1st Edition 2018

geoLOGIC NEWS

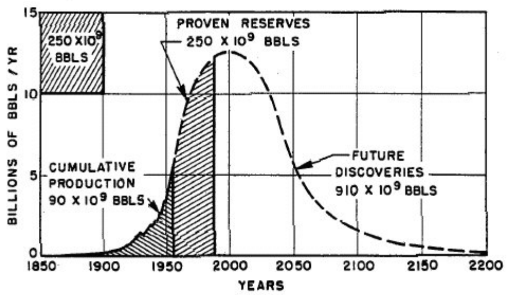
A publication of Subsurface Consultants & Associates, LLC

The New Definition of Peak Oil

A message from our President

Do you remember when Peak Oil referred to peak extraction, after which global production enters terminal decline due to the approaching limit of a finite resource? When M. King Hubbard made his statistically (not geologically) based peak oil prediction in 1956 following a bell-shaped curve[1] (see below), he had no concept of the vast amounts of oil yet to be found in the deep water and arctic environments, or from oil sands and source rocks. Fresh thinking and new technologies continue to change our understanding of how much oil is out there and how much of that can be recovered commercially.

As worldwide production approaches 100 mmbopd, Peak Oil now refers to the demand side: the point in time when alternative and renewable energy sources become sufficiently preferable to consumers to send oil consumption into terminal decline. To quote former Saudi Arabian oil minister Sheikh Zaki Yamani in 2000, "Thirty years from now there will be a huge amount of oil - and no buyers. Oil will be left in the ground. The Stone Age came to an end, not because we had a lack of stones, and the oil age will come to an end not because we have a lack of oil."[2]



Recently published predictions by forecasters with major banks and oil companies are now putting a range on the timing of Peak Oil demand, varying from as early as 2025 to 2040 and beyond. There are many factors that will influence the approach of peak oil demand: growth of global economies, oil price, market penetration by renewable fuels, electric cars, fuel efficiency, environmental policies, power storage capabilities, and petrochemical needs to name a few. Even what was once considered the unbroachable domain of energy-intensive, hydrocarbon-based fuels, commercial air travel may one-day use battery power as hybrid electric commercial jet planes are under development by two major manufacturers.

The good news for our industry is that the "post-carbon" world will not occur at the "flick of a switch." Growth in demand for petrochemicals will continue to support long-term oil demand. Heavy industries like iron, steel, cement, and plastics will continue to require extremely high temperatures that for the foreseeable future can only be generated at reasonable cost by energy-intensive hydrocarbons. Advances in carbon capture technology may further extend the use of carbon-based fuels. There is still time for a full and rewarding career in the oil business.

1 Hubbard, M. King. "Hubbert's Peak Bell Curve." *Globalization 101*. http://www.globalization101.org/c-hubberts-peak-theory/.

2 Editor, Mary Fagan Deputy City. "Sheikh Yamani Predicts Price Crash as Age of Oil Ends." The Telegraph, Telegraph Media Group, 25 June 2000, www.telegraph.co.uk/news/uknews/1344832/Sheikh-Yamani-predicts-price-crash-as-age-of-oil-ends.html.

Hal Miller
President

in this issue:

SCA
SUBSURFACE CONSULTANTS

Stay connected with SCA

The Basics of Artificial Lift Systems

by Rajan N. Chokshi, Ph.D.

According to World Oil annual production reviews, around 95% of producing wells in the United States are on some form of artificial lift and this proportion has remained constant for the last fifteen years as shown in *Figure 1*. Informal estimates indicate this number is closer to over 75% for the global producing well population.

In this introductory article, we will review "W5H" of Artificial Lift – Why, When, Where, Who, What, and How. This is an essentials article aimed at all petroleum industry professionals interested in understanding the impact of this important technology on the production of oil and gas.

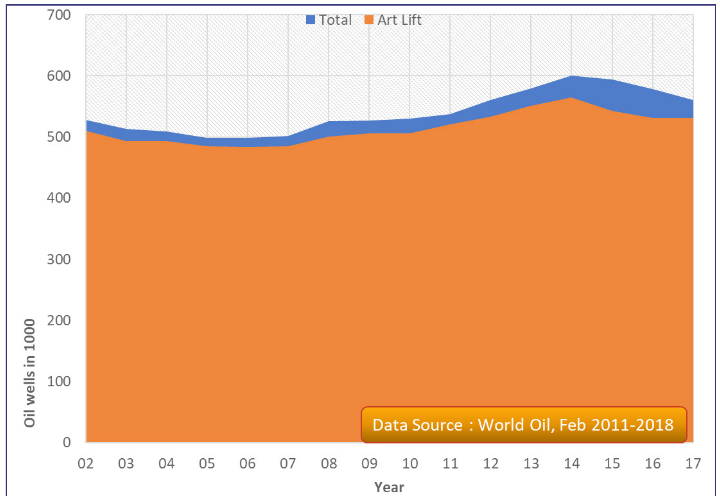


Figure 1. Artificially Lifted Oil Wells in the USA (Data Source: World Oil, Feb 2011-2018)

Why and When is an Artificial Lift System Needed?

The importance of artificial lift cannot be understated for the productive life of oil and gas assets. ***Figure 2*** shows results of a field viability analysis for a Latin American location. In this case, deployment of gas-lift extends field life by almost three years while cumulative production increases by 115,000 bbls. Electronic Submersible Pump, another form of artificial lift, extends the field life by about four years while improving cumulative production to the tune of 230,000 bbls.

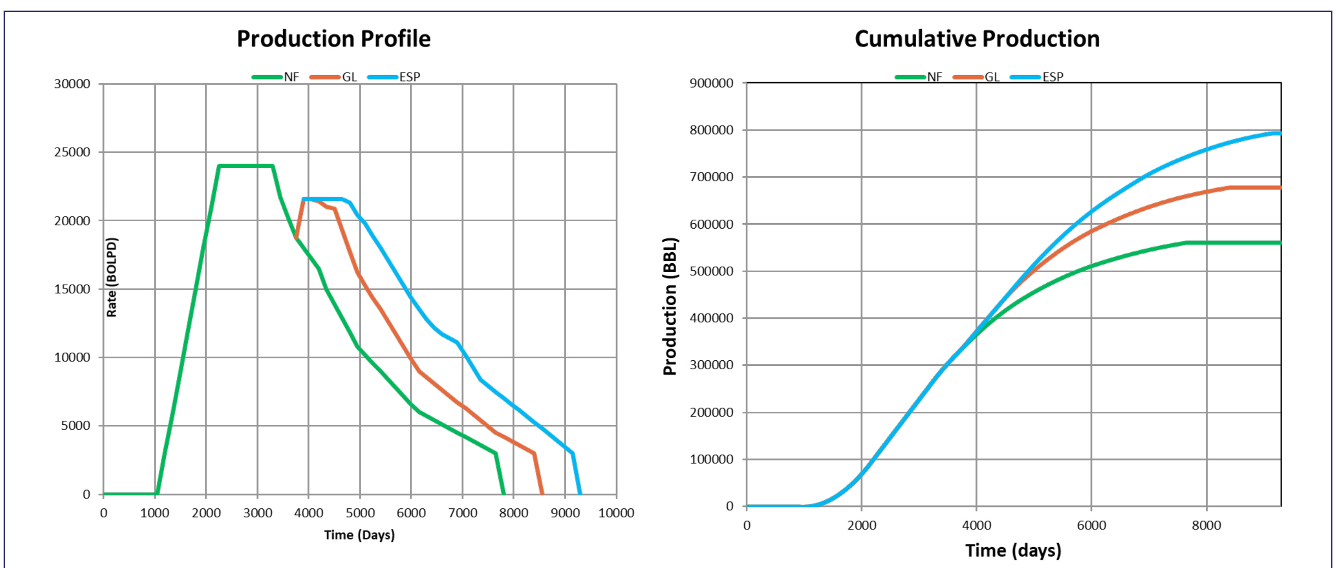


Figure 2. Artificial Lift Extends Life of a Field

Figure 3 shows the production profile change that occurs over time for a conventional oil or gas well. After an oil or gas well is put on production, it is usually produced in a self- or naturally-flowing phase during which the production profile is relatively stable and flat. As depletion increases, reservoir energy (pressure), the main motive force behind production, declines and consequently so do production rates.

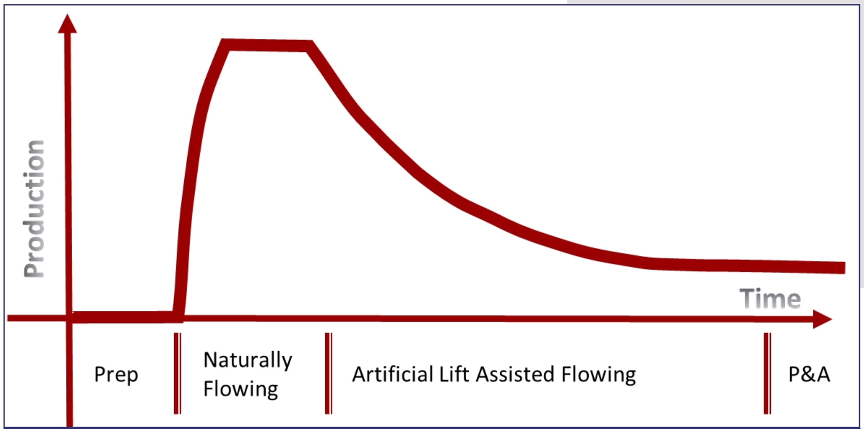


Figure 3. Production Lifecycle of a Conventional Oil or Gas Well

For oil wells, often the water cut and/or gas-oil ratio increases depending on the reservoir drive mechanism. In the case of gas wells, liquid loading (or liquid fall back) intensifies as the condensate-gas ratio and/or water-gas ratio increases and reservoir pressure decreases. To manage/maintain production levels, operators implement artificial lift in these wells. In many cases, like particularly expensive developments, operators choose to implement artificial lift from the beginning of a well's life cycle to produce at greater than natural rates and to recover investments faster.

For unconventional or tight wells, the production profile experiences a sharp decline and it happens much earlier as shown in ***Figure 4***. Consequently, operators need to consider applying artificial lift techniques in a considerably shorter time frame and much earlier in the well's life cycle when compared to conventional wells.

In summary, when available reservoir energy becomes lower than what is necessary to bring reservoir fluids in the desired quantity to the surface, you need artificial lift systems. To analyze the need for an artificial lift system, a NODAL analysis or total systems analysis is performed. The concept is described in brief below.

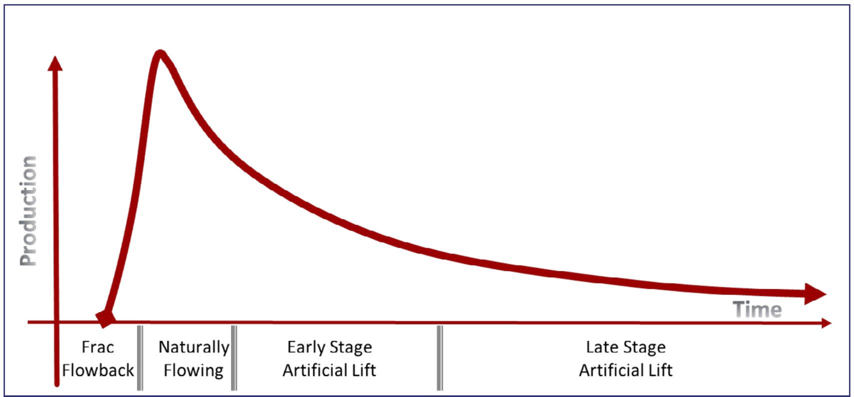


Figure 4. Production Lifecycle for an Unconventional Well

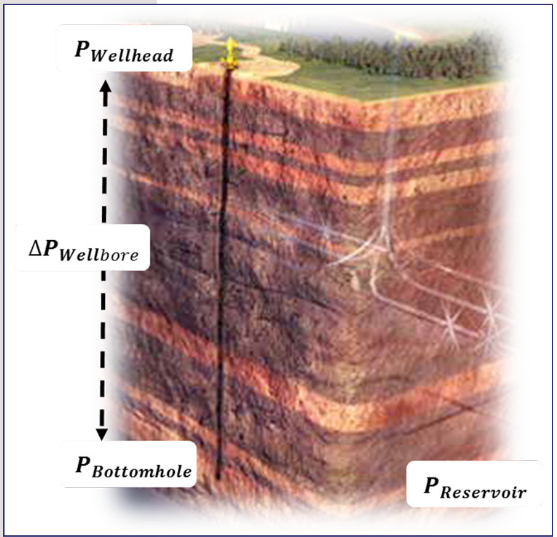


Figure 5. Pressure Losses in a Wellbore

If the following inequality holds true for a given flow rate, an artificial lift system is needed:

$$P_{\text{Bottomhole}} < \Delta P_{\text{Wellbore}} + P_{Wellhead}$$

$P_{\text{Bottomhole}}$ is the pressure inside the wellbore at the mid-perforations level, and it is linked to the flow rate and the reservoir pressure through an inflow performance relationship (IPR).

$\Delta P_{\text{Wellbore}}$ represents wellbore pressure losses and can be calculated by integration of the following pressure gradient expression:

$$\left(\frac{dP}{dZ}\right)_{total} = \left(\frac{dP}{dZ}\right)_{elevation} + \left(\frac{dP}{dZ}\right)_{friction} + \left(\frac{dP}{dZ}\right)_{acceleration}$$

$$= \left(\frac{g}{g_c}\rho \sin\theta\right)_{ele} + \left(f\frac{\rho v^2}{2g_c D}\right)_{fri} + \left(\frac{\rho v}{g_c}\frac{dv}{dz}\right)_{acc}$$

As shown in the expression, the mixture density, ρ, flow path configuration (diameter, D, inclination, θ, and roughness) are important parameters besides length of the total flow path. $P_{Wellhead}$, the wellhead pressure, is a function of flow rate, a configuration of surface flowline to the processing facilities, and separator pressure. The relationship between the flowrate and pressure losses in the wellbore is typically referred to as vertical lift performance (VLP) or outflow performance.

Figure 6 shows flow performance in terms of inflow and outflow curves. Operating point, shown as the intersection of two curves, provides the well's capability to deliver fluids to the surface. If this intersection doesn't exist then the well is non-flowing and an artificial lift system is needed. Also, if the desired flow rate quantity is higher than the operating point, then an artificial lift system is needed. Any selected artificial lift system in that case needs to provide boost, often referred to as the Total Dynamic Head (TDH), which is equivalent to the pressure difference between outflow and inflow curves at a flow rate.

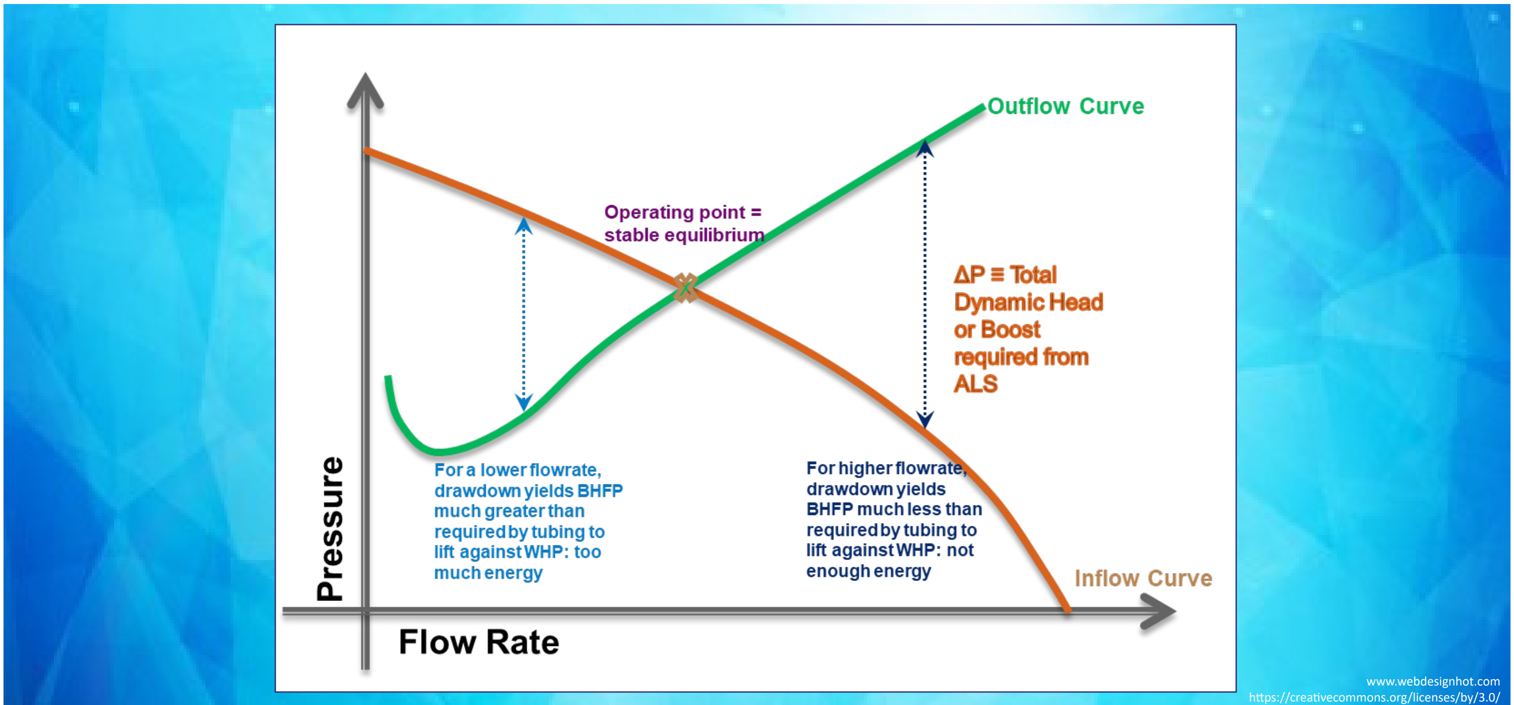


Figure 6. Inflow and Outflow Performance

Where is an Artificial Lift System Applied?

An artificial lift system is lowered into an oil or gas well. Artificial lift applications are found in all hydrocarbon producing regions worldwide in most types of flow situations: high or low flow rates; deep or shallow wells; green field, brown field; onshore, offshore, subsea; mature fields on secondary or tertiary recovery; HP/HT environments; bitumen, heavy oil, light oil to condensate; and gas wells including Coalbed Methane/Coal Seam Gas.

Who Are the Main Providers of Artificial Lift Systems?

The artificial lift system market tends to grow ~10% per year during up-years; however, the down-years are not as harsh as the broader oil field services market as shown in ***Figure 7***. According to the 2017 Spears oilfield market report, the following oilfield service providers cover about 75% of the market share in decreasing order of market share: BH-GE, Schlumberger, Weatherford, Dover, Borets. Each of these companies have at least 5% of the market share. Other notable service providers are Halliburton, Novomet, NOV, Tenaris, and Liberty Lift.

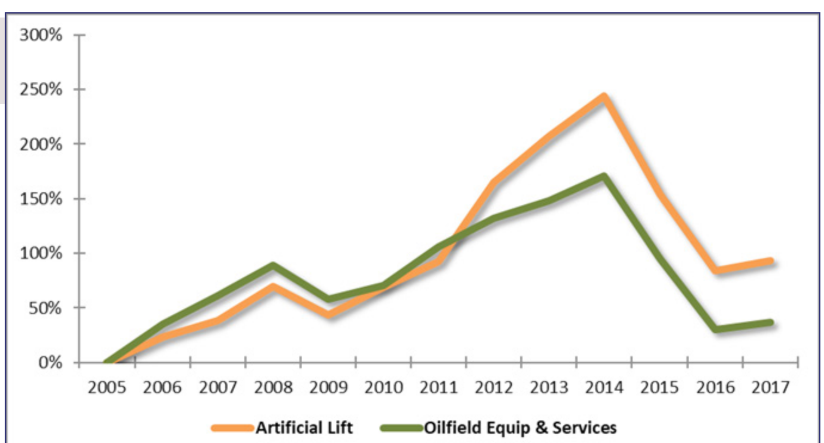


Figure 7. Artificial Lift in Oilfield Services Market
(Data Source: Spears Oilfield Market Report)

What are the Major Forms of Artificial Lift Systems?

Most artificial lifted wells deploy one of the following forms of artificial lift methods: Electrical Submersible Pump (ESP), Foam-Lift (FL), Gas-Lift (GL), Hydraulic Jet Pump (HJP), Hydraulic Piston Pump (HPP), Plunger Lift (PL), Progressing Cavity Pump (PCP), or Reciprocating Rod Lift (RRL or Sucker Rod Pump or Beam). Increasingly, artificial lift practitioners include the following methods into the artificial lift umbrella: Velocity Strings (VS), Dead Strings (DS), Surface Compressors (SC), Surface Jet Pump (SJP), and Surface Multiphase Pump (SMP).

- Foam, GL and PL are dependent on reservoir energy so they are often referred to as reservoir-assisted lift methods. The other lift methods, ESP, HJP, HPP, PCP and RRL, are pump assisted methods where a pump is lowered into the wellbore and energized from the surface.
- In terms of liquid lifting capacity, PL and FL are at the lower end of the spectrum, producing typically less than 100 bbls/day. HJP, GL and ESP are at the higher end of rate spectrum and are capable of producing more than 10,000 bbl/day. HPP, PCP and RRL produce typically less than 2,000 bbls/day. Artificial lift vendors can provide lift systems that cover a range of flowing conditions. For example, available ESP systems have flow rate capabilities from 50 bbls/day to over 40,000 bbls/day.
- In terms of number of installations, RRL has the most number of wells. Most of them are in North America, primarily the USA.
- In terms of gross oil production rates, ESP and GL are the leaders.
- In terms of annual capital spending, ESP has been capturing around 50% of total capital expenditures per Spear's OMR.

Featured SCA Instructor
Rajan N. Chokshi, Ph.D.

Dr. Chokshi works as an artificial lift and production 'optimizer' for Accutant Solutions, a consulting firm out of Houston, TX. He has over 30 years of work experience in petroleum and software industries. He has worked at ONGC of India, artificial lift projects at The University of Tulsa, CEALC and ConnectShip, and Weatherford. His roles with these companies include petroleum engineer, research engineer, software developer, project manager, trainer, senior consultant, and senior business leader. He has worked on many petroleum and software projects globally in the areas of multi-phase flow, artificial lift, production optimization, well performance improvement and real-time production monitoring.

Dr. Chokshi has taught many courses and conducted workshops for practicing professionals around the globe in public and private forums. He has co-authored over fifteen SPE papers. He has led the development of a semester-long curriculum and taught for senior-level university students in artificial lift and production optimization at Texas Tech and Missouri S&T universities. He led and guided industry experts in developing digital content like animations, iPad app, iBooks and webinars. Dr. Chokshi was an SPE Distinguished Lecturer for the 2015-2016 year, has delivered several SPE webinars, has co-chaired an SPE artificial lift workshop, and serves on the SPE global committee for training and for production awards.

Artificial Lift and Production Optimization Solutions

Register for SCA's upcoming offering July 30th - August 3rd

Learning outcomes of this five- day course include:

- A thorough understanding of artificial lift techniques for production optimization.
- Fundamental and advanced concepts of each form of artificial lift system.
- Use of appropriate software tools.
- Knowledge of the challenges facing lift applications and how digital oilfield tools help address them.
- Artificial lift selection and life cycle.

Artificial Lift and Real-Time Optimization for Unconventional Assets

Register for SCA's upcoming offering October 22nd - 24th

Learning outcomes of this three- day course include:

- Why and how production differs in unconventional wells.
- Artificial lift and production optimization concepts applicable to unconventional wells.
- Basics of artificial lift and the artificial lift life cycle.
- Real-time measurements and optimization in unconventional wells.

How is an Artificial Lift System Selected?

Figures 8 and 9 (abstracted from Weatherford's literature) list the relative capabilities and limitations of various forms of artificial lift systems. These tables are used to eliminate artificial lift mechanisms not suitable in terms of parameters in the first column. Another point to note is the numbers shown for maximum values are optimistic and, when operating conditions are approaching these limits, the end-user needs to take extra precaution by working with a knowledgeable equipment supplier. After elimination of unsuitable lift methods, a detailed design process is conducted beginning with evaluation of reservoir conditions, production limits, and changes in production parameters over the time horizon. Outflow performance with a particular lift system is conducted and then followed by economic calculations.

	GL	FL	PL
Max Depth	18,000 ft 5,486 m	22,000 ft 6,705 m	19,000 ft 5,791 m
Max Volume	75,000 bpd 12,000 M³/D	500 bpd 80 M³/D	200 bpd 32 M³/D
Max Temp	450°F 232°C	400°F 204°C	550°F 288°C
Corrosion Handling	Good to excellent	Excellent	Excellent
Gas Handling	Excellent	Excellent	Excellent
Solids Handling	Good	Good	Fair
Fluid Gravity (°API)	>15°	>8°	>15°
Servicing	Wireline or workover rig	Capillary unit	Wellhead catcher or wireline
Prime Mover	Compressor	Well natural energy	
Offshore	Excellent	Good	Special
System Efficiency	N/A	N/A	N/A

Figure 8. Capabilities of Reservoir Assisted Lift Systems (Source: Weatherford)

	RRL	PCP	ESP	HJP	HPP
Max Depth	16,000 ft 4,878 m	8,500 ft 2,591 m	15,000 ft 4,572 m	20,000 ft 6,100 m	17,000 ft 5,182 m
Max Volume	6,000 bpd 950 M³/D	5,000 bpd 790 M³/D	60,000 bpd 9,500 M³/D	35,000 5,560 M³/D	8,000 bpd 1,270 M³/D
Max Temp	550°F 288°C	302°F 150°C	550°F 288°C	550°F 288°C	550°F 288°C
Corrosion Handling	Good to Excellent	Fair	Good	Excellent	Good
Gas Handling	Fair to good	Good	Fair	Good	Fair
Solids Handling	Fair to good	Excellent	sand<40ppm	Good	Fair
Fluid Gravity (°API)	>8°	8°<API<40°	Viscosity <400 cp	≥6°	>8°
Servicing	Workover or pulling rig	Wireline or workover rig		Hydraulic or wireline	
Prime Mover	Gas or electric		Electric	Gas or electric	
Offshore	Limited	Limited	Excellent	Excellent	Good
System Efficiency	45% to 60%	50% to 75%	35% to 60%	10% to 30%	45% to 55%

Figure 9. Capabilities of Pump Assisted Lift Systems (Source: Weatherford)

In conclusion, artificial lift systems are important and essential tools for profitable and sustainable operations. They enable our broader goal of improving ultimate recovery by producing reservoirs beyond natural and enhanced recovery mechanisms.

Nomenclature:

ALS - Artificial Lift System
CBM, CSG - Coal Bed/Seam Methane Gas
ESP - Electronic Submersible Pump
FL - Foam Lift
GL - Gas-Lift System
HJP - Hydraulic Jet Pump System
HPP - Hydraulic Piston Pump System
HP - High Pressure
HT - High Temperature
IPR - Inflow Performance Relationship
NL - Naturally Lifted (Flowing) Well
OPR - Outflow Performance Relationship
PCP - Progressing Cavity Pump System
RRL - Reciprocating Rod Lift System
TDH - Total Dynamic Head

Symbols:

D - Diameter of Flow Path
f - Multiphase Friction Factor
P - Pressure
Z - Depth or Length
g, g_c - Gravitational Constants
v - Velocity of the Multiphase Mixture
θ - Angle of Inclination with Horizontal
ρ - Mixture Density

Upcoming Training Courses

Month	Dates	Course	Instructor
MAY	4/30-5/04	Well Log Interpretation	Willis
	07-08	PRMS & SEC Reserves and Resources Regulations	Lee
	09-10	Production Forecasting for Low Permeability Reservoirs	Lee
	14-16	Unconventional Resource Plays: Workshop	Sonnenberg
	17-18	Geosteering: Best Practices, Pitfalls & Applied Solutions	Woodward
	29-31	QC Techniques for Reviewing Prospects & Acquisitions	Shoup
JUNE	04-08	Applied Subsurface Geological Mapping 🚩	Agah
	11-13	Hydraulic Fracturing: Theory and Application	Miskimins
	18-22	Cased Hole and Production Log Evaluation	Smolen
	25-27	Petroleum Fluids and Source Rocks in E&P Projects	Milkov
JULY	09-13	Transient Well Testing	Kamal
	16-18	Reservoir Management of Unconventional Reservoirs: From Inception to Maturity (Midland, TX)	Kabir
	18-19	Petroleum Investment Analysis	Dalthorp
	26-27	Reservoir Scale Geomechanics	Fox
	7/30-8/03	Seismic Data (2D/3D/4D) Interpretation	Willis
	7/30-8/03	Artificial Lift and Production Optimization Solutions	Chokshi
AUG	06-10	The Book Cliffs Utah (Salt Lake City, UT)	Little
	06-10	Applied Subsurface Geological Mapping (Denver, CO) 🚩	Agah
	8/13-11/02	The Daniel J. Tearpock Geoscience Certification Program (Geoscience Bootcamp) 🥾	SCA Staff
	13	Basics of the Petroleum Industry 🥾	Howes
	14-17	Structural Styles in Petroleum Exploration and Production 🥾	Taylor
	18-19	Structural and Sequence Stratigraphy (Hill Country) 🥾	Taylor
	20-24	Practical Interpretation of Open Hole Logs 🥾	Maute
	27-31	Practical Seismic Exploration and Development 🥾	Willis
SEPT	04-07	Sequence Stratigraphy Applied to O&G Exploration 🥾	Lopez-Gamundi
	10-14	Applied Subsurface Geological Mapping 🚩 🥾	Agah
	17-19	Mapping Seismic Data Workshop 🥾	Cherry
	20-21	Basic Petroleum Engineering for Non-Engineers 🥾	Howes
	22	Modern Coastal Systems of Texas (Galveston, TX) 🥾	Wellner
	24-28	Carbonate Sedimentology and Sequence Stratigraphy	Lopez-Gamundi

🚩 = Flagship course 🥾 = Bootcamp course

All courses are located in Houston unless noted otherwise.

Reserve your seat today! For our full course listing, visit: www.scacompanies.com

About SCA

Our Services

Subsurface Consultants & Associates, LLC provides upstream consultancy and training to professionals in the oil and gas industry. Founded in 1988 by Daniel J. Tearpock, SCA's primary services are consulting and direct-hire recruiting, training, upstream projects and studies, quality assurance, and oil and gas advisory.

Excellence That Runs Deep

SCA is considered an industry leader in subsurface exploration and development interpretation and mapping. We provide the personnel, technology, and proven methodologies that foster success by enabling better business decisions.

AUTHORIZED IACET PROVIDER

IACET Authorized Provider

We have been accredited as an Authorized Provider by the International Association for Continuing Education and Training, which authorizes SCA to offer CEUs for its programs that qualify under the ANSI/IACET Standard. Professionals can fulfill their requirements by attending SCA training courses.

The People & Activities of SCA

Get an Edge

SCA's VP of Engineering Susan Howes (pictured right) presented at Rice University for SPE's "Get an Edge" Seminar. She spoke about resume development, interviewing skills, the hiring process, and the importance of soft skills.

Managing Your Career

Susan (pictured left, center) also spoke to a group of YPs at another SPE event entitled "Managing Your Career". Topics included what critical documents should be maintained throughout your career, how to gather information about opportunities, moving within your current company or looking for a role elsewhere, and what to expect after lining up a new job.

10700 Richmond Ave., Suite 325 Houston, TX 77042 | 713.789.2444 | www.scacompanies.com