

ENGINEERING STANDARD

FOR

PROCESS DESIGN OF LPG RECOVERY

AND SPLITTER UNITS

ORIGINAL EDITION

DEC. 1997

This standard specification is reviewed and updated by the relevant technical committee on Dec. 2002(1) and Apr. 2015(2). The approved modifications are included in the present issue of IPS.

FOREWORD

The Iranian Petroleum Standards (IPS) reflect the views of the Iranian Ministry of Petroleum and are intended for use in the oil and gas production facilities, oil refineries, chemical and petrochemical plants, gas handling and processing installations and other such facilities.

IPS are based on internationally acceptable standards and include selections from the items stipulated in the referenced standards. They are also supplemented by additional requirements and/or modifications based on the experience acquired by the Iranian Petroleum Industry and the local market availability. The options which are not specified in the text of the standards are itemized in data sheet/s, so that, the user can select his appropriate preferences therein.

The IPS standards are therefore expected to be sufficiently flexible so that the users can adapt these standards to their requirements. However, they may not cover every requirement of each project. For such cases, an addendum to IPS Standard shall be prepared by the user which elaborates the particular requirements of the user. This addendum together with the relevant IPS shall form the job specification for the specific project or work.

The IPS is reviewed and up-dated approximately every five years. Each standards are subject to amendment or withdrawal, if required, thus the latest edition of IPS shall be applicable

The users of IPS are therefore requested to send their views and comments, including any addendum prepared for particular cases to the following address. These comments and recommendations will be reviewed by the relevant technical committee and in case of approval will be incorporated in the next revision of the standard.

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GENERAL DEFINITIONS

Throughout this Standard the following definitions shall apply.

COMPAN:

Refers to one of the related and/or affiliated companies of the Iranian Ministry of Petroleum such as National Iranian Oil Company, National Iranian Gas Company, National Petrochemical Company and National Iranian Oil Refinery And Distribution Company.

PURCHASER:

Means the "Company" where this standard is a part of direct purchaser order by the "Company", and the "Contractor" where this Standard is a part of contract document.

VENDOR AND SUPPLIER:

Refers to firm or person who will supply and/or fabricate the equipment or material.

CONTRACTOR:

Refers to the persons, firm or company whose tender has been accepted by the company.

EXECUTOR:

Executor is the party which carries out all or part of construction and/or commissioning for the project.

INSPECTOR:

The Inspector referred to in this Standard is a person/persons or a body appointed in writing by the company for the inspection of fabrication and installation work.

SHALL:

Is used where a provision is mandatory.

SHOULD:

Is used where a provision is advisory only.

WILL:

Is normally used in connection with the action by the "Company" rather than by a contractor, supplier or vendor.

MAY:

Is used where a provision is completely discretionary.

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0. INTRODUCTION

The purpose of LPG Unit is to process light hydrocarbons (C₁-C₅) into required component streams. The LPG Unit feed streams in a refinery are usually obtained from refinery Units such as Atmospheric Crude Distillation, Plat former, Hydro cracker and/or other processing Units. LPG is also produced in gas fractionation units charged by associated gas from oil reservoirs or gas from gas reservoirs. However, any LPG stream, which is economically justified for recovery of the components, shall be routed to the LPG recovery Unit.

"Design of Non-Licensed Process Units" is broad and contains various subjects of paramount importance. Therefore, a group of process engineering standards are prepared to cover this subject.

This group includes the following:

STANDARD CODE	STANDARD TITLE
IPS-E-PR-360	"Engineering Standard for Process Design of Liquid and Gas Transfer and Storage"
IPS-E-PR-491	"Engineering Standard for Process Requirements of Crude Distillation and Hydrogen Production Units"
IPS-E-PR-500	"Engineering Standard for Process Design of LPG Recovery & Splitter Units"
IPS-E-PR-551	"Engineering Standard for Process Design of Gas Treating Units"

This Engineering Standard Specification covers:

"PROCESS DESIGN OF LPG RECOVERY & SPLITTER UNITS"

In this standard, some of the subjects are adapted from the following handbook:

GPSA (GAS PROCESSORS SUPPLIERS ASSOCIATION) "Engineering Data Book", twelfth edition, 2004.

1. SCOPE

This Engineering Standard Specification covers minimum process design requirements for LPG recovery & splitter Units. It should be expressed that only general process requirements are covered in this Standard and the Unit specific design conditions shall be determined based on the feed analysis and final product specifications during execution of the Unit conceptual design.

Note 1:

This standard specification is reviewed and updated by the relevant technical committee on Dec. 2002. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No. 190 on Dec. 2002. These modifications are included in the present issue of IPS.

Note 2:

This standard specification is reviewed and updated by the relevant technical committee on Apr. 2015. The approved modifications by T.C. were sent to IPS users as amendment No. 2 by circular No. 453 on Apr. 2015. These modifications are included in the present issue of IPS.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

ASTM (AMERICAN SOCIETY FOR TESTING OF MATERIALS)

ASTM D-2163	Standard Test Method for Determination of Hydrocarbons in Liquefied Petroleum (LP) Gases and Propane/Propene Mixtures by Gas Chromatography
ASTM D-2420	Standard Test Method for Hydrogen Sulfide in Liquefied Petroleum (LP) Gases (Lead Acetate Method)
ASTM D-3227	"Standard Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosene, Aviation Turbine, and Distillate Fuels (Potentiometric Method)"
ASTM D-323	"Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)"

GPA standard 2140-92 "Liquefied Petroleum Gas Specifications and Test Methods"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-G-ME-150	"General Standard for Towers, Reactors, Pressure Vessels & Internals"
IPS-E-PR-360	"Engineering Standard for Process Design of Liquid and Gas Transfer and Storage"

IPS-E-PR-491	"Engineering Standard for Process Requirements of Refinery Non-Licensed Units"
IPS-E-PR-850	"Engineering Standard for Process Requirements of Vessels, Reactors and Separators"

3. DEFINITIONS AND TERMINOLOGY

3.1 Absorption

The operation in which one or more components in the gas phase are transferred to (absorbed into) a liquid solvent.

3.2 Adsorbent

A solid substance used to remove components from natural gas being processed.

3.3 Lean Oil

Absorption oil as purchased or recovered by the plant, or oil from which the absorbed constituents have been removed.

3.4 Liquefied Petroleum Gas (LP-Gas or LPG)

Predominately propane or butane, either separately or in mixtures, which is maintained in a liquid state under pressure within the confining vessel.

3.5 Reid Vapor Pressure (RVP)

The vapor pressure of a material measured by the Reid Method and apparatus as detailed in ASTM Test Procedure D-323.

4. SYMBOLS AND ABBREVIATIONS

APC	Advanced Process Control.
LPG	Liquefied Petroleum Gas.
PFD	Process Flow Diagram.
RVP	Reid Vapor Pressure.

5. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

6. BASIC DESIGN REQUIREMENTS

6.1 Process configuration of the LPG recovery Units shall be established based on the following factors and submitted for Company's approval:

- Feed composition and condition;
- Upstream Unit process configurations;
- Ultimate product consumption/distinction;

- Product specifications;
- Minimum C₃, C₄ and C₅ (if any) recovery.

6.2 Unless otherwise specified economical study shall be practiced to justify provision of the absorption/stripping lean oil system if required by the minimum product recovery specification as instructed by the project scope of the work for minimum C₃ recovery.

6.3 The final process configuration shall be approved by the Company. For C₄ and C₅ the following requirements should be considered.

- Minimum C₄ recovery: 98 (vol. %).
- Minimum C₅ recovery: 99.5 (vol. %).

6.4 The Unit product minimum specifications shall be as follows, unless otherwise specified in the project specification.

Product Characteristics	Product Designation				
	Commercial Propane	Commercial Butane	Commercial B-P Mixtures	Propane HD-5	Test Methods
Composition	Predominantly propane and/or propylene.	Predominantly butanes and/or butylenes.	Predominantly mixtures of butanes and/or butylenes with propylene.	not less than 90 liquid volume percent propane; not more than 5 liquid volume percent propylene.	ASTM 0-2163-87
Vapor pressure at 100-°F. psig, max. at 37.8-°C, kPa (ga), max.	208 1434	70 483	208 1434	208 1434	ASTM 0-1267-89
Volatile residue: temperature at 95% evaporation. °F, max. or °C, max. butane and heavier, liquid volume percent max. pentane and heavier, liquid volume percent max.	-37 -38.3 2.5 —	36 2.2 — 2.0	36 2.2 — 2.0	-37 -38.3 2.5 —	ASTM 0-1837-86 ASTM 0-2163-87 ASTM 0-2163-87
Residual matter: residue on evaporation of 100 cm ³ . max. oil stain observation	0.05 cm ³ Pass (1)	— —	— —	0.05 cm ³ Pass (1)	ASTM 0-2158-89 ASTM 0-2158-89
Corrosion, copper strip. mx.	No. 1	No. 1	No. 1	No. 1	ASTM 0-1838-89 (Note A)
Total sulfur, mg/ka	185	140	140	123	ASTM 0-2784-89
Moisture content	pass	—	—	pass	GPA Propane Dryness Test (Cobalt Bromide) or 0-2713-86
Free water content	—	none	none	—	—
(1) An acceptable product shall not yield a persistent oil ring when 0.3 cm ³ of solvent residue mixture is added to a filter paper in 0.1 increments and examined in daylight after 2 minutes as described in ASTM 0-2158.					+
NOTE A: "This method may not accurately determine the corrosivity of the liquefied petroleum gas if the sample contains corrosion inhibitors or other chemicals which diminish the corrosivity of the sample to the copper strip. Therefore, the addition of such compounds for the sole purpose of biasing the test is prohibited."					

6.5 If required by the feed compositions, and product specifications, treating facilities shall be provided.

6.6 The Unit design throughput shall be based on the sum of maximum flow rates of various feed streams to the Unit when the upstream Units are operating at their design capacities.

6.7 When LPG blending is desired, C₃ and C₄ products must be produced separately and each

stream must be suitable for LPG blending as per LPG specification, typical blending characteristics, shown in Appendix A.

6.8 To meet the required product specification Drying facilities for C₃/C₄ product shall be provided if required.

6.9 Feed surge drum shall be provided to receive all feed streams into the LPG recovery Unit.

6.10 Unless otherwise specified, the Unit turndown capacity shall be 60% of design throughput, without loss of efficiency in fractionation while meeting the product specifications.

6.11 The Unit design capacity shall be determined based on the design information on the upstream Process Units and shall take into consideration the variations resulted in the relevant process Units.

6.12 General equipment design criteria shall be according to the relevant specification standard in IPS.

6.13 Reference shall be made to [IPS-E-PR-360](#), "Process Design of Liquid and Gas Transfer and Storage", for LPG storage and handling.

6.14 The following design notes shall be taken into consideration if LPG caustic treating section to be supplied as per feed and product specifications.

- Caustic dissolving facilities shall be included if supply of the caustic outside of the Unit battery limit is not feasible.
- Caustic regeneration facilities shall be provided, if economically are justified.
- Spent caustic treatment and neutralization and disposal facilities shall be provided by considering environmental limitation.

6.15 HSE considerations shall be fully complied.

6.16 Special attention shall be made to the flexibility and ease of operations, equipment interchangeability and optimization.

6.17 Maximum energy conservation shall be applied.

6.18 Unless otherwise specified kettle type reboilers shall be provided to maintain the bottom temperature of the following towers:

- Deethanizer;
- Depropanizer;
- Propane dryer;
- Debutanizer.

7. FRACTIONATION AND SYSTEM CONFIGURATION

7.1 General

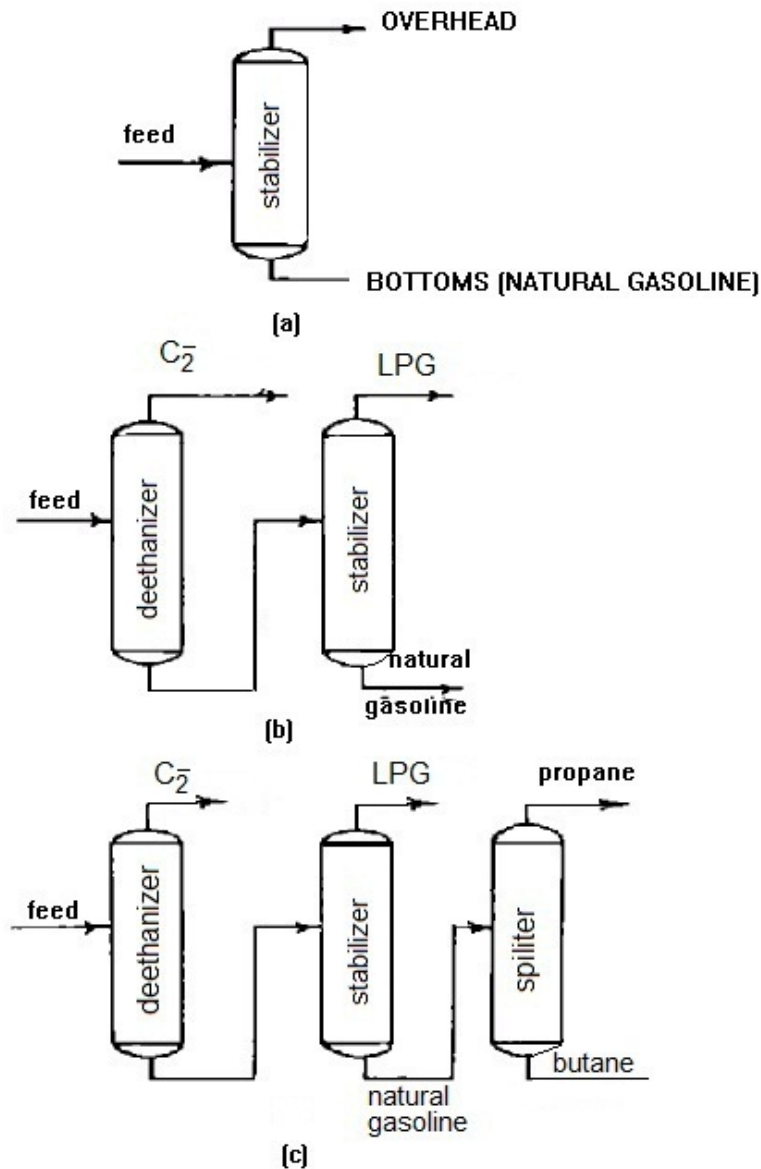
Some of typical LPG fractionation system configuration are demonstrated as follow:

7.1.1 Stabilization tower shall be used where a natural gasoline or stable liquid to be produced [see Fig. 1(a)].

7.1.2 The two-tower system shown in Fig. 1(b) is most commonly used to produce an LPG mixture in the overhead and a natural gasoline product as the bottoms. In this system, the deethanizer must remove all methane, ethane and light component from the second tower. Any material that enters the second tower must necessarily leave in one of the product streams.

7.1.3 The three-tower system shown in Fig. 1(c) most commonly produces commercial propane, commercial butane and natural gasoline as products. In this system also, the deethanizer must work properly to remove ethane and light component. The sequence of fractionation following the deethanizer may be varied. In the second tower, an LPG mixture could be produced overhead with natural gasoline produced as bottoms. The third tower would then split the LPG into commercial

propane overhead and commercial butane as bottoms. This sequence is favored sometimes where the market situation is variable and a market for LPG only exists during a portion of the year. During this period, the third tower would be shut down and not operated.



TYPICAL LPG FRACTIONATION SYSTEMS

Fig. 1

7.1.4 Regardless of how the fluids are removed from natural gas and/or gasoline, fractionation is necessary if products that meet any kind of rigid specification are to be made. The number of fractionating columns required depends on the number of products to be made and the character of the liquid, which serves as feed. The single tower system shown in Fig. 1 (a) ordinarily produces one specification product from the bottom stream, with all other components in the feed passing overhead.

7.1.5 The operating pressure of a fractionation tower is ordinarily fixed by the condensing temperature of the overhead product. Temperature in the condenser is normally controlled by the cooling medium. Allowing for sufficient temperature difference between the cooling medium and the overhead product, condenser temperature is fixed by the designer. In the case of a liquid distillate, the bubble point pressure is then calculated; for a vapor distillate product the dew point pressure

would be calculated. This pressure is the minimum pressure at which the tower can operate at the chosen condenser temperature. For vapor pressure chart, reference could be made to Appendix B (for the source, reference is made to GPSA in Section 2).

7.1.6 Economic evaluation shall be made for selection of a total and partial condenser for a tower. At a given pressure, the dew point is always a higher temperature than the bubble point, and this tends to minimize cooling costs, where all other elements are equal.

7.2 Fractionation Design Considerations

7.2.1 If the tower involved is the first one in a fractionation system, the conditions of the feed to the column will be fixed by the separation process. A surge vessel prior to this tower might change the analysis of the feed if some vapor is withdrawn at that point. (An example of this is a rich oil flash drum situated between the absorber and the deethanizer). For a system containing several towers, the split desired in each column should be made before completing analysis of any one. This assures that the splits set up for the different towers produce satisfactory products in all streams. A perfect separation between adjacent components cannot be specified. This will lead to a situation impossible to achieve in an actual column. In producing propane, for example, it must be allowed that a small amount of ethane and butanes be present. In this case, however, the propane must still meet the purity specifications demanded.

7.2.2 There are three ways in which the desired operation of a fractionation column is usually specified:

- A specified percentage recovery of one component in the distillate or one component in the bottom.
- A specified composition of one component in the distillate or bottom stream.
- A specified vapor pressure for either the distillate or bottom product.

7.2.3 For the design of fractionators the following parameters shall be considered:

- Feed composition, quantity, temperature and pressure;
- Desired products and their specifications;
- A reasonable condensing temperature for the overhead stream;
- Degree of separation between products.

7.2.4 Overall tray efficiency for the most fractionators typically as shown on Table 1.

TABLE 1 - TYPICAL FRACTIONATOR PARAMETERS*

DESCRIPTION	OPERATING PRESSURE kPa (ga)	NUMBER OF ACTUAL TRAYS	REFLUX ¹ RATIO	REFLUX ² RATIO	TRAY EFFICIENCY (%)
Demethanizer	1400- 2800	18 - 26	Top feed	Top feed	45 - 60
Deethanizer	2600- 3100	25 - 35	0.9 - 2.0	0.6 - 1.0	50 - 70
Depropanizer	1700- 1900	30 - 40	1.8 - 3.5	0.9 - 1.1	80 - 90
Debutanizer	500- 620	25 - 35	1.2 - 1.5	0.8 - 0.9	85 - 95
Butane splitter	550- 700	60 - 80	6.0 - 14.0	3.0 - 3.5	90 - 110
Rich oil fractionator (still)	900- 1100	20 - 30	1.75 - 2.0	0.35 - 0.40	Top 67, bottom 50
Rich oil deethanizer	1400- 1750	40	---	---	Top 25 - 40, bottom 40 - 60
Condensate stabilizer	700- 2800	16 - 24	Top feed	Top feed	40 - 60

1 reflux ratio relative to overhead product, (mol/mol)

2 reflux ratio relative to feed, dm³/dm³ (gal/gal)

***Note:**

For source of these figures see GPSA in Clause 2.

8. ABSORPTION/STRIPPING

8.1 Basic Requirements

8.1.1 The Absorption/Stripping Process may be used in LPG recovery Unit if needed by the minimum recovery specification of the product streams as requested in the project scope of the work.

8.1.2 Absorption is one of the oldest unit operations used in the gas processing industry. Rich gas enters the bottom of the absorber and flows upward contacting the countercurrent lean oil stream. The lean oil preferentially absorbs the heavier components from the gas and is then termed "rich oil". The rich oil is sent to a stripper (or still) where the absorbed components are removed by heating and/or stripping with steam. The lean oil is recycled to the absorber to complete the process loop.

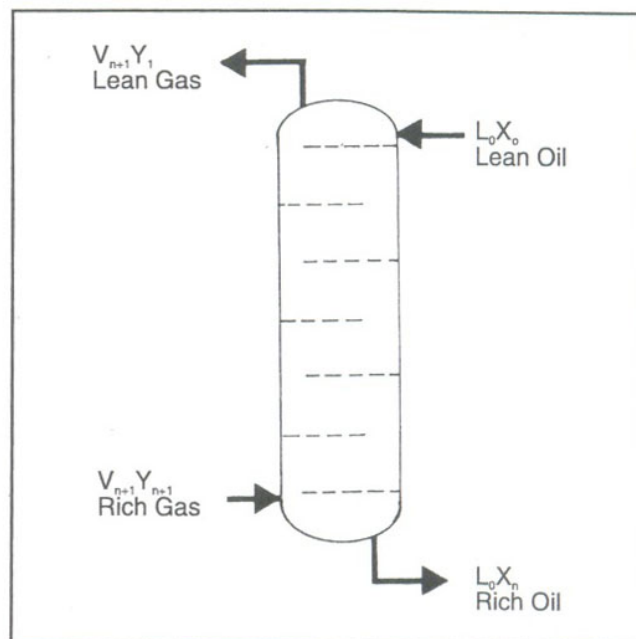
For a given gas, the fraction of each component in the gas that is absorbed by the oil is a function of the equilibrium phase relationship of the components and lean oil, the relative flow rates, and the contact stages. The phase relation is a function of pressure, temperature, and the composition of the lean oil. Nomenclature for an absorber is shown in Fig. 2.

As components are absorbed, the temperature of the gas and oil phases will increase due to heat of absorption. The heat released is proportional to the amount of gas absorbed. In many cases, side coolers are used on the absorber to limit the temperature rise and aid in absorption.

Lean oil will have a molecular weight in the 100 to 200 range. For ambient temperature absorbers, a heavy lean oil of 180 to 200 molecular weight will normally be used. For refrigerated absorbers, a lighter lean oil of 120 to 140 molecular weight is used. A lower molecular weight lean oil will contain more moles per gallon resulting in a lower circulation rate. However, lower molecular weight lean oil will have higher vaporization losses.

8.1.3 The design should incorporate both stripper and absorber towers with all associated facilities.

8.1.4 The resultant rich oil shall be stripped or denuded of the absorbed materials in the stripper tower. The stripped oil shall be recirculated to the Absorber tower as lean oil for Absorption of the LPG components.



ABSORPTION NOMENCLATURE

Fig. 2

8.2 Design Considerations

8.2.1 A temperature rise of 6°C - 16°C is usually designed into initial condition for the Absorption Process. The rise above this must be handled by intercoolers.

8.2.2 Absorbent is usually those hydrocarbons which have molecular mass of about 100-180 and maximum final boiling point of 160°C (e.g., Naphtha).

9. CONTROL AND OPTIMIZATION

9.1 Control Scheme

Unless otherwise specified Control scheme design shall generally be according to [IPS-E-PR-491](#), Appendix A.

9.2 Reboiler Control

Control system of the reboilers shall be investigated for proper functioning based on the tower feed compositions.

9.3 Advanced Process Control and Optimization

9.3.1 Advanced Process Control (APC) and optimization may be applied to upgrade plant safety, product quality and quantity and plant operation. The extent of application shall be as per Company's instructions.

9.3.2 The following APC loops may be incorporated in the process design as typical. The APC loops shall preferably be functioned without implementation of on line process analyzer.

a) Deethanizer tower:

- Control system for matching specification of C₂ at bottom and LPG recovery at top.

b) Depropanizer and Debutanizer towers:

- C₃ quality control.
- C₄ quality control.

APPENDICES

**APPENDIX A
LPG SPECIFICATION**

	SPECIFICATION		TEST METHODS
C ₂ Hydrocarbon	% vol.	0.2 max	ASTM D 2163
C ₃ Hydrocarbon	% vol.	*	ASTM D 2163
C ₄ Hydrocarbon	% vol.	*	ASTM D 2163
C ₅ Hydrocarbon	% vol.	2 max.	ASTM D 2163
Hydrogen Sulphide		Negative	ASTM D 2420
Mercaptan Sulphur	mg/dm ³	0.23 max. ⁽¹⁾	ASTM D 3227
Odorizing Agent	g/m ³	12	

1) The limit applies to the product before addition of odorizing agent (Ethyl mercaptan).

* Varies seasonally for refineries as follows:

(ABADAN, BANDAR ABBAS)

	1 st KHORDAD TO 1 st MEHR	1 st MEHR TO 1 st AZAR	1 st AZAR TO 1 st ESFAND	1 st ESFAND TO 1 st KHORDAD
C ₃ 's vol%	15-35	30-50	50-70	30-50
C ₄ 's vol%	85-65	70-50	50-30	70-50

(TEHRAN, ARAK, SHIRAZ, KERMANSHAH, ESFAHAN)

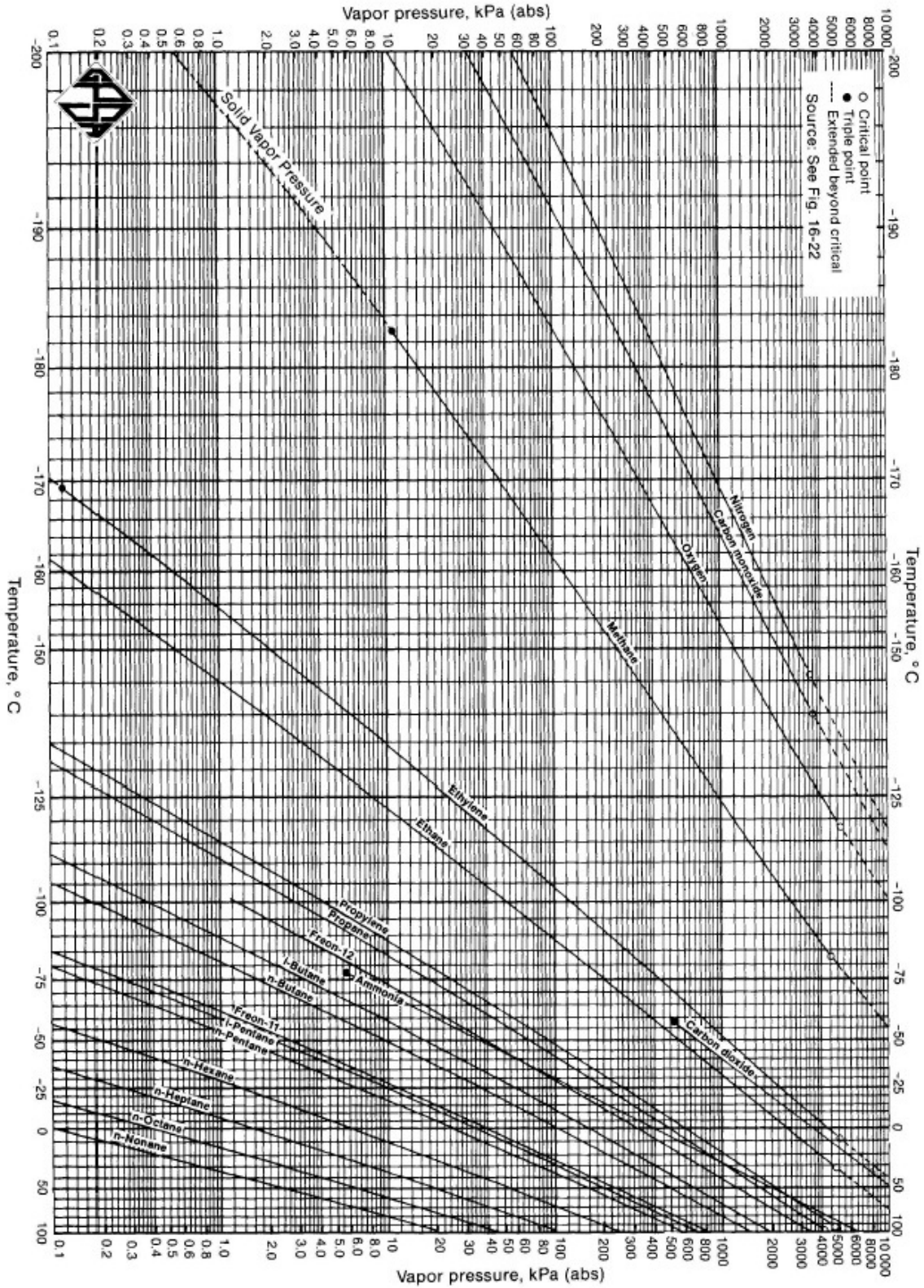
	1 st KHORDAD TO 1 st SHAHRIVAR	1 st SHAHRIVAR TO 1 st ABAN	1 st ABAN TO 1 st FARVARDIN	1 st FARVARDIN TO 1 st KHORDAD
C ₃ 's vol%	15-35	30-50	50-70	30-50
C ₄ 's vol%	85-65	70-50	50-30	70-50

(TABRIZ)

	1 st TIR TO 1 st SHAHRIVAR	1 st SHAHRIVAR TO 1 st ABAN	1 st ABAN TO 1 st ORDIBEHEST	1 st ORDIBEHEST TO 1 st TIR
C ₃ 's vol%	15-35	30-50	50-70	30-50
C ₄ 's vol%	85-65	70-50	50-30	70-50

The latest issues of the relevant test methods shall be used.

APPENDIX B
VAPOR PRESSURE CHART

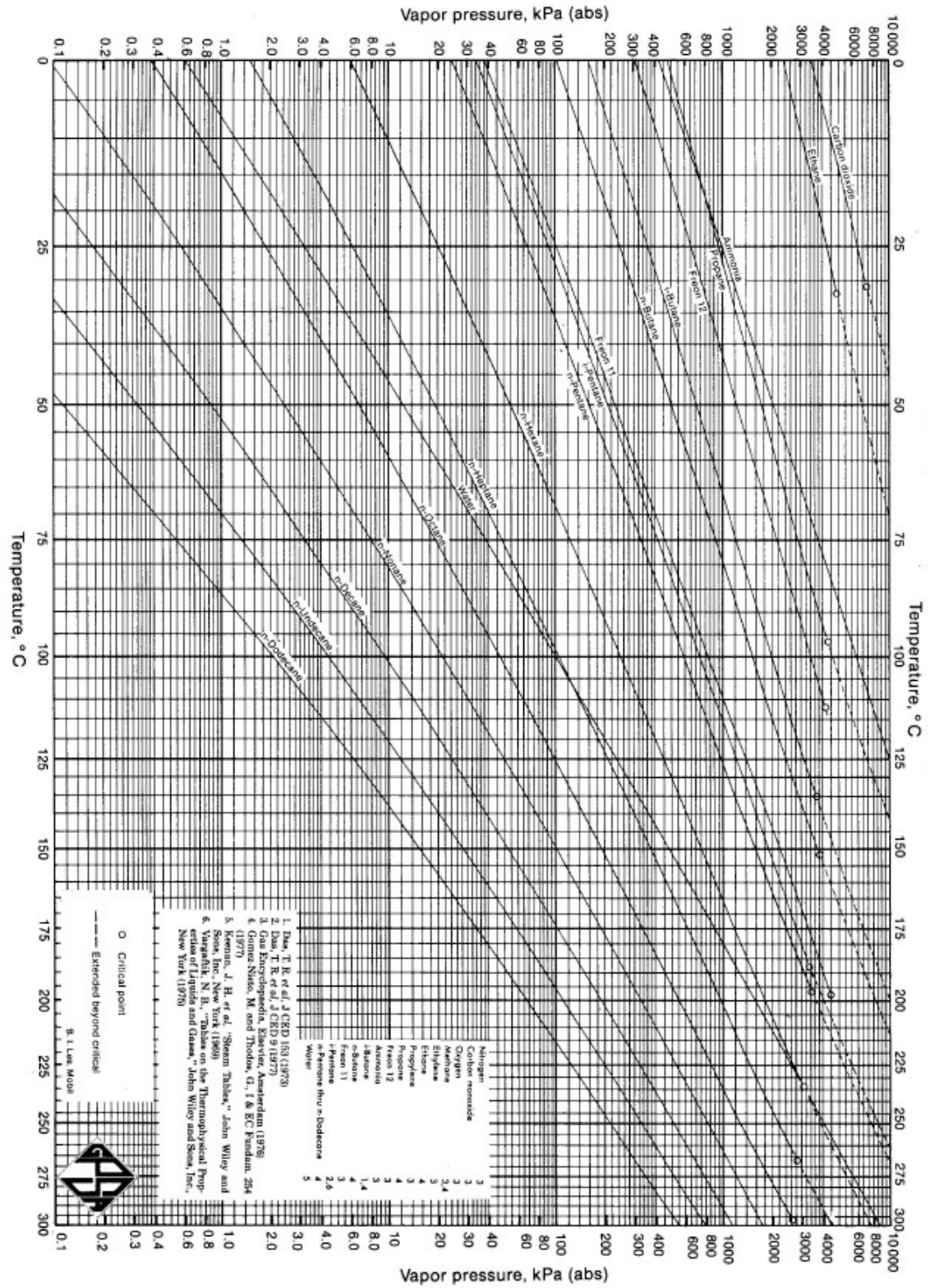


LOW-TEMPERATURE VAPOR PRESSURES FOR LIGHT HYDROCARBONS

Fig. B.1

(to be continued)

APPENDIX B (continued)



HIGH-TEMPERATURE VAPOR PRESSURES FOR LIGHT HYDROCARBONS
 Fig. B.2