CLASSIFICATION AND NOMENCLATURE SYSTEMS FOR PETROLEUM AND PETROLEUM RESERVES

1987 REPORT

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Abstract. The terminology used in classifying petroleum substances and the various categories of reserves has been the subject of much study and discussion for many years. The need for an increased degree of standardization has been long recognized but significant difficulty has been encountered in achieving this objective. This is not surprising given the global nature of the petroleum industry and the many languages in which the industry operates and reports petroleum statistics.

A Study Group, comprised of representatives of five member countries of the World Petroleum Congresses (Canada, the Netherlands, the United Kingdom, the United States and Venezuela), reviewed the classification and nomenclature systems for oil and gas and for reserves as used by various countries and recommended systems for universal adoption. Its Interim Report was presented at the 11th Congress held in London in 1983. It has been revised on the basis of comments since that time.

The recommended systems are scientifically sound, and yet at the same time, practical and simple enough to be readily understood even by those not involved on a daily basis in technical aspects of the industry. The recommended terminology is as close to current common usage as possible in order to minimize the changes necessary to bring about wide acceptance.

Due to the many forms of occurrence of petroleum, the wide range of its characteristics, and the lack of accurate knowledge respecting the principles of its origin, migration and accumulation, a precise system of classification and reserves nomenclature which will satisfy all petroleum scientists is not practical. Furthermore, the establishment of a precise system would detract from its understandability by the average layman who is becoming increasingly interested and concerned with petroleum matters. The recommended systems thus stress known facts and the classification of petroleum substances is based primarily on the state of occurrence and the viscosity and density of the substances. For reserves, the recommended system is not a major change from systems which are well established in many countries but it is hoped that the recommendations will help in achieving better consistency in the reserves data presented by different authors and organizations.

The recommended systems are broad in nature and petroleum scientists will likely further sub-divide the defined categories in order to facilitate detailed use. In summary, the Study Group defines petroleum as a naturally occurring mixture of predominantly hydrocarbons in the gaseous (natural gas), liquid (crude oil), or solid (natural bitumen) phases. The characterization of petroleum as a crude oil or natural bitumen is recommended to be made on the basis of viscosity of 10,000 mPa·s (centipoise) at original reservoir temperature and atmospheric pressure, on a gas free basis.

The system recommended by the Group for petroleum reserves refers to Proved Reserves, Unproved Reserves (which are categorized as Probable Reserves or Possible Reserves), and Undiscovered Potential Recovery. Future Potential Recovery is the sum of the Proved Reserves, the Unproved Reserves and the Undiscovered Potential Recovery, and the Ultimate Potential Recovery is the sum of the Cumulative Production and the Future Potential Recovery.

Résumé. La terminologie employée pour classer les substances pétrolières et les différentes catégories de réserves a été l'objet de beaucoup d'études et de discussions depuis de nombreuses années. On reconnait depuis longtemps qu'il faut la normaliser davantage, mais la tâche ne va pas sans rencontrer de grandes difficultés. Ceci n'est d'ailleurs pas surprenant, étant donné la dimension mondiale de l'industrie pétrolière et les nombreux langages utilisés par l'industrie pour exploiter et pour publier les statistiques pétrolières.

Un Groupe d'Etudes, composé de représentants de cinq pays du Congrès Mondial du Pétrole (Canada, Pays-Bas, Royaume-Uni, États-Unis et Venezuela), a examiné les systèmes de classement et de nomenclature employés par divers pays pour le pétrole, le gaz et les réserves, et il a recommandé l'adoption de systèmes universels. C'est le rapport intérimaire présenté au 11ème Congrès tenu à Londres en 1983 et révisé depuis sur la base des commentaires.

Les systèmes recommandés s'appuient sur des notions scientifiques reconnues, tout en étant assez simples et pratiques pour être facilement compris, même par ceux qui ne sont pas impliqués quotidiennement par les
1. INTRODUCTION

The classification of hydrocarbons and the nomenclature of oil and gas reserves have featured in several World Petroleum Congresses in one form or another. Two panel discussions in the 7th Congress dealt with the occurrence and prospects of tar sands and oil shales; problems related to the location and exploration of new oil and gas resources, and the world reserves of oil and gas were studied in Tokyo at the 9th Congress; and reserves terminology and estimation methods was the theme of a panel discussion at the 10th Congress in Bucharest. The need for some standardization of definitions and concepts was in all cases strenuously emphasized, with the suggestion that the Congresses, as an organization of recognized high scientific and technical repute, attempt a consensus expression in a multi-author paper at a future Congress.

On the recommendation of the Scientific Programme Committee, the Executive Board decided to set up for the first time a Study Group for the 11th, the Jubilee Congress in London, to review

(a) the oil and gas classification systems in current use, and focus on the development of a universal system embracing all types of naturally occurring hydrocarbons of present and potential commercial interest, and
(b) the nomenclature used by various countries and organizations in reporting estimates of reserves, and focus on the development of a simple, practical, readily understandable system which would receive general acceptance.

Canada, the Netherlands, the Union of Soviet Socialist Republics, the United Kingdom, the United States of America and Venezuela were to be invited to nominate one person to the Group.

The Study Group (SGR-1), formally installed in London in November, 1980, was made up of representatives appointed by the National Committees of Canada, the Netherlands, UK, USA and Venezuela. Dr. Martinez agreed to co-ordinate the subject of petroleum classification systems (Section 2), and Mr. Ion agreed to co-ordinate the petroleum reserves aspects (Section 3). Mr. DeSorcy agreed to act as Chairman of the discussion session at the London Congress, and to present the 1987 Report at the Houston Congress. The nominee of the USSR National Committee was unable to attend any meeting; the USSR National Committee was kept aware at all times of the progress of the work of the Group and sent material for study as requested.

National Committees were asked for pertinent information on both aspects of the Study. The Study Group members exchanged research material, lists of primary definitions and references, and sought opinions from a wide circle of contacts.

The Interim Report of the Group had a much wider circulation and preparatory discussion than any other submitted to a World Petroleum Congress. Close contacts established through a Venezuelan subcommittee with the Information Centre of the UN.
Institute for Training and Research (UNITAR) resulted in the adoption of definitions identical with the recommendations of the Study Group. The Interim Report was discussed at the 11th WPC in London (1983). Additionally, comments were requested from all of the National Committees of the WPC and from certain other organizations. This 1987 Report, which reflects those comments, was agreed upon by the Group following meetings in Montreal (October 1984) and New York (July 1985). We very much regret the death of Mr. Ion shortly afterwards.

The work of the Study Group as envisaged in 1980, is completed with this 1987 Report. The World Petroleum Congresses endorses the recommended terminology and definitions for use whenever practical. If deemed necessary, the 1987 Report might be updated or revised at a later date, in whatever way the World Petroleum Congresses considers appropriate.

2. PETROLEUM—CLASSIFICATION AND NOMENCLATURE

2.1. Objectives of Study Group

The need for one classification system and one set of definitions for all types of petroleum that exist in natural underground reservoirs or in natural deposits has always been appreciated; however, there has been limited acceptance of such systems and definitions whenever proposed. The Group decided to proceed on the basis of the following terms of reference.

It was agreed to include in the report what are commonly called crude oils and natural bitumens, as well as all hydrocarbon-bearing natural gases and natural gas liquids, including condensate. It was also agreed to discuss synthetic oil from natural bitumen and oil shales. Coals (pyrobitumens) and kerogens have been excluded.

Petroleum was accepted as a general term to apply to all naturally occurring mixtures of predominantly hydrocarbons. Portions of petroleum exist in the gaseous phase, other portions in the liquid phase and still other portions of petroleum exist only in the semi-solid or solid phase. The Group has named each of these portions respectively, Natural Gas, Crude Oil and Natural Bitumen.

As a major objective was simplicity, the Group tried to reduce the number of factors characterizing these different types of petroleum. Viscosity was taken as the factor to differentiate between Crude Oil and Natural Bitumen, and then density to differentiate between Extra-heavy, Heavy and other Crude oils.

The Group reviewed, as completely as possible, the existing definitions and systems. They were those in use in the principal producing countries, those recommended by important organizations and those in use in legislation and in banking. The review included bibliographies, where available. The aim was to incorporate the common elements of these systems and, at the same time, attempt a simple, practically oriented scheme which could be expanded by specialists for their own use. As the involvement is international, however, it was recognized that the problem of subtle connotations and, perhaps, false interpretations may occur with the translation from English into other languages.

2.2. Recommended definitions

Petroleum is a naturally occurring mixture of predominantly hydrocarbons in the gaseous, liquid or solid phase.

Hydrocarbons are chemical compounds consisting wholly of hydrogen and carbon.

Crude Oil is the portion of petroleum that exists in the liquid phase in natural underground reservoirs and remains liquid at atmospheric conditions of pressure and temperature. Crude Oil may include small amounts of non-hydrocarbons produced with the liquids. Crude Oil has a viscosity of less than or equal to 10 000 millipascal seconds (mPa·s) at original reservoir temperature and atmospheric pressure, on a gas free basis.

Natural Gas is the portion of petroleum that exists either in the gaseous phase or is in solution in crude oil in natural underground reservoirs, and which is gaseous at atmospheric conditions of pressure and temperature. Natural Gas may include amounts of non-hydrocarbons.

Natural Bitumen is the portion of petroleum that exists in the semi-solid or solid phase in natural deposits. In its natural state it usually contains sulphur, metals and other non-hydrocarbons. Natural Bitumen has a viscosity greater than 10 000 mPa·s measured at original temperature in the deposit and atmospheric pressure, on a gas free basis. Natural Bitumen generally requires upgrading prior to normal refining.

* The mPa·s, an SI-derived unit for dynamic viscosity, equals the centipoise (CP), a CGS unit of measurement of general usage in the oil industry.
2.3. Discussion

2.3.1. Crude oil

It is common practice to report classes of crude oil by density, usually expressed as degrees on a scale standardized by the American Petroleum Institute—API 'gravity'. A review of classifications used or recommended by various countries and organizations was made but it was found that there is not a consensus on the limits of each class.

Moreover, the marketing of different crude oils produced by a single nation usually carries the connotation of 'light' or 'heavy'; this gives significant monetary value to certain segregations for its international marketing. Actually, a crude oil such as 'Arabian Heavy' might be classified at the border of 'light' crude oil in Venezuela or in the USSR. As the use of such terms, each with a specific local meaning, has been firmly established and accepted in world trade, no change is recommended. It is obvious, therefore, that for purposes of comparisons or world-wide compilations, the terms 'heavy', 'medium' and 'light' are bound to be confusing and that any classification should preferably be done only by clearly indicating the density ranges used.

A classification limit of definitive value is found in the density of water at 4°C (1000 kilograms per cubic metre or 10⁶ in terms of API 'gravity'). Although the Group believes that the density range used should always accompany the terms, it presents the following as acceptable ranges for further classification of crude oil:

- greater than 1000 kg/m³ (less than 10 °API 'gravity') for Extra Heavy,
- 1000–920 kg/m³ (10–22.3 °API 'gravity') for Heavy,
- 920–870 kg/m³ (22.3–31.1 °API 'gravity') for Medium, and
- less than 870 kg/m³ (greater than 31.1 °API 'gravity') for Light.

Crude oils are sometimes called 'Sour' or 'Sweet', according to the content of sulphur compounds, which usually have distinctive odours, cause corrosion and so have an adverse environmental impact. There are no criteria generally used on a world-wide basis to differentiate between sour and sweet crude oils.

Similarly, although sometimes crude oils are classified as 'waxy' or 'non-waxy' there are no generally accepted criteria for this differentiation.

Crude oil may also be classified as naphthenic to paraffinic on the basis of a widely-used 'characterization factor' determined from density and atmospheric boiling point curves.

The term non-conventional, as applied to crude oils, is now less frequently used, referring in some instances to its type of occurrence or extraction, in others to its processing or refining, and in still others to both operations. It might be said generally that 'non-conventional crude oils' will, with time, become 'conventional'. The term 'non-conventional crude oils' is used in some countries for extra-heavy oil or natural bitumen.

2.3.2. Natural gas

In addition to natural gas as described in the basic definitions, there are a number of classifications and other related terminology that should be discussed to ensure consistency in the exchange of information.

Raw Natural Gas is natural gas as it is produced from the reservoir. It includes varying amounts of the heavier hydrocarbons which liquefy at atmospheric conditions, and water vapour; and may also contain sulphur compounds such as hydrogen sulphide, and other non-hydrocarbon gases such as carbon dioxide, nitrogen or helium, but which, nevertheless, is exploitable for its hydrocarbon content. Raw Natural Gas is often not suitable for direct utilization by most types of consumers.

Marketable Natural Gas is available for sale for direct consumption as a domestic, commercial or industrial fuel, or as an industrial raw material, whether it occurs naturally or results from the processing of Raw Natural Gas.

Marketable Natural Gas has to meet certain minimum specifications which vary from case to case. Within such specifications, the gas composition may vary with respect to the content of the heavier hydrocarbons and non-hydrocarbon gases, which do not render the gas unmarketable. Consequently, the heating value of Marketable Natural Gas may vary considerably and therefore quantities are usually expressed not only in volumes, but also in terms of energy content.

Wet (Rich) Gas is a natural gas containing hydrocarbons heavier than methane in such quantities that they may be extracted commercially, or that they may require removal to render the residue gas suitable for fuel use or pipeline transit.

Dry (Lean) Gas is a natural gas containing insufficient quantities of hydrocarbons heavier than methane to allow their commercial extraction or to require their removal in order to render the gas suitable for fuel use.
There are no universal standards for classification of natural gas as ‘wet’ or ‘dry’.

Raw natural gas may also be categorized depending on its content of hydrogen sulphide or other sulphur compounds. *Sweet Natural Gas* is a natural gas that contains no sulphur or sulphur compounds at all, or in such small quantities that no processing is necessary for their removal in order that the gas may be used directly as a non-corrosive domestic heating fuel. *Sour Natural Gas* is a natural gas that contains sulphur, sulphur compounds and/or carbon dioxide in quantities that may require removal for effective use.

The mode of occurrence of natural gas also features in classifications that are often referred to. *Non-Associated Gas* is a natural gas found in a natural reservoir that does not contain crude oil. *Associated Gas* is a natural gas found in contact with or dissolved in crude oil in the reservoir. ‘Associated’ gas can be further categorized as *Gas-Cap Gas* which is a free natural gas which overlies and is in contact with crude oil in the reservoir, or *Solution Gas* which is a natural gas dissolved in crude oil in the reservoir at the prevailing conditions of pressure and temperature.

A distinction which is occasionally made with respect to natural gas relates to the type of occurrence. *Conventional Gas* is a natural gas occurring in a normal porous and permeable reservoir rock, either in the gaseous phase or dissolved in crude oil, and which technically can be produced by normal production practices. *Non-Conventional Gas* is a natural gas found in unusual underground conditions such as very impermeable reservoirs which require uneconomic massive stimulation in order to be recovered, or in underground occurrences of gas hydrates, or dissolved in formation water, or gas from *in situ* gasification of coal. None of these occurrences are known to be exploited commercially, as yet, although various pilot projects have been tried for some time.

Natural gas which contains predominantly methane and ethane, for ease of transportation in some cases is being liquefied by lowering its temperature, and is then termed *Liquefied Natural Gas* (LNG).

### 2.3.3. Natural gas liquids

It is common practice in the oil industry to designate as *Natural Gas Liquids* those portions of natural gas which are recovered as liquids in separators, field facilities or gas processing plants. Natural Gas Liquids include but are not limited to ethane, propane,-butanes, pentanes, natural gasoline and condensate; they may include small quantities of non-hydrocarbons.

*Gas Plant Products* are natural gas liquids recovered from natural gas in gas processing plants and, in some situations, from field facilities. Gas Plant Products include ethane, propane, butanes, butanes-propane mixtures, natural gasoline and plant condensates.

*Liquefied Petroleum Gases* (LPG) is a term commonly used to refer to hydrocarbon mixtures consisting predominantly of propane and butanes.

*Condensates* are natural gas liquids, consisting mostly of pentanes and heavier hydrocarbon components. These include *Lease Condensate*, recovered from gas-well gas (associated and non-associated), in gas-liquid separators or field facilities, and *Plant Condensate*, recovered in a plant in a natural gas gathering, compression and associated gas treating system.

Lease Condensate may, in some circumstances, be mixed with crude oil for marketing, and in these cases, it is often reported as crude oil. Plant Condensate is not suitable for blending with natural gasoline or refinery gasoline.

### 2.3.4. Natural bitumen

The Group considered it appropriate to use the term *Natural Bitumen* for the portion of petroleum that exists in the semi-solid or solid phase in natural deposits, and has a viscosity greater than 10 000 Pa·s measured at original temperature in the deposit and atmospheric pressure, on a gas free basis.

Natural Bitumen includes substances frequently referred to as ‘oil-sands oil’, ‘bitumens’, ‘tar-sands oil’ or simply ‘tar’; it does not include kerogen or ‘shale-oil’. ‘Shale-oil’ is not a naturally occurring substance, but the result of upgrading of kerogen contained in sedimentary rocks commonly called ‘oil shales’. Kerogen is a fossilized, insoluble organic material, made up principally of various polymers and with small amounts of hydrocarbons; it is usually found in shales and can be converted by distillation to ‘shale-oil’. It is a material sometimes called ‘proto-petroleum’ to indicate it is a substance undergoing transitional physico-chemical processes.

‘Bituminous schists’ or ‘bituminous slates’ are translation terms often used when referring in languages other than English to shales capable of producing ‘shale-oil’.

The Group notes that the United Nations UNI-TAR/UNDP Information Centre has defined Natural
Asphalt as a portion of natural bitumen, normally composed of complex mixtures of hydrocarbons, asphaltenes and resins, with significant quantities of mineral matter and variable amounts of water. It occurs in deposits, or in rocks such as limestones and sandstones, at the surface or very near the surface.

*Synthetic Crude Oil* is a mixture of hydrocarbons, which is derived by upgrading natural bitumen or kerogen in oil shales (or other substances such as coals) and may contain sulphur or other non-hydrocarbon compounds.

Synthetic Crude Oil has many similarities to crude oil and is used as feedstock for refining or other chemical processing operations.

3. PETROLEUM RESERVES—CLASSIFICATION AND NOMENCLATURE

3.1. Objectives of Study Group

The considerations to be taken into account for the objective of developing a generally acceptable and readily understandable system may be characterized as general, physical and economic.

3.1.1. General considerations

Reserves are the recoverable portion of petroleum deposits. Reserves of petroleum have become of interest to many outside the petroleum industry. Therefore, the Group considered that there was a responsibility to be intelligible to economists, policy-makers, politicians and laymen, as well as to satisfy the professional needs of petroleum scientists and technologists.

The interest in energy reserves is not confined to the immediate or short-term future. Therefore, it was necessary to cover the more speculative categories as well as those designated Proved Reserves, which are the working inventories from which almost all of the next year's production must come. Nor is the interest confined to one country or language. Therefore, whilst the Group worked and reported in English, the possible translation into other languages was borne in mind.

Reserves data vary greatly in degree of uncertainty. Therefore it is essential that in publishing reserve estimates, terminology be used which indicates this degree of uncertainty. The not unusual practice of expressing uncertain reserve estimates as ranging between a given low and a given high amount is recommended; if such an uncertain estimate, however, is expressed as a single figure it is obvious that this should be neither the low nor the high estimate but a realistic intermediate reserve figure in which all the uncertainties have been incorporated.

In its Interim Report the Group recommended that the use of the term 'resource' as a synonym for 'reserves' be avoided. One of the reasons for this is because the term resource is variously used to refer to: the total petroleum-in-place, the recoverable portion of that total, the undiscovered petroleum-in-place, or the recoverable portion of that petroleum. This leads to obvious confusion and although the Group is not including the term resource in its list of definitions, it urges that when such terminology is used, the total petroleum-in-place be referred to as the 'resource-base'.

3.1.2. Physical considerations

The degree of geological knowledge of the nature and size of petroleum deposits and the engineering capability to extract economically from the deposit are the main physical aspects which reflect on reserve evaluation. The reasons for such evaluations are many. For example, if the reason was the general planning of exploration and production activity in an area, one would wish to cover not only known reserves but also the expected results of further exploration and appraisal drilling, and of new technological developments. Another reason might be the need to decide on building a pipeline to a new production area; the evaluation would then concentrate mainly on indicated recoverable oil from known discoveries, and the likely rates of production. If, as a third example, the reason was the closing of a sales contract which would guarantee the delivery of certain volumes of natural gas, the evaluation might well be restricted to those amounts which were considered producible with the highest chance of probability. These examples illustrate the importance of appreciating that operational decisions can rest on varied degrees of physical certainty.

However, there are many other uses of reserves data outside the practical operational sphere. Therefore, it would seem impossible to aim for a system which would fit all purposes. The Group decided that only broad categories could be considered in this Report, for, whilst closer subdivision, or even a number of distinct systems, might be of value to the petroleum scientists, they could be very confusing to other people.
3.1.3. Economic considerations

At the time that any estimate is made, only the economic conditions of contract terms, taxation, price and cost prevailing at the time will be known.

For many years prior to 1970 the petroleum industry had relatively stable conditions so that the economic parameters changed very little. Since then, circumstances have been more dynamic. Although price changes and cost inflation have occurred worldwide, there have been marked local variations because of differing local conditions. Predictability of future economic conditions has become more uncertain. Consequently, there was no attempt by the Group to create or adopt economic categories such as 'sub-economic' or 'marginally economic'. The distinction may have practical value in countries with an extensive data base, but world-wide it might cause distortion through the collator or reporter attempting to squeeze more from the data than was appropriate.

The Group rejected, for Proved Reserves, the concept of estimating future economic conditions and adhered to the widely accepted principle of restricting these estimates to the amounts recoverable under the economic conditions at the time of the estimate. The Group recognizes, however, that in special cases, future contractually committed prices may be taken into account such as in the case of a contractually committed and price related future gas delivery.

The other categories of reserves which may be developed and produced in the distant future cannot have the same restrictions, either in the physical or economic parameters. Effects of possible future improvements of economic conditions and also of foreseen new technological developments can be expressed by allocating appropriate amounts of reserves in the probable or possible categories. Of course, assumptions respecting future economic and technological parameters must be realistic, and uncertainties inherent to such future circumstances must be taken into account.

3.2. Recommended nomenclature system for petroleum reserves

Proved Reserves of petroleum are the estimated quantities, as at a specific date, which analysis of geological and engineering data demonstrates, with reasonable certainty, to be recoverable in the future from known reservoirs under the economic and operational conditions at the same date.

Proved Developed Reserves are those Proved Reserves that can be expected to be recovered through existing wells and facilities and by existing operating methods. Improved recovery reserves can be considered as Proved Developed Reserves only after an improved recovery project has been installed and favourable response has occurred or is expected with a reasonable degree of certainty.

Proved Undeveloped Reserves are those Proved Reserves that are expected to be recovered from future wells and facilities, including future improved recovery projects which are anticipated with a high degree of certainty in reservoirs which have previously shown favourable response to improved recovery projects.

Unproved Reserves of petroleum are the estimated quantities, as at a specific date, which analysis of geological and engineering data indicates might be economically recoverable from already discovered deposits, with a sufficient degree of probability to suggest their existence. Because of uncertainties as to whether, and to what extent, such Unproved Reserves may be expected to be recoverable in the future, the estimates should be given as a range but may be given as a single intermediate figure in which all uncertainties have been incorporated. Unproved Reserves may be further categorized as Probable Reserves or Possible Reserves.

Probable Reserves of petroleum are the estimated quantities, as at a specific date, which analysis of geological and engineering data indicates might be economically recoverable from already discovered deposits with a reasonably high degree of probability, which suggests the likelihood of their existence, but not sufficient to be classified as proved. Because of uncertainties as to whether, and to what extent, such Probable Reserves may be expected to be recoverable in the future, the estimates should be given as a range but may be given as a single intermediate figure in which all uncertainties have been incorporated.

Possible Reserves of petroleum are the estimated quantities, as at a specific date, which analysis of geological and engineering data indicates might be economically recoverable from already discovered deposits with only a moderate degree of probability, which suggests the chance of their existence, but not sufficient to be classified as probable. Because of uncertainties as to whether, and to what extent, such Possible Reserves may be expected to be recoverable in the future, the estimates should be given as a range but may be given as a single intermediate figure in which all uncertainties have been incorporated.

Undiscovered Potential Recovery is the estimated quantity of petroleum, as at a specific date, which has not been discovered, but which general geological
and engineering judgment suggests may eventually be economically obtainable. Because of the great uncertainties, estimates should be given as a range. (In the Interim Report, the Group referred to this component as 'Speculative Reserves'. The Group has changed its recommended terminology because a large number of comments were received expressing concern that petroleum not yet discovered would be termed a 'reserve'.)

*Petroleum-in-Place* is the total quantity of petroleum that is estimated to exist originally in naturally occurring reservoirs. (Oil-in-place, gas-in-place, bitumen-in-place, are defined in the same manner.)

*Future Potential Recovery* is the estimated quantity of petroleum, as at a specific date, which will be produced in the future from the Proved Reserves, the Unproved Reserves and the Undiscovered Potential Recovery. Because of the great uncertainties in the estimation of some of the components, the estimates should be expressed as a range.

*Ultimate Potential Recovery*, as at a specific date, is the sum of the Cumulative Production and the Future Potential Recovery.

*Primary Recovery* is the extraction of petroleum from naturally occurring reservoirs utilizing only the natural energy available in the reservoirs to move fluids through the reservoir rock to wellbores or other points of recovery.

*Improved Recovery* is the extraction of additional petroleum, beyond Primary Recovery, from naturally occurring reservoirs by supplementing the natural energy or altering the natural forces in the reservoir. It includes waterflooding, secondary processes, tertiary processes and any other means of supplementing natural reservoir recovery processes.

### 3.3. Discussion

Various member countries of the World Petroleum Congresses responded to a request for information on their usage of reserves classification and nomenclature, and this information has been summarized in Appendix II. From this information it was concluded that there is already a reasonable similarity between the existing systems and on that basis the Group has defined the various terms and their relationships as demonstrated in Fig. 1.

The starting point is 'petroleum-in-place' which is referred to by some as the resource-base. (The terminology can be used for oil, natural gas or natural bitumen, but for purposes of simplicity this discussion will refer only to petroleum.)

The primary subdivision is between petroleum-in-place in deposits which have already been discovered and petroleum-in-place which undoubtedly exists in other deposits in the earth's crust which have not yet been discovered.

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**Fig. 1. Illustration of basic framework of recommended nomenclature for petroleum reserves.** (Not to scale).
Looking first at the petroleum already discovered, only a portion of that is recoverable, some of which has already been produced. The figure shows that the recoverable portion remaining in the ground is termed ‘reserves’. The probability that these reserves will be recovered varies; some are ‘proved’ because there is little doubt as to their existence and producibility, while others are less certain and are termed ‘probable’ or ‘possible’ in descending order of probability. The figure shows that these two latter categories, when combined, are termed ‘unproved’ reserves.

Turning now to the petroleum-in-place which is not yet discovered, there is naturally a great deal of uncertainty as to what these volumes are. There is even greater uncertainty as to what portion of that petroleum will eventually be discovered, and even more respecting the volume which will ultimately be recoverable. The Group recommends that the portion estimated as recoverable be termed the ‘Undiscovered Potential Recovery’. (The term speculative reserves was used in the Interim Report.)

Referring again to Fig. 1, the petroleum expected to be produced in future from a discovered deposit is the sum of its proved reserves, probable reserves and possible reserves; the petroleum expected to be produced in future from an undrilled petroleum prospect is its undiscovered potential recovery. If one wishes to refer collectively to future production from discovered and undiscovered deposits, for instance by owner company, by geological province, by country or from the world as a whole, the relevant reserves and undiscovered potential recovery are added* to result in the ‘future potential recovery’. If one wishes to refer to the total petroleum which will ultimately be recovered, including the production to date, this volume is simply added to the future potential recovery to result in the ‘ultimate potential recovery’.

Proved Reserves generally must be supported by actual production or by meaningful formation tests. Petroleum recoverable by means of improved recovery is considered proved reserves only after a project has been installed or is anticipated with a high degree of certainty, and where favourable response has occurred or can be expected because similar improved recovery projects have shown favourable response in the same reservoir.

The subdivision of Proved Reserves into Proved Developed Reserves and Proved Undeveloped Reserves is a reporting requirement in certain countries.

For other countries such a procedure is only recommended where practical.

The terms Probable Reserves and Possible Reserves are used in many countries and although the usage may vary somewhat, it is recommended that these terms be adopted. However, because the dividing line between these two categories is not very precisely defined, the allocation of reserves between the two categories will remain rather subjective. Therefore it was considered practical for the subdivision into Probable and Possible to be only optional and to introduce the term ‘Unproved Reserves’ as the aggregate of these two categories. (Venezuela uses the term ‘semi-proved’ which was not considered appropriate because it could be interpreted to mean 50% proved.)

Some people consider that a distinction should be drawn between those reserves which could be available for production and those subject to some restriction arising, for example, from government policy, the location of the deposit or current economics, which effectively renders them ‘static’ or ‘restricted’.

This may be a useful concept, for example, when used in a single organization in which the parameters can be closely defined. However, the Group considered that the adoption of such a category for all circumstances in all countries would decrease, rather than increase, comparability of aggregated reserve estimates.

The basic definitions of reserves, given earlier, emphasize the decreasing knowledge of the geological, engineering and economic parameters in the estimation of reserves from the Proved Reserves category to the increasingly less well known and definable categories.

As mentioned before, the uncertainty of a reserve estimate can be expressed by presenting it as ranging between a low and a high reserve figure. Where in practice uncertain reserve data, such as probable and possible reserves are often given as single figures, it is important in order not to be misleading, that such figures should represent realistic intermediate estimates in which all the uncertainties have been incorporated.

Aggregation of different reserve categories is only acceptable when for each category all the uncertainties have been taken into account resulting in realistic estimates of expected recovery in the future.

As an example, take the effect of improved recovery on the estimates for a particular oil reservoir; assume that preparatory studies indicate that successful improved recovery could provide 20 million m³ of additional oil but that the chance of successful application is only 50%; at that stage the realistic assess-

* Regarding adding of reserve data, refer to Appendix I.
ment of additional recovery should be 10 million m$^3$ of unproved reserves, rather than 20 million m$^3$.

As another example, take the effect of an uncertain oil/water contact in an oil reservoir; assume that a crestal well has proved producible oil in a reservoir down to 1500 m depth and that a downdip well has proved the reservoir to be waterbearing up to 1600 m depth. The whole reservoir rock volume between 1500 m and 1600 m has a probability of containing recoverable oil, i.e. there are Unproved Reserves ranging between very small, if the oil/water contact would be just below 1500 m, and very large, if the oil/water contact would be just above 1600 m. A realistic estimate of unproved reserves at that stage might best be based on an assumed oil/water contact at 1550 m.

More sophisticated methods to incorporate the uncertainties which are inherent in the estimating of reserves have been in use for some time in the petroleum industry and a comment on these methods is given in Appendix I.

Usually reserve estimates are revised at least annually; new geological information, technological progress, changed economic circumstances and the past year’s production will all contribute to the new estimate, whereby in general the ranges of uncertainty will tend to be smaller than for the previous estimate. For oil as well as for gas, the Group recommends that statements on reserves should never be limited to total figures only but should always show the breakdown at least into the categories Proved Reserves, Unproved Reserves and Undiscovered Potential Recovery. For certain purposes, reporting aggregated figures for liquid and gaseous petroleum reserves may be desirable; but the Group recommends that in such cases the separate reserve figures for oil and gas should also be given.

Reserves and production of crude oil are usually reported within the industry by volume, yet reporting in units of mass is not uncommon. The conversion requires multiplication by a known or, in some cases estimated, density factor. The conversion factor used should always be given, but where not essential, conversion should be avoided.

Reserves and production of natural gas are normally reported in volume and less commonly in units of mass. However, the volumes are given at various standard pressures and temperatures; standards are often built into regulations for different purposes in different countries. Therefore, the Group recommends that the standards used should be quoted in every case. No universal standards are suggested, particularly as the effect of these inconsistencies is considered of comparatively little consequence in view of the order of magnitude of the uncertainties which are inherent in the estimates of reserves.

The proportion of non-flammable gas in many natural gases can be high and seriously affect the estimate of recoverable hydrocarbons. Whenever this is the case, either the heat content of the total gas, or the percentage of non-hydrocarbon gas should be given and the appropriate correction made; otherwise, the gross figure may give a most misleading estimate of the reserves. It was not considered that any more specific requirement could be set which would have universal acceptance.

The Group chose the term ‘Improved Recovery’ because of the confusion which currently exists as to whether ‘Enhanced Recovery’ methods include the ‘Secondary’ recovery methods such as waterflooding, or only the less conventional methods. ‘Improved Recovery’, as recommended by the Group, includes all methods of recovery beyond ‘Primary Recovery’, whether so-called ‘Secondary’ or ‘Tertiary’, or even ‘Quaternary’.

**APPENDIX I.**

**Probabilistic methods in reserves estimation**

Probabilistic methods were developed because, under certain situations, oil companies needed a better idea of the potential recovery of an oil field than could be given by the imprecise ‘proved’, ‘probable’ and ‘possible’ concepts. These terms reflect increasing uncertainty without quantification of this uncertainty.

However, under certain conditions, such as large discoveries in a new oil province requiring major initial investments and long development periods, the uncertainties can play an essential role in decision-making.

Especially in the 1960s, when competition within the international oil business started to become more intensive, the need arose for better quantification in such cases. Probabilistic methods were developed, whereby the need for the probable and possible subdivision diminished.

In principle, the method consists of a systematic review of each of the factors which determine the magnitude of the reserves of a partly drilled field. For instance, as regards the productive area, a minimum value can be determined on the basis of the area drilled assuming only little extension and a maximum value on the basis of a most optimistic geological interpretation of the possible field size. The range
from minimum to maximum is broken down into intervals, and probabilities of occurrence can be allocated to each interval. In a similar manner the other factors, such as reservoir thickness, porosity, connate water content and recovery efficiency, are reviewed and for each a probability distribution between a reasonable minimum and maximum can be determined. By multiplication of these factors or by means of Monte Carlo techniques, one can obtain the estimate of reserves expressed in terms of a probability distribution, which can be displayed in graphical form as shown in Fig. 2.

A point, P, on the curve of Fig. 2 means that according to the estimator there is a Y percent chance that the reserves will be equal to or greater than X units. Point A indicates the amount of reserves which has a high degree of certainty to be recovered, i.e. the Proved Reserves. By measuring the area under the curve one finds the total ‘expectation of reserves’, which sums up all the various possibilities and each according to its likelihood of occurrence. The expectation curve as shown in Fig. 2 indicates a total reserve expectation of about 30 units of which some 15 units (point A) could be considered as Proved Reserves and the remaining 15 units would then be designated as Unproved Reserves.

For many purposes, such as aggregating statistics, it is not practical to use the expectation curve as such. In practice, therefore, this curve is often described by three of its points:

- a low value with high degree of certainty (say in the 85–95% range), e.g. point A, corresponding with the Proved Reserves.
- an intermediate value, e.g. point B, which represents the ‘expectation of reserves’ or Proved plus Unproved Reserves.
- a high value with low certainty (say 5–15% chance), e.g. point C, indicating something like a reasonable upper limit.

The important value is represented by point B, which also might be described as the best geological and engineering assessment of reserves. When applying such methods there is little need for a defined subdivision into probable (the middle part of the curve) and possible reserves (the tail end of the curve).

There are many circumstances under which such an elaborate probabilistic approach would not be warranted; when a field has been drilled up; when reservoir conditions are well known; when there is enough production history; the uncertainties are relatively small and the expectation curve would be rather steep. In such cases the widespread use of separate probable and possible categories remains suitable, provided that the degree of uncertainty is reflected in the figures that are provided.

The probabilistic approach has found extensive application for the quantitative assessment of Undiscovered Potential Recovery. In this case an extra dimension is introduced by the uncertainty as to whether there is an oil field at all. This affects the shape of the expectation curve, which will then be, for instance, as indicated on Fig. 3. For literature on this subject reference is made to the publications of Nederlof (1979 and 1980) and Miller (1982).

Addition of reserves

A complication arising from the probabilistic approach is the manner in which reserves or undiscovered potential recoveries of several fields or geological prospects should be added.

If, for instance, the proved reserves of one oil field based on 90% certainty are 50 units and of a second oil field are 100 units, the algebraic sum of 150 units
would have more than 90% chance to be attained. Therefore, one can see that the proved reserves of the two fields together is more than 150 units and should be determined by probabilistic addition instead of algebraic addition.

Similarly, a single geological prospect may have only 20% chance of containing a producible oil field; but if one had 10 such prospects together, the chance of finding at least one producible oil field increases considerably, depending on the degree of geological interdependency of prospects. In the case of complete independency, the chance would increase to almost 90%.

Such probabilistic addition, however, also has its complications:

- In a single oil province the geological and reservoir parameters which affect the prospectivity of each geological structure and the reserves of each field usually will not be independent from each other; this interdependency would have to be quantified and incorporated in the probabilistic addition.
- The extra proved reserves due to probabilistic addition cannot be allocated to any one specific field.
- The effect of probabilistic addition will depend on the manner in which oil fields are grouped together, i.e., by owner company, by geological province, by oil gravity, etc.
- The US Securities and Exchange Commission will not likely accept statements of proved reserves based on probabilistic addition.

In view of these complications, it is recommended that for general statistic purposes the current practice of algebraic addition should be adhered to. Probabilistic addition should be limited to special cases for a well defined purpose and in such cases the calculating procedures should be clearly explained.
## APPENDIX II.

### Comparison of reserves classification systems

<table>
<thead>
<tr>
<th>Group Recommendation</th>
<th>Proved</th>
<th>Unproved</th>
<th>Undiscovered</th>
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<td></td>
<td>Potential</td>
<td>+ speculative</td>
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<td>B</td>
<td>C</td>
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<td>Proved and Probable</td>
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<td>P₂ (incl. P₁)</td>
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### Sources: Country terms supplied by WPC National Committees except for USSR and for Ecuador. Changes since the Interim Report have been based on comments received from the various countries.

### Notes on Table of Comparison of Reserves Classification Systems

1. Australia
   B. Australian Minerals and Energy Council system indicates categories as P₁ (Proved), known with 93% certainty, P₂, (Proved + Probable) 60% probability, P₃ (Proved + Probable + Possible) 5% probability.
   C. National Energy Advisory Committee adopted the 'McKelvey' system, but uses the word 'resources' and subdivides into Recoverable, Economic, Sub-economic (Paramarginal & Submarginal), Identified (Demonstrated and Inferred) and Undiscovered (Hypothetical & Speculative).

2. Austria
   Proved is defined as having more than 90% certainty, Probable as 50-90% certainty, Possible as less than 50% certainty.

3. Brazil
   Proved reserves are those delineated by producing wells and geological barriers. Probable and Possible are estimated by a statistical approach.

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4. **Canada**
   
   Established, best current estimate and upside are used by some and correlate to 90%, 50% and 10% probability estimates.

5. **Denmark**
   
   A. Producing companies preference.
   
   B. Government preference.

6. **Ecuador**
   
   A. Ministry for Natural Resources and Energy treats Primary Reserves as Probable and Possible, and, separately, reserves from secondary recovery.
   
   B. The State Oil Company (CEPE) considers the Proved and Probable as being the total reserves, but then allows Possible Reserves as those indicated by only geological and geophysical methods.
   
   (Source: Ing. M. Toscano, CEPE, Subgerencia de Planificacion, Quito, 1981.)

7. **France**
   
   Comité des Techniciens, Chambre Syndicale de la Recherche et de la Production du Pétrole et du Gaz Naturel.

8. **India**
   
   Recoverable reserves are only calculated for categories A, B and C1; for oil-in-place there is an additional category C2, and a category, called Jabalance, for discovered, non-economic oil; for prognosticated reserves there are two categories, D1 and D2. D1 reserves are calculated for rock units with proved oil and gas potential within the limits of a basin; D2 reserves are calculated in rock units with proved oil and gas potential in areas with similar geological framework. D2 reserves are also calculated for other rock units not considered earlier in a proved petroliferous basin.

9. **Iran**
   
   Proposes that a probabilistic approach should define the classes given.

10. **Netherlands**
    
    The system is based on a probabilistic approach whereby the total reserves correspond with the expectation of reserves as described in Appendix I. Of these total reserves, the amount that has a 90% chance of being exceeded is called proved and the remainder is called unproved.

11. **PR China**
    
    Proved reserves are made up of developed, undeveloped and basically proved reserves. Basically proved reserves are those in geologically complex reservoirs which will take considerable time to drill and prove up.

12. **United Kingdom**
    
    Proved Reserves are virtually certain; Probable Reserves have above 50% certainty; Possible Reserves less than 50% certainty.

    
    UN Expert Group Report, ‘A recommended basic format for the classification of international data on crude oil and natural gas reserves and resources’ Natural Resources Forum, Vol. 1, No. 4 July 1977, pp. 387-402.

14. **United Nations, 1979**
    

15. **United States of America**
    
    The system adopted by the US Bureau of Mines and the US Geological Survey (USGS Circular 531) also groups the Measured and Indicated as Demonstrated and, with the Inferred category, as Identified Resources. All these categories can be subdivided into Economic, Marginally Economic and Sub-economic sub-categories.

16. **Union of Soviet Socialist Republics**
    

17. **Venezuela**
    

    
    Questionnaire sent to all countries before compilation of answers into published Report. Some modifications made for 1986 survey.

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