Liquefied Petroleum Gas

Volume 1

Large Bulk Pressure Storage and Refrigerated LPG

Model Code of Safe Practice

Part 9

Second Edition

INSTITUTE OF PETROLEUM

Liquefied Petroleum Gas

Volume 1

LARGE BULK PRESSURE STORAGE AND REFRIGERATED LPG

Being the first of a two volume revision of Part 9 of the
Institute of Petroleum
Model Code of Safe Practice in the
Petroleum Industry

February
1987

A Code jointly prepared by The Institute of Petroleum,
The Institution of Gas Engineers and
The Liquefied Petroleum Gas Industry Technical Association (UK)

Published on behalf of
THE INSTITUTE OF PETROLEUM, LONDON

John Wiley & Sons
Chichester · New York · Brisbane · Toronto · Singapore

British Library Cataloguing in Publication Data:
Institute of Petroleum
Liquefied Petroleum gas: a code.—
2nd ed.—(Model code of safe practice
in the petroleum industry. Pt. 9).
Vol. 1
1. Liquefied petroleum gas—Storage—
Standards
I. Title II. Institution of Gas Engineers
III. Liquefied Petroleum Gas Industry
Technical Association III. Series
665.7'42 TP756
ISBN 0 471 91612 9

Printed and bound in Great Britain By
Galliard (Printers) Ltd., Great Yarmouth,
Norfolk.

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FOREWORD

1. This Code is Part 9 of The Institute of Petroleum Model Code of Safe Practice in the Petroleum Industry. It supersedes the edition published in 1967, the technical recommendations of which have both been amplified and brought up to date. Its purpose is to provide a general guide to safe practice in storing, handling and transport of Liquefied Petroleum Gas (LPG), and it gives, for the most part, recommendations for safe practice rather than a set of rigid rules. It is the intention that this approach should more easily allow the use of new methods, techniques, materials, etc., which may be developed in the future and which meet the requirements for safe practice given in this Code.

   It must be stressed that in determining any required safe procedure the effect of any unusual circumstances, on which it is impossible to generalize, must receive due consideration and, further, that design, construction and operation of plant and equipment must be carried out only by suitably trained personnel.

   Attention is drawn to the Institute's Area Classification Code which should also be considered during the design of LPG facilities.

2. Attention is also drawn to the fact that in many countries there exist statutory requirements, both local and national, relating to LPG, and this Code should be regarded as being complementary to such requirements.

3. This Code is arranged as two volumes containing six separate chapters supported by a number of Appendices.

   The volumes and chapters are as follows:

   Volume 1

   Chapter 1—General information applicable to LPG.

   Chapter 2—Pressure storage at refineries, bulk distribution plants and also industrial consumer premises, where such storage is large.

   Chapter 3—Refrigerated LPG.

   This subject was previously dealt with in Clause 2.4 of Chapter 2 of the 1967 Code under the title Low Pressure Refrigerated Storage. However, because of the evolution of new techniques for handling refrigerated products, the increase in quantities being stored and handled and the resulting need for special safety considerations with respect to these large quantities, it has been decided to consider refrigerated storage separately.

   Relevant Appendices

   Volume 2

   Chapter 1—Pressure storage at industrial, commercial and domestic premises (originally Chapter 3 of the 1967 Code).

   Chapter 2—Plant for the filling, handling and storage of cylinders (originally Chapter 4 of the 1967 Code).

   Chapter 3—Transport by road and rail (originally Chapter 5 of the 1967 Code).

   For marine transport reference should be made to the International Safety Guide for Oil Tankers and Terminals (ISGOTT), and for pipeline transport to the IP Code of Practice for Petroleum Pipelines.

   Relevant Appendices.

4. The Liquefied Petroleum Gas Sub-Committee, which prepared this Code, is a Sub-Committee of the Engineering Committee of the Institute. It comprises representatives of The Institute of Petroleum, The Institution of Gas Engineers and

The Liquefied Petroleum Gas Industry Technical Association (UK).

5. For the purpose of this Code certain interpretations which are given in Appendix 7 apply irrespective of any other meaning the words may have in other connections. Where used in the Code such defined terms are printed in italics.
6. Although it is believed that adoption of the recommendations of the Code will help to reduce the risk of accident, The Institute of Petroleum, The Institution of Gas Engineers and The Liquefied Petroleum Gas Industry Technical Association (UK) cannot accept any responsibility, of whatever kind, for damage or alleged damage arising or otherwise occurring in or about premises, areas or vehicles to which this Code has been applied.

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1

PROPERTIES OF LIQUEFIED PETROLEUM GAS

1.1 LIQUEFIED PETROLEUM GAS (LPG)

1.1.1
The term Liquefied Petroleum Gas or LPG includes commercial propane, commercial butane and mixtures thereof.

1.1.2
LPG at ambient temperature and normal atmospheric pressure is usually a gas but is readily liquefied by either additional pressure, or refrigeration, or a combination of both.

It is stored and handled:

(a) as a liquid under pressure at ambient temperatures,
(b) as a *fully refrigerated liquid* kept at sufficiently low temperature to produce a pressure substantially atmospheric,
(c) as a *semi-refrigerated liquid* kept at a higher temperature than (b) to produce an intermediate pressure.

1.1.3
LPG is supplied against product specifications, e.g. BS 4250, Gas Processors Association of the USA (GPA).

1.1.4
The two grades of LPG most commonly handled are referred to as commercial butane and commercial propane respectively. Mixtures of commercial butane and commercial propane are also handled.

1.1.5
LPG may be produced as an odourless product. For general usage it is odorized as necessary to permit detection of leakage by smell (see 1.4).

1.2 PROPERTIES AND CHARACTERISTICS

1.2.1
Commercial butane is a hydrocarbon mixture consisting predominantly of a mixture of normal and isobutane and/or butylene, i.e. C4s.

1.2.2
Commercial propane is a hydrocarbon mixture consisting predominantly of propane and/or propylene, i.e. C3s.

1.2.3
Physical properties of these two commercial grades are given in Table 1.

1.3 HAZARDS

1.3.1
LPG is usually stored and transported as a liquid. Leakage of liquid results in the formation of large volumes of vapour as 1 volume of liquid produces approximately 250 volumes of vapour at atmospheric pressure.

1.3.2
Even small quantities of LPG vapour in air may form a *flammable* mixture. The limits of flammability of LPG are approximately 2% to 10% volume of gas in air and this results in LPG leakage forming large volumes of *flammable* gas–air mixtures.

1 volume of vapour can form 10 to 50 volumes of *flammable* gas–air mixture.
1 volume of liquid can form 2,500 to 12,500 volumes of *flammable* gas–air mixture.

Table 1
Typical properties of commercial LPG grades.

Property	Commercial butane	Commercial propane
Density at atmospheric boiling point, kg/litre	0.60	0.57
Density at 15 °C, kg/litre	0.57	0.51
m^3/tonne at 15 °C	1.72	1.96
Density of vapour compared with air at 15 °C and 1 bara	2.00	1.50
Ratio of vapour volume to liquid volume at 15 °C and 1 bara	230	270
Boiling point at atmospheric pressure	0 °C	−44 °C
Vapour pressure bara, −40 °C	—	1.4
0 °C	0	8.0
45 °C	5	18
Latent heat of vaporization, kJ/kg at 15 °C	372	358
Specific heat of liquid at 15 °C, kJ/(kg °C)	2.4	2.5
Limits of flammability vol% in gas–air mixture at atmospheric pressure	1.8–9.0	2.1–10

1.3.3
LPG at ambient temperature and normal atmospheric pressures is normally a gas which is heavier than air. Commercial butane vapour and commercial propane vapour are approximately 2.0 and 1.5 times as heavy as air, respectively. LPG vapours will therefore sink to the lowest levels of the surroundings and flow along the ground or through drains or such-like passages. Under still air conditions the natural dissipation of accumulated vapour may be slow.

1.3.4
A small release of LPG into the atmosphere will result in a *flammable* mixture which may be ignited some distance from the point of leakage.

1.3.5
LPG has a low viscosity; hence it has little or no lubricating properties and it is more likely to find a leakage path than water or most other petroleum products. These facts are significant with respect to the design of plant and have particular relevance to the glands and seals of pumps, compressors and valves.

1.3.6
Whilst LPG is colourless both in the liquid and vapour phases the cooling which takes place when the liquid evaporates results, in cases of leakage, in water condensation and even freezing of water vapour contained in the air; this appears as a white mist or cloud.

The cooling which occurs on evaporation of liquid LPG causes frost burns to the skin and damage to eyes if protection, e.g. gloves and goggles, is not used when contact with LPG is a possibility.

Refrigerated LPG causes severe frost burns and eye damage even if little or no evaporation occurs.

1.3.7
LPG whether in liquid or vapour form is only slightly toxic. The vapour is an asphyxiant in high concentrations and is anaesthetic. Thus precautions must be taken in entering confined spaces such as tanks because of these properties of the LPG (and also because of its flammability and the risk of reduced oxygen levels).

1.3.8
Liquid LPG has a high coefficient of expansion. Adequate ullage must therefore always be provided in *storage vessels* (static and transport) to prevent them becoming hydraulically full as a result of temperature rise. Pipelines and equipment which are normally liquid full must be protected, by operating procedures and/or safety equipment, against the high pressure which would result from the liquid's expansion with temperature rise.

1.3.9
A *container* which has held LPG and is nominally empty is still potentially dangerous. In this state the internal pressure is approximately atmospheric and should the valve be open or leaking a *flammable* mixture may result due to air diffusing into the *container* when temperatures fall or vapour issuing from the *container* when temperatures rise.

1.3.10
The density of liquid LPG is approximately half that of water, and when leakage occurs in low ambient temperatures the product could be carried away by water.

1.3.11
If water is used for hydraulic testing of storage etc. then its weight and not that of the LPG contents is relevant for foundation design.

1.3.12
The presence of water in LPG systems presents a hazard from icing under certain conditions (see 1.5).

1.4 ODORIZATION

Odorization is not required if harmful in the use or further processing of the LPG or if it will serve no useful purpose as a warning agent in such use. In other circumstances the odour should be distinctive, unpleasant and non-persistent and should indicate the presence of gas in the air at a level in excess of 20% of the lower limit of flammability.

The odorization requirement can be met by the addition of controlled quantities of suitable odorizing agents, e.g. ethyl mercaptan, dimethyl sulphide. Care is necessary in handling those odorants which are toxic in concentrated form.

1.5 PREVENTION OF WATER DEPOSITION

Methanol or propylene glycol may be added to LPG to prevent water deposition and hydrate formation. For *refrigerated product* water and other trace components must be removed prior to refrigeration.

2

PRESSURE STORAGE AT REFINERIES, BULK DISTRIBUTION PLANTS AND LARGE INDUSTRIAL CONSUMER PREMISES

2.1 SCOPE

2.1.1 Inclusions
This chapter covers LPG *pressure storage* installations, *above ground*, *mounded* or *below ground*, at refineries and bulk distribution plants as well as at large industrial consumer plants where storage involves *vessels* of individual *capacity* greater than 135 m^3 or group storage greater than 450 m^3.

2.1.2 Exclusions

2.1.2.1 This code does not cover storage in frozen earth pits or underground caverns.

2.1.2.2 This chapter is not intended to cover either *refrigerated storage*, which is covered in Chapter 3, or storage of LPG at the smaller industrial consumer premises, which is covered in Volume 2.

2.1.3 Object

2.1.3.1 The object of this chapter is to recommend basic safety requirements and practice for the design, construction and use of LPG *pressure storage*, *partially refrigerated storage* and ancillary facilities.

2.1.3.2 It is not intended to preclude the use of alternative designs, materials and methods where these provide equivalent standards of safety.

2.2 REQUIREMENTS FOR THE LAYOUT, LOCATION AND SPACING OF LPG PRESSURE STORAGE INSTALLATIONS

2.2.1 General Layout Principles
The layout of LPG Storage Installations shall ensure that in the event of ignition of leakage of product the effect on other parts of the installation or on people or property located outside the installation is minimized.

The principles to be followed in the location and spacing of *Pressure storage vessels* and ancillaries are set out in 2.2.2. These are based on the consideration of the possible effects of leakage of LPG.

Measures aimed at preventing leaks are set out in 2.3 to 2.10. Additional measures to minimize the effects of leakage to ensure that the facilities are adequately protected are set out in 2.2.3 to 2.2.7.

2.2.2 Location and Spacing

2.2.2.1 LPG *pressure storage vessels*, pump bays and loading and discharge facilities shall be located and spaced to ensure:

(a) That they are sufficiently distanced from fixed sources of ignition.
(b) In the event of a fire as described in 2.2.2.3 the heat radiation flux levels resulting will not exceed the relevant maximum levels given in Table 1 of Appendix 1.
(c) Accessibility for fire fighting.

(d) That spillage from one *vessel* or work area does not flow under any other *vessel* or directly to any other important facility/work area.

2.2.2.2 LPG pressure storage vessels, pump bays and loading/discharge facilities shall be located to ensure the following minimum distances to fixed sources of ignition irrespective of the requirements of 2.2.2.1:

22.5 m For *storage vessels* not exceeding 337 m^3
30 m For *storage vessels* exceeding 337 m^3
25 m For pump bays and loading/unloading facilities

Deflection walls may be used to extend the vapour travel path from leakage as identified in 2.2.2.4 to meet these safety distances.

Such walls should be so located as to minimize the risk of flame engulfment of *storage vessels*, in the event of ignition of escaped product and also so as to ensure free ventilation of the storage area from at least three directions, taking account of prevailing winds.

2.2.2.3 The radiation flux levels laid down in Table I of Appendix 1 shall be based on the ignition of product discharging from the *vessel's* relief valves as well as spillage from the *vessel*, its appurtenances and other identified leak sources (see Appendix 3), and possibly forming a pool of a size dictated by the spillage rate, evaporation rate and duration (see 2.2.2.4) and the local topography/location of a *bund* or *impounding basin*.

The atmospheric conditions relevant to the site shall be applied in determining the flux levels.

Calculation methods are described in Appendix 2.

2.2.2.4 The rate of spillage and its duration used in 2.2.2.3 shall be based on identified potential leak sources in the system. The identification and quantitative assessment of such leak sources require a systematic evaluation of the design and operating procedures, taking into account failure modes and the likelihood of their occurring.

Examples of potential leak sources and indications of leakage rates from them under specific conditions and using a simplified typical equation are given in Appendix 3.

2.2.2.5 Provision should be made to minimize the probability of a *flammable* cloud resulting from a spill as defined in 2.2.2.3 from reaching the site boundary. Typical provisions may include such measures as spacing, limitation of spill pool area, screening and vapour dispersion equipment.

Appendix 3 provides examples of potential leak sources and typical leak rates and Appendix 4, references to mathematical models for calculating hazard distances arising from such releases.

2.2.2.6 The permitted radiation level on *thermally protected* adjacent LPG *storage vessels* is based on the protection of the adjacent *vessel*, e.g. by the application of cooling water at the rate specified in 2.9.6.4.

Where cooling water is the method of protection then its provision and application must be reliable. Equivalent protective systems are acceptable provided their efficiency can be demonstrated at the specified radiation level and over the expected duration of the fire.

2.2.2.7 The minimum cooling water application rate of 7 litres/(minute m^2) specified in 2.9.6.4 is based on protection of a *pressure storage vessel* against flame engulfment, rather than by thermal radiation, and is therefore higher than would be calculated when using the method given in Appendix 5.

The required cooling water application rate for other equipment referred to in Appendix 1 may be calculated by the method in Appendix 5.

2.2.2.8 In the case of *below-ground/mounded LPG pressure storage*, in addition to meeting the requirements of Appendix 1 for a relief valve and spill fire, there shall also be a minimum spacing of 3 metres between the *vessel* shell and the site boundary.

2.2.2.9 In the event that the requirements of Table 1 of Appendix 1 dictate lesser distances then there shall be a minimum spacing between adjacent *above-ground LPG pressure* vessels of 1.5 metres or 0.25 times the sum of the adjacent *vessel* diameters, whichever is the greater. For *below-ground mounded storage* the spacing between adjacent *vessels* shall be determined by the site conditions and the requirements for safe installation/removal of such *vessels* as well as their inspection, testing and maintenance.

2.2.2.10 The maximum number of *vessels* in any Group shall be 6. Any one group shall be separated from any other group by 15 m.

2.2.2.11 In any group *vessels* shall be in a single line, i.e. shell to shell and not end to shell or end to end.

2.2.3 Bunds and Separation Kerbs

2.2.3.1 The provision of *bunds* around *above-ground LPG pressure storage* designed and constructed in accordance with the requirements of this code is not normally required.

2.2.3.2 Separation kerbs, low to avoid gas traps, with a maximum height of 0.6 m may be required to direct spillage to suitable places away from *storage vessels* and other vulnerable equipment.

2.2.4 Ground Conditions
Ground beneath *above-ground pressure storage and vessels* in unfilled below-ground chambers should be either concreted or compacted and graded to levels to ensure that any spillage has a preferential flow away from the *vessel* and its connections.

2.2.5 Pits and Depressions in the Storage Area
To prevent the formation of gas pockets, pits and depressions, other than those which are provided as catchment areas, should be avoided in and close to the storage area.

2.2.6 Other Hazardous Storage
No *pressure vessel* for LPG should be located within the *bunded enclosure* of:

(a) a *tank* containing any *flammable* liquid,
(b) a *tank* containinig liquid oxygen or other hazardous or cryogenic substance,
(c) a *tank* containing *refrigerated LPG* or liquefied natural gas (LNG),
(d) a heated storage *tank*, e.g. residual fuel oil or bitumen.

2.2.7 Layout of Storage
The layout and grouping of *above-ground vessels*, as distinct from spacing, should receive careful consideration to ensure accessibility for fire-fighting and to avoid spillage from one *vessel* flowing under any other or to any vulnerable equipment.

2.2.8 Protection of Facilities

2.2.8.1 To prevent unauthorized access, the area which includes *vessels*, pumping equipment and loading/unloading facilities should be enclosed by an industrial type fence at least 2 m high unless it is otherwise adequately protected, e.g. the area comes within a greater fenced plant area or is otherwise isolated from the public.

2.2.8.2 When damage to LPG systems from vehicular traffic is a possibility, precautions to guard against such damage must be taken.

2.2.8.3 Below-ground and mounded storage should be protected from above-ground loadings due to vehicular traffic or other cause, either by fencing off the area under which the storage is buried or by the use of reinforced concrete slab or other cover adequate to prevent the weight imposing concentrated direct loads on the *vessel*.

If the storage area is not fenced off, the *vessel* manhole cover and other fittings should be protected against damage and tampering.

The perimeter of the area under which storage is buried should be permanently marked.

2.2.8.4 Below-ground and mounded storage vessels should have a minimum cover of 500 mm.

2.3 PRESSURE STORAGE

2.3.1 Design Code

2.3.1.1 Vessels should be designed, fabricated, inspected and tested in accordance with a recognized *pressure vessel* code as appropriate, e.g. BS 5500, ASME Section VIII.

2.3.1.2 Careful consideration should be given to the material used for construction, bearing in mind the minimum temperature that the material of the *vessel* could reach in service or an emergency. Such a minimum temperature may well be below the minimum ambient temperature in emergency situations and may also be so for *vessels* with high offtake rates in normal service.

2.3.1.3 Vessels for a *partially refrigerated product* should be designed in accordance with the low temperature requirements of the code referred to in 2.3.1.1.

2.3.2 Design Criteria

2.3.2.1 The design pressure of the *container* should be not less than the vapour pressure of the actual LPG to be stored in it, at the highest temperature that such contents will reach in service and should also take into account any additional pressures developed in operation.

The vapour pressure is dependent on the surface temperature of the contents and not the bulk mean temperature.

2.3.2.2 For *partially refrigerated pressure storage* the capacity of the refrigeration plant and/or the insulation system should be such that the LPG is maintained at a temperature at which its vapour pressure is below the set to discharge pressure of the relief valve.

2.3.2.3 The design of the *buried/mounded vessel* should allow for any differential settlement/movement (including frost heave) as well as for the weight of superimposed loads.

2.3.2.4 Vacuum conditions
If operating conditions may be expected to lower product temperatures to the extent that the vapour pressure of the stored product falls below atmospheric pressure, e.g. butane under very cold conditions, then either the *vessel* should be designed for the necessary degree of vacuum or the system should