HISTORICAL BACKGROUND OF OIL INDUSTRY, WORLD SUPPLY-DEMAND

Proven Reserve: Proven reserves are those quantities of petroleum which, by analysis of geoleogical and/or engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under current economic conditions, operating methods and government regulations[5].

Reserve/Production (R/P) Ratio: If the reserves remaining at the end of any year are divided by the production in that year, the result is the length of time that those remaining reserves would last if production were to continue at that level.

International Organizations

OPEC (Organization of Petroleum Exporting Countries)

OPEC is an international Organization of eleven developing countries, which are heavily reliant on oil revenues as their main source of income. Membership is open to any country which is a substantial net exporter of oil and which shares the ideals of the Organization. The current Members are **Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela.**

Since oil revenues are so vital for the economic development of these nations, they aim to bring stability and harmony to the oil market by adjusting their oil output to help ensure a balance between supply and demand. Twice a year, or more frequently if required, the Oil and Energy Ministers of the OPEC Members meet to decide on the Organization's output level, and consider whether any action to adjust output is necessary in the light of recent and anticipated oil market developments. OPEC's eleven members collectively supply about 40 per cent of the world's oil output, and possess more than three-quarters of the world's total proven crude oil reserves.

The Organization of the Petroleum Exporting Countries (OPEC) is a permanent, intergovernmental Organization, created at the Baghdad Conference on September 10–14, 1960, by Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. The five Founding Members were later joined by eight other Members: Qatar (1961); Indonesia (1962); Socialist Peoples Libyan Arab Jamahiriya (1962); United Arab Emirates (1967); Algeria (1969); Nigeria (1971); Ecuador (1973–1992) and Gabon (1975–1994). OPEC had its headquarters in Geneva, Switzerland, in the first five years of its existence. This was moved to Vienna, Austria, on September 1, 1965.

OPEC's objective is to co-ordinate and unify petroleum policies among Member Countries, in order to secure fair and stable prices for petroleum producers; an efficient, economic and regular supply of petroleum to consuming nations; and a fair return on capital to those investing in the industry.

1960-1970: These were OPEC's formative years, with the Organization, which had started life as a group of five oil-producing, developing countries, seeking to assert its Member Countries' legitimate rights in an international oil market dominated by the 'Seven Sisters' multinational companies. Activities were generally of a low-profile nature, as OPEC set out its objectives, established its Secretariat, which moved from Geneva to Vienna in 1965, adopted resolutions and engaged in negotiations with the companies. Membership grew to ten during the decade.

1970-1980: OPEC rose to international prominence during this decade, as its Member Countries took control of their domestic petroleum industries and acquired a major say in the pricing of crude oil on world markets. There were two oil pricing crises, triggered by the Arab oil embargo in 1973 and the outbreak of the Iranian Revolution five years later, but fed by fundamental imbalances in the market; both resulted in oil prices rising steeply. The first

Summit of OPEC Sovereigns and Heads of State was held in Algiers in March 1975. OPEC acquired its 11th and final current Member, Nigeria, in 1971.

1980-1990: Prices peaked at the beginning of the decade, before beginning a dramatic decline, which culminated in a collapse in 1986 - the third oil-pricing crisis. Prices rallied in the final years of the decade, without approaching the high levels of the early-1980s, as awareness grew of the need for joint action among oil producers if market stability with reasonable prices was to be achieved in the future. Environmental issues began to appear on the international agenda.

1990-2000: A fourth pricing crisis was averted at the beginning of the decade, on the outbreak of hostilities in the Middle East, when a sudden steep rise in prices on panic-stricken markets was moderated by output increases from OPEC Members. Prices then remained relatively stable until 1998, when there was a collapse, in the wake of the economic downturn in South-East Asia. Collective action by OPEC and some leading non-OPEC producers brought about a recovery. As the decade ended, there was a spate of mega-mergers among the major international oil companies in an industry that was experiencing major technological advances. For most of the 1990s, the ongoing international climate change negotiations threatened heavy decreases in future oil demand.

API (American Petroleum Institute)

The origins of the American Petroleum Institute date back to World War I, when Congress and the domestic oil and natural gas industry worked together to help the war effort. At the time, the industry included the companies created in 1911 after the court-imposed dissolution of Standard Oil and the "independents." These were companies that had been "independent" of Standard Oil. These companies had no experience working together, but they agreed to work with the government to ensure that vital petroleum supplies were rapidly and efficiently deployed to the armed forces. The National Petroleum War Service Committee, which oversaw this effort, was initially formed under the U.S. Chamber of Commerce and subsequently as a quasi-governmental body. After the war, momentum began to build to form a national association that could represent the whole industry in the postwar years. The industry's efforts to supply fuel during World War I not only highlighted the importance of the industry to the country but also the industry's obligation to the public, as the original charter shows.

The American Petroleum Institute was established on March 20, 1919. API offices were established in New York City, and the organization focused its efforts in several specific areas.

Statistics: The first was to develop an authoritative program of collecting industry statistics. As early as 1920, API began to issue weekly statistics, beginning first with crude oil production. Later the report, which was shared with both the government and the press, was expanded to include crude oil and product stocks, refinery runs and other data.

API statistics remain one of the most credible sources of industry data and they are used worldwide.

Standardization: The second was the standardization of oil field equipment. During World War I, drilling delays resulted from shortages of equipment at the drill site, and the industry attempted to overcome that problem by pooling equipment. The program reportedly failed because there was no uniformity of pipe sizes, threads and coupling. Thus, the new association took up the challenge of developing industry-wide standards and the first standards were published in 1924. Today, API maintains more than 500 standards and recommended practices covering all segments of the oil and gas industry to promote the use of safe, interchangeable equipment and proven and sound engineering practices.

Taxation: The third major area of activity was taxation. Initially the efforts included working with the Treasury Department and Congressional committees to develop an orderly, logical and easily administered way to tax oil assets. In the 1930s, these efforts extended to working state governments. Both the federal and state governments tax highways fuels to fund the building of roads, and the industry supported tougher laws against tax evasion. This led to the formation of the API state petroleum council network. API now has offices in 27 state capitals and represents members in 33 states, all east of the Rocky Mountains. In late 1969, API made the decision to move its offices to Washington, D.C., where we remain today.

IADC (International Association of Drilling Contractors)

Since 1940, the International Association of Drilling Contractors (IADC) has exclusively represented the worldwide oil and gas drilling industry.

Mission: promote commitment to safety, preservation of the environment and advances in drilling technology.

IADC's resources offer diverse benefits to its membership of drilling contractors, producers and associates. Membership is open to any company involved in oil and gas exploration and production, well servicing, oil field manufacturing and other rig site services.Through conferences, training seminars and a comprehensive network of technical publications, IADC continually fosters education and communications within the upstream petroleum industry.

IADC has a global reach operating wherever its members operate...in Europe, the Americas, Africa, Asia, Australia and the Middle East.

AIME (The American Institute of Mining, Metallurcigal, and Petroleum Engineers)[10]

AIME was founded in 1871 by 22 mining engineers in Wilkes-Barre, Pennsylvania, as the American Institute of Mining Engineers. AIME is a diverse organization, comprising five separately incorporated units with a combined membership of more than 90,000 professionals. Under the current organizational structure, one of the units--the AIME Institute Headquarters--serves as the unifying forum for the four Member Societies: The Minerals, Metals, and Materials Society (TMS), The Society for Mining, Metallurgy, and Exploration (SME), The Society of Petroleum Engineers (SPE), The Iron and Steel Society (ISS)

SPE (Society of Petroleum Engineers)

(SPE) was founded in 1957. SPE is the international technical and professional association for engineers and the management of energy resources produced through the wellbore. SPE collects, distributes, and exchanges information on techniques and operations to nearly 49,500 members in 125 countries through a broad range of activities, including section meetings, publications, continuing education programs, and technical meetings and exhibitions.

Mission Statement: To provide the means for collection, dissemination, and exchange of technical information concerning the development of oil and gas resources, subsurface fluid flow, and production of other materials through wellbores for the public benefit; and to provide opportunities through its programs for interested (and qualified) individuals to maintain and upgrade their individual technical competence in the aforementioned areas for the public benefit.

SPE has a section in Turkey as the part of South and Central Europe Region. SPE sponsors student chapters all over the world. With 102 student chapters in 36 countries, SPE is a vital part of the academic success for many petroleum engineering students around the world. There are two student chapters in Turkey, Istanbul Technical University and Middle East Technical University SPE Student Chapters.

IEA (International Energy Agency)

The International Energy Agency, based in Paris, is an autonomous agency linked with the Organization for Economic Co-operation and Development (OECD).

The IEA is the energy forum for 26 Member countries (One of the members is Turkey). IEA Member governments are committed to taking joint measures to meet oil supply emergencies. They have also agreed to share energy information, to co-ordinate their energy policies and to co-operate in the development of rational energy programmes.

Pricing:

Crude oil is sold through a variety of contract arrangements and in spot transactions. Oil is also traded on futures markets but not generally to supply physical volumes of oil, more as a mechanism to distribute risk. These mechanisms play an important role in providing pricing information to markets.

From it's beginning, the international crude market was highly volatile (Figures 3.15, 3.16)[6]. Since major crude oil discoveries were random events that defied planning or scheduling, the supply of crude was usually to long or too short, generating wide swings in price. This environment was discouraging to investment of the huge sums the emerging industry needed. Some stabilization was clearly in everyone's interest.

The first effort to bring order to make the market was made by the Texas Railroad Commission (TRC) in the 1930's, and it was quite successful. At the time, the United States –

principally Texas- was the world's biggest crude producer and exporter. The TRC was therefore able to cut back or increase Texas' production as needed to bring world supply and demand into rough balance. Working closely with the major oil companies who controlled the foreign-produced crude, the TRC was able to maintain relative price stability well into the 1960s.

By the early 1970s, the United States lost its position of leading producer in the World, and in fact had become a net importer. This eliminated the TRC as a player, leaving the multinationals to manage the international crude markets alone. It also gave OPEC new life as its members realized that they now dominated world crude supplies. In 1973, a wave of nationalizations by the producing countries started. OPEC quickly took control of the crude market and in October of 1973 more than tripled prices.

Since then, OPEC has tried to stabilize prices by adjusting member's production rates to meet market demand. Their efforts have been successful at times, but at other times major price accumulations have occurred. This is not surprising considering the diversity of interests that exist between individual state member states. For example, OPEC member Iraq invaded fellow member Kuwait in Gulf war.

Another factor weakening OPEC is the substantial non-OPEC production that has recently developed around the world (North Sea, Brazil, Mexico etc.). As of late 1990s OPEC production has been reduced to only 40% of world production. It is significant, however, that OPEC, particularly Saudi Arabia, still has virtually all the world's surplus producing capacity. This assures them continued influence on crude prices.

In fact the pricing of crude oils has become increasingly transparent from the 1990s onwards through the use of *marker crudes (benchmark crude oil)* such as West Texas Intermediate (WTI – USA), Brent (Europe and Africa), Dubai and Oman (Middle East), and Tapis and Dubai (in Asia) Table 3.2). The main criteria for a marker crude is for it to be sold in sufficient volumes to provide liquidity (many buyers and sellers) in the physical market as well as having similar physical qualities of alternative crudes. In addition the marker crude should provide pricing information.

Properties of Marker Crudes[1]

Crude	API Gravity	Sulphur content (%)
West Texas Intermediate	38 - 40	0.3
West Texas Sour	33	1.6
Brent	38	0.3
Dubai	31	2.0
Tapis	46	0.03

WTI does this through its use on the New York Metals Exchange as the basis of a futures contract where trade is equivalent to many hundreds of millions of barrels per day, even though physical WTI production is less than 1 million barrels per day. A futures contract for crude oil is a promise to deliver a given quantity of crude oil but this rarely occurs as participants are more interested in taking a position on the price of the crude oil. Futures markets are a financial instrument to distribute risk among participants with the side effect of providing transparency on the pricing of crude oil.

Brent offers pricing information based more on the physical trading of oil through spot trading, and forward trading but also offers futures trading but not to the same extent as WTI.

Dubai and Oman pricing is based more on the physical trades of Dubai and Oman but due to falling production levels questions are being raised about the appropriateness of Dubai as marker crude.

In Asia there is no futures exchange where crude oil is traded and which would provide pricing information to the same extent as WTI and Brent. In Asia the pricing mechanism for say Tapis, a marker for light sweet crude in the region, is based on an independent panel approach where producers, refiners and traders are asked for information on actual trades and where there have been none, their best guess. (Any estimates that are wildly high or low are discarded and the quoted price is then an average of views on the market price for Tapis.

Pricing of Physical Crude Oil Trades: Generally this is based on a formula approach where a marker crude is used as the base and then a quality differential as well as a demand/supply (premium/discount) is added depending on the crude being purchased. Thus in times of tight supply this premium will rise and gradually drag up the Marker crude price, whilst in times of surplus supply, a reduced premium or even a discount will drag down the Marker crude price. Of course big changes/announcement/events that can significantly influence crude supply levels will sometimes result a large step change in the prices of crudes (eg. OPEC announcements; a war; major refinery outages). That is, crudes being purchased do not always slavishly follow marker crudes. Marker crudes are indicators of what is happening in markets.

Crude Oil as an Input Cost to Refiners: It is true to say that the cost of crude oil is the major input cost for refiners. However the relationship between such a cost and the final price for a product produced from that crude such as petrol or diesel is not as direct as one would think. There are, for instance, additional petroleum product markers, which give a guide to prices ie. Prices are not just a function of cost-push, but are also strongly influenced by demand-pull (eg USA environmental requirements for gasoline have at times pushed up the prices in the USA by significantly more than the movements in crude prices over 2001. This is the market working as refiners who see these prices work hard to increase production to capture some of these high prices before they dissipate under competitive pressure – both from within the

USA and from the resulting massive influx of product cargoes from other producing centers in the world). There are also a number of other variables, which affect the price of products such as gasoline. In addition the perception of the purchasers and sellers in the market as to the price risk over time can also add or subtract premiums to the product marker price.

Prices of crude oil markers and gasoline markers are affected by a countless of factors from overall supply/demand for crude oil, supply/demand for gasoline, freight rates and competition in the crude markets, and competition in the regional and domestic markets for petrol. They all have a role in determining the final price charged to consumers and the role that each of these elements plays can change over time. It is this very complexity in markets which makes it very difficult to determine a theoretical price as part of regulation in markets because there may be a perception that because the theoretical price is different from the market price that the market price is 'not fair' for some reason.

DIMENSIONAL ANALYSIS

Quantities:

Most engineering problems are solved using mathematical approaches. Mathematics is, in fact, one of the primary disciplines necessary to becoming an engineer. One of the first and most important aspects of understanding engineering problems and models is thus to understand the nature of different mathematical “quantities”.

In general, mathematical quantities can be grouped into three main categories:

Variables — quantities that vary within a given problem.

Parameters —quantities which are fixed for a given physical system, but which may change from problem to problem.

Constants — quantities that do not vary from problem to problem.

Variables are often further categorized as *independent* or *dependent*. Independent variables are those that can be arbitrarily designated within a problem. The most common independent variables are time or spatial location. Other common independent variables might be pressure, temperature, etc.

Dependent variables are usually dependent upon at least one independent variable. Independent variables may take on any value “spanning” the problem of interest. Generally, although not always, it is dependent variables that are solved for when searching for a problem solution.

Parameters can either be single-valued or multi-valued, however, they should be “known”, or at least have known relationships with other quantities. For example, if a given system can be treated as isothermal, temperature would be a parameter — fixed in a given problem, but variable from problem-to-problem. Also, if a known fluid is specified for a given problem it’s viscosity would be a parameter, even if allowed to vary with pressure and temperature. The "parameter" in this case would be the functional relationship of viscosity as a function of pressure and temperature. Sometimes parameters are solved for in a problem.

Parameters are sometimes subdivided as to: a) design parameters (those that may be fixed or altered by the designer), and b) descriptive parameters (those that describe a given system, but are out of the control of the designer). Both variables and parameters may be stochastic, that is, they could have a probabilistic representation.

Some parameters that remain the same from system to system are treated as constants. For example, the acceleration due to gravity is essentially the same over the surface of the earth and for most problems may be treated as a constant. However, should the problem move to the moon, gravitational acceleration would have to be treated as a parameter. Other constants, such as pi and the speed of light, are true constants that never vary.

Any given quantity can be a variable, parameter, or constant depending on the particular problem.

Specification of an engineering quantity typically includes: a) definition, b) symbol, c) value(s), and d) units.

Symbols: In general, all symbols used in equations, figures, and tables should be defined upon their first use in any written document. If it is necessary to use the same symbol with two different meanings, both must be defined. Greek letters are often used for certain quantities. Standard symbols used in petroleum engineering can be found in the SPE Letter and Computer Symbols Standard (1993).

Units, unit systems:

In engineering, the value of a quantity is not completely specified without units. In petroleum engineering, two different unit systems are used: a) what is sometimes referred to as *oilfield* (or English) units, and b) SI units. SI (which stands for Le System International d'Unités or

The International System of Units) is a standardized metric system that has been adopted by the Society of Petroleum Engineers (SPE) and other engineering societies. The SI system of units and its relationship with oilfield units is discussed in detail in two articles from the *Journal of Petroleum Technology* (Campbell and Campbell, 1985). A partial list of units conversions is also included in this docment. The complete units standard is available in the *Petroleum Engineering Handbook* (1987)[4].

SI is not identical with any of the former cgs, or mks systems of metric units but is closely related to them and is an extension of and improvement over them. SI is based on seven well defined "base units" that quantify seven base quantities that by convention are regarded as dimensionally independent. SI has chosen the seven base quantities and base units listed below.

SI base quantities and units

Base quantity or "Dimension"	**SI Unit**	**SI Unit Symbol**
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

In addition, there are two "supplementary units"; radian (rad) for plane angle and steradian (sr) for solid angle. Following table contains the definitions of the base and supplementary units.

Definition of SI base and supplementary units

Unit	Definition
Meter	The meter is the length to 1 650 763.73 wavelength in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom
Kilogram	The kilogram is the unit of mass (and is the coherent SI unit); it is equal to the mass of the international prototype of the kilogram
Second	The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom
Ampere	The ampere is the constant current that, if maintained in two straight, parallel conductors of infinite length, of negligible circular cross section, and placed 1 m apart in vacuum, would produce between these conductors a force equal to 2×10^{-7}N·m of length
Kelvin	The Kelvin, a unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water
Mole	The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kg of carbon-12
Candela	The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz (Hz) and that has a radiant intensity in that direction of 1/683 watt per steradian
Radian	The radian is the plane angle between two radii that cut off on the circumference of a circle an arc equal in length to the radius
Steradian	The steradian is the solid angle that, having vertex at the center of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere

SI "derived units" are a third class, formed by combining, as needed, base units, supplementary units, and other derived units according to the algebraic relations linking the corresponding quantities. The symbols for derived units that do not have their own individual symbols are obtained by using the mathematical signs for multiplication and division, together with appropriate exponents (e.g., SI velocity, meter per second, m/s or $m \cdot s^{-1}$; SI angular velocity, radian per second, rad/s or $rad \cdot s^{-1}$).

The following figure shows the basic relationship between units. The base units are shown in the left column. The next column shows four forms of length and time terms used to define the derived units shown in the right column.

Each circle representing a derived unit has one or more lines entering or leaving it. Each line is connected to a base unit or to another derived unit. A solid line indicates multiplication; a dashed (broken) line indicates division. Notice the circle for FORCE in the upper right corner. It has two solid lines entering it from mass (kg) and acceleration (m/s^2). This means that force in newton (N) is the product of these two quantities.

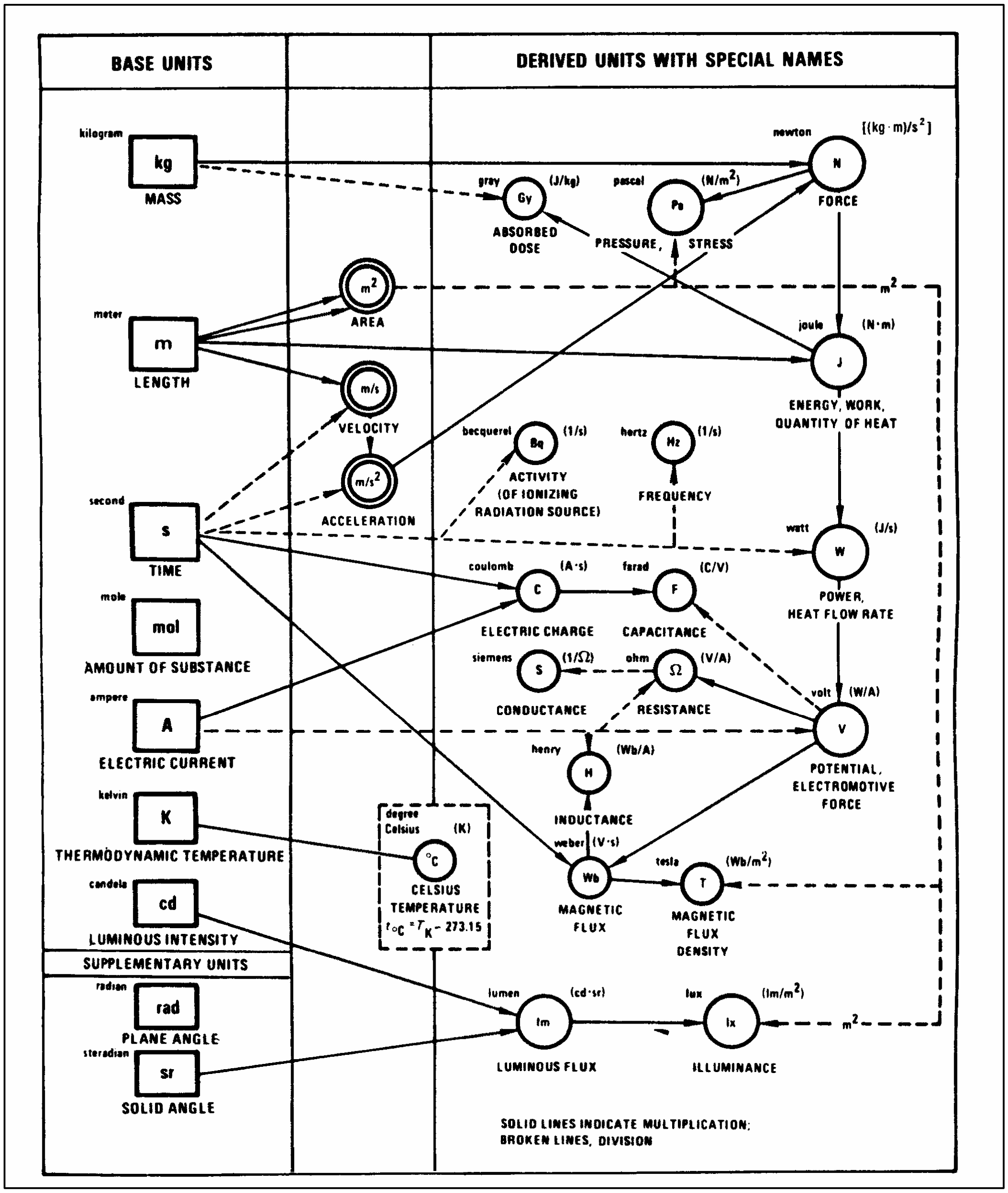
Notice also that there are two solid lines leaving the FORCE circle. One goes to the PRESSURE circle and one to the ENERGY, WORK circle. Consider pressure, which by definition is force per unit area. The PRESSURE circle has two lines entering it, a solid one from FORCE and a dashed one from AREA. This means that pressure is force divided by area: pascal (P) equals N/m^2.

Basic dimension symbols

Base Unit	Length	Mass	Time	Temperature
Symbol	L	m	t	T

Basic dimensions for commonly used units

Unit	Force	Pressure	Area	Volume	Density	Work
Symbol	mL/t^2	m/Lt^2	L^2	L^3	m/L^3	mL^2/t^2



Relationship between SI metric units[2].

Oil field Units

Most of the customary units used in petroleum engineering are not used in the SI metric system. These customary units are known as oil field units and the most common oil field units are listed in following table with their corresponding SI units.

Common oil field and SI units

Quantity	**Symbol**	**Dimension**	**Oilfield Units**	**SI Units**
Mass	*m*	m	lbm	kg
Moles	*n*	n	lbmol	kmol
Force	*F*	mL/t^2	lbf	N
Length	*L*	L	ft	m
Area	*A*	L^2	acres	m^2
Volume – liquids	*V*	L^3	bbl	m^3
Volume – gases	*V*	L^3	ft^3	m^3
Pressure	*p*	m/Lt^2	psi	kPa
Temperature	*T*	T	R	K
Flow rate – liquids	*q*	L^3/t	bbl/d	m^3/d
Flow rate – gases	*q*	L^3/t	ft^3/d	m^3/d
Viscosity	□	m/Lt	cp	mPa·s
Permeability	*k*	L^2	md	□m^2

*Unit Conversions***:** Even many experienced engineers have difficulty with the use and conversion of units. This problem seems to be particularly troublesome in petroleum engineering because of the many non-standard units used in the discipline. Often equations are given in textbooks only in oilfield units. When trying to use other units or trying to use combinations of equations, problems often arise. This write-up will contain a few simple rules to avoid common pitfalls.

Conversion of numbers from one set of units to another is usually fairly straightforward. A technique which has been taught for many years to engineering students is to place unit conversion factors above and below a horizontal line and "canceling" units until the desired set is achieved. The following is an example showing how to convert from psi to kPa.

$$\left[\frac{1\text{ lbf}}{\text{in}^2}\right]\left[\frac{12\text{ in}}{\text{ft}}\right]^2\left[\frac{4.448\text{ N}}{\text{lbf}}\right]\left[\frac{\text{ft}}{0.3048\text{ m}}\right]^2\left[\frac{\text{m}^2\text{ Pa}}{1\text{ N}}\right]\left[\frac{\text{kPa}}{1000\text{ Pa}}\right]=6.895\text{ kPa}$$

Dealing with units in equations always seems to create difficulties. However, if one rule is remembered, this can be done easily and correctly: ***Convert numbers, not equations!*** The best way to show this is by example. Consider Darcy's law in steady-state linear form:

$$q=\frac{kA\Delta p}{\mu L}$$

where,

q	=	flowrate, cm^3/sec
k	=	rock permeability, darcies
A	=	cross-sectional area to flow, cm^2
Δp	=	flowing pressure difference, atm
μ	=	fluid viscosity, cp
L	=	flow length, cm

	SI	**Oilfield**
Mass	1 kg	2.2046225 lbm
Length	0.3048 m	1 ft
		12 in
Area	4,046.873 m^2	1 acre = 43,560 ft^2
Volume	1 m^3	6.2898106 bbl
		1 bbl = 5.614583 ft^3
Temperature	1 K	1.8 R
	K = °C+273.15	R = °F+459.67
	°C = (°F-32)/1.8	°F = 1.8 °C+32
Pressure	6.894757 kPa	1 psi
	1 MPa	145.03774 psi
	101.325 kPa	1 atm = 14.69595 psi
	1 bar = 100 kPa	14.503774 psi
Dynamic viscosity	1 mPa·s	1 cp
Density	1000 kg/m^3	62.42797 lbm/ft^3
		8.345405 lbm/gal
Water density @ 60°F/1atm	999.04 kg/m^3	62.368 lbm/ft^3
Energy	1.055056 kJ	1 btu
	1 kWh	3412.14 btu
		1 btu=778.169 ft·lbf
Force	4.448 N	1 lbf
Power	745.700 W	1 hp=550 ft·lbf/s
Universal gas constant	$8.31441 \frac{kPa \cdot m^3}{kmol \cdot K}$	$10.7315 \frac{psia \cdot ft^3}{lbmol \cdot R}$
	$8.31441 \frac{kJ}{kmol \cdot K}$	$1.98586 \frac{btu}{lbmol \cdot R}$
Molecular weight of air	28.9625 kg/kmol	28.9625 lbm/lbmol
Gravitational conversion constant	$9.80665 \ \frac{kg \cdot m}{s^2 \cdot kgf}$	$32.1740 \ \frac{lbm \cdot ft}{s^2 \cdot lbf}$
Permeability	1 □m^2	1013.25 md
	$1\ \mu m^2 = 0.0864 \frac{m^2 \cdot mPa \cdot s}{d \cdot kPa}$	$158.0206\ md = 1 \frac{ft^2 \cdot cp}{d \cdot psi}$
		$887.220\ md = 1 \frac{bbl \cdot cp}{ft \cdot d \cdot psi}$

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