





THE UNIVERSITY OF TEXAS AT AUSTIN PETROLEUM EXTENSION SERVICE

Well Servicing and Workover, Lesson 5

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A Primer of Oilwell Service, Workover, and Completion

# Well Servicing and Workover Series

- r er Profit. Retroleum

WELL SERVICING AND WORKOVER SERIES Lesson 5

# Petroleum Extension The University of Texas at Austin



2013

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About the Author

William Lane has 35 years of experience in the oil and gas industry performing roles in engineering, manufacturing, global product

line management, and artificial lift training. He has been directly involved with surface service equipment, completions, compression, artificial lift, and unconventional resources. He has been working with Weatherford International and the former EVI Oil Tools Ltd. for 18 years in various executive positions and is currently serving as the vice president of emerging technologies for Weatherford Artificial Lift Systems Inc.

Lane holds several U.S. patents, and in 2003 was the recipient of a Harts E&P Special Meritorious Award for Engineering Innovation. He holds a B.S. degree in Mechanical Engineering and an M.S. degree in Mechanical Engineering Design, both from the University of Texas at Arlington.

oftexasatAustin

Units of Measurement, using the world, two systems of measurement of the system and the system a hroughout the world, two systems of measurement dominate: the English system and the metric system. Today, the United States is one of only a few countries that employ the English system.

The English system uses the pound as the unit of weight, the foot as the unit of length, and the gallon as the unit of capacity. In the English system, for example, 1 foot equals 12 inches, 1 yard equals 36 inches, and 1 mile equals 5,280 feet or 1,760 yards. The metric system uses the gram as the unit of weight, the metre

as the unit of length, and the litre as the unit of capacity. In the metric system, 1 metre equals 10 decimetres, 100 centimetres, or 1,000 millimetres. A kilometre equals 1,000 metres. The metric system, unlike the English system, uses a base of 10; thus, it is easy to convert from one unit to another. To convert from one unit to another in the English system, you must memorize or look up the values.

PetroleumExtensi In the late 1970s, the Eleventh General Conference on Weights and Measures described and adopted the Systeme International (SI) d'Unites. Conference participants based the SI system on the metric system and designed it as an international standard of measurement.

The Well Servicing and Workover Series gives both English and SI units. And because the SI system employs the British spelling of many of the terms, the book follows those spelling rules as well. The unit of length, for example, is metre, not meter. (Note, however, that the unit of weight is gram, not gramme.)

To aid U.S. readers in making and understanding the conversion system, we include the table on the next page.

| United by<br>Length,<br>depth,<br>or heightEnglish Units DyThese S Units<br>(m)Length,<br>depth,<br>or heightinches (in.)2.5.4<br>(cutimetres (m))or heightfeet (it)<br>yards (yd)0.9144<br>(1609.3444miles (mi)1609.3444<br>(1609.3444metres (m)Hole and pipe diameters, bit sizeinches (in.)2.5.4<br>(1609.3444Drilling ratefeet per hour (fr/h)<br>pounds (lb)0.3048<br>(1609.3444Weight on bitpounds (lb)0.445Mozzle size32nds of an inch0.8<br>(1609.377)Weight on bitpounds (lb)0.159<br>(lb)cubic petter (lm))<br>(lb)Nozzle size32nds of an inch0.8<br>(lb)gallons per stroke (gal/stroke)<br>(gallons (gal)<br>gallons (gal)0.00379<br>(lb)cubic centimetres (m)<br>(lb)<br>(lb)Volumecubic feet (fr)2.83160<br>(lb)litres (L)<br>(lb)<br>(lb)gallons (gal)<br>gallons (gal)3.7854<br>(lb)litres (L)<br>(lb)<br>(lb)<br>(lb)pump output<br>gallons per hour (gph)<br>barrels per ton (bb/h)0.00379<br>(lb)<br>(lb)<br>(lb)cubic metres (m)<br>(litres (L))<br>(lb)<br>(lb)<br>(lb)Pump output<br>gallons per hour (gph)<br>barrels per for (lb/h)1.585<br>(lb)<br>(lb)<br>(lb)litres (L)<br>(lb)<br>(lb)<br>(lb)Pump output<br>gallons per hour (gph)<br>and flow ratepounds per square fish (fish)6.895<br>(lb)<br>(lb)<br>(lb)<br>(lb)Pump output<br>gallons per hour (gph)<br>and flow ratepounds per square fish (fish)1.632<br>(lb)<br>(lb)Pump output<br>gallons per foot (lb/  | Quantity                       | English Units F                             | Multiply                                | To Obtain   |
|--|--------------------------------|---|---|---|
| Length,<br>or heightinches (m.)25.4<br>25.4millimetres (mm)<br>metres (m)<br>metres (m)or heightfeet (h)0.3048metres (m)<br>metres (m)iles (mi)1609.344metres (m)iles (mi)1609.344metres (m)iles and pipe diameters, bit sizeinches (in.)25.4Drilling ratefeet per hour (fr/h)0.3048metres (mm)Weight on bitpounds (lb)0.445decanewtons (dN)Nozzle size32nds of an inch0.8millimetres (ml)159cubic metres (m)159cubic metres (m')gallons per stroke (gal/stroke)0.00379cubic metres (m')outbic metres (m)16.387cubic metres (m')gullons (gal)0.006379cubic metres (m')cubic (refe (fi')28.3169litres (l.)gullons (gal)0.006379cubic metres (m')gullons (gal)0.00379cubic metres (m')gullons (gal)0.006895metres per none (m'/n)pounds per barrel (ptr)159cubic metres (m')pounds per square (pth)0.159cubic metres (pt nom (m/h)pounds per  | or Property                    | English Units El                            | nglish Units By                         | These SI Units                                    |
| $\begin{array}{c c c c c c c c c c c c c c c c c c c $   | Length,                        | inches (in.)                                | 25.4                                    | millimetres (mm)                                  |
| or height feet (ft) 0.3048 metres (m)<br>miles (m) 1609.344 metres (m)<br>1.61 kilometres (km)<br>1.61 metres per hour (nt/h)<br>1.62 metres per hour (nt/h)<br>1.62 metres per hour (nt/h)<br>1.63 metres per stroke (gal/stroke)<br>0.00379 cubic metres per stroke (m)/stroke<br>0.00379 cubic metres (m)<br>1.63 metres (m)<br>1.64 metres per none (m)/h)<br>1.64 metres per none (m)/h)<br>1.64 metres per none (m)/h)<br>1.64 metres per none (m)/h)<br>1.65 metres per none (m)/h)<br>1.64 metres per none (m)/h)<br>1.64 metres per none (m)/h)<br>1.65 metres per none (m)/h)<br>1.60 metres per none (m)/h)<br>1.6 | depth,                         |   | 2.54                                    | centimetres (cm)                                  |
| $\begin{array}{c c c c c c c c c c c c c c c c c c c $   | or height                      | feet (ft)                                   | 0.3048                                  | metres (m)  |
| $\begin{array}{c c c c c c c c c c c c c c c c c c c $   |                                | yards (yd)                                  | 0.9144                                  | metres (m)  |
| $1.61 	 kinometres (km) \\ 1.61 	 kinometres (km) \\ 1.62 	 kinometres (km) \\ 1.62 	 kinometres (km) \\ 1.63 	 kinometres (km) \\ 1.61 	 kinometres (km) \\ 1.62 	 kinometres (km) \\ 1.63 	 kinometres (km) \\ 1.64 	 kinometres ($  |                                | miles (mi)                                  | 1609.344                                | metres (m)  |
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| $\begin{array}{c c c c c c c c c c c c c c c c c c c $   | Hole and pipe diameters, bit s | size inches (in.)                           | 25.4                                    | millimetres (mm)                                  |
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| Nozzle size32nds of an inch0.8millimetres (mn)<br>tires (L)barrels (bb)0.159cubic metres (m)gallons per stroke (gal/stroke)0.00379Volumecubic interies (m.)cubic interies (m.)16.387cubic interies (m.)16.387cubic interies (m.)0.0283guarts (qt)0.9464gallons (gal)0.00379pounds per barrel (lb/bb)0.0379pounds per barrel (lb/bb)0.0379pountage per marke (gpm)0.00379pountage per barrel (lb/bb)0.0379pountage per marke (gpm)0.00379gallons per minute (gpm)0.00379pump outputgallons per minute (gpm)and flow ratepounds per square floch (bb/stroke)Pump outputgallons per nour (gph)and flow ratepounds per square floch (bb/stroke)Pressurepounds per square floch (bb/stroke)Pressurepounds per square floch (bb/stroke)Pressurepounds per square floch (bb/stroke)Mass (weight)onces (oz)Pressure gradientpounds per cubic col (bb/tri)Pressure gradientpounds per cubic col (bb/tri)Pump outputgallons per square floch (bb/stroke)Mass (weight)onces (oz)Pass (hb/stroke)0.9072tooma (bb/stroke)0.9072tooma (bb/stroke)0.9072tooma (bb/stroke)0.9072tooma (bb/stroke)0.9072tooma (bb/stroke)0.9072tooma (bb/stroke)0.9072 <td>Weight on bit</td> <td>pounds (lb)</td> <td>0.445</td> <td>decanewtons (dN)</td>   | Weight on bit                  | pounds (lb)                                 | 0.445                                   | decanewtons (dN)                                  |
| $\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$   | Nozzle size                    | 32nds of an inch                            | 0.8                                     | millimetres (mm)                                  |
| (159(159(159(159(159(159(159(159(159(159(159(159(159(159(159(159(159(159(150 </td <td></td> <td>barrels (bbl)</td> <td>0.159</td> <td>cubic metres (m<sup>3</sup>)</td>  |                                | barrels (bbl)                               | 0.159                                   | cubic metres (m <sup>3</sup> )                    |
| Volume29.57Colspan="2">Colspan="2">Colspan="2">Colspan="2">Colspan="2">Colspan="2">Colspan="2">Colspan="2">Colspan="2">Colspan="2">Colspan="2">Colspan="2">Colspan="2"Colsp  |                                | gallons per stroke (gal/stroke)             | 159<br>0.00379                          | litres (L)<br>cubic metres per stroke (m³/stroke) |
| Volumecubic incles $(n, \cdot)$ 16.387<br>16.387cubic entimetres $(m^2)$<br>itres $(L)$ cubic incles $(n, \cdot)$ 16.387<br>cubic feet $(t^2)$ cubic entimetres $(m^2)$<br>itres $(L)$ quarts $(qt)$ 0.0283cubic metres $(m^3)$<br>itres $(L)$ quarts $(qt)$ 0.9464itres $(L)$<br>cubic metres $(m)$<br>pounds per barrel (lh/bl)cubic metres $(m)$<br>cubic metres $(m)$ pump output<br>and flow rategallons per hour $(gph)$<br>barrels per stroke (bbl/stroke)0.00370<br>0.00370cubic metres per minute $(m'/min)$<br>pounds per square floh/bl)Pump output<br>and flow rategallons per hour $(gph)$<br>barrels per stroke (bbl/stroke)0.159<br>0.00379cubic metres per minute $(m'/min)$<br>pounds per square floh $(m)$ Pressurepounds per square floh $(m)$ 0.453<br>0.006895kilograms per cubic metre $(kg'm)$<br>cubic metres per minute $(m'/min)$ Pressuredegrees featurentie ("F)<br>pounds per square floh $(m)$ $\frac{\circ F - 32}{1.8}$<br>degrees Celsius ("C)Mass (weight)onces (oz)<br>pounds per foot (lb/ft)28.35<br>1.488grams $(g)$<br>kilograms per cubic metre $(kg'm)$ Mud weightpounds per quare inch<br>pounds per cubic foot $(lb/ft)$ 14.88kilograms per cubic metre $(kg'm)$ Pressure gradientpounds per square feet $(lb/100 ft^2)$ 0.483<br>0.483pascals $(Pa)$ Finnel viscosityseconds per quart $(s/qt)$ 1.057seconds per litre $(s/L)$ Yield pointpounds per 100 square feet $(lb/100 ft^2)$ 0.48<br>0.483pascals $(Pa)$ Finnel viscosityseconds per non $k(sd)$ 0.75kilowatt  |                                | ounces (oz)                                 | 29.57                                   | millilitres (mI)                                  |
| VolumeCenter metres (tr.)20:36<br>(28:316)Center cubic (tert (s. (tr.))cubic feet (tr.)0.0037<br>(20)cubic metres (m.)quarts (qt)0.7854<br>(qallons (gal)3.7854<br>(cubic metres (m.))gallons (gal)0.0037<br>(cubic metres per ton (bb/tn)cubic metres (m.)pounds per barrel (lb/bbl)2.895<br>(cubic metres per minute (m./min))pump output<br>and flow rategallons per minute (gpm)<br>(pallons per minute (bb/tm)0.00379<br>(cubic metres per minute (m./min))Pump output<br>and flow rategallons per struck (bb/stroke)<br>(barrels per struck (bb/stroke)0.159<br>(cubic metres per minute (m./min))Pressurepounds per square flow (bb)<br>(bb/stroke)6.895<br>(cubic metres per minute (m./min))Pressurepounds per square flow (bb)<br>(bb)453.59<br>(cubic metres (gr))Mass (weight)onices (oz)<br>(cubic struck (gr))28.35<br>(cubic metres (gr))Mud weightpounds per gallon (ppg)<br>(pounds per foot (bb/ft))19.82<br>(kilograms per cubic metre (kg/m))Pressure gradientpounds per gallon (ppg)<br>(pounds per 100 square feet (bb/100 ft²))1.488<br>(kilograms per cubic metre (kg/m))Pressure gradientpounds per 100 square feet (bb/100 ft²)0.48<br>(kilograms per cubic metre (kg/m))Punnel stocsityseconds per quart (s/qt)1.057<br>(cubic metres (m²))Punnel stocsityseconds per quart (s/qt)1.057<br>(cubic metres (m²))Powerhorsepower (hp)0.75<br>(kilowatts (kW))Powerhorsepower (hp)0.75<br>(kilowatts (kW))Area  | Volume                         | (02)  | 16 387                                  | cubic centimetres (cm <sup>3</sup> )              |
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| quares (q)0.7474Intres (L)gallons (gal)3.7874intres (L)gallons (gal)0.00370cubic metres (m)pounds per barrel (lb/bb)2.897kilograms per cubic metre (g/m)pump outputgallons per ninute (gpm)0.00379cubic metres per ninute (m)/nin)Pump outputgallons per hour (gph)0.00379cubic metres per ninute (m)/nin)Pump outputgallons per square fact (hb)0.0379cubic metres per nor (m)/h)Pressurepounds per square fact (hb)0.159cubic metres per ninute (m)/nin)Pressureopounds per square fact (hb)0.006895megapascals (MPa)Mass (weight)obnecs (oz)28.35grams (g)pounds (bb)433.59grams (g)pounds per foot (lb/ft)1.488kilograms per metre (kg/m)Mud weightpounds per square inch<br>per foot (psi/ft)119.82Kilograms per cubic metre (kg/m)10.07seconds per duci (m)/ninFunnel vscositvseconds per quart (s/qt)1.057Seconds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Funnel vscositvseconds per quart (s/qt)1.057Square inches (n.')0.48pascals (Pa)Filte cake thickness32nds of an inch0.8Areasquare inches (n.')6.45square metres (m²)square inches (m.')2.59square metres (m²)Areasquare inches (n.')2.59square metres (m²)Areasquare inches (n.')<   |                                | quarte (at)                                 | 0.0203                                  | V CUDIC Interfes (III')                           |
| Janons (gal)Janons (gal)Janons (gal)pounds per barrel (b/bbl)2.895cubic metres (m')barrels per ton (bbl/m)(175cubic metres per tonne (m'/t)Pump outputgallons per minute (gpm)0.00379cubic metres per minute (m'/min)and flow rategallons per stroke (bbl/stroko)0.159cubic metres per minute (m'/min)Pressurepounds per square fach (hsi)6.895kilopascals (kPa)Outic metres per minute (m'/min)0.159cubic metres per minute (m'/min)Pressurepounds per square fach (hsi)6.895grams (g)Temperaturedegrees Famenheit (°F)1.8degrees Celsius (°C)Mass (weight)ources (oz)28.35grams (g)pounds per foot (lb/ft)1.488kilograms per metre (kg/m)Mud weightpounds per square inch<br>per foot (lb/ft)kilograms per cubic metre (kg/m)Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621Kilopascals per metre (kg/mi)1.057seconds per litre (s/L)Vield pointpounds per foot (lb/fti)0.48pascals (Pa)Funnel viscosityseconds per foot (b/fti)0.48pascals (Pa)Fiber cake thickness32nds of an inch0.8millimetres (mri)Areasquare inches (in.2)6.45square centimetres (mri)agure horsepower (hp)0.75kilomatters (hm)Areasquare feet (fti) 00 fti)0.48pascals (Pa)Powerhorsepower (hp)0.75 <td></td> <td>quarts (qt)</td> <td>2 7954</td> <td>- Intres (L)</td>   |                                | quarts (qt)                                 | 2 7954                                  | - Intres (L)                                      |
| Dependence of the parter (ht/bbl)Dependence of the parter (ht/bbl)Pump output<br>and flow rategallons per minute (gpm)<br>gallons per hour (gph)0.00379<br>0.00379cubic metres per minute (m <sup>1</sup> /min)<br>cubic metres per hour (m <sup>1</sup> /h)<br>cubic metres per hour (m <sup>1</sup> /h)<br>cubic metres per minute (bbl/mn)Pressurepounds per square floh (hsi)0.159<br>0.008695cubic metres per minute (m <sup>1</sup> /min)<br>cubic metres per minute (m <sup>1</sup> /min)Pressurepounds per square floh (hsi)0.895<br>0.008695kilopascals (MPa)<br>megapascals (MPa)Mass (weight)ounces (oz)<br>pounds per foot (lb/ft)28.35<br>1.8grams (g)<br>grams (g)<br>tonns (t)Mud weightpounds per gallon (ppg)<br>pounds per foot (lb/ft)119.82<br>1.6.0kilograms per cubic metre (kg/m)<br>kilograms per cubic metre (kg/m)Pressure gradientpounds per gallon (ppg)<br>pounds per foot (lb/ft)119.82<br>1.6.0kilograms per cubic metre (kg/m)<br>kilograms per cubic metre (kg/m)Mud weightpounds per guare inch<br>per foot (lb/ft)119.82<br>1.6.0kilograms per cubic metre (kg/m)<br>kilograms per cubic metre (kg/m)Funnel of scosityseconds per quart (s/qt)1.057seconds per litre (s/L)<br>kilograms per cubic metres (m <sup>1</sup> )<br>kilograms per cubic metre (kg/m)Filet cafte thickness32nds of an inch0.8millinetres (m <sup>1</sup> )<br>kilograms per cubic metre (kg/m)Filet cafte thickness32nds of an inch0.8millinetres (m <sup>1</sup> )<br>kilograms per cubic metre (kg/m)Filet cafte thickness32nds of an inch0.8millinetres (m <sup>1</sup> )<br>kilograms per cubic metre (kg/m) <td></td> <td>gallons (gal)</td> <td>0.00270</td> <td>nures (L)</td>  |                                | gallons (gal)                               | 0.00270                                 | nures (L)   |
| Product (ut/bit)Product (ut/bit)Product (ut/bit)barrels per ton (bb/tn)cubic metres per tonne (ut/s)Pump output<br>and flow rategallons per nunute (gpm)<br>gallons per nunute (bb/tnin)0.00379<br>0.00159cubic metres per tonne (ut/s)<br>tobic metres per stroke (ml/s)<br>tobic metres per stroke (ml/s)Pressurepounds per square fach (psi)<br>0.0068956.895<br>megapascals (MPa)Temperaturedegrees Famemetit (°F) $\frac{PF - 32}{1.8}$ degrees Celsius (°C)Mass (weight)onces (oz)<br>pounds (lb)28.35<br>453.59<br>tons (m)grams (g)<br>0.9072<br>tonnes (t)Mud weightpounds per square inch<br>per foot (lb/ft)1.488<br>1.488kilograms per cubic metre (kg/ml)<br>kilograms per cubic metre (kg/ml)Pressure gradientpounds per square inch<br>per foot (lb/ft)1.488kilograms per cubic metre (kg/ml)<br>kilograms per cubic metre (kg/ml)Pressure gradientpounds per square (kft)1.057seconds per litre (kf2/ml)<br>kilograms per cubic metre (kg/ml)Pressure gradientpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Funnel viscosityseconds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Fiber cake thickness32nds of an inch0.8millimetres (mn)Powerhorsepower (hp)0.75kilowatts (kW)Areasquare feet (ft²)0.0929square metres (m²)<br>square feet (ft²)0.259Areasquare inches (m²)2.59square metres (m²)<br>square feet (ft²)Diriling line wearton-mi   |                                | ganons (gan)                                | 0.00579                                 | lilo momo por subio motro (log/m3)                |
| Darrets per ton (b0/ft)Pump output<br>and flow rategallons per hour (gph)<br>barrels per stroke (bbl/stroke)0.00379<br>0.159cubic metres per minute (m³/min)<br>cubic metres per hour (m²/t)<br>cubic metres per stroke (m²/stroke)<br>cubic metres per stroke (m²/stroke)Pressurepounds per square fach (nsi)0.159cubic metres per minute (m³/min)<br>cubic metres per stroke (m²/stroke)<br>cubic metres per stroke (m²/stroke)Temperaturedegrees Famenheit (°F) ${}^{\circ}F - 32$<br>1.8degrees Celsius (°C)Mass (weight)omces (oz)<br>pounds (lb)28.35<br>0.99grams (g)<br>tons (g)Mud weightpounds per square inch<br>pounds per foot (lb/ft)1.488kilograms per metre (kg/m)Mud weightpounds per gallon (ppg)<br>pounds per square inch<br>per foot (psi/ft)119.82<br>tkilograms per metre (kg/m)Funnel viscosityseconds per quart (s/qt)1.057seconds per litre (s/L)Yield pointpounds quare feet (lb/100 ft²)0.48<br>tkilograms per metre (kg/m)Funnel viscosityseconds per quart (s/qt)0.75<br>kilowatts (kW)Area32.ds of an inch0.8<br>square feet (lb/100 ft²)0.48<br>tonse (m²)<br>square metres (m²)<br>square feet (lt²)Areasquare inches (in.2)<br>square feet (lt²)0.0929<br>tonse square metres (m²)<br>square metres (m²)<br>square feet (lt²)Areasquare feet (lt²)<br>square feet (lt²)0.836<br>tonse (m²)<br>square metres (m²)<br>square metres (m²)<br>square metres (m²)<br>square metres (m²)<br>square metres (m²)<br>square metres (m²)<br>tareaDrilling line wear </td <td></td> <td>pounds per barrel (10/001)</td> <td>2.895</td> <td>kilograms per cubic metre (kg/m<sup>3</sup>)</td>  |                                | pounds per barrel (10/001)                  | 2.895                                   | kilograms per cubic metre (kg/m <sup>3</sup> )    |
| gallons per minute (gpm)<br>gallons per stroke (bbl/stroke)<br>barrels per stroke (bbl/stroke)<br>barrels per stroke (bbl/stroke)<br>barrels per stroke (bbl/stroke)<br>barrels per stroke (bbl/stroke)<br>0.159cubic metres per minute (m³/min)<br>cubic metres per stroke (m³/stroke)<br>cubic metres per stroke (m³/stroke)<br>cubic metres per stroke (m³/stroke)<br>cubic metres per stroke (m³/stroke)Pressurepounds per square inch (psi)<br>degrees Fahrenheit (°F) $\overline{Pr} - 32$<br>$1.8$ degrees Celsius (°C)Mass (weight)ounces (oz)<br>pounds (lb)28.35<br>453.55grams (g)<br>grams (g)<br>tonnes (t)Mud weightpounds per gallon (pg)<br>pounds per cubic foot (lb/ft)1.488<br>1.488kilograms per metre (kg/m)Mud weightpounds per square inch<br>per foot (lb/ft)1.488<br>1.60kilograms per metre (kg/m)Funnel viscosityseconds per quart (s/qt)1.057<br>1.057seconds per litre (s/L)Yield brintpounds per 100 square feet (lb/100 ft²)0.48<br>0.48pascals (Pa)<br>pascals (Pa)Fibre cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)Areasquare inches (in.²)<br>square inles (m²)0.436<br>2.59square metres (m²)<br>square miles (m²)Drilling line wearton-miles (tn•mi)14.317<br>1.459megaioules (MJ)Tormuefoot-nounds (ft•th)1.4558newton metres (t•wn)  |                                | barrels per ton (bbi/th)                    | 0.175                                   | cubic metres per tonne (m <sup>7</sup> t)         |
| Pump output<br>and flow rategallons per hour (gph)<br>barrels per stroke (bbl/stroke)<br>barrels per stroke (bbl/stroke)0.159<br>0.159cubic metres per hour (m <sup>3</sup> /m)<br>cubic metres per stroke (mbl/stroke)<br>oubic metres per stroke (bbl/stroke)<br>0.159Pressurepounds per square inch (nsi)6.895<br>0.006895kilopascals (kPa)<br>megapascals (MPa)Temperaturedegrees Famenheit (°F) $\frac{°F - 32}{1.8}$ degrees Celsius (°C)Mass (weight)ounces (oz)<br>pounds (lb)28.35<br>0.9072grams (g)<br>kilograms (kg)<br>tonnes (t)Mud weightpounds per foot (lb/ft)1.488kilograms per metre (kg/m)Mud weightpounds per square inch<br>per toot (psi/ft)119.82kilograms per cubic metre (kg/m)Pressure gradientpounds per square inch<br>per foot (psi/ft)1.057seconds per litre (s/L)Yield pointpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Getterength<br>powerpounds per feet (lb/100 ft²)0.48pascals (Pa)Fibre cake thickness32nds of an inch0.8millimetres (cm²)<br>square feet (ft²)Areasquare parks (yd²)0.8361square metres (m²)<br>square metres (m²)<br>square metres (m²)Areaton-miles (m²)2.59square metres (m²)<br>square metres (m²)Drilling line wearton-miles (tn·mi)14.317megajoles (MI)<br>tonne-kilometres (twin)Torquefoot-nounds (ft•th)1.3558newton metres (twin)  | D                              | gallons per minute (gpm)                    | 0.00379                                 | cubic metres per minute (m <sup>3</sup> /min)     |
| and flow ratebarrels per stroke (bbl/stroke)0.159cubic metres per stroke (m³/stroke)barrels per minute (bbl/min)0.159cubic metres per stroke (m³/stroke)Pressurepounds per square inch (nsi)6.895kilopascals (kPa)Temperaturedegrees Famenheit (°F) $\frac{°F - 32}{1.8}$ degrees Celsius (°C)Mass (weight)onces (oz)28.35grams (g)pounds (lb)453.59grams (g)tons (n)0.9072tonnes (t)pounds per foot (lb/ft)1.488kilograms per metre (kg/m)Mud weightpounds per gallon (ppg)119.82kilograms per cubic foot (lb/ft)16.0kilograms per cubic metre (kg/m)Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621Vield pointpounds per quart (s/qt)1.057seconds per litre (s/L)Yield pointpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Fiber cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)square inches (in.²)6.45square metres (m²)Areasquare inches (in.²)0.8451square centimetres (m²)Areasquare inches (in.²)0.8451square metres (m²)Areasquare inches (in.²)0.8451square centimetres (m²)Areasquare inches (in.²)0.8451square metres (m²)Areasquare inches (in.²)0.8451square metres (m²)Areasquare metres (m²)0.8451 </td <td>Pump output</td> <td>gallons per hour (gph)</td> <td>0.00379</td> <td>cubic metres per hour (m<sup>3</sup>/h)</td>  | Pump output                    | gallons per hour (gph)                      | 0.00379                                 | cubic metres per hour (m <sup>3</sup> /h)         |
| barrels per minute (bbl/min) $0.159$ cubic metres per minute (m³/min)Pressurepounds per square inch (psi) $6.895$ kilopascals (kPa)Temperaturedegrees Fahrenheit (°F) $\frac{°F - 32}{1.8}$ degrees Celsius (°C)Mass (weight)ounces (oz)28.35grams (g)pounds (lb)453.59grams (g)tons (tn)0.9072tonnes (t)pounds per foot (lb/ft)1.488kilograms per metre (kg/m)Mud weightpounds per gallon (ppg)119.82pounds per square inchper foot (lb/ft')16.0Pressure gradientpounds per square inchper foot (psi/ft)22.621Vield pointpounds per feet (lb/100 ft²)Vield pointpounds per feet (lb/100 ft²)Powerhorsepower (hp)0.75kilowatts (kW)square inches (in.²)6.45square michssquare feet (ft²)0.0929square metres (m²)acre (ac)0.40hectare (ma)Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)Tormuefort-nounds (ft•th)Tormuefort-nounds (ft•th)1358newton metres (Nem)   | and flow rate                  | barrels per stroke (bbl/stroke)             | 0.159                                   | cubic metres per stroke (m <sup>3</sup> /stroke)  |
| Pressurepounds per square inch (nsi) $6.895$<br>$0.006895$ kilopascals (kPa)<br>megapascals (MPa)Temperaturedegrees Falmenheit (°F) $\frac{°F - 32}{1.8}$ degrees Celsius (°C)Mass (weight)onces (oz)28.35grams (g)<br>grams (g)pounds (lb)453.59grams (g)<br>tons (n)0.9072tons (n)0.9072Mud weightpounds per foot (lb/ft)1.488Mud weightpounds per gallon (ppg)<br>pounds per cubic foot (lb/ft)119.82Mud weightpounds per square inch<br>per foot (clb/ft)kilograms per cubic metre (kg/m)Pressure gradientpounds per quare feet (lb/100 ft²)0.48Pascals (Pa)filter cake thickness32nds of an inch0.8Gef strengthpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Filter cake thickness32nds of an inch0.8millimetres (mm)Areasquare inches (in.²)<br>square miles (in.²)6.45square metres (m²)<br>square metres (m²)<br>acre (ac)Areaton-miles (tn*m)14.317<br>negajoules (MJ)Drilling line wearton-miles (tn*m)14.317<br>negajoules (MJ)Tormuefort-nounds (ft*lb)1.3558<br>newron metres (Nem)  |                                | barrels per minute (bbl/min)                | 0.159                                   | cubic metres per minute (m <sup>3</sup> /min)     |
| $0.006895$ megapascals (MPa)Temperaturedegrees Fahrenneit (°F) $\frac{^{\circ}F - 32}{1.8}$ degrees Celsius (°C)Mass (weight)ounces (oz)28.35grams (g)pounds (lb)453.59grams (g) $0.4536$ kilograms (kg)tons (tn)0.9072mud weightpounds per foot (lb/ft)11.488kilograms per metre (kg/m)Mud weightpounds per gallon (ppg)pounds per cubic foot (lb/ft)Pressure gradientpounds per square inch<br>per foot (psi/ft)Pressure gradientpounds per quart (s/qt)1.057seconds per litter (s/L)Yield pointpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Get strengthpounds per 100 square feet (lb/100 ft²)0.48millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)square inches (in.²)6.45square miles (m²)2.59square miles (m²)2.59square miles (m²)2.59square metres (m²)acre (ac)0.40hectare (ha)Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)tornewer (freth)1.3558newton metres (t•km)Tornuefoot-nounds (ft•lb)13558newton metres (t•km)   | Pressure                       | pounds per square inch (psi)                | 6.895                                   | kilopascals (kPa)                                 |
| Temperaturedegrees Falmenheit (°F) $\frac{^{\circ}F - 32}{1.8}$ degrees Celsius (°C)Mass (weight)ounces (oz)28.35grams (g)pounds (lb)453.59grams (g)tons (tn)0.9072tonnes (t)pounds per foot (lb/ft)1.488kilograms per metre (kg/m)Mud weightpounds per gallon (ppg)119.82pounds per cubic foot (lb/ft)16.0kilograms per cubic metre (kg/m)Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621Vield pointpounds per 100 square feet (lb/100 ft²)0.48Get strengthpounds per 100 square feet (lb/100 ft²)0.48Filter cake thickness32nds of an inch0.8Square inches (in.²)6.45square metres (m²)Areasquare feet (ft²)0.0929square metres (m²)Areaton-miles (in.²)6.45square metres (m²)acre (ac)0.40hectare (ha)14.317Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)Tarmefoot-nounds (ft•lb)1.3558newton metres (N•m)  |                                |   | 0.006895                                | megapascals (MPa)                                 |
| Temperaturedegrees transmitter (F)1.8degrees Census (C)Mass (weight)ounces (oz)28.35grams (g)pounds (lb)453.59grams (g)0.4536kilograms (kg)tons (tn)0.9072tonnes (t)pounds per foot (lb/ft)1.488kilograms per metre (kg/m)Mud weightpounds per gallon (ppg)119.82kilograms per cubic metre (kg/m)Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621kilopascals per metre (kg/m)Funnel viscosityseconds per quart (s/qt)1.057seconds per litre (s/L)Yield pointpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Gef strengthpounds per 100 square feet (lb/100 ft²)0.48mascals (Pa)Filte cake thickness32nds of an inch0.8millimetres (mm)Areasquare inchs (in.²)6.45square metres (m²)square feet (ft²)0.0929square metres (m²)Areasquare (gd²)0.8361square metres (m²)acre (ac)0.40hectare (ha)Drilling line wearton-miles (m•mi)14.317Tarmefoot-nounds (ft•lb)1.3558newton metres (N•m)  | T                              | Langer Establish (PE)                       | °F - 32                                 | damage Calaire (8C)                               |
| Mass (weight)ounces (oz)28.35grams (g)pounds (lb)453.59grams (g)0.4536kilograms (g)tons (tn)0.9072tons (tn)0.9072founds per foot (lb/ft)1.488Mud weightpounds per gallon (ppg)119.82kilograms per metre (kg/m)Mud weightpounds per square inch<br>per foot (psi/ft)Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621kilograms per metre (kPa/m)Funnel viscositvseconds per quart (s/qt)1.057seconds per litre (s/L)Yield pointpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Getstrengthpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Filter cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)square inches (in.²)6.45square gradis (yd²)0.8361square miles (mi²)2.59square miles (mi²)2.59square miles (mi²)2.59square miles (mi²)2.59square (ac)0.400.40hectare (ha)Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)Torquefoot-pounds (ft•lb)1.3558Torquefoot-pounds (ft•lb)1.3558   | Temperature                    | degrees ramenneit ('F)                      | 1.8                                     | degrees Celsius (°C)                              |
| pounds (lb)453.59grams (g)0.4536kilograms (kg)tons (tn)0.9072pounds per foot (lb/ft)1.488Mud weightpounds per gallon (ppg)119.82kilograms per metre (kg/m)Mud weightpounds per gallon (ppg)Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621kilograms per cubic metre (kg/m)Funnel viscosityseconds per quart (s/qt)1.057seconds per litre (s/L)Yield pointpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Get strengthpounds per 100 square feet (lb/100 ft²)0.48mascals (Pa)Filter cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)square feet (ft²)0.0929square feet (ft²)0.0929square miles (mi²)2.59square miles (mi²)2.59square miles (mi²)2.59square klometres (km²)<br>acre (ac)0.40Drilling line wearton-miles (tn•mi)1.459tonne-kilometres (them)Tormefoot-pounds (ft•lb)1.3558newton metres (N•m)  | Mass (weight)                  | ounces (oz)                                 | 28.35                                   | grams (g)   |
| Mud weight0.4536<br>tons (tn)kilograms (kg)<br>tonnes (t)Mud weightpounds per gallon (ppg)<br>pounds per cubic foot (lb/ft3)119.82<br>16.0kilograms per metre (kg/m3)<br>kilograms per cubic metre (kg/m3)Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621kilopascals per metre (kPa/m)Funnel viscosityseconds per quart (s/qt)1.057seconds per litre (s/L)Yield pointpounds per 100 square feet (lb/100 ft2)0.48pascals (Pa)Get strengthpounds per 100 square feet (lb/100 ft2)0.48pascals (Pa)Filter cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)Areasquare inches (in.2)<br>square feet (ft2)6.45<br>0.0929square metres (m2)<br>square metres (m2)<br>acre (ac)Drilling line wearton-miles (tn•mi)14.317<br>14.317megajoules (MJ)<br>tonne-kilometres (t*km)Tormefoot-nounds (ft•lb)1.3558newton metres (N*m)   |                                | pounds (lb)                                 | 453.59                                  | grams (g)   |
| tons (tn)0.9072<br>pounds per foot (lb/ft)tonnes (t)Mud weightpounds per gallon (ppg)<br>pounds per cubic foot (lb/ft3)119.82<br>16.0kilograms per cubic metre (kg/m3)<br>kilograms per cubic metre (kg/m3)Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621kilopascals per metre (kPa/m)Funnel viscosityseconds per quart (s/qt)1.057seconds per litre (s/L)Yield pointpounds per 100 square feet (lb/100 ft2)0.48pascals (Pa)Get strengthpounds per 100 square feet (lb/100 ft2)0.48mascals (Pa)Fibrer cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)Areasquare inches (in.2)<br>square feet (ft2)0.492square metres (m2)<br>square metres (m2)<br>square metres (m2)<br>acre (ac)0.400Drilling line wearton-miles (tn•mi)14.317<br>1.459megajoules (MJ)<br>tonne-kilometres (t*km)Torquefoot-nounds (ft•lb)1.3558newton metres (N•m)  |                                |   | 0.4536                                  | kilograms (kg)                                    |
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| Pressure gradientpounds per cubic foot (lb/ft³)16.0kilograms per cubic metre (kg/m³)Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621kilograms per cubic metre (kg/m³)Funnel viscosityseconds per quart (s/qt)1.057seconds per litre (s/L)Yield pointpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Get strengthpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Filter cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)Square inches (in.²)6.45square centimetres (cm²)Areasquare feet (ft²)0.0929square metres (m²)square micles (in.²)2.59square metres (m²)acre (ac)0.40hectare (ha)Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)Torquefoot-pounds (ft•lb)1.3558newton metres (N•m)   | Mud weight                     | <b>6</b> pounds per gallon (ppg)            | 119.82                                  | kilograms per cubic metre (kg/m <sup>3</sup> )    |
| Pressure gradientpounds per square inch<br>per foot (psi/ft)22.621kilopascals per metre (kPa/m)Funnel viscosityseconds per quart (s/qt)1.057seconds per litre (s/L)Yield pointpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Get strengthpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Filter cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)Areasquare inches (in.²)6.45square centimetres (cm²)square feet (ft²)0.0929square metres (m²)square miles (mi²)2.59square metres (m²)acre (ac)0.40hectare (ha)Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)Torquefoot-nounds (ft•lb)1.3558newton metres (N•m)   |                                | pounds per cubic foot (lb/ft <sup>3</sup> ) | 16.0                                    | kilograms per cubic metre (kg/m <sup>3</sup> )    |
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| Getstrengthpounds per 100 square feet (lb/100 ft²)0.48pascals (Pa)Filter cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)Square inches (in.²)6.45square centimetres (cm²)Areasquare feet (ft²)0.0929square metres (m²)Areasquare yards (yd²)0.8361square metres (m²)Square miles (mi²)2.59square kilometres (km²)Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)Torquefoot-pounds (ff•lb)1.3558newton metres (N•m)   | Yield point                    | pounds per 100 square feet (lb/100          | ft <sup>2</sup> ) 0.48                  | pascals (Pa)                                      |
| Filter cake thickness32nds of an inch0.8millimetres (mm)Powerhorsepower (hp)0.75kilowatts (kW)Square inches (in.2)6.45square centimetres (cm2)Areasquare feet (ft2)0.0929square metres (m2)Areasquare yards (yd2)0.8361square metres (m2)Square miles (mi2)2.59square kilometres (km2)Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)Torquefoot-pounds (ft•lb)1.3558newton metres (N•m)   | Gel strength                   | pounds per 100 square feet (lb/100          | ft <sup>2</sup> ) 0.48                  | pascals (Pa)                                      |
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| Square inches (in.2) $6.45$ square centimetres (cm2)Areasquare feet (ft2) $0.0929$ square metres (m2)Areasquare yards (yd2) $0.8361$ square metres (m2)square miles (mi2) $2.59$ square kilometres (km2)acre (ac) $0.40$ hectare (ha)Drilling line wearton-miles (tn•mi) $14.317$ megajoules (MJ) $1.459$ tonne-kilometres (t•km)Torquefoot-pounds (ft•lb) $1.3558$ newton metres (N•m)  | Power                          | horsepower (hp)                             | 0.75                                    | kilowatts (kW)                                    |
| Areasquare feet (ft²)<br>square yards (yd²) $0.0929$<br>$0.8361$ square metres (m²)<br>square metres (m²)<br>square miles (m²)<br>acre (ac)Drilling line wearton-miles (tn•mi)14.317<br>$1.459$ megajoules (MJ)<br>tonne-kilometres (t•km)Torquefoot-pounds (ft•lb)1.3558<br>$1.3558$ newton metres (N•m)  | V                              | square inches (in. <sup>2</sup> )           | 6.45                                    | square centimetres (cm <sup>2</sup> )             |
| Area square yards (yd²)<br>square miles (mi²)<br>acre (ac) 0.8361<br>2.59 square metres (m²)<br>square kilometres (km²)<br>hectare (ha)   Drilling line wear ton-miles (tn•mi) 14.317 megajoules (MJ)<br>1.459   Torque foot-pounds (ft•lb) 1.3558 newton metres (N•m)   | 1                              | square feet (ft <sup>2</sup> )              | 0.0929                                  | square metres (m <sup>2</sup> )                   |
| square miles (mi²)<br>acre (ac)2.59<br>0.40square kilometres (km²)<br>hectare (ha)Drilling line wearton-miles (tn•mi)14.317<br>1.459megajoules (MJ)<br>tonne-kilometres (t•km)Torquefoot-pounds (ft•lb)1.3558newton metres (N•m)   | Area                           | square yards (yd <sup>2</sup> )             | 0.8361                                  | square metres $(m^2)$                             |
| acre (ac)0.40hectare (ha)Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)1.459tonne-kilometres (t•km)Torquefoot-pounds (ft•lb)1.3558newton metres (N•m)  |                                | square miles (mi <sup>2</sup> )             | 2.59                                    | square kilometres (km <sup>2</sup> )              |
| Drilling line wearton-miles (tn•mi)14.317megajoules (MJ)1.459tonne-kilometres (t•km)Torquefoot-pounds (ft•lb)1.3558newton metres (N•m)   |                                | acre (ac)                                   | 0.40                                    | hectare (ha)                                      |
| Torque foot-pounds (ft•lb) 1.357 megapounds (hf)   1.3558 pewton metres (N•m)  | Drilling line wear             | ton-miles (tn•mi)                           | 14.317                                  | megajoules (MI)                                   |
| Torque foot-pounds (ft•lb) 1 3558 newton metres (N•m)  |                                |   | 1.459                                   | tonne-kilometres (t•km)                           |
|  |                                |   |   | · /   |

# English-Units-to-SI-Units Conversion Factors

# - of texas at Austin **Artificial Lift Overview**

# In this chapter:

- How artificial-lift systems produce fluids •
- Current lift technologies used on land and offshore •
- Factors to consider when selecting a lift system •
- Environmental and operator-discretionary factors •

Tdeally, a hydrocarbon-bearing reservoir should contain enough Inatural pressure to enable *fluids* to flow to the surface for several years without requiring external energy. Over time, however, energy in the formation will decline to the point that pressure and/or flow velocity will no longer be adequate to move fluids to the surface. When a well reaches this point in its lifecycle, fluids must be produced (or lifted) to the surface through artificial means.

Notable exceptions include wells completed in prolific water drive reservoirs where wells continue to flow water under natural reservoir energy after hydrocarbon production has ceased. Likewise, large gas-cap reservoirs can contain sufficient energy to produce much of the recoverable hydrocarbons without artificial lift. However, more often, wells require artificial lift at some point in their economic life. Even gas wells typically require some sort of deliquification system to remove water. Water accumulating in the wellbore creates a back-pressure that limits gas inflow from the reservoir, so the water must continually or periodically be removed to allow for the free flow of gas.

# Austin Aust Reciprocating **Rod Lift**

# In this chapter:

- Typical applications of reciprocating rod systems
- Operating principles of a sucker rod pump
- Rod pump system design and components •
- Types of surface rod pumping units
- Factors to consider when selecting and using rod string

The history of reciprocating rod lift is closely tied to the early ▲ oilwells that were established in 1859 by Edwin Drake in the small, rural community of Titusville, Pennsylvania. Commonly referred to as the Drake well, this earliest of drilling sites forever shaped industry and trade while advancing human mobility. Around 300 to 400 gallons (about 1,135 to 1,514 litres) were reportedly lifted from the site each day; however, the drilling process was expensive, tedious, and extremely dangerous.

Within ten years of the Drake well, conventional rod pumping was becoming increasingly popular. Early rod-pumping systems consisted of a standard cable tool drilling rig, placed in such a way that the walking beam could be used to operate the pump. Prior, rod-activated pumps had been used to produce brine. Similar to the pump illustrated in figure 1, they consisted primarily of a cylinder made up in the tubing string, a standing valve seated in the tubing string, a plunger, and traveling valve. It is likely that flapper valves were used rather than *ball valves*, which are depicted in the figure. Originally, the plunger was reciprocated in the cylinder by means of wooden sucker rods with wrought-iron end fittings for connections.

The majority of artificiallift systems in use are reciprocating rod lift systems.

# s city of the states of the st **Electric Submersible** Pumps

In this chapter:

- Typical applications of electric submersible pumps
- Operating principles for high volumes of fluids
- Key system components and how they function
- Basic ESP system design factors to conside

Tn 1916, Armias Arutunoff developed the first cylindrical multistage Lelectric submersible pump (ESP) for dewatering mines and ships. He formed the Russian Electrical Dynamo of Arutunoff Company (REDA) and applied the technology to oilwells, first in Russia and then in Germany. Mr. Arutunoff immigrated to the United States and installed the first ESP in the Western Hemisphere in a Phillips Petroleum well in Kansas in 1928. By 1938, approximately 2% of artificially lifted oil in the United States was lifted by REDA pumps.

Today, ESPs have become the preferred lift technology for many pumping applications, from shallow dewatering of mines to high-volume offshore oil production. High-temperature systems have been developed to allow ESPs to pump in applications traditionally serviced only by rod pumping systems. Special gas-handling features have made it possible to use ESPs in some gaseous well applications. As a result, more capital is spent on procurement of ESP systems today than all other lift technologies combined.

# Conventional Gas Lift

In this chapter:

- Typical applications of conventional gas-lift systems
- Distinctions between continuous and intermittent gas lift
- Key factors to consider when using gas lift
- Achieving maximum efficiency with a gas-lift system

A ir lifting of water with a small amount of oil was first known to A be used in the United States as early as 1846, but compressed air was reportedly used to lift water from wells in Germany as early as the eighteenth century. These systems operated initially in a very simple manner by induction of air to the bottom of the tubing and out into the casing. *Acration* of the fluid in the casing-tubing annulus decreased the weight of the mixture to the extent that fluid would rise to the surface and flow out of the well. The process was sometimes reversed by injecting down the casing and producing through the tubing.

# In this chapter:

- •

, plications of plunger lift perating principles and functionality System components and their effectiveness Factors to consider when designing a plunger-lift system Plunger lift is a method of lifting fluid by produced gas to drive a free-piston (plunger) from the lower end of the tubing string to the surface. This is done to remove accumulated fluid from the tubing string. Plunger lift is similar to intermittent gas lift in that it uses stored gas energy from the annulus or wellbore to periodically lift slugs of liquid, rather than lifting the entire column of fluid all at once.

The plunger lift overcomes two of the efficiency challenges of intermittent gas lift. First, the plunger acts as a mechanical interface seal between the slug of liquid that is lifted and the gas that moves the plunger and liquid Thus, fluid fallback is greatly reduced, resulting in improved lifting efficiency. Second, the fluid is lifted using the energy of the formation rather than requiring pressurized injection gas energy from the surface. The result is the most cost efficient lift technology for low-volume applications (fig. 61). Retrolet

# ity of texas at Austin Velocity Strings and Foam Lift

# In this chapter:

- Typical applications of foam-lift technology
- Operating principles and the role of critical velocity
- Using surfactants to lower surface tension
- How system components work to extend well life

In a flowing gas well, liquids entrain in the gas and accumulate at the bottom of the well. This increases the bottomhole pressure (BHP) in the well and inhibits gas inflow. Also, accumulated liquids displace gas in the near-wellbore formation, reducing gas permeability and hindering gas migration to the wellbore. If flow velocities are sufficiently high, the flowing gas will continuously blow liquids out of the well to keep the well unloaded, or clear of liquids. However, at lower gas velocities liquids accumulate in the wellbore, slowing gas inflow. Eventually the entrained and accumulating liquids can increase BHP to the point that gas production ceases.

The term liquid loading refers to the accumulation of liquids in a wellbore that inhibits gas inflow. One way to prevent or relieve liquid loading is to enhance gas velocities; another way is to cause the liquid to foam so that it can be more easily displaced.

Flow velocities can be increased by reducing the cross-sectional how area of the gas stream. This can be accomplished by flowing the well fluids through reduced diameter tubing (velocity string) or through the annulus around an inserted *dead string* of tubing. Gas flow velocities can also be increased by injecting gas to comingle with produced gas.

Foam lift is primarily a dewatering technology, although effective surfactants have been developed for hydrocarbons.

# **Hydraulic Lift**

In this chapter:

- Typical applications of hydraulic lift •
- Configurations of hydraulic-lift systems
- Principles of hydraulic jet and piston pumps
- Surface equipment required for hydraulic lift

In 1932, C.J. Coberly installed the first hydraulic piston pump in Inglewood, California as a solution to pumping oil without using a sucker rod string. Later, Coberly formed Kobe, Inc., and the company was the first to successfully use a hydraulic jet pump to produce an oilwell. Since then, jet pumps have been used to pump up to 35,000 barrels of well fluids per day. Hydraulic pumping represents one of the most flexible forms of artificial lift; it can often successfully produce wells in which other lift technologies have failed (fig. 71).

Hydraulic-pumping systems consist of four basic parts:

- Power-fluid conditioning and supply •
- Surface power unit and hydraulic pump
- Piping to transfer the high-pressure power fluid to the subsurface pump

The fluid-conditioning system cleans and prepares the power fluid, which is typically a produced well fluid, such as water or oil.



Figure 71. Hydraulic-lift system

# oftexasathustin **Production** Optimization

## In this chapter:

- ersity Maximizing production throughout the life of a well
- Addressing factors that can hinder production •
- How systems collect and transmit well data •
- Key elements of a production-optimization system

The previous sections of this book all deal with selecting, designing, and effectively applying lift technologies based on assumptions about how the reservoir will deliver fluids. In reality, production always varies somewhat from what was expected because well conditions, inflow volumes, and fluid phases change over time.

The artificial-lift system should be adjusted as needed to match the inflow rates from the reservoir. As fluid production declines, the lift system pumping rate must be similarly reduced or the well might become pumped dry of fluids, causing damage to the lift systems and potentially to the reservoir. In other situations, improved reservoir management techniques can increase reservoir deliverability, but production might then be constrained by lift system performance. Until the lift system is adjusted to produce at the new deliverability rates, the lift system can cause an undetected bottleneck. Damage to lift systems and lost potential production from suboptimum lift performance are easily prevented but are often overlooked by manual surveillance practices.

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