropriate.

1.1.3 It is applicable to the following installations:-

Refineries
Chemical plants
Terminals
Offshore installations
Crude oil and gas gathering centres
Pipelines: buried, above ground, or sub-sea
Storage installations
Floating production systems

This Recommended Practice is based on:-

[API RP 520](#) Part I 5th Edition (July 1990)

[API RP 520](#) Part II 3rd Edition (1988)

[API RP 521](#) 3rd Edition (November 1990)

1.2 Application of this Recommended Practice

In the application of this Recommended Practice, BP may select options or waive requirements, depending on the nature of the project concerned. This may involve any requirement stated in this Recommended Practice, but particularly the BP involvement marked with asterisks.

Within a formal construction project the Project Manager will need to delegate the authority to issue waivers as appropriate to the management structure. In smaller modification teams there will be a chain of command and this should be used



alongside the site safety and environment checking procedure to authorise waivers where appropriate.

1.3 Quality Assurance

Verification of the vendor's quality system is normally part of the pre-qualification procedure, and is therefore not specified in the core text of this specification. If this is not the case, clauses should be inserted to require the vendor to operate and be prepared to demonstrate the quality system to the purchaser. The quality system should ensure that the technical and QA requirements specified in the enquiry and purchase documents are applied to all materials, equipment and services provided by sub-contractors and to any free issue materials.

Further suggestions may be found in the BP Group RPSEs Introductory Volume

2. CHOICE OF DISPOSAL SYSTEMS

2.1 Where permitted by local statutory regulations, for relief of other than non-hazardous fluids, the choice of pressure relief discharge location shall be generally in the following order of preference, subject to the detailed limitations of this Recommended Practice:-

- (a) Other parts of the process plant or system.
- (b) Atmosphere, subject to the requirements of 3.3.1 and 3.3.4.
- (c) Closed system, subject to the requirements of Section 4.

Note that:-

- (i) In general, the magnitude and frequency of relief discharge should be reduced by the use of pressure-limiting instrumentation, in accordance with 3.3.3 of BP Group [RP 44-1](#).
- (ii) Constraints on atmospheric relief may be imposed by compact installations, e.g. offshore.

2.2 Normal venting of flammable and toxic materials arising from controlled process variations and sustained discharges for plant operability, shall usually be taken to a closed system; however, in remote or offshore locations where there are fewer potential sources of ignition, such flammable and toxic discharges may be to atmosphere, subject to approval by BP.

Environmental considerations of all releases need to be discussed thoroughly with the Regulatory Authorities, at the earliest stage of process design in order to implement the most cost effective solutions and to minimise the effects on the environment.



3. ATMOSPHERIC VENTING

3.1 General Requirements

- * 3.1.1 Atmospheric relief shall present no unacceptable secondary hazard. The definitions and calculation methods used to justify this general criterion, where not covered by this Recommended Practice or BP Group [RP 44-1](#), will be specified or approved by BP for each project.

Guidance in assessing the consequences and acceptability of secondary hazards can be obtained from BP Corporate Safety Services.

- * 3.1.2 Where required by a regulating authority, an integrity assessment analysis study shall be made or approved by BP to assess the estimated frequency and duration of atmospheric emergency reliefs covered by 4.4 of BP Group [RP 44-1](#). Credit for the use of automatic pressure-limiting instrumentation should be taken, as justified by the study.
- 3.1.3 General rules for atmospheric discharge from pressure relief devices in processing installations are given in BP Group [RP 44-7](#). However, all flammable and toxic discharges shall comply with the requirements of 3.3 of this Recommended Practice, which may dictate modified distances.
- 3.1.4 Noise limits shall be maintained in normally manned areas to meet the Special Limits given in BP Group [RP 14-1](#).
- 3.1.5 Where atmospheric relief discharge is acceptable to the local authorities, no additional closed system need be provided for such discharges.
- 3.1.6 Where pressure relief devices discharge to atmosphere, each individual discharge line should have at least the same bore as the outlet from the pressure relief device (see also 3.3.1(b)). Where an acceptable discharge velocity cannot be attained with this tail pipe bore, the outlet end of the tail pipe may be reduced in diameter. To minimise the ingress of rainwater, the end of the tail pipe may be angled at 45 degrees or covered with a loose-fitting plastic cap.
- 3.1.7 Where the discharge is not flammable or toxic, the discharge line to atmosphere shall have a 10 mm (3/8 in) diameter drain hole at its lowest point.
- 3.1.8 Where the discharge is flammable or toxic, the discharge line to atmosphere shall have a drain at its lowest point. The drain shall be piped to a safe location and may contain a locked-open isolation valve in an easily accessible location.



3.2 Non-hazardous Discharge

- * Safety relief devices discharging air, steam or other non-flammable and non-toxic gases shall discharge to atmosphere at a safe location, as approved by BP.

3.3 Flammable and Toxic Discharge

- * 3.3.1 The duration of atmospheric relief discharge is in general limited by the use of pressure-limiting instrumentation or operator intervention. However, in addition the following criteria shall be met for flammable reliefs, and toxic reliefs as defined by BP:-

- (a) The discharge velocity should be sufficient to reduce the concentration of flammable material at a suitable distance downstream of the point of discharge to below the lower flammable limit, but not so high that a build-up of static electricity might arise. The additional effect of wind-assisted dispersion between the jet and any source of ignition may be taken into consideration subject to the approval of BP. The use of pilot-assisted relief valves may be necessary to achieve adequate jet velocities. The distance downstream will be set by plant layout and environmental considerations.

Guidance in calculating the turbulent jet dispersion and wind assisted dispersion can be obtained from BP Corporate Safety Services.

- (b) To maximise dilution in atmospheric discharge, every pressure relief device should have its own discharge line. This shall be adequately supported, and should be sized to give an exit velocity of 0.9 Mach No. at the maximum discharge capacity of the device.

Note that the relief valve set pressure may not be sufficiently high to permit a velocity of 0.9 Mach No. at the actual point of atmospheric discharge. In such cases, the highest practical discharge velocity should be selected. There may also be noise problems in the case of very large reliefs.

- (c) There shall be no unacceptable safety and environmental hazards from the dispersion of toxic material. It may be necessary to carry out a dispersion study to confirm this.
- (d) There shall be no significant condensation of flammable or toxic material.

Criteria for assessing condensibility require specific calculation for each case. As a guide, a hydrocarbon vapour of average molecular weight 100 or less should not generally condense in typical discharge conditions. For



higher molecular weights a more detailed analysis will be required. This will involve the examination of vapour cooling rates and dew point conditions at the specified minimum ambient temperature for the site.

- (e) There shall be no direct flame impingement or unacceptable radiation levels at operating positions.
- (f) The calculation methods used to justify these general criteria shall be subject to approval by BP.

3.3.2 Where multiple pressure relief devices are fitted on a system, the set pressures shall be staggered to assist in maintaining a high discharge velocity and to minimise chatter in the case of relief valves.

Note that the main pressure vessel design codes require the maximum set pressure to be not more than 5% above design pressure, and it may be necessary to provide an additional margin between operating and design pressures to permit adequate staggering of set pressures. See also Section 4.3.4 of BP Group [RP 44-1](#).

An alternative means of obtaining high discharge velocities and minimum blowdown is to use pilot-assisted pressure relief valves. The design shall be such that, in the event of failure of the pilot device, the main unloading valve will open automatically at the system design pressure and will discharge its full rated capacity. To enable the valve to act in this way, the pilot set pressure requires to be not less than 5% below system design pressure.

- * 3.3.3 The possibility of ignition of a relief discharge, coincident with the presence of an operator in the vicinity shall be considered, and specific means for operator protection or escape provided where necessary. These shall be subject to approval by BP. See 5.7.3 for permissible maximum radiation levels. Suitable methods for estimating thermal radiation intensities will be found in [API RP 521](#).

Although not normally necessary, for a critical situation consideration should be given to quantifying, by means of a risk analysis, the likelihood of ignition of a relief discharge.

The combination of (a) a process upset causing a flammable discharge, (b) the possible ignition of this discharge, and (c) the possible presence of an operator at a point close enough to be significantly affected, may well be considered to be remote. The permissible radiation levels which have been established in BP Group [RP 44-1](#) are more stringent than those of [API RP 521](#).

- * 3.3.4 When specified by BP, steam or inert gas connections shall be provided for atmospheric reliefs at ambient temperatures or above, for extinguishing any residual burning only. This shall be by hand control from grade level using double block-and-bleed valves, connected to the vent after the relief device. A drain hole, left permanently open, shall be provided in the vent line. The vent line drain hole shall be fitted with



a short line to a safe location, or be located to discharge away from any operating platform. Such locations shall be subject to approval by BP.

- * 3.3.5 At discharge temperatures below 0°C (32°F), extinguishing connections shall be inert gas instead of steam. The use of Halons (bromochlorofluorocarbons) and other vaporising liquids shall be avoided where possible, and shall be considered only where there is no practical alternative and where approved by BP. In this eventuality, all reasonable steps shall be taken to minimise the release of the vaporising liquid to atmosphere.

Chlorofluorocarbons (CFCs) and bromochlorofluorocarbons (Halon) are now generally accepted as being significant man-made contributors to the depletion of the ozone layer.

In support of international efforts to reduce the release of these materials into the atmosphere, BP has adopted the following policy with regard to the use of Halons:-

- (i) *Elimination of the release of Halons in all existing applications where suitable substitute materials and technology are available.*
- (ii) *Where this is not possible, to take all reasonable steps to minimise the release of Halons to the atmosphere.*

The implications of this philosophy for the BP Group are contained in [Safety Guidance Note No. 90/2: The use of Halons in Firefighting](#) (Feb 1990), published by Group Safety Centre (now Corporate Safety Services). This document outlines the approach which should be taken when selecting an extinguishant for various applications, and should be consulted wherever a new use for a Halon is being considered.

In many applications, the use of an inert gas or steam will be a practical, if more expensive, alternative which should be thoroughly evaluated.

4. CLOSED SYSTEMS

4.1 General

- * 4.1.1 Closed relief systems will most frequently be flare systems incorporating knock-out drums where necessary (refer to 4.1.7) but may in some cases be absorbers, scrubbers, quench towers, dump tanks, etc. Such closed systems will be subject to approval by BP.
- 4.1.2 Fluids returned to other parts of the process shall be compatible in composition and temperature, to avoid any violent vaporisation or the possibility of the formation of solids.
- * 4.1.3 The following reliefs shall be taken to a closed system:-



- (a) Reliefs that do not satisfy the requirements for atmospheric relief as given in 3.3.
- (b) Reliefs that do satisfy the atmospheric relief requirements but where the regulating authorities prohibit atmospheric venting.

Normal venting of flammable and toxic materials arising from controlled process variations and sustained discharges for plant operability, shall also be taken to a closed system; however, in remote or offshore locations where there are fewer potential sources of ignition, such flammable discharges may be to atmosphere, subject to approval by BP.

4.1.4 Attention is drawn to the possibility of condensation in a closed relief system immediately following pressure relief device operation, leading to the ingress of air into the system. It may be necessary to provide an emergency supply of non-condensable purge gas to avoid this condition (see 7.1.6).

- * 4.1.5 When any addition or modification is being made to an existing closed relief system, BP practice may be met by equipment modification, installation of suitable protective instrumentation, utility rearrangement or closed system modifications, using the principles of reliability analysis as outlined in BP Group [BP 44-1](#) Section 4.4. The resulting design measures may not necessarily be identical to those for new designs, but they shall meet the requirements of this Recommended Practice unless otherwise approved by BP.

Any such modifications will need to be phased in with operating requirements, but acceptable closed system capacity shall be maintained during all phases of the modification.

Where a small proportion of low-pressure vessels share a common closed relief system with higher-pressure vessels, it may be economical to up-rate the lower-pressure vessels rather than size the collecting system for the lowest back-pressure or use two separate systems.

4.1.6 Knock-out drums shall be provided where it is necessary to prevent liquid being carried over to the disposal system (see Section 6).

- * 4.1.7 Where specified by BP, the feasibility of installing a flare gas recovery system shall be investigated. This may be for economic or environmental reasons. Where a flare gas recovery system is installed, a free path through a liquid seal to flare, independent of instrumentation, shall be provided to allow for failure of the recovery system. (See general requirements for seal drums Section 7.2).



4.2 Sizing

4.2.1 Closed relief systems shall be sized on the basis of the normal venting, plus the emergency load arising from the most severe single event, taking account of interaction. The following are some examples:-

- (a) A failure affecting a single equipment item together with its related effects.
- (b) The failure of a utility section, or other limited condition, affecting a number of relieving points simultaneously.
- (c) An overall utility failure or event affecting a number of relieving points simultaneously.
- (d) A fire affecting the whole of the largest single section of plant that can be readily isolated by fire-fighting personnel and their equipment.
- (e) The failure of any flare gas recovery plant associated with the closed system.
- (f) The failure of the whole or part of any instrument system.
- (g) The emergency depressuring load shall be added to the worst relief load which could be the cause of the need for depressuring e.g. a fire.

In determining the above, good engineering judgement shall be used in accordance with [API RP 521](#) generally, and BP Group [RP 44-1](#) in particular.

4.2.2 No nominal size restriction shall be placed on any closed relief system, e.g. on flare system capacity or closed system header diameter.

4.2.3 In all cases, the discharge pipe size shall be as large as, or larger than, the size of the pressure relief device outlet.

The line shall be sized using a pipe roughness of 0.46 mm (0.018 in) instead of the normally adopted value for clean steel pipe of 0.046 mm (0.0018 in). This reflects BP experience of increased roughness in relief headers.

Where back pressure is not significant, and the governing factor is fluid velocity, the line shall be sized to limit the maximum velocity to 0.8 Mach No.

4.2.4 The discharge piping shall be self-draining to the relief header, which shall itself be self-draining towards the knock-out drum. The header upstream of the flare shall similarly drain back to the drum.



- * 4.2.5 A closed system receiving multiple reliefs, where vessels may be fitted with pressure-limiting instrumentation, shall be sized on the general basis of [API RP 521](#), Para 5.2, which states the maximum load as the sum of the loads of the individual devices connected to it which are assumed to be relieving under the governing emergency condition. The number 'assumed to be relieving' simultaneously may be reduced if credit for the operation of pressure-limiting instrumentation is taken.

Credit taken in this way for the operation of pressure-limiting instrumentation will be subject to approval by BP for each project, in accordance with the general principles of this Recommended Practice.

Where credit is taken for the operation of pressure-limiting instrumentation in the sizing of closed relief systems, this instrumentation shall be regarded as an integral part of the pressure-relieving system.

In general, estimates shall be made of the possible incidence of pressure relief devices lifting simultaneously due to the failure of pressure-limiting instrumentation or devices in response to estimated demand rates. The criteria for sizing a closed relief system shall be established using the principles of Quantified Risk Assessment as detailed in BP Group [RP 50-2](#) to be such that the design flowrate is not likely to be exceeded within a period to be determined for each case. This will depend upon the consequences of failure, but in no case shall this be less than ten times the anticipated working life of the plant.

4.3 Special Relief Arrangements

4.3.1 Hydrogen Sulphide Relief

- * Since hydrogen sulphide is a highly toxic material that is frequently encountered, general practice rules for selection of disposal means have been established and should be applied as follows:-

% by Volume H ₂ S	Disposal means
less than 1	Atmosphere
1 - 2	BP to approve
2 - 10	Flare
greater than 10	Flare, with separate line

However, all discharges shall comply with 3.3.

4.3.2 Corrosive Reliefs

- * Specific arrangements shall be made for corrosive reliefs, and these shall be subject to approval by BP. Discharge of corrosive substances will normally involve special materials of construction, and the economics of segregating such discharges shall be evaluated. Materials



shall be in accordance with BP Group [GS 136-1](#) or other appropriate standards which shall be subject to approval by BP.

4.3.3 Low-Temperature Relief

Pressure relief header systems for refrigerated storage should be designed to:-

- (a) *Provide a high-toughness material in the flare header. Failures have occurred where steels appropriate for the temperature of gas entering the header were not used (auto-refrigeration effect).*
- (b) *Not have low points in which liquid could accumulate to prevent adequate relief flow.*
- (c) *Provide a very low pressure drop to flare, so that the probability of opening any atmospheric vent is greatly reduced.*
- (d) *Provide independent lines for differing liquids such as propane and butane.*

- 4.3.3.1 Low-temperature relief of fluids shall be segregated from other streams that are wet, to avoid freezing of lines. For other than atmospheric discharge, a separate knock-out drum and closed vent system shall be provided using materials of construction specifically selected for low-temperature service.

In designing the segregation of cold and wet streams, involvement of operations staff is vital. On the Sullom Voe blowdown system there were serious problems in 1982 due to insufficient consideration of the effects of leaking block valves and the need to dispose to alternate systems.

- 4.3.3.2 Independent lines to the knock-out drum should be provided for liquids of distinctly differing boiling point, e.g. for propane and butane.

- 4.3.3.3 Where appropriate, consideration shall be given to the provision of methanol injection facilities to prevent hydrate formation.

4.4 Winterisation

- 4.4.1 Where the danger of freezing of vent lines or relief valves exists, heat tracing or other positive precautions shall be taken. See also BP Group [RP 44-2](#).

- 4.4.2 If any overpressure protection is by pressure-limiting instrumentation which relies on heat tracing, the heat tracing shall be included in reliability considerations where necessary.



5. FLARE SYSTEMS

5.1 Component Parts of the Systems

The Flare System may comprise some or all of the following:-

- Lateral discharge lines from individual fluid discharge devices.
- Relief headers connecting the lateral discharge lines together.
- Flare line, to which relief headers from different units are connected, and which leads to:-
 - knockout drum(s)
 - quench drum(s)
 - liquid seal drum(s)
 - flare, consisting of:-
 - flare tip or flare burners
 - flare stack (if elevated) or enclosure (if ground flare)
 - stack support system
 - continuous pilots
 - pilot igniters
 - piping
- Ignition system
- Flame supervision
- Flashback prevention
- Purge system
- Isolation system
- Smoke suppression control system
- Gas sampling system
- Oxygen analyser
- Flow, temperature and level measurements and alarms
- Pump out facilities for drums
- Fire protection
- Insulation
- Heating and heat tracing
- Cold liquid/vapour vaporisation and heating system
- Flare gas recovery system

5.2 Design Considerations

*

The following points shall be given specific attention in the overall design of the flare system:-

- (1) The safety and well being of all personnel in the vicinity (both on-site and off-site) under all conditions of flare operation. This



shall include start-up, purging, operational and emergency flaring, shut-down, inspection and maintenance of all or parts of the system.

- (2) The protection of plant and equipment in the vicinity of the flare system under all conditions.
- (3) The protection of the flare system from damage by external events, e.g. fires.
- (4) The inherent safety of the flare system itself especially in respect of the following:-
 - (a) Flammable or explosive mixtures.
 - (b) Blockages or flow restrictions.
 - (c) Toxic components.
 - (d) Chemical reactions.
 - (e) Mechanical damage.
 - (f) Corrosion, erosion and hydrogen embrittlement.
 - (g) Flare flame stability.
 - (h) Security of ignition.
 - (i) Security of pilots.
 - (j) Change over to another flare
- (5) The flowrate, composition, molecular weight, temperature, frequency and duration of process streams discharging into the flare system at any one time and any inherent restrictions imposed, e.g. allowable back pressure, solids deposition. Particular attention should be paid to depressuring flowrates especially if depressuring is activated because of a fire.

BP will approve or provide design data such as flare gas composition, molecular weight, flow rates and services available.

- (6) Materials of construction for flare systems should be selected to be suitable for operation at the minimum temperature of the system, allowing for any auto-refrigeration from depressuring.

To prevent or reduce ground contamination local regulations may well require the use of lines or impervious barriers. These regulations will need to be investigated locally.

- (7) The required life of the flare system components.
- (8) The philosophy to be adopted on inspection and maintenance of the flare system and the impact of these requirements on plant



operation (flare system sparing requirements). See BP Group [RP 32-3](#), [32-4](#), [32-5](#) and [32-6](#).

- (9) Meteorological and any other relevant environmental conditions pertaining to the site.
- (10) Any national and local regulations, particularly concerning smokeless burning, flare visibility, pollution and noise restrictions.
- (11) The need for winterisation, especially of water seals.
- (12) The need for segregation of relief headers for reasons of temperature, toxicity, corrosive materials, etc. Segregation is particularly required to prevent freezing of water wet streams, solidification of viscous materials or reactions which could lead to plugging of lines.
- (13) Handling systems for the safe disposal of condensed hydrocarbons and sour water from both knock-out and seal drums.
- (14) A secure supply of seal fluid to the seal drum.
- (15) The requirement for a cold liquid/vapour vaporisation and heating system in situations where a cold flare cannot be justified.

The following is a checklist of possible hazards which should be considered in the design of flare systems.

(a) *Flammable/Explosive Mixtures in the Flare System.*

These may result from air entering the system by any of the following mechanisms:-

<i>DOWN DRAFT</i>	<i>due to buoyancy effects, loss of purge gas flow, failure of the molecular seal.</i>
<i>CONDENSATION</i>	<i>of vapours in the flare system can cause air to be sucked in at the flare tip or through open vents or drains. This can be a very serious problem since the capacity of the flare pipework to absorb heat can lead to a very large and rapid contraction in volume.</i>
<i>COOLING</i>	<i>of hot vapours discharged into a cold flare system can also lead to air being sucked into the system.</i>

	BUOYANCY	of light gases can create sub-atmospheric pressure in the low level flare pipework. The resultant pressure differential may induce air to enter the system through any openings, vents, drains, etc.
	VACUUM	systems connected to the flare can cause air to be sucked in. Especially high integrity segregation mechanisms are required to prevent this.
	PROCESS AIR	may enter the flare due to loss of control in oxidation plants or uncontrolled air purging.
(b)	Blockages/Flow Restrictions	
	FREEZING	of water seals, or condensate in flare lines or molecular seals due to low ambient temperatures, low temperature discharges or auto- refrigeration.
	POLYMERISATION	hydrates - waxes - corrosion products.
	SOLIDS	carried forward from the plants, catalyst, polymers etc.
	LIQUIDS	trapped through faulty drains, bad design, level control failure.
	VALVES	incorrectly closed or failing closed.
(c)	TOXIC COMPONENTS	Streams containing more than 10% H ₂ S or other highly toxic material should be run in a separate line to the flare (as required by BP Group RP 44-1), and should preferably be coupled to the main flare gas stream near the flare tip to minimise exposure of the main flare pipework to the corrosive effects of H ₂ S. Careful consideration should be given to the disposal of foul liquid effluents from flare seals, drains, etc.
(d)	CHEMICAL REACTIONS	within the flare system, pyrophoric scale, acetylides, peroxides, etc.
(e)	MECHANICAL DAMAGE	hydraulic surge of liquid slugs, propulsion of solid ice-slugs, hydrates, impact, low temperature embrittlement through auto-refrigeration, external fire damage, burn-back at the flare tip, flame lick, venting of high temperature gases into the flare system.

5.3 Engineering Line Diagrams

5.3.1 These shall show separately the whole of the flare system from the downstream flange of the pressure relief valve or liquid drain valve, including knock-out drums, liquids disposal, purging arrangements, seals and flares.

- * 5.3.2 Engineering line diagrams, process line diagrams, line sizing calculations and material specifications shall be subject to approval by BP before mechanical design is finalised.

Sizing of the system will probably be carried out by BP or a main contractor. In the latter case the main contractor must obtain BP approval before the information is passed to the flare contractor for mechanical design.

5.4 Flare Types

5.4.1 Flare Structure

- * All flare structures shall be designed to withstand the loads imposed by all known environmental conditions (wind, ice, temperature, etc.), which will be specified by BP.

In addition to the environmental loadings, the structure shall be designed to withstand the thrusts from liquid slugs (where these can occur), gas discharging from flare tips and the imposed structural and equipment loads. The structure shall also be designed for maintenance loads such as a spare flare tip, additional scaffolding, lifting beams, tools, personnel, etc.

- * 5.4.1.1 Elevated Flares

Elevated flares should be guy-supported where practicable, unless special requirements call for another type.

When the diameter of the riser is small, necessitating a large number of levels of guys, or where multiple risers are required, a guyed supporting mast may be used encompassing the risers.

Multiple elevated flares may be provided to maintain capacity during partial shutdown for inspection or maintenance. Where this is the case the flares should be sited sufficiently far apart to reduce the possibility of thermal damage, and so that these activities can be safely carried out on one flare while the others remain in operation.

If this arrangement is not feasible (e.g. due to space limitations) a tower-supported multiple flare system may be proposed for BP approval. In such an arrangement, each individual flare shall be designed to be dismantled and lowered while the adjacent flares remain in operation. The time required and cost of such dismantling should be evaluated at an early stage in a design. Where necessary, protection



against thermal radiation shall be provided for personnel involved in dismantling, inspection and maintenance.

When, due to small diameter of the riser, more than four levels of guys would be required, a mast support of the flare should be considered.

The tower-supported multiple flare system presents a particular problem with regard to safe access for inspection and maintenance of the supporting tower structure while flares are operational.

*

5.4.1.2

Ground Flares

For conditions where the emission of light and noise to the surroundings has to be reduced, box-type multi-burner ground flares may be used subject to the approval of BP.

Such a flare generally consists of a refractory lined box of a cylindrical or rectangular shape enclosing multiple burners.

The air inlet at the bottom of the box shall be screened by a wall or a fence to cut off the direct route for light and noise to the surroundings.

To allow for greater turn-down, burners may be divided into zones coming consecutively into operation. Some of the groups may be smokeless, others non-smokeless. The control shall be automatic and may be by means of valves. However if valves are used, liquid seals shall be installed in parallel to retain full flaring capacity in the event of primary control system failure.

On sites where space for the Restricted Access Zone (see 5.7.5) and the dispersion of atmospheric pollution are not limiting, low-level, single-burner ground flares may be used (these may be conventional pipe flares). These may be non-smokeless, totally smokeless or partially smokeless up to a specified burning rate.

Flare lines leading to low level single burner flares shall not be buried.

Experience has shown that flare lines leading to low-level un-screened flares present no problem from radiation provided that they are not lagged nor buried. Although radiation increases with flow, so does the cooling effect and lines remain cool. If the lines are buried for protection from radiation, the fill above the line may reach a high temperature during prolonged heavy flaring. When flow stops it will heat the pipe which will expand and may lift out of the ground.

Where air and flare gas velocities are suitable, ceramic fibre should be used for ground flare lining, to avoid refractory cracking due to sudden firing rate changes. Generally gas velocities in excess of 10 m/s (33 ft/s) are a potential problem for ceramic fibre blanket, although there are ways to overcome the problem, such as covering with expanded metal lathe, covering with metal sheet or wet felt soaked in hardener. The choice will depend on the temperature envisaged.

The application of the ceramic fibre rolls or blocks should eliminate potential gas traps or areas where gas could gain entry. All edges should be downstream of the gas flow and fixed securely.



Any maintenance problems with ground flares should be identified at an early stage in a project. The ease with which the refractory could be damaged should be evaluated.

5.4.2 Types of Combustion Device

- * The type of combustion device or flare to be used will be specified by BP or shall be proposed by the flare vendor for approval by BP.

The selection of the type shall be based on the following:-

- (a) Nature, frequency and quantity of relief.
- (b) Space available.
- (c) Effect on surrounding plants and neighbourhood.
- (d) Environmental requirements regarding smoke, pollution, noise, radiation and emission of light.

5.4.2.1 Steam-assisted Gas Flares

Steam-assisted flares may be external, internal, combined steam jet type or Coanda type. Where there is a risk that freezing of condensate in the flare could occur then only the external type shall be used.

* 5.4.2.2 Air-assisted Gas Flares

When smokeless combustion of a gas stream is required and where this requirement can only be satisfied by the use of an assisting fluid, air may be used as the assist fluid if this is either a more convenient or more economical means than using steam, high-pressure gas or water. The means by which the air is provided will be specified by BP or shall be proposed by the flare vendor for approval by BP.

Air is not usually available in the large quantities required and therefore this system is not much used. However, there are circumstances when it is the most suitable type.

5.4.2.3 High-Pressure Gas-assisted Flares

High-pressure flares should be considered when it is advantageous to minimise the heat radiated from the flare, or when there is a possibility of liquids passing to the flare.

When high-pressure Coanda type flares are used, the calculation of radiation and dispersion shall take into account the lower heat radiation factor (F) and the shorter, stiffer flame produced by these flares, especially the internal Coanda type.

Typical coanda type flares are the INDAIR and the MARDAIR.



* 5.4.2.4 Water-assisted Gas Flares

Water may be used for inspiration of air, particularly for installations at ground level; however relatively large volumes of water are required. Proposals to use water shall be submitted for approval by BP before proceeding with design.

5.4.2.5 Unassisted Gas Flares (pipe flares)

Pipe flares shall be used only for duties where there are no restrictions on radiation and production of smoke. A pipe flare should consist of pilot, igniters, wind deflectors and flame stabiliser.

* 5.4.2.6 Liquid Burners

Liquid burners (guns) may be steam, air or gas atomised, as approved by BP. They shall be easily removable for maintenance. Each liquid gun shall have individual isolation for the liquid fuel and atomising medium. Provision should be made for purging the liquid fuel side of the gun before removal.

It is preferable that more than one liquid gun is fitted such that full load can be achieved with one gun out of service.

A permanent gas or light oil pilot complete with ignition system shall be located so that it will cross-light to all the liquid guns.

Provision shall be made to drain or blow through all liquid lines, and for filtration of the liquid and atomising media.

Specific attention shall be given to the volatility of the liquids and if necessary a means of preventing vapour locking shall be provided.

Low temperature liquids shall not be atomised with media that contain water, water vapour or any liquid likely to freeze at the lowest possible operating temperature.

Where sufficient space is available and air pollution control regulations permit the emission of dense smoke clouds, large quantities of waste liquids may be disposed of in a burn pit. The pit should be an excavated or bunded area, typically in excess of 1.5 or 2 m deep and 10 to 13 m square. The flare line should be installed so that it slopes continuously towards the pit, with the end projecting through the side wall. Igniters and pilots may be installed.

5.4.2.7 Low Pressure Gas Flares

Low pressure gas flares may be either pipe or Coanda type.

If the required purge rate cannot be adequately maintained, consideration may be given to the installation of a flame arrester immediately upstream of the flare tip, subject to the restraints of 7.4.



Where a flame arrester is used, the type and location of the arrester should be chosen taking into account:-

- (a) Ease of access for maintenance (see 5.11).
- (b) The need to minimise back pressure on process equipment upstream.

Where operational process vents are connected to a low-pressure flare system, the materials of construction shall be suitable for the minimum temperature the system could reach during a possible cold relief.

Flame arresters are installed in low-pressure flare systems handling gases which may be contaminated with air or oxygen e.g. de-oxygenation towers, compressor lube and seal oil tanks etc. Flame arresters should also be installed in cold maintenance vents where air can be present.

5.4.2.8 Mixed Pressure Flares

Mixed pressure flares should be considered when space and weight are at a premium. These flares generally use a combination of pipe type and Coanda type flare tips.

The combined sections of the tip and associated pipework should be designed so that the possibility of defects leading to leakage from the high pressure stream to the low pressure stream is avoided.

The LP and HP headers and the associated ancillary system upstream of the mixed pressure flare tip should be designed for independent operation.

5.4.3 Onshore Installations

- * BP will specify, or the flare vendor may propose, the flare to be an elevated or ground flare, using a suitable flare tip selected from 5.4.2.

5.4.4 Offshore Installations

- * BP will specify, or the flare vendor may propose, the flare as a tower or a boom type, either on a platform or remote.

The design of the flare structure shall take into account the heat radiated, the possibility and effect of liquid carry-over, and the dispersion and location of the hot gas plume. Where several flare tips have to be sited in close proximity, attention shall be given to the possibility of interactive thermal damage.

The flare structure, riser and flare tip shall be constructed of materials suitable for both the operating temperatures and the marine environment. Materials for the structure shall, where specified by BP, comply with BP Group [GS 136-2](#).



Access will be required to the flare tip and a maintenance platform capable of withstanding the operating temperatures shall be provided.

A further consideration for the design of the structure could be the effect of using a more efficient flare tip. The tip would radiate less heat, enabling the use of a shorter boom or tower, but the increased weight of the tip would require a stronger structure.

5.4.4.1 Boom and Tower Mounted Flares

Boom and tower mounted flares should, wherever possible, be situated downwind of the helideck, drilling deck and operating area of the platform. The wind 'rose' applicable to the area concerned will be supplied by BP.

If a single boom cannot be satisfactorily located, the use of two booms or one tower and one boom should be considered with the facility to switch over as and when wind conditions change.

A mechanical system shall be provided to allow removal and replacement of the flare tip. The system shall be capable of being stored in an area where it will not be affected by the flare operation. Permanent fittings on the boom such as rails, sleeves, etc. should be shielded from radiant heat. The system should be stored so that full load testing is not required when the system is re-used.

5.4.4.2 Remote Flares

BP preference is for on-platform flare systems because of the lower cost, and for ease of operation and maintenance. However, where the amount of gas to be flared is so high that an on-platform flare is not practicable, or where local statutory regulations require, remote flare facilities shall be provided.

These facilities may be a bridge-linked remote or a fully remote structure. Bridge-linked structures can be floating, fixed or articulated. Fully remote structures can be fixed or articulated.

Specific attention shall be given in the design of the system to include:-

- (1) Subsea equipment (lines and risers, knock-out drum, etc.).
- (2) Condensate removal methods.
- (3) Maintenance and repair (no hoists or cranes permanently available).

The location of the bridge-linked flare shall be chosen to avoid the wind-carried hot gas stream affecting personnel and equipment on the main platform.

Fully remote flares comprise an HP flare only. LP flare pressure may be sufficient to allow mounting on a bridge-linked structure; otherwise facilities for LP flaring should be provided on the main platform.

* 5.4.4.3 Flare Snuffing

Where specified by BP, flare tips and pilots shall be fitted with a means of extinguishing the flames, such that they do not re-ignite when the extinguishant is exhausted. The effect of back pressure, during snuffing, on the relief upstream system shall be given specific attention.

The system shall incorporate means by which the complete arrangement, from initial switch to delivery valve, can be easily tested without actual discharge of the snuffing medium. Halons (bromochlorofluorocarbons) shall be considered for this duty only where there is no practical alternative and where approved by BP. In this eventuality, all reasonable steps shall be taken to minimise the release of the material to atmosphere.

The system shall be installed in a weather-tight enclosure to minimise the risk of malfunction due to corrosion.

5.5 Smokeless Flaring

5.5.1 Provision for smokeless flaring shall be made to comply with any national or local regulations applicable to the site.

As a minimum, the design shall provide smokeless flaring for:-

- (1) All cases of operational flaring, i.e. a controlled release of fluid to the flare system for a continuous period exceeding 30 minutes.
- (2) 10-15% of the maximum flaring capacity.

To achieve smokeless combustion:-

- (a) *a minimum critical combustion temperature must be maintained, and*
- (b) *an adequate supply of air mixed sufficiently with the fuel.*

Where the calorific value of the vented gases is not adequate to fulfil condition (a) above, an incinerator should be used.

Requirement (b) may be achieved by any of the following methods:-

1. *Premixing Air With Fuel*

In this method, gas jets are used in bunsen type burners to inspirate air and mix it with the fuel. This type of tip may be used in ground flares, but requires adequate gas pressure and has a poor turndown ratio. To improve the latter, burners should be used in groups operated in sequence,



either by liquid seals of increasing head, or by automatic valves backed by liquid seals.

2. *Inspiring Additional Air Into The Combustion Zone*

This method usually utilises the aero-dynamic skin-adhesion effect known as the Coanda effect, in which steam, high pressure gas or air flowing from a narrow slot follows the profile of a curved surface, entraining air up to twenty times its own volume and introducing oxygen and turbulence required for complete combustion.

The slot may be facing inwards for internal mixing; outward for external mixing, or may be linear. Slots may be fixed or variable. Slots should be wide enough not to get blocked by impurities in the smoke suppressing media. With variable slots, the mechanism should be robust and well protected against ambient conditions.

Steam may be used in Coanda effect to draw in air for mixing with gas in single large units with steam flowing outwardly, i.e. with external injector, or with multiple units in a single tip, with steam flowing inwardly in each unit, i.e. with internal injectors.

3. *Providing a Highly Turbulent Condition Within The Flame*

Highly turbulent conditions within the flame required for smokeless combustion may be achieved as a by-product of inspiration of air as in Coanda effect flares, or by causing the turbulence by steam or air jets.

The latter may be achieved either by the discharge of multiple steam jets into the combustion zone which also inspirates air thereto, or by a high velocity steam jet centrally placed in the tip which entrains air and creates enough turbulence to attain efficient mixing of fuel and air. Both these methods may be combined in one tip.

From all the above steam assisted flare types, the Coanda external injector types are preferred.

- * 5.5.2 The requirements for smokeless flaring may be relaxed by agreement with BP for periods of non-normal operation e.g. initial commissioning, start-up, shut-down.
- * 5.5.3 BP will specify, or the flare vendor shall propose and submit to BP for approval, the flow rates for both smokeless and non-smokeless flaring.
- 5.5.4 Steam, high-pressure gas, air, or water may be used for smoke suppression in flaring.
- * 5.5.5 When using steam for smoke suppression, the following points shall be observed:-
 - (1) The system shall be designed to provide dry steam at the flare tip with the steam pipework suitably insulated.

- (2) Drainage, with steam traps, shall be provided at all the low points and the steam lines frost protected in accordance with BP Group [RP 44-2](#).
- (3) Unless otherwise specified by BP, steam flow shall be automatically controlled either in relation to the gas flow or by the characteristics of the flame (see 9.4). The latter method is preferred.
- (4) Steam lines should be suitably filtered as close to the flare base as practicable, but upstream of the flow control valve.
- (5) In order to cool the pipework at the tip, a minimum flow of steam shall be maintained by a bypass round the steam control valve.

5.6 Sizing of Flare Systems

5.6.1 The capacity and conditions for which the flare system is designed shall be based on the requirements of BP Group [RP 44-1](#). As well as overpressure situations, the vapour loads to which the flare system can be subjected as a result of opening equipment depressuring valves shall be taken into account in the design.

General sizing requirements are contained in 4.2.

The back pressure limitation on relief valves should be noted. Except for special low-pressure valves, the back pressure on a balanced relief valve cannot be more than 50-60% of the absolute set pressure. This requires special attention for relief valves set in the 2-5 bar (ga) range. At an early stage it is worthwhile checking the size of relief lines required and the cost of increasing vessel design pressure to reduce the flare main size required. See BP Group [RP 44-1](#).

5.6.2 Pressure drop limitations may dictate the flare stack diameter.

- * 5.6.3 The flare vendor shall refer the calculated flare tip velocity to BP for approval. The velocity shall be chosen to satisfy requirements for flame stability, noise and dispersion.

In pipe flares a figure of 0.2 Mach No. has been previously accepted as the maximum tip velocity for smokeless flaring. The latest designs of flare tips permit smokeless flaring at velocities above 0.2 Mach No., but if this velocity is exceeded then experience of satisfactory operation of the design should be examined. For emergency flaring 0.5 Mach No. is accepted as a maximum. Above that figure, the flame becomes unstable and lifts off, resulting in the risk of flame extinction.

- * 5.6.4 The total allowable pressure loss through the flare system including stack, liquid seal (if any), knock-out drums and piping is normally



dictated by the back pressure limitation on critical relief valves, and shall be subject to approval by BP.

The evaluations shall take account of:-

- (a) all potential relief, depressuring and process venting conditions
- (b) a pipe roughness consistent with the pipe material and operating conditions
- (c) the final piping configuration including all fittings, entrance losses, etc.

The basis and methods to be used for determining system pressure losses shall be submitted to BP for approval.

It should be noted that carbon steel pipe will normally be rusty before it is commissioned unless great care is taken.

In general, piping losses may be calculated using data from any recognised source, e.g. Flow of Fluids Through Valves, Fittings and Pipe; Crane Technical Paper No. 410. However, in many cases the published data is thought to significantly underestimate losses through tees. For these calculations, the data of Internal Flow Systems edited by D.S. Miller - BHRA Fluid Engineering, published by Gulf Publishing or VDI Waermeatlas shall be used.

- 5.6.5 Unless the piping system is constructed of corrosion resistant materials, the flowing pressure drops shall be calculated on the basis of a roughness of at least 0.46 mm (0.018 inches).

The use of an equivalent roughness of 0.00015 ft (0.0018 inches) as proposed in [API RP 521](#) (Table 6) is not considered to be sufficiently conservative basis for the sizing of relief headers and relief valve discharge lines. Recent investigations have indicated that a figure of 0.0015 ft (0.018 inches) is more representative and should therefore always be used.

The effect of using a higher pipe roughness will vary with the system concerned. It is possible for pressure losses to be increased by as much as 50-80%.

The justification for using the increased roughness has been summarised in a Technical Bulletin (see Appendix A).

- 5.7 Siting

- 5.7.1 General Principles

No detailed rules can be given regarding the location of flares, as each installation has its own specific characteristics. However, the following general principles should be applied:-

- (a) A flare should be as close as possible to the unit or units it serves. However, consideration should be given to possible future expansion requirements into what will become the sterile area.
- (b) The siting should take account of the likely route for the flare line (see 8.1).
- (c) Unless a shutdown of all flares is an operational requirement, the position of one flare in relation to another should be selected so that either can be maintained during the other's operation.
- (d) Prevailing wind direction should be taken into account in siting the flare to minimise environmental effects whenever possible.
- (e) The area required to contain excessive thermal radiation levels should be considered in relation to the design rates of both operational and emergency flaring and the height of the flare.
- (f) The additive effect of radiation from any other elevated flare(s) located on the site and which would flare simultaneously with the flare under design should be considered. The direction and magnitude of solar radiation should also be included.

Radiation from several flares relieving simultaneously can be additive with solar radiation. Since radiation intensities are quoted normal to the direction of transmission, addition of radiation from several sources should take account of the reduction due to the receiving surface not being normal to the direction of radiation from all the sources.

- (g) The possibility of burning droplets being emitted from the flare tip should be taken into account in the siting.

In very exceptional circumstances burning droplets of liquid could be discharged from the tip of a flare. The area which could be affected by the burning droplets would depend upon the size of the droplets and the wind conditions. If the least favourable extremes of droplet size and wind speed are combined to calculate the extent of the possible area which could be affected by the burning droplets, an improbably large area would result. It is recommended, therefore, that the estimated average droplet size and average wind speed should be used in such calculations due to the improbability of the worst conditions occurring in combination.

5.7.2 Height of Flares

*

The height of a flare shall be determined by the following considerations:-

- (1) The maximum allowable thermal radiation levels as specified in 5.7.3.



- (2) An adequate dispersion of toxic gases at ground level, even with the flare extinguished, such that their concentration shall be acceptable to any local regulations. Calculations of ground level concentrations shall be submitted for BP's approval. The method of calculating the maximum concentration of polluting gas and the corresponding distance at which it occurs is given in API Manual on Disposal of Refinery Wastes Volume II. The acceptable concentrations shall be based on the period over which the conditions leading to the release can be sustained and the health hazard which they represent.
- (3) Any local or national height restrictions, e.g. for aircraft movements.

The calculation method given in the API Manual on Disposal of Refinery Wastes, Volume II is acceptable; however, for critical applications the method available from the Custodian of this Recommended Practice (BP Research and Engineering Centre) or Corporate Safety Services is a superior technique.

5.7.3 Radiation Levels

*

The maximum permissible design level of radiation for exposure of personnel at maximum emergency flaring shall be based on the following:-

(a)	Continuous full shift exposure	-	1.6 kW/m ² (500 Btu/ft ² h)
(b)	Operational blowdown (max. 30 minutes)	-	3.2 kW/ 1000 Btu/ft ² h)
(c)	60-second peak exposure (escape time to safe haven)	-	4.7 kW/m ² (1500 Btu/ft ² h)
(d)	20-second peak exposure (escape-time to safe haven)	-	6.3 kW/m ² (2000 Btu/ft ² h)

NOTES

- (1) The figures given assume at least single-layer whole-body working clothing and hard hat.
- (2) The figures include solar radiation, and an appropriate allowance, dependent on latitude, should be made when determining permissible flare radiation. The average solar radiation levels to be used follow in Commentary.



- (3) Metal surfaces irradiated at any of the time/level ratios given may produce burns on contact with bare skin.
- (4) In general, it will not be difficult to comply with the above requirements for onshore flares. For offshore flares it may not be possible to satisfy some of the requirements. Access to some areas may therefore have to be restricted, e.g. the flare structure, the bridge for a linked flare and the drilling tower. It should be possible for any vital work in these areas to be carried out under specified and controlled conditions.
- (5) If necessary, these design levels may be achieved by the use of displacement or shielding. The requirements for any shielding system and the type of system to be employed shall be agreed with BP at an early stage.
- (6) On towers or other elevated structures where rapid escape is not possible, ladders shall be provided on the side away from the flare, so that the tower or structure can provide some degree of shielding where necessary.
- (7) In tower-supported multiple flare systems, all access requirements shall be considered. Shielding shall be provided when specified by BP.
- (8) A maximum ground level radiation will be specified by BP, either where access across a restricted access zone without shielding is required or where the ground covering may be ignited, e.g. grass or peat.
- (9) The effect of flaring on equipment in the vicinity shall be considered, using the same design level above, from the following aspects:-
 - high temperature from radiation;
 - large temperature gradients, between exposed and non-exposed surfaces;
 - corrosive action of pollutants;
 - possibility of burning of un-ignited droplets;
 - effect of hot gases.

The following values should be used for the solar radiation allowance unless specific measured values are available for the site. The average value should be



used in conjunction with the 1.6 kW/m² (continuous full shift) value and the peak value with all others.

Linear interpolation between latitudes can be used.

Solar Radiation Table

Latitude degrees	Peak radiation kW/m ²	Average radiation kW/m ²
0	0.98	0.73
10	0.99	0.74
20	1.00	0.73
30	1.01	0.69
40	1.00	0.63
50	0.96	0.54
60	0.88	0.44

These figures are taken from data supplied by the Meteorological Office, Bracknell, England, ref D/Met 01/21/1/2/L. The data refer to the global irradiance received on a horizontal surface, for an air mass appropriate to a suburban environment.

The peak radiation is the maximum of the monthly peak irradiance received at 1200 (Local Apparent Time, LAT) solar time.

The average radiation is the arithmetic mean of the monthly average irradiance, for the period 0800-1600 LAT, except when the day length is less than 8 hours (only Nov-Jan, latitude 60°), then the mean is for the daylight period only.

Each monthly value used for the particular latitude refers to the 15th day in each month. The data are derived from latitude averages of the correlation of sunshine and irradiation (i.e. the Angstrom relation) and should be considered to be only rough approximations to the actual values at specific sites.

The main problem with exceeding the full shift or blowdown exposure levels is one of heat exhaustion rather than overt burns.

The maximum levels given will probably be suitable for 90% of the time, but there may be occasions, e.g. in summer, when the solar radiation contribution will give levels outside these limits. On these occasions, precautions such as shading, shielding or personnel rotation should be observed.

The design limits are those recommended in the BP Group [Occupational Health Memorandum No. 25-70-0041](#) 'Exposure of Personnel to Thermal Radiation'. Advice should be sought from BP Group Health and Safety if there is doubt about the application of these recommended design levels to specific problems.

5.7.4

Calculation Methods for Flare Radiation

*

The flare vendor or contractor shall use a differential type of calculation method which will realistically predict the radiation levels. The flare vendor/contractor shall indicate the basis for the calculations and supply calculated results for flame length, flame shape and emmissivity. BP will specify the points where flare radiation calculations are required and the environmental and operating conditions.



The flare vendor radiation calculations may be checked against the preferred BP model; experience with this programme exists within BP Research and Engineering.

The API RP 521 method can be used for initial rough calculations but it is significantly inaccurate at under 2 flame lengths. BP would want to check (say) 6 points at one or two different flowrates.

ositions critical to Flare Radiation Calculations, particularly offshore, are:-

*ase of flare boom
Nearest edge of platform
Helideck
Crane cabs
Monkey board (drilling derrick)
Radio mast (includes fittings)
Drillers pipe rack.*

Environmental Conditions which should be used in the radiation calculations are:-

- (i) No wind*
- (ii) 50 km/h (30 mph) wind*
- (iii) 100 km/h (60 mph) wind*
- (iv) Maximum design wind speed.*

5.7.5 Restricted Access Zone (Sterilisation Zone)

To minimise the risk of injury to personnel through thermal radiation or related heat exhaustion, the volumetric zone around the flare flame within which the radiation may exceed the levels specified in 5.7.5.1 shall be designated a Restricted Access Zone. At places where it may be possible for personnel to enter this zone, (usually at ground level but also possibly via elevated structures), access shall be restricted by warning notices located in prominent positions.

Equipment may be located within a restricted access zone provided that:-

- (1) It is designed such that it will not be damaged by the highest levels of thermal radiation to which it could be exposed.
- (2) The equipment requires no regular operator attention or maintenance whilst the flare is in operation.
- (3) It is possible to carry out emergency maintenance without risk of injury from thermal radiation to personnel (wearing protective clothing or using radiation shields if necessary).

- * 5.7.5.1 A Restricted Access Zone shall be specified around the flare tip unless otherwise approved by BP. The radius of this zone shall be defined by the larger of the distances calculated as follows:-



(a) Operational (for periods of one shift or more)

The distance from the flare tip beyond which the thermal radiation level does not exceed 1.6 kW/m^2 ($500 \text{ Btu/ft}^2\text{h}$) at maximum operational flaring rate and a wind speed determined by local environmental conditions.

(b) Emergency (for periods up to 60 seconds)

The distance from the flare tip beyond which the thermal radiation level does not exceed 4.7 kW/m^2 ($1500 \text{ Btu/ft}^2\text{h}$) at maximum flaring rate and a wind speed determined by local environmental conditions.

(c) Blowdown (for periods up to 30 minutes)

The distance from the flare tip beyond which the thermal radiation level will not exceed 3.2 kW/m^2 ($1000 \text{ Btu/ft}^2\text{h}$) for more than 30 minutes.

The contribution from solar radiation shall be taken into account unless otherwise specified by BP.

5.8 Elevated Flares

5.8.1 Construction

*

The structural design of elevated flares, whether they are guyed, mast or tower supported shall be carried out by specialists in this field with a proven record of experience.

The design, detailing, supply and erection should preferably be the responsibility of a single contractor, but in any case the materials of construction, standards for fabrication, inspection and nominated fabricator shall be subject to approval by BP.

The flare vendor shall satisfy himself as to the meteorological conditions and all other relevant conditions likely to be encountered.

To lengthen the time period between inspections, the following constructional requirements shall be satisfied unless otherwise specified by BP:-

- (1) all load carrying connections shall be bolted,
- (2) all steelwork and bolting shall be galvanised or aluminium sprayed after fabrication.



The design of the flare stack shall take into account the proposed method of transportation and erection.

The structural calculations shall be submitted to BP for review and shall demonstrate that the following aspects of design have been investigated:-

- (a) Static wind loading.
- (b) Dynamic effect of wind, including:-
 - (i) The effect of wind turbulence on the dynamic response of the structure.
 - (ii) The vortex shedding phenomenon.
 - (iii) The dynamic response of guys, including 'galloping' response.
- (c) Ice loading on the structure and its effect on the static and dynamic response.
- (d) Local stress at guy attachment points and local stress due to the choice of structural element, i.e. in the case of tubular joints, punching shear stress.
- (e) Radiant heat and its effect on the riser, guys, upper guy fixings and upper members in the case of a structure.
- (f) The effect of fatigue. Analysis shall be carried out in accordance with the Department of Energy guidance notes - Offshore Installations: Guidance on design and construction - using n/N no greater than 0.5 for the design life. The fatigue design shall take into account the full extent of the allowable misalignment of circumferential seams.
- (g) Shell and strut buckling for the static and dynamic loads.

The specification for the bolting of flanges shall take fatigue into consideration.

5.8.1.1 Foundations

The foundation design should be by the main civil contractor, to the loads and moments specified by the supporting structure designers. See BP Group [RP 4-3](#).

In cases where guys are used, specific attention shall be paid to the possibility of differential settling of the main foundation and those of

deadmen. Earthing of the flare structure and riser shall be independent of the foundation reinforcement and piling.

Templates for anchor bolts shall be supplied and delivered to site in good time for associated civil works to commence.

It is essential to ensure by writing it into the contract of supply that the templates for anchor bolts and the details of deadmen are supplied by the vendor to site in time for foundation construction.

5.8.1.2 Flare Supporting System

Guylines and Terminations

Guylines and terminations shall comply with BP Group [GS 138-5](#) and the following:-

- (a) A radiation shield in type 321 stainless steel shall be provided where the effect of the incident heat flux will reduce a termination efficiency by more than 5%.

The calculated heat flux is used to derive an equilibrium temperature for the termination or guyline. For example, the incident heat load per unit length of a guyline is proportional to the flux, the projected area in the flux plane, emissivity and diameter of the guyline.

- (b) Sufficient articulation shall be provided in the connections between guy rope terminations at one end and rigging screws at the other end, to ensure that no bending moment is transmitted to their respective attachment points.

In the light of past experience guys and the associated equipment (i.e. shackles, turnbuckles, anchor points) should be checked and re-greased every 4-5 years.

In this connection, the effect of wind blowing the guylines sideways as well as other changes in the catenary form shall be accommodated.

Guys should be re-tensioned after the first year of operation and every 4-5 years thereafter.

Effect of Temperature

Structural components shall be designed to ensure that allowable stresses will not be exceeded at the temperatures which may be reached due to thermal radiation, hot gas flow and, if applicable, flame impingement. In carrying out this analysis, specific attention should be given to wind effects.

This analysis should recognise:-

- (a) *A high wind speed will increase flame tilt and therefore radiation levels on structures below the height of the tip. The high wind will also increase the cooling air flow around the structures.*
- (b) *In a guy-supported structure the guy ropes on the downwind side of the flare will receive the highest radiation levels. However at this time they will be carrying a reduced load.*
- (c) *Account should be taken of the minimal windspeed case. Here the flame is vertical or near vertical and incident radiation on the flare tip and structure is usually higher than in the high windspeed case. Further, little or no wind cooling is applied and so equilibrium temperatures can be high.*

* 5.8.1.3 Self-erecting Flares

To reduce erection costs, self-erecting flares may be used for high elevated flares, unless specified otherwise by BP.

A considerable portion of the cost of erection of high flares consists of the cost of using a crane. This can be reduced by using a self-erecting flare.

5.8.1.4 Flanges for Guyed Flares

Flanges for the risers of guyed flares shall be of forged weld neck type with flat faces. The jointing faces of the flanges should be machined after welding the flanges to the pipe. The accuracy shall be such that after assembly the deviation of the centre line from vertical shall not be greater than 30 mm in 100 metres.

The gas inlet to the guyed flares should be of the same size as the riser and may be in the form of either a 'tee' branch or a bend.

In both cases, sufficient reinforcement shall be provided to transmit the vertical loads in the riser from above the inlet to below the inlet without exceeding allowable stress levels.

The near-atmospheric pressure in the riser does not demand the use of raised face flanges. Flat face flanges also reduce stresses in the bolting, when the flare riser in a guyed flare is subjected to bending from wind loads.

5.8.1.5 Gaskets on Guyed Flare Risers

Full face gaskets with supporting inner and outer rings should be used.

5.8.2 Flare tips

* 5.8.2.1 General

The smokeless capacity and total capacity of the flare tip(s) will be specified or subject to approval by BP.

Flare tips shall be designed to burn with a stable flame for the full operating range at all anticipated wind speeds.



Flare tips shall be designed for minimum maintenance. The object is that no maintenance should be needed between unit overhauls.

Flare tip design and materials selection shall be made to minimise the potential damage to the tip and ancillaries due to high temperatures and corrosion. The design shall be suitable to survive flame lick.

The following lists some Coanda-effect flare tips made by various manufacturers (believed accurate in November 1983):-

With slots facing inwards, for internal mixing:-

FLAREJECTORS, by Airoil-Flaregas Ltd. where multiple Flarejectors are mounted on a steam chest forming a funnel shaped tip, or used in ground flares.

MARDAIR by Kaldair Ltd. for continuous flaring in off-shore installations: short flame length, low radiation and noise level.

With outward facing slot, for external mixing:-

INDAIR with gas-entrained air, STEDAIR with steam-entrained air, both by Kaldair Ltd.

* 5.8.2.2 Materials

The materials of construction of tips shall be suitable for the full range of metal temperatures to be encountered. These are dependent on the design of the tip, gases burnt, flow rate, cooling effect of the smoke-suppressing steam or air, burn-back at low flows or purge flow, etc.

Materials for the tip and related components shall be subject to approval by BP.

Where damaging burn-back inside the tip cannot be prevented or is anticipated, refractory lining of the tip should be considered. The type of refractory and method of application shall be subject to approval by BP.

Depending on service conditions, flare tip components will need to possess acceptable fatigue and elevated temperature strength. They may also need to be resistant to thermal cycling, stress corrosion cracking, high temperature corrosion (in reducing or oxidising atmospheres) or ambient temperature corrosion. Tip materials would normally consist of austenitic stainless steels or high nickel alloys depending on the particular duty.

The following materials have given acceptable performance:-

Type	Highest Temperature	Less exacting duties: Top of Tip Lower Part and Pilot and Igniter Piping	
		Type 310 S/S	Type 321 S/2
Wrought	INCOLOY 800 INCOLOY DS annealed		
Cast	PARALOY CR 32 W, MANAURITE 900 THERMALLY 52		
Bolts	ASTM A 193 Grade B8T Class 1 (i.e. not cold worked)		
Nuts	ASTM A 194 Grade 8T		

Note: Type 316 S/S should not be used and Type 316 L is not recommended both because of the possibility of catastrophic oxidation.

Bolting of grades B8M and Class 2 of B8T should be avoided for fear of stress corrosion cracking.

Logic dictates that tips prone to burn back should be refractory lined. This is to ensure minimal tip wall damage, and therefore maximum tip life under burn back conditions. However the alternatives of tips manufactured from temperature resistant material, or tip designs not prone to burn back, should be economically assessed at an early stage of development.

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, though not exhaustive, 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

This may be based on 'bull horns', 'hexmesh' etc., with consideration given to the means of its installation, repair, and its potential for creating shear planes in the lining.

(c) Refractory Reinforcement

This may be in the form of stainless steel needles, which act as 'crack stoppers'.

(d) Refractory Repair

With certain refractories, the repair or replacement of a lining may be considered a specialist task.

(e) *Refractory Curing*

Since most refractory material have been produced for burners, kilns and furnaces, some refractories require a carefully controlled curing and heat-up procedure.

However with most lined tips warm air curing may be practical, though gradual heat-up is impossible. Therefore particular attention should be paid to this point at the development stage. Often the refractory requires sealing after curing. The instructions of the refractory manufacturer should be followed rigorously.

(f) *Storage*

Refractory materials can be damaged if allowed to become wet before setting or if exposed to frost after setting.

5.8.3 Platforms and Ladders

Elevated flares shall be provided with ladders and platforms to provide access for maintenance and inspection of the tip and on guyed flares for the inspection of guy attachment points. These ladders and platforms shall be in accordance with BP Group [RP 4-2](#).

Where two or more stacks are within 150 m (490 ft) of each other, the access ladder shall be placed so that the stack shields the ladder from heat radiation from the other stacks.

Platforms and ladders on flare stacks should present minimal wind resistance.

5.8.4 Derrick for Tip Removal

5.8.4.1 Where the height of the flare is such that mobile lifting facilities available at the site are stated by BP as not adequate for removing and replacing the tip, the flare stack shall be provided with a derrick or other suitable handling appliance.

5.8.4.2 In normal flaring operations, the derrick shall be lowered below the level of the top platform or below the bottom of the inverted gas seal if fitted, to a position where it will not be affected by the flare. It shall be stored in a manner so that full load testing is not required before subsequent re-use.

5.8.4.3 Suitable lifting tackle shall be provided to raise the derrick to the lifting position. The wire ropes used for lifting the derrick and the tip, and the seal if fitted, shall be replaced by reeving lines and removed to storage.

The derrick anchor system and all associated lifting equipment shall be designed for the temperatures to which it will be subjected during

flaring without significant deterioration. It shall also be capable of operation after exposure to these temperatures.

5.8.4.4 The necessary moveable winch or winches shall also be provided.

5.8.5 Guarantees

The flare vendor shall guarantee:-

- (a) The capacity and pressure drop of the flare over the specified operating range.
- (b) The smokeless capacity range.
- (c) The required flow rate and pressure of smoke suppressing fluid.
- (d) The required flow rate and pressure of pilot gas.
- (e) Stability of pilots at the specified wind speed.
- (f) Safe operation at the specified purge rate.
- (g) The combustion support gas flow required.
- (h) The life of the flare tip.
- (i) The combustion efficiency at design flow.
- (j) The noise at design flow.

5.9 Ground Flares

5.9.1 Process Design

5.9.1.1 The ground flare shall be capable of providing stable combustion performance for the gas flow and composition ranges specified, and will satisfy the maximum allowable emission requirements. These will be provided by BP.

* 5.9.1.2 The ground flare chamber shall be designed to operate at a temperature sufficient to allow the complete combustion of all incoming gases and hydrocarbon fuels. The chamber temperature and residence time shall be agreed with BP.

* 5.9.1.3 The proposed height for the ground flare shall be submitted for approval by BP.



5.9.1.4 The exit area of the ground flare should be such as to provide adequate dispersion of all combustion products exiting the ground flare.

5.9.2 Construction

5.9.2.1 Chamber

The casing plate shall be seal welded to prevent air and water infiltration.

Structural steel shall be designed to permit lateral and vertical expansion of all ground flare parts.

All ladders and platforms, including bolting and other attachments, shall be hot-dip galvanised.

Consideration shall be given to the possibility of low temperature conditions occurring, particularly below acid dew-point level, and the possible effects of the resultant condensation within the ground flare.

Protection shall be provided against lightning. Earthing of the structure shall be as recommended by [BS 6651](#) or equivalent national standards.

5.9.2.2 Lining

The ground flare shall be lined with an acid-resistant material. The lining shall be capable of withstanding, without damage, a temperature 165°C (300°F) above the normal maximum flue gas operating temperature, and be capable of withstanding rapid change in temperature during excursion periods.

Walls, arches and floors shall be designed to allow for proper expansion of all parts under design conditions. Where multilayer linings are used, expansion joints shall not be continuous throughout the adjacent layer.

When ceramic fibre construction is used, the casing shall have an internal protective coating to prevent corrosion and a vapour barrier shall be required. Joints shall not be continuous through adjacent layers of ceramic fibre linings.

Access doors shall be protected from direct radiation by a material of at least the same quality as the adjacent liner.

5.9.2.3 Wind Fence

The ground flare shall be provided with a wind fence to prevent the wind from extinguishing the flames or causing vortices within the ground flare. The wind fence shall be designed such that adequate dispersion of combustion products is not impaired.

If a forced air purge is not to be used, then a means of opening the wind fence shall be provided to allow purging of high molecular weight gases on start-up.



Access ways shall be provided through the wind fence and into the ground flare to allow access for maintenance and inspection purposes.

5.9.3 Burners

The ground flare gas burner(s) shall be capable of stable firing within the specified range of gas flow and composition.

Combustion of the waste gases shall be completed within the combustion chamber without any flames issuing from the ground flare stack.

The gas jets in the main burners shall be sized sufficiently to remain free from blockage during all operating conditions and with all possible gas conditions. Generously sized jets are preferable to the use of filters in the main line.

The burners should be capable of turndown from the maximum flare gas flow to the minimum purge gas requirements.

5.9.4 Materials

*

The materials of the structures and accessories shall be adequate for all load conditions at the lowest specified ambient temperature when the ground flare is not in operation.

Furnace refractories shall conform to the relevant grade in [ASTM C 401](#) or [C 155](#).

The refractory shall be capable of withstanding, without damage, a temperature of 165°C (300°F) above the maximum operating furnace temperature, and shall be capable of a fast warm-up.

Surfaces of the ground flare which may come into contact with corrosive gases shall be given a protective coating against acid attack resulting from possible downwash of gases, in addition to protection from atmospheric corrosion. The acid-resistant protection is required in addition to galvanising for all ladders and platforms. The precise type of coating selected by the vendor shall be approved by BP.

Due to the possibility of failure in the event of fire, the use of brittle materials (e.g. cast iron, spheroidal graphite cast iron, malleable iron) and low melting point materials (e.g. copper or aluminium and their alloys, plastics) is not accepted for any burner pressure parts of their associated supports, bolts, nuts, springs etc.

5.9.5 Purging

*

Any proposal to pre-purge the ground flare with air shall be submitted to BP for approval. Fans provided for this purpose shall have anti-vibration mounts and conform to the requirements of [API 673](#) for centrifugal fans of more than 20 kW power.



5.9.6 Noise

Noise levels shall meet the general requirements of paragraph 5.12, and in addition shall be sufficiently low not to cause nuisance to local residents.

5.9.7 Instrumentation

General instrumentation requirements shall be as specified in section 9.

Additionally, each main flame zone of the ground flare shall be individually monitored with a flame detector capable of discriminating between it and adjacent flame zones, including the pilot flames. Alarms shall be provided to indicate loss of a main flame.

Facilities shall be provided for the permanent monitoring of the ground flare chamber temperature and draught.

5.9.8 Guarantees

The flare vendor shall guarantee:-

- (a) The performance of the ground flare hydraulically, mechanically and electrically.
- (b) The capacity of the flare for the specified composition range.
- (c) The smokeless capacity range.
- (d) The turndown ratio.
- (e) The minimum purge gas requirement for each burner.
- (f) Emission levels over the specified operating range.
- (g) Noise levels over the specified operating range.
- (h) That the flame envelope will be contained within the confines of the ground flare chamber.
- (i) That the ground flare lining will not suffer deterioration/degradation between anticipated overhauls.
- (j) The combustion efficiency at design flow.
- (k) The noise at design flow.

These guarantees apply to both summer and winter operation.



- 5.10 Ignition Systems
- 5.10.1 General
- 5.10.1.1 The flare tip or burners shall be provided with pilot burners capable of igniting flare gas under all relevant flow conditions and ambient conditions.
- 5.10.1.2 The pilot burners shall be ignited by a reliable ignition system capable of operating under all relevant ambient conditions.
- 5.10.1.3 A suggested arrangement of the pilot and igniter gas and air supply system is shown in Figure 1, although an equivalent arrangement may be provided, e.g. as a packaged unit.
- 5.10.2 Pilots
- 5.10.2.1 Pilots should be of an energy efficient design proved by at least 2 years operation in similar use, and capable of remaining lit in at least a 130 kph (80 mph) wind, or higher if appropriate to the site. At least 3 pilots shall be provided for each flare tip. For a ground flare, a minimum of 2 burners per zone shall be provided to ensure safe and reliable light-up of the main gas burners on commencement of gas flow and during all operating conditions.
- The pilot head assemblies should be manufactured from high-nickel alloy to ensure long service life.*
- Flame retention devices and wind shrouds may be used to achieve reliable ignition and stable pilot flames.*
- 5.10.2.2 A pilot flame failure detector shall be fitted to each pilot burner. This device, normally a thermocouple or a flame ionisation probe, shall be required to perform the functions specified in 9.3.
- 5.10.3 Igniters
- 5.10.3.1 The ignition of the pilots shall be achieved by a flame-front produced in the ignition panel and propagated through individual ignition pipes to each pilot. In the case of a ground flare, the use of high energy igniters shall be considered as an alternative ignition for the gas pilots.
- 5.10.3.2 Igniters shall form an integral part of the pilot heads and shall be similarly proved (See 5.10.2.1).
- 5.10.3.3 The ignition panel shall if possible be located in a non-hazardous classified area. The igniter fuel gas system shall be designed so that it is

not in itself a source of hazard, and the igniter electrical fittings shall be suitable for the surrounding zone classification.

Note that in offshore installations and other compact, restricted-ventilation areas, the location of the ignition panel in a non-hazardous classified area is unlikely to be practicable. Regardless of the panel location relative to the tip, care should be given to compliance with manufacturer's recommendations regarding pipe routing between the panel and the flare tip to be ignited.

5.10.4 Pilot Gas Supply

- * 5.10.4.1 The pilot gas supply shall be from a high-reliability source approved by BP. Automatic back-up gas supplies should be used where necessary to achieve an acceptable overall reliability.

The vendor shall confirm over what pilot gas molecular weight and calorific value range their flame front pilot ignition system will work satisfactorily without adjustment to the air and gas flows.

- 5.10.4.2 The pilot gas supply should be sweet and taken directly from the plant fuel gas main where available. This shall be by a top mounted branch, with two filters in parallel or a dual filter.

- 5.10.4.3 To check the pressure drop through the filter a differential pressure gauge shall be fitted across it.

- 5.10.4.4 The filter elements shall have a mesh size of approximately 0.5 mm (0.020 inch). The filter and piping and fittings downstream from filters shall be in type 321 or 347 stainless steel to avoid jet blockages by products of corrosion.

- 5.10.4.5 The pressure reducing valve shall be of a self-operating type, placed downstream of the filters.

5.11 Flashback Prevention

- * A reliable method of flashback prevention shall be incorporated into the flare system design. The following methods may be used, either singly or in combination:-

- (1) Gas purge - refer to 7.1.
- (2) Liquid seals - refer to 7.2.
- (3) Gas seals - refer to 7.3.
- (4) Efflux velocity accelerators - refer to 7.5.



The above methods are primarily intended to prevent diffusion of air into the flare stack. Where condensable materials are being flared, there will be a significant probability of large amounts of air being sucked back. Where flare gas recovery is used both gas purge and liquid seals should be installed.

The use of a flame arrester shall be considered only in cases where none of the above methods are suitable and subject to the restrictions of 7.4.

The choice of method will be subject to approval by BP.

If air (or oxygen) enters a flare system and forms a flammable mixture of gases within the system, the mixture will be ignited by the pilot burners at the flare tip. If the flash back velocity of the mixture exceeds the efflux velocity, the flame will burn back into the flare stack and an explosion is likely to result. Flare stacks have been ruptured by such explosions.

If the efflux velocity is very close to the flash back velocity, fairly steady combustion may occur within the flare stack, which may lead to overheating and loss of mechanical integrity. (To achieve such internal combustion for long enough to overheat the flare stack in this way would require the in-leakage of sufficient air to sustain the combustion).

Some of the conditions conducive to the formation of flammable mixtures within the flare system are:-

- (a) Where vacuum systems are linked to the flare.*
- (b) Where lighter-than-air gases are being flared.*
- (c) Where condensation or rapid cooling can occur within the flare system. (It may be possible to reduce or even prevent condensation by heating and insulating the flare line; however, such measures may be expensive to install and difficult to maintain in a reliable condition).*
- (d) Where air or oxygen is used in processes connected to the flare system.*

The flare flame will not travel back into the flarestack provided that the efflux velocity of the flare gas exceeds the flash back velocity. (This still applies even if the flare gases have been premixed with air upstream of the flare tip).

To achieve this essential condition, the efflux velocity may be increased by the addition of purge gas or by the use of the velocity accelerator (see 5.5), or the flash back velocity may be reduced by the addition of inert gases to the flammable mixture. The best location for the addition of inert gas is as close to the flare tip as possible compatible with good mixing of the gases before burning at the tip.

The practicability of using inert gas to reduce the flash back velocity would depend upon the availability of a very high integrity source of inert gas at the site, in sufficient quantity at an economic price.

Velocity accelerators and inert gas addition may be used in combination.

The main advantages of using inert gas is that a properly designed system will give protection against flash back through air ingress from any source. The major disadvantage is that at low flare gas flow rates, the gas mixture may become non-combustible due to the excess of inert gas present. Unburned toxic and/or strong smelling components may escape to atmosphere and possibly cause a nuisance.

Method of Calculating the Flash Back Velocity:-

A method of calculating the flash back velocities for some gases commonly occurring in flare systems when mixed with nitrogen, carbon dioxide or both, has been developed by Van Krevelin and Chermin and reported in the transactions of the Seventh International Symposium on Combustion, 1959, pages 358-368.

This method may be used to calculate the inert gas flow corresponding to the peak flash back velocity of the gas mixture. An excess inert gas flow of twenty five percent above the calculated value should provide an ample margin of safety to compensate for measuring errors and minor flow disturbances.

A flame arrester should be considered only when there is no other viable or economic alternative.

(e) Where relief valves are removed for servicing.

5.12 Noise Levels

- * 5.12.1 The flare shall be sited such that the noise at positions normally accessible to personnel, at the maximum emergency flow should not exceed 115 dB(A), except with the approval of BP. A lower noise limit may be specified by BP to be applied in a particular case, e.g. offshore platform, ground flare.

To reduce the noise in specific areas, the siting of the flare, if possible, should be such that the flare is not in the direct line of sight from the area.

The main contributor to the noise in a smokeless flare is the steam jet noise. Therefore, in general, the lower the ratio of steam to flared gas, the quieter the flare.

- 5.12.2 Flare vendors, in their quotations, shall provide information on the noise emission from the flare at maximum emergency flow and at the maximum smokeless flaring rate. The noise emission data shall be provided as a test report containing the sound-power levels in octave bands from 31 Hz to 8 kHz. All measurements shall be made according to [CONCAWE report 2/79](#).



5.13	Auxiliary Flare Piping
5.13.1	All the auxiliary flare piping required for flare operation shall be provided. This may include the following:- - pilot gas line - flame front igniter line to each pilot - steam line to the main smoke suppression system - steam line to the auxiliary system - oxygen sampling lines
5.13.2	Piping shall be generally in accordance with BP Group RP 42-1, and as specified below. <i>In a potentially high temperature environment, galvanised and stainless steel pipe and fittings should not be in contact with each other.</i>
5.13.3	The differential thermal expansion of the auxiliary flare piping shall be specifically allowed for in the design. The method preferred by BP in an elevated flare is to have the piping anchored at the top of the stack in the vicinity of the bottom of the tip and guided along the length of the stack; the expansion will be taken up by the flexing of a sufficient horizontal length of the connecting piping at ground level. <i>The described preferred method to allow for the thermal expansion is considered much simpler and better than the often-used expansion loops, one per riser section. The loops produce additional wind loads, are often subject to vibration, and are difficult to insulate and inspect properly.</i>
5.13.4	Pilot gas piping and oxygen sampling lines shall be of type 321 or 347 stainless steel, with the oxygen sampling line in 15 mm o.d. (1/2 in o.d.).
5.13.5	In an elevated flare, piping shall be flanged at the base of the tip for ease of tip removal, with suitable flanges for spading points at the base of the stack.
* 5.13.6	The location of connecting joints and the type of joints at grade will be specified by BP.
5.14	Trace Heating Trace heating used for winterisation shall be in accordance with BP Group RP 44-2.
5.15	Flare Sparing Philosophy
*	Sparing of flares shall be considered to allow for maintenance, inspection and breakdown. When a flare system serves more than one



unit which can function independently, then some form of sparing may be specified by BP.

The time between overhauls will be specified by BP. Adequate provision shall be made to enable the full specified range of continuous and intermittent flaring operations to be sustained during this period.

Where a flare serves one unit only, maintenance and inspection can be performed during normal shut down periods. Breakdown may be considered unlikely to occur, and where this would in any case involve shut down of one unit only, may be considered an acceptable risk.

Where two or more flares are available, the flare lines may be configured to allow one of the flares to be taken out of service. In this instance back-up shall be provided in the form of atmospheric discharge; such discharge should meet the requirements of BP Group [RP 44-1](#) for atmospheric discharge.

Where actual sparing is required, i.e. having an additional spare flare which can replace if necessary other flares during maintenance, inspection or breakdown, the most economical way of providing this may be the use of common structure supported multiple risers, which together with their tips can be individually lowered during operation of others. This allows for maintenance, inspection and replacement of risers, tips and auxiliaries. Special arrangements for the inspection and maintenance of the supporting structure are required.

A spare flare involves not only extra cost for the additional flare, but also for piping and valving and, what is often more difficult to obtain, the extra area for siting.

6. LIQUID REMOVAL

6.1 On-site Knock-out Drum (Onshore)

The essential purpose of this drum is the removal of the bulk of the liquid carry-over.

The choice between a horizontal and a vertical drum should be made on economic considerations, taking into account the vapour flow rate, the liquid storage required and the necessary slope of the flare header.

- 6.1.1 An on-site knock-out drum should normally be provided within the battery limit of each plant or group of plants served by the flare system. A drum shall be provided in all cases where significant quantities of liquid can be relieved from within the battery limit.
- 6.1.2 This drum design shall comply with the appropriate sections of BP Group [RP 46-1](#). Drums shall be designed for full vacuum and a maximum allowable working pressure of at least 3.5 barg, (50 psig).
- 6.1.3 Attention is drawn to the requirements of 6.3, which may lead to a requirement for separate knock-out drums to maintain segregation



between 'cold' and 'wet' streams. Vaporisation facilities shall be provided for liquid disposal.

It may be necessary to consider facilities to vaporise and superheat cold vapour before it enters the main flare header.

- 6.1.4 The liquid storage capacity of the drum shall allow for a minimum of 20 minutes hold-up at maximum liquid in-flow to the drum. This capacity shall be provided between the maximum normal liquid level (i.e. the pump trip-in level) and the maximum level allowable in the drum taking into account:-
- (a) Any simultaneous requirements for vapour/liquid separation.
 - (b) Any flashing of the relieved liquid at the knock-out drum pressure.
- 6.1.5 Because of the potential for blockage from scale or waxy deposits, the use of a demister pad to limit the size of the drum should be avoided. Applications shall be restricted to clean systems where there is no practical alternative.
- * 6.1.6 The knock-out drum shall be provided with automatic hydrocarbon liquid removal unless otherwise specified by BP.
- Since the liquid in the KO drum may be toxic or flammable, or have toxic or flammable material dissolved in it, particular care should be taken in the design and operation of any drain points. If there is any risk of toxic materials being released, then the drain should be routed to a closed system. If there is any risk of the materials freezing, a second valve in series is required as a minimum.*
- * 6.1.7 Where appropriate, separate facilities for water or heavy hydrocarbon removal shall also be provided; these may be automatic or manual. The disposal route and facilities for these liquids shall be approved by BP. Particular attention should be paid to prevent the creation of a hazard due to the release to atmosphere of flammable or toxic materials from drain points.
- 6.1.8 Instrumentation and control systems for the drum shall be in accordance with Section 9 of this Recommended Practice.
- 6.1.9 Piping systems entering and leaving the drum shall be in accordance with Section 8 of this Recommended Practice.
- 6.1.10 Winterisation shall be provided for the drum in accordance with BP Group [BP 44-2](#).



- 6.1.11 Personnel protection shall be provided in accordance with BP Group [RP 52-1](#).
- 6.1.12 Facilities shall be provided for isolation, venting and purging, inspection, maintenance and cleaning of the drum.
- * 6.1.13 Specific attention shall be given to the requirements of inspection, maintenance and cleaning where the associated plants cannot be shut down and proposals shall be submitted for BP approval.
- 6.2 Off-site Knock-out Drum (Onshore)
- 6.2.1 Off-site knock-out drums shall be provided for each flare system. The drums shall be located as close as practicable to the flare taking account of access requirements and the possible use of liquid seals which shall be located downstream of the drum.
- 6.2.2 The off-site knock-out drum design shall comply with BP Group [RP 46-1](#). Drums shall be designed for full vacuum and a maximum allowable working pressure of at least 3.5 barg, (50 psig).
- * 6.2.3 The off-site knock-out drum shall be sized to remove liquid droplets above 600 µm at the maximum emergency gas flow to the flare, and above 150 µm from the gas flow equivalent to the maximum smokeless capacity of the flare. In exceptional cases, for flares which are capable of burning larger sized droplets, a waiver of these requirements may be accepted, subject to BP approval.
- The calculation method shall be in accordance with [API RP 521](#).
- 6.2.4 In all other respects the off-site knock-out drum shall comply with the requirements for on-site knock-out drums detailed in 6.1.4 to 6.1.12 of this Recommended Practice with the exception of section 6.1.4 relating to liquid hold-up.
- 6.3 Cold Service
- 6.3.1 Specific attention shall be given to liquid removal facilities in flare systems which are required to dispose of both 'cold' and 'wet' streams. In this context, a 'cold' stream is defined as a stream at a temperature below 0°C which could cause freezing of water in a knock-out drum, or on mixing with a stream containing free or dissolved water. The situation is most likely to occur in plants handling liquefied gases or gas streams at high pressure.
- * 6.3.2 Wherever practicable, separate systems shall be provided for cold streams with segregation maintained until the streams become



compatible. The flare vendor's proposals shall be submitted for BP approval. Cold-liquid collection drums may require vaporisation facilities.

The relief of liquid propane and butane will frequently result in a cold two phase discharge. Unless the disposal system is specifically designed to handle low temperature fluids, it will be necessary to provide a heating system to vaporise any liquid and then superheat the cold vapour before it enters the main flare system.

The system should make use of indirect heating to avoid the possible contact of cold fluid with steam condensate in the event of tube rupture in the heat exchanger. Suggested heating media are methanol or glycol, but others may be considered.

- 6.3.3 Attention shall also be given to the presence of other materials that freeze or are highly viscous at temperatures above 0°C.
- 6.3.4 Attention is drawn to the special sealing provisions for cold service in Section 7 of this Recommended Practice.
- 6.4 Liquid Removal (Offshore)
 - 6.4.1 The liquid removal facilities should be designed to remove entrained droplets (which may carryover as burning hydrocarbons) from the gas flow and provide sufficient liquid hold-up capacity to collect any surges of liquid. The hold-up capacity should be based on the longest estimated time required to isolate the incoming flow, taking account of the reliability of any Category 1 instrumentation systems (see 4.3.2 of BP Group [RP 44-1](#)).
 - 6.4.2 Maximum use should be made of surge capacity within the process area to accommodate liquid relief.
 - 6.4.3 Devices which provide warning (and if necessary execute shutdown action) shall be fitted to all relief valves which can discharge liquids to flare.
 - 6.4.4 The minimising of possible liquid relief to the flare system should be a normal feature of any design. Category 1 trip systems should be installed on all equipment capable of discharging liquids into the flare system.
 - 6.4.5 Category 1 shut-off systems should be installed on the inlet lines to separators. (See BP Group [RP 30-6](#)).

7. FLARE PURGING AND SEALING

7.1 Gas Purge

- * Unless otherwise specified by BP, a continuous purge system shall be used.

The choice of inert gas or fuel gas is based primarily on economic assessment.

- * 7.1.1 Flammable gas or inert gas, e.g. nitrogen, may be used for purging. The choice should be evaluated on cost. Lower molecular weight gases require larger quantities of purge gas to achieve similar safe conditions within the stack. (See 7.1.4). When deciding to use an inert purge specific attention shall be given to the consequences of releasing unburned toxic materials to the atmosphere.

The purge gas supply shall be from a high-reliability source approved by BP. Automatic back-up supplies should be used when necessary to achieve an acceptable overall reliability.

In choosing between a fuel gas and an inert gas purge, it should be noted that one volume of fuel gas will produce about ten volumes of inert gas in an inert gas generator. However, the inert gas generator must be purchased and a back-up supply must be provided, since it must be inherently less reliable than its feed gas supply.

The methods given for calculating the required quantity of purge gas are based on a sufficiently high efflux velocity to prevent the oxygen concentration 8 m from the top of the stack becoming more than half the lower flammable limit. This is intended to prevent flash-back down the stack. If an inert gas is used the flash-back velocity (the speed with which a flame travels through the mixture) is significantly reduced. This has the advantage of significantly reducing the risk of a damaging explosion in the event of an unforeseen occurrence such as a suck-back.

With an inert gas purge, the object is to ensure that the efflux velocity is always greater than the flash-back velocity. For a given relief composition there is a maximum required purge rate which can be significantly smaller than the purge rates required by the Husa formulae. This maximum purge rate is calculated by establishing the required purge rate to balance flash-back and efflux velocities for a variety of relief flow rates.

- 7.1.2 The minimum flow rate of the purge gas to prevent flashback shall be such that the oxygen content in the flare gases 8 m (25 ft) or 15 diameters, whichever is the less, down from the top of the flare shall be less than 6 percent. For flared gases containing more than 85% hydrogen the maximum oxygen content shall be reduced to 2%.

When recommissioning an air-filled stack, a high initial purge flow shall be used.



- * 7.1.3 BP will specify when it is necessary to maintain the flare alight, even though in such cases the minimum purge referred to in 7.1.2 will be very small.
- 7.1.4 For any purge gas lighter than air, the required purge rate shall be calculated using the modified H.W. Husa's correlation formulae given in Appendix C.
- 7.1.5 For minimum purging, to check if the safe oxygen levels specified in 7.1.2 are maintained, the stack shall be equipped with an oxygen monitoring system as described in 9.7.
- 7.1.6 For flammable purge gases heavier than air, the minimum purge rate could be achieved with very low flow rates. This may result in burning inside the tip, resulting in higher tip temperatures and shorter tip life, or flame extinguishment. In such cases the minimum flow rate required shall be adequate to maintain the flare alight, whilst the problem of internal burning shall be economically evaluated against the following alternatives:-
- (1) To increase the purge gas velocity at the tip to typical velocities of between 0.15 m/s and 0.3 m/s (0.5 f/s and 1.0 f/s).
 - (2) To upgrade the material specification of the tip.
 - (3) Provided there is an alternative relief route during flare shut down, to replace the tip more often.
 - (4) To provide tip cooling.
- 7.1.7 Emergency purge gas should be provided to the flare system, where appropriate, to prevent the formation of a vacuum as the system cools following a release. The supply should be automatically initiated and controlled by pressure, temperature, or a combination of both.
- With a liquid seal, the relief disposal piping system upstream of the seal will be subject to vacuum conditions when a hot relief flow stops and cools. This is not necessarily a dangerous condition, provided that:-*
- (a) *The equipment is designed for the maximum vacuum conditions that can occur.*
 - (b) *No unintended flows are initiated because of increased pressure differential.*



7.2 Liquid Seals

7.2.1 Uses of Seals

- 7.2.1.1 Liquid seals may be employed for flashback prevention and for diversion of vapour flows. (See [API RP 521](#)). Liquid seals should be incorporated in relief disposal systems as close as practical to all elevated flares and shall be used wherever there is a flare gas recovery system.

A liquid seal is only one of a number of methods of preventing the ingress of air into a flare system via the flare tip. It will normally be utilised in conjunction with continuous or emergency gas purging. Although traditionally provided, its effectiveness may be limited in situations where hot flare gas can cause significant boil-off of the seal liquid.

- 7.2.1.2 Where more than one flare is connected to a relief header and automatic pressure-actuated valves are used, a full capacity back-up route to the flare shall be provided via a liquid seal.

These valves are used to accommodate increasing flow rates, and either to differentiate between smokeless and non-smokeless flaring, or to increase turndown and burning efficiency. Where liquid seals are impractical, another system is required which provides both a guaranteed emergency relief route and a guaranteed protection against suck-back.

7.2.2 Types of Liquid Seals

- * 7.2.2.1 Water seals shall only be used if the temperature of the vapour cannot fall below 0°C. To guard against freezing in cold weather the seals shall be fitted with automatic heating, either electrical or steam coil, as specified by BP.

Some chemicals can raise the freezing point of water above 0°C. If such chemicals could be relieved, then suitable adjustments should be made to the water seal or the seal liquid.

- 7.2.2.2 For cold service, glycol or other suitable material shall be used, either pure or with water, depending on the anticipated temperature of vapours.

7.2.3 Design (See Figure 1)

- 7.2.3.1 The vertical leg of the flare header above the liquid level shall form a vacuum leg of adequate length for the maximum vacuum expected in the header due to cooling and/or condensing of hot vapours. It shall be at least 3 m (10 ft) high. The volume of liquid in the seal drum above the level of the top of the submerged weir shall be sufficient to fill this vacuum leg.



With materials less volatile than LPG (C-4) a vacuum leg of 3 m is unlikely to be an adequate safeguard. At this pressure (0.7 bar abs), the dew point of C-5 hydrocarbons is ca 20°C and that of C-6 hydrocarbons 50 to 70°C. The flare header must be maintained above these temperatures for a 3 m vacuum leg to be effective. With a vacuum leg increased to 5 m high, the corresponding temperatures are 15°C and 40 to 60°C respectively. In many cases, it would be necessary to use an impractically high vacuum leg to avoid suck back.

The traditional style of a single dip-leg with a serrated end was satisfactory when there was always an appreciable flow of gas to the flare tip. The reduction of leakage and the addition of flare gas recovery systems has changed that significantly. The one large dip-leg invariably leads to flow pulsations which are seen at the flare as flame pulses. These make the flare more noticeable and defeat any attempt at maintaining a controlled steam flow to keep the flare smokeless. A more effective system is based on separate dip-legs of different sizes, sometimes with side slots, so that each release route allows a progressively larger flow without any noticeable pulsation. To provide enough circumference for placement of serrations and reduce the gas velocity the dip pipe diameter may have to be increased. The diameter of the baffle sheath should be 1.8 to 2.0 times the diameter of the dip leg, with 13 mm dia. holes on 75 mm diagonal centres.

In all cases the dip-leg should be surrounded by an anti-splashing perforated baffle sheath.

- 7.2.3.2 The maximum depth to which the inlet pipe may be submerged shall be based on the maximum exit back pressure allowable in the relief header.

To prevent surges of gas flow to the flare, the free area for the gas flow above the liquid should equal at least 3 times the inlet pipe cross-section area.

- * 7.2.3.3 Details of the dip leg design shall be submitted for BP approval. The design shall be capable of flowing all quantities from maximum emergency flow down to 1/2000th of that flow without causing flow pulsations which cause nuisance.

The flow range of maximum to 1/2000th may be too small a range. Some recent refinery designs have shown a need to provide pulse free flaring from about 300,000 Kg/hr (for the maximum emergency case) to about 100 Kg/hr (for the normal leakage case).

- 7.2.3.4 A minimum pressure of 3.5 barg (50 psig) shall be used for the design of the seal drum.

- 7.2.3.5 All the equipment shall be provided to maintain the design seal level. Make-up lines shall be sized to replace the seal within 10 minutes.

The design of the seal system shall provide for:-

- (a) prevention of hydrocarbon build up,
- (b) prevention of displacement of seal liquid,



- (c) maintaining the correct seal liquid level, over the operating pressure range.

7.2.3.6 The flare header shall slope from the top of the vacuum leg back to the off-site knock-out drum.

7.2.3.7 Where water is used for the seal, the design of the disposal system for excess water shall take into account the likely contamination with relieved materials, e.g. H₂S. Alternatively, a recirculating system may be provided with capacity to allow for make-up and for checking the liquid inventory. This latter option should be provided for the systems containing anti-freeze.

7.2.3.8 Where make-up requirements are not significant (i.e. static liquid seals), antifreeze systems may be used. In this case, the requirements of 7.2.3.5 may be under manual control.

7.3 Gas Seals

- * 7.3.1 Neither gas seals of the labyrinth type; nor seals of the flow restriction type are recommended, but they may be used, subject to BP approval.

If in exceptional circumstances it is intended to use either type of seal, it is impossible to quantify the benefit and hence no reduction in purge flow should be used.

There are two main types of gas seals: the labyrinth type and the flow restriction type.

The labyrinth type, also referred to as an inverted gas seal is known under the trade name of John Zink Molecular seal, or Flaregas 'Flarex', etc. The flow restriction type, exemplified by National Airoil's Fluidic Seal, consists of a flow restriction in the form of a series of stepped cone sections of changing diameter, the purpose of which is to reflect back the atmospheric ingress turbulence. Though called seals, neither stop the reverse flow completely, only reduce it. They are both installed immediately below the flare tip. However, when the volumetric condensation or cooling rate of vapour in the relief system exceeds the purge rate plus the incoming gas volume, air entry can no longer be precluded and a risk of an explosion exists.

In the labyrinth type of seal when using purge gas lighter-than air, the buoyancy of the purge gas creates a zone of greater-than- atmospheric pressure at the top of the seal, which prevents air from entering the flare stack. Purge gas heavier-than-air 'floods' the seal, and the labyrinth prevents atmospheric ingress.

Due to the ingress of rain water and the possibility of condensation, labyrinth gas seals require drains. These can block with ice or carbon, or with refractory, if any, dislodged from the flare tip, and therefore such seals are not recommended.



7.4 Flame Arresters

*

Flame arresters are another way of preventing flashback, but they have been found notoriously unreliable due to blockage. They shall be used only in clean systems and where there are no practical alternatives. Provision shall be made for checking their condition, and it shall be possible to maintain or replace them without shutting the plant down. Their use shall be subject to BP approval.

These are not very commonly used, but could be effective against both causes of flash back. Their disadvantage comes from the fact that they can easily become blocked by dust, carry-over, corrosion products, materials liable to polymerisation, etc.

Published information on flame arresters is very limited, and the best available on design is contained in the Health and Safety Series booklet HS(G)11 entitled: 'Flame Arresters and Explosion Relief', although this is limited in application to flare stacks of up to 900 mm (36 in) diameter.

7.5 Efflux Velocity Accelerators

Flashback from the flare flame into a flare stack will not occur provided that the efflux velocity of the flare gases always exceeds the flashback velocity. The efflux velocity may be increased by the use of an orifice plate with a single or multiple orifice.

If it is intended that an efflux velocity accelerator will be used the following points should be given due consideration:-

- 1. Possible back mixing and deceleration effects due to wind.*
- 2. Deceleration or reverse flow due to condensation of vapour or gas cooling and contraction within the flare system.*
- 3. The possibility of ignition occurring below the velocity accelerator from any conceivable cause.*
- 4. The increased back pressure imposed by the orifice plate, especially at high discharge rates.*
- 5. The possibility of the orifice plate becoming blocked or corroded in service.*

8. FLARE LINES

8.1 Routing

*

A flare line should be routed to avoid fire risk or otherwise hazardous areas, e.g. other process plants. If this is not practicable, the routing and protection of the line supports shall be proposed for BP approval.

The route shall avoid areas of high fire risk, whether in the unit of origin or in another unit.



An incident is known in which, during a fire on a refinery unit, a neighbouring unit had to be shutdown for safety reasons. This involved dumping to the flare through a flare line passing through the unit on fire. The line was damaged by the fire and fed it with additional material.

8.2 Design and Construction

- * 8.2.1 Thermal movement of flare lines shall preferably be accommodated by providing flexibility in the piping layout or alternatively by expansion loops. Sliding expansion joints shall not be used. Any use of piping bellows shall be subject to approval by BP.

When flaring streams likely to contain H₂S or water vapours, bellows should only be used when essential.

- 8.2.2 The flare lines should slope all the way towards the knock-out drums at 1 in 400 minimum; if this is not possible, drainage pots shall be provided at low points. The pots shall be fitted with a level gauge, automatic pump-out facilities and frost protection where required.

Horizontal sections of line to accommodate possible flow in either direction are not acceptable.

- 8.2.3 Individual relieving devices in closed systems shall be located above the header.

- * 8.2.4 Where several units are connected to one flare system, isolating block valves, with flushing connections unless otherwise specified by BP, shall be provided in the sub-headers at the unit battery limits. Such valves shall be provided with locking devices which can be locked open, position indicators and with spectacle blinds upstream. Valves shall be installed so that the gates cannot fall into the closed position should they become detached.

- 8.2.5 A valved, blanked, drain branch shall be provided upstream of the block valve to facilitate the draining and purging of the isolated branch.

- * 8.2.6 Purge gas connections, including vents and drains, shall be provided to enable all parts of the relief system to be purged and steamed out. These shall be connected to the fuel gas system or nitrogen supply as specified by BP. See also 6.5.2 of BP Group [RP 44-1](#).

- 8.2.7 Where headers of different materials of construction are connected together, in view of possible backflow, the higher quality material shall be used for at least 10 m (33 ft) upstream of the change in the process conditions.



- 8.2.8 Pipe stressing and anchor and support design shall allow for thermal expansion or contraction, two-phase flow, slugs of liquid, ice formation in cold service and fire protection, if any. In order to avoid expensive overdesign, the flare header mechanical design should be based on a realistic evaluation of the maximum temperatures and durations of each relief situation, and not simply the maximum specified relief temperatures.
- 8.2.9 Consideration shall be given to the need for hydrotesting after construction. If it is required, all components, particularly foundations and supports, shall be designed for this condition.

9. CONTROLS AND INSTRUMENTATION

- 9.1 General
- * Attention shall be given to the effects of radiation on instrumentation.
- Other BP Group Recommended Practices give recommended design guidance for instrumentation.*
- 9.2 Pilot Ignition (See Figure 1)
- * 9.2.1 The ignition of the gas-air mixture in the ignition chamber shall be by a sparking plug which may be energised by a mains transformer. Back-up ignition of piezoelectric means shall be provided. The ignition may be manual or fully automatic as specified by BP.
- 9.2.2 The ignition panel shall contain, on both the gas and air lines, stop valves, regulating needle valves, pressure gauges and non-return valves. Downstream of the mixer and the ignition chamber, means shall be provided to direct the flame front to each of the pilots in sequence.
- 9.2.3 If fully automatic, the ignition system shall carry out the following:-
- (1) On press-button initiation, open the flow of the ignition gas and air, fire the sparking plug to ignite the first pilot.
 - (2) Monitor, through the thermocouples installed in the pilots, whether the pilots are on.
 - (3) If a pilot is not on, make 3 attempts to re-light that pilot. If this fails, give an alarm.
 - (4) As each pilot is ignited, turn the distributing valve and repeat the actions to ignite the second pilot, and so on until all the pilots are lit.



In addition, full manual operation shall be provided.

9.3 Pilot Flame Failure Detection (See Figure 1)

Each pilot shall be fitted with flame failure detection, which is required to perform the following functions:-

- (1) Alarm to indicate a detector fault.
- (2) Alarm on pilot flame failure.
- (3) Indicate 'pilot on'.

A common alarm in the control room shall be activated for any of the above failures. The local ignition panel shall indicate the location and type of failure.

9.3.1 *Although in practice pilot flame failure detection thermocouples are not reliable, there is presently no reliable alternative.*

9.4 Automatic Smoke Control (See Figure 1)

- * 9.4.1 When specified by BP, smokeless flares using steam for smoke suppression shall be equipped with automatic control systems which will apportion the suppressant to the flare gas, to produce clean burning without excess flow.

Excessive steam flow is not only costly but also increases flare noise.

9.4.2 The three main types of control system that may be used are:-

- (a) ground mounted optical flare radiation sensor
- (b) high level flare radiation sensor
- (c) based on measurement of the flow rate of the flare gas.

As the flare will operate over a very wide range of flow rates, the flow-measuring device shall not obstruct the line or reduce its capacity. The preferred method of control is (a), but if (b) is to be used, the flow measurement should be by flow sensing thermistors (see 9.8.1).

9.4.3 System (a) depends on the fact that the radiation from a smoking flame is greater than that from a smokeless one. The measuring of the radiant-heat energy from a portion of the flame may be achieved either by an optical monitor located at ground level at a moderate distance from the base of the flare stack, and trained on the base region of the flame, or by paralleled high level radiation sensors spaced around the stack just below the tip.

Density measurement and compensation need only be considered when flared gas accounting is necessary.

- 9.4.4 The optical monitor shall be a rugged telescope with a restricted field of view, equipped with a photo-cell sensitive to near infra-red radiation. The telescope shall be of waterproof design and allow regular cleaning of the lenses.

The advantage of an optical monitor is that it is located at ground level and therefore can be checked and maintained at any time; it also has a fast response. The disadvantages are that it requires a very precise aiming which can easily be disturbed, and is not sufficiently selective to permit its use for multi-burner installations.

- 9.4.5 In system (b), the high level radiation sensors, because they cannot be reached during flare operation, shall be non-optical, strongly constructed and maintenance-free.

- 9.4.6 For both types of radiant heat measurement, compensation for ambient variations (night/day, sun/cloud) may be required. Signals from the monitor shall operate the steam control valve via appropriate converters, adjustable for range and zero. Manual control shall also be provided.

- * 9.4.7 If system (c) is proposed, it shall contain facilities for on-stream inspection and maintenance of all the important parts of the system, and where specified by BP the system shall include a density-measuring device to provide corrections allowing more suppressant for heavier hydrocarbon gases.

9.5 Burn-back Detection

- * Where burn-back in the tip can occur, burn-back detection shall be provided by one or more thermocouples in thermopockets whose location inside the flare tip will be subject to approval by BP. The thermocouples shall be wired to control room alarms through a temperature switch adjustable for a temperature range appropriate for the tip.

9.6 Purge Control

The flow rate of the continuous purge of the flare system shall be based on the oxygen concentration in the stack as specified in 7.1.2.

9.7 Oxygen Monitoring (See Figure 1)

- * 9.7.1 Oxygen monitoring shall be provided on all flares unless otherwise specified by BP.



The primary purpose of oxygen monitoring equipment is to ensure that if a minimum purge rate is used an explosive atmosphere does not result. It may also highlight the spurious ingress of oxygen due to operating deviations, e.g. suck-back.

If inert gas is being used for flashback prevention and the system is of high integrity, then oxygen monitoring may not be required.

Experience indicates that the provision of oxygen monitoring equipment may be waived on certain installations. These include installations using the KALDAIR MARDAIR flare or HP INDAIR flare, since chance of oxygen ingress is reduced by virtue of their design. Also waivers may be granted for ground flare installations or certain offshore installations where minimum purge conditions are either difficult to monitor or unlikely to be necessary.

9.7.2 The oxygen sampling probe shall be located 8 m (25 ft) or 15 diameters, whichever is the smaller, below the tip exit. The probe piping shall be in accordance with 5.13.4.

9.7.3 The oxygen analysing installation should be located at the base of the stack or at the boundary of the Restricted Access Zone. If located in an area where radiation level may exceed 4.73 kW/m² (1500 Btu/ft²h) it shall be provided with suitable shielding.

* 9.7.4 The sample gas shall be withdrawn by a diaphragm type vacuum pump, fitted upstream with liquid knock-out pot, and returned to the stack above the sample point. This is required to avoid a fluctuating pressure in the sampling line, due to changes in the pressure drop through the stack induced by changes in the flow rates.

A portion of the sample gas shall be taken through a regulating needle valve to an oxygen analyser of a type specified by BP, and exhausted to atmosphere. Local and control room indications and alarms shall be provided as specified by BP.

9.8 Flow Measurement

9.8.1 Flow measurement of the flare gas may be required for two reasons:-

- (a) For control of the flow rate of the smoke suppressant.
- (b) For information.

Function (a) is better performed by monitoring the luminosity of the flame.

The very wide range of the flow rates between a purge and a full emergency release presents a difficult problem for the instrumentation. An additional problem is dirt that is often present in the gas.

Based on BP experience (1983) the best available equipment for the task is that supplied by Redland Automation Ltd. (Instrumentation Division), previously J. AGAR Instrumentation Ltd., which should be first considered where flow measurements are required and specified by BP.

Typically the range from low flow to non-smoking capacity may be required to be measured, and it would not be possible to cover this with one instrument.

It would not be usual for the flow during emergency flaring, usually of short duration, to be measured, but if this is required, additional probes suitable for the higher flows should be used.

Wherever the flare gas temperature range is such that it will not damage the sensing thermistors, direct-insertion flow probes with flow sensing thermistors mounted in the probe's tip should be used, e.g. AGAR's FM700 series.

In applications where high velocity gas flows and high gas temperatures are present, a sampling probe with an externally-mounted flow sensor unit should be used. This measures the flow in a by-pass loop, after suitable conditioning such as cooling, etc.

* 9.8.2 Flow measurement should be by use of flow sensing thermistor probes unless an alternative is approved by BP.

9.8.3 Where flow sensing thermistor probes are used, they shall be mounted in the flare line downstream of the off-site knock-out drum, inserted via a seal housing and isolating valve, and capable of being withdrawn during flare operation.

9.9 Requirements for Instrumentation

BP normal requirements for flare system instrumentation are as follows:-

For steam to flare stack (where installed):-

flow control: auto and manual
flow indication and recording

For flare stack internal atmosphere:-

oxygen sampling equipment and analyser)
oxygen contents indication)
high oxygen contents alarm) where installed
burn-back detection alarm)

For each knock-out drum:-

level indication
high level alarm
level switches for automatic operation of pumps
level gauge
upstream pressure gauge

For each liquid seal:-

- level indication
- low level alarm
- high level alarm
- liquid temperature indication
- temperature control (by steam or electricity)
- adequate instrumentation for liquid sump tank and liquid overhead drum if fitted

For pilot gas:-

- flow indication
- pressure control valve
- low flow alarm
- indication of back-up supply in operation
- pilot flame failure

For purge gas:-

- flow indication
- flow control
- low flow alarm

For air to pilots (if a separate source):-

- flow indication
- low flow alarm
- pressure control valve
- pressure indicator

Supplementary (optional) requirements are as follows:-

For flare gas from knock out drum to flare stack:-

- flow indication and recording
- temperature indication
- high temperature alarm) either or both as appropriate
- low temperature alarm)

For steam to flare stack:-

- closed circuit television monitoring

10. SURFACE PROTECTION

- * 10.1 Unless otherwise specified by BP, the surface protection of the flare system, (structural steel, flare pipe, etc.) for both onshore and offshore installations shall be in accordance with BP Group [GS 106-2](#), Schedule B.



Where the flare stack is of bolted galvanised construction, for service up to 350°C (660°F), over- painting to BP Group [GS 106-2](#) should be carried out.

Where only part of a flare stack requires a higher temperature coating, it is usually more economical to use it throughout.

- 10.2 Towers supporting multiple riser flares, serving a number of units that are not shut-down simultaneously, are most demanding regarding inspection and maintenance, and therefore require special treatment. They shall have surface protection, applied after fabrication, to enable the tower to operate maintenance-free for 2 to 3 years.

11. WINTERISATION

- * 11.1 Where cold weather, auto-refrigeration, or viscous or congealing liquids may occur, heating of vessel contents and vent lines shall be provided. The proposed winterisation shall be based on BP Group [RP 44-2](#) and be subject to BP approval.
- * 11.2 When electric heating is used, the installation shall be in accordance with BP Group [RP 12-15](#). The use of proprietary electric surface heating devices shall be subject to approval by BP.

12. TESTING

The decision on the acceptability of pneumatic testing should be taken at an early stage in the design and cannot be left until the line is constructed. On many construction sites there is a great reluctance to carry out such testing. Apart from procurement difficulties, consideration must be given to selecting welding consumables with good fracture toughness to guard against brittle fracture and give additional confidence in the safety of the line during test.

- 12.1 The flare vendor shall carry out the flushing, cold testing and static testing of the flare system in accordance with BP Group [RP 32-2](#), and provide any special equipment required for this testing.
- * 12.2 The flare vendor shall produce documentation for BP approval, listing the precommissioning and commissioning activities based on BP Group [RP 32-2](#).
- * 12.3 Any further requirements of the flare vendor for the attendance of specialist operators and service staff during the precommissioning, commissioning and performance testing of the flare system will be specified by BP.



13. SPARES

13.1 The procedure and the documentation for the purchase of spares, their protection and delivery shall be in accordance with BP Group [RP 48-2](#).

* 13.2 Spares lists shall be compiled by the flare vendor and submitted for BP approval.

They shall include the following as a minimum:-

- (1) Replacement for all the gaskets for the joints that have to be broken during construction or after testing.
- (2) One set of spares to cover the first overhaul.
- (3) One complete pilot burner.
- (4) One complete set of spare thermocouples.
- (5) One of each type of the equipment forming part of the ignition panel.
- (6) One set of spares for the smoke-suppressant apportioning instrumentation.

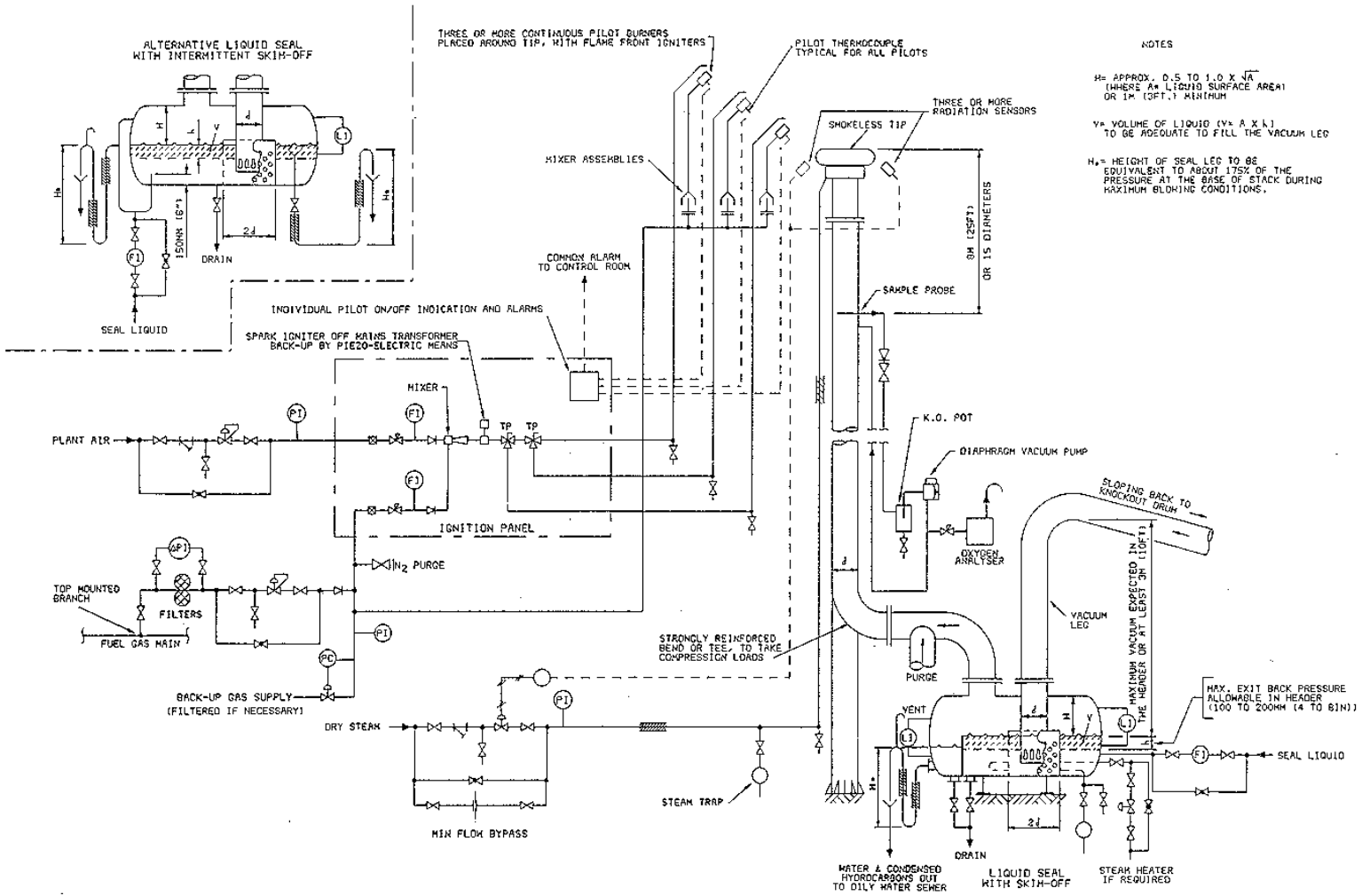
If purge is at the minimum rate and only sufficient to prevent air ingress at the tip, then burning in the tip and higher metal temperature may result. This will shorten the tip life but may produce significant energy saving, usually greater than the cost of replacing a tip.

This should be evaluated on economic grounds, including an allowance for change-out time.



TYPICAL ARRANGEMENT OF A FLARE SYSTEM

FIGURE 1



DEFINITIONS AND ABBREVIATIONS

Definitions

Standardised definitions may be found in the BP Group RPSEs Introductory Volume.

coanda:	an aero-dynamic skin-adhesion effect in which gas follows the profile of a curved surface, entraining air up to twenty times its own volume.
combustion support:	the addition of fuel gas to the effluent to be flared for any of the following reasons:- (a) to increase fuel concentration in order to make the effluent flammable, (b) to increase the volume of the effluent in order to increase flare tip velocity, to avoid burn-back in the flare tip or flame lick outside the flare tip or a lazy flame situation which could damage an adjacent flare tip, (c) to maintain an adequate slot velocity in a flare tip using the Coanda effect.
flare:	a burner or burners for waste gas, including supporting structure and auxiliaries. It may take the form of flare stack, flare boom or ground flare.
flare boom:	horizontally displaced or inclined boom, together with all the other items listed for flare stack.
flare stack:	a vertical stack, either self-supported, guyed, or structure-supported, a flare tip, pilot burners, igniters, smoke-suppressing devices, service pipes, and miscellaneous auxiliaries.
flare system:	the whole closed disposal system for fluids discharged from pressure relief valves, other pressure relief devices, control valves or manually operated valves, terminating in one or more flares.

flare tip:	a burner, with all the auxiliaries, as attached to the supporting stack or boom.
flare vendor:	a contractor who under-takes the design, supply and erection of a flare.
ground flare:	a burner system at low level, surrounded, or not, by a refractory enclosure, together with all the other items listed for flare stack.
mast:	structure guy-supported.
maximum flaring rate:	the maximum rate of flow to the flare calculated in accordance with the specified blowdown and relief philosophy for the plant.
maximum smokeless rate:	the maximum rate of flow to the flare which is required to be burned smokelessly.
operating range:	the range of gas flows and conditions for which the flare is required to operate.
purge rate:	the rate of flow of an inert or combustible gas required to prevent the oxygen concentration exceeding a specified level at a specified location in the flare stack or supply ducting, when oxygen ingress is undesirable.
self-erecting flare:	flare which can be erected without the use of cranes.
smokeless:	without emitting 'dark smoke' as defined in the UK Clean Air Act 1956 Section 34(2).
tower:	structure, self-supporting.

Abbreviations

ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
BS	British Standard
CONCAWE	Conservation of Clean Air and Water - Europe
H ₂ S	Hydrogen Sulphide
HP	High pressure
ISO	International Organisation for Standardisation
LNG	Liquefied natural gas
LP	Low pressure
LPG	Liquefied petroleum gas



NGL	Natural gas liquids
NPS	Nominal pipe size
QA	Quality Assurance
SI	Systeme International d'Unites



LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

[ISO 9001](#) Quality systems - Model for quality assurance in design/development, production, installation and servicing.

[Department of Energy - Offshore Installations:](#)
Guidance on design and construction.

[UK Clean Air Act, 1956](#)

[BS 6651](#) Code of Practice for protection of structures against lightning.

[API Manual on Disposal of Refinery Wastes, Volume II](#)

[API RP 520: Part I](#) Sizing, selection and installation of pressure-relieving devices in refineries.
Fifth Edition 1990
Part I - Sizing and Selection

[API RP 520: Part II](#) Sizing, selection and installation of pressure-relieving devices in refineries.
Third Edition 1988
Part II - Installation

[API RP 521](#) Guide for pressure-relieving and depressurising systems.
Third Edition 1990

[API 673](#) Special-purpose centrifugal fans for general refinery service.

[ASTM C 155](#) Classification of insulating firebrick.
[ASTM C 401](#) Classification of castable refractories.

BP Group [RP 4-2](#) Structures
(replaces BP CP 6)

BP Group [RP 4-3](#) Foundations and General Civil Works
(replaces BP CP 4)



BP Group RP 12-15	Electrical Systems and Installation - Electric Surface Heating (replaces BP CP 17 Part 15)
BP Group RP 14-1	Noise Control (replaces BP CP 2)
BP Group RP 24-2	Fire Protection - Offshore (replaces BP CP 15 and BP CP 16)
BP Group RP 32-2	Site Inspection, Testing and Pre-commissioning of New Plant (replaces BP CP 20)
BP Group RP 32-3 to RP 32-6	Inspection and Testing of Plant in Service (replaces BP CP 52)
BP Group RP 34-1	Rotating Machinery (replaces BP CP 10)
BP Group RP 42-1	Piping Systems (replaces BP CP 12)
BP Group RP 44-1	Overpressure Protection Systems (replaces BP CP 14)
BP Group RP 44-2	Winterisation (replaces BP CP 24)
BP Group RP 44-7	Plant Layout (replaces BP CP 3)
BP Group RP 46-1	Unfired Pressure Vessels (replaces BP CP 8)
BP Group RP 48-2	Spares for Plant and Equipment (replaces BP CP 23)
BP Group RP 50-1	Guide to the Application of Criticality Ratings (replaces BP CP 53)
BP Group RP 50-2	Guide to Reliability Engineering (replaces BP CP 62)
BP Group RP 52-1	Thermal Insulation (replaces BP CP 13)
BP Group GS 106-2	Painting of Metal Surfaces



(replaces BP Std 141)

BP Group GS 136-1	Materials for Sour Service to NACE Standard MR-01-75 (1980 Revision) (replaces BP Std 153)
BP Group GS 136-2	Materials for Offshore Structures (replaces BP Std 109)
BP Group GS 138-5	Guylines (replaces BP Std 114)

Useful references are:-

1. Extract from 'Purging requirements of large diameter stacks', by H.W. Husa, Amoco Oil Company, presented at the Fire/Safety Engineering Sub- committee meeting of the American Petroleum Institute, September 13-15, 1977.
2. Safety Guidance Note No. 90/2: The use of Halons in Firefighting (February 1990), published by Group Safety Centre (now Corporate Safety Services).
3. [CONCAWE report 2/79](#).
4. *BP Group Occupational Health Memorandum No. 25-70-0041 'Exposure of Personnel to Thermal Radiation'.*
5. *Flow of Fluids Through Valves, Fittings and Pipe: Crane Technical Paper No. 410. (see 5.6.4 of this RP)*
6. *Internal Flow Systems edited by D.S. Miller - BHRA Fluid Engineering, published by Gulf Publishing or VDI Waermeatlas.*
7. *Method of Calculating Flash Back Velocities, developed by Van Krevelin and Chermin and reported in the transactions of the Seventh International Symposium on Combustion, 1959, pages 358-368.*
8. *Health and Safety Series booklet HS(G)11: Flame Arresters and Explosion Relief (flare stacks up to 900 mm (36in) diameter)*



H.W. HUSA'S CORRELATION FORMULAE

This slightly modified version of the Husa correlation shall be used to calculate minimum purge gas flowrates for gases lighter than air. For gases heavier than air it is recommended that the purge rate for nitrogen be used.

The Husa correlation may be expressed either as:-

$$Q = 201.659 \quad D^{3.46} \left(\frac{1}{L} \ln \frac{20.9}{O_2} \right) \sum_{n=1}^{n=i} (F_i^{0.65} K_i)$$

or

$$V = 0.0745053 \quad D^{1.46} \left(\frac{1}{L} \ln \frac{20.9}{O_2} \right) \sum_{n=1}^{n=i} (F_i^{0.65} K_i)$$

where	Q	=	purge rate	m ³ /h
	V	=	purge velocity	m/s
	D	=	stack diameter	m
	L	=	distance below tip exit	m
	O ₂	=	% oxygen (by volume)	
	F _i	=	mole fraction of the i th component of the purge gas	
	K _i	=	a constant for the i th component.	

Values of K_i for gases lighter than air are determined from

$$K_i = \exp (0.065 (29-MW_i))$$

Values of K_i for gases heavier than air are determined from an amended Husa correlation where (MW_i-29)) is substituted for MW_i as follows:-

$$K_i = \exp (0.065 (MW_i-29))$$

where MW_i = molecular weight of the i th component of n components.

Values of K_i for various purge gas components are given below:-

Gas	K
Hydrogen	5.78
Helium	5.08
Methane	2.33
Nitrogen	1.71 - light wind 1.07 - no wind
Ethane	0.94 *
Propane	0.38 *
Carbon dioxide	0.38 *
Butane plus	0.15 *

* These constants are for heavier than air components derived from the amended Husa correlation.

Notes

1. It should be recognised that the Husa correlation was derived under calm or no wind conditions.
2. In view of the uncertainties involved in purging a flare, the calculated purge rates should be multiplied by factors ranging from 2 for light gases, to about 5 for gases similar in density to air in high wind conditions.

