Gas Lift Applied to Heavy Oil

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Outlin

Objective

Introduction (Subsea Layout and Gas Lift Arrangemen

Selection of the Artificial Lift Method

Fluid Properties

Multiphase Simulation x Test Result

Lessons Learned

Conclusion and Recommendation

Objecti

Some questions still rely on the ability of the gas-lift method to do good job when applied to heavy oil wells, mainly under a dee water scenario.

The aim of the forward analysis was to evaluate the performance he continuous gas lift method applied to lift heavy oil at lon distance satellite production wells in a low temperature deep wat scenario.

To compare predicted flow parameters against measured da (well production test).

As a basis to support the analysis, a satellite horizontal well Albacora Leste field, Campos Basin, Brazil has been selected.

7-ABL-62-H; Oil density 15 ºAPI)

Albacora Leste F

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bacora Leste: petroleum field located in the deep north area of
ampos Basin, offshore Brazil by 393,701 ft (120 Km) off the coa
rst oil Feb 2006).

Vater depths range: 2,624 to 6,562 ft (800 to 2000 m)

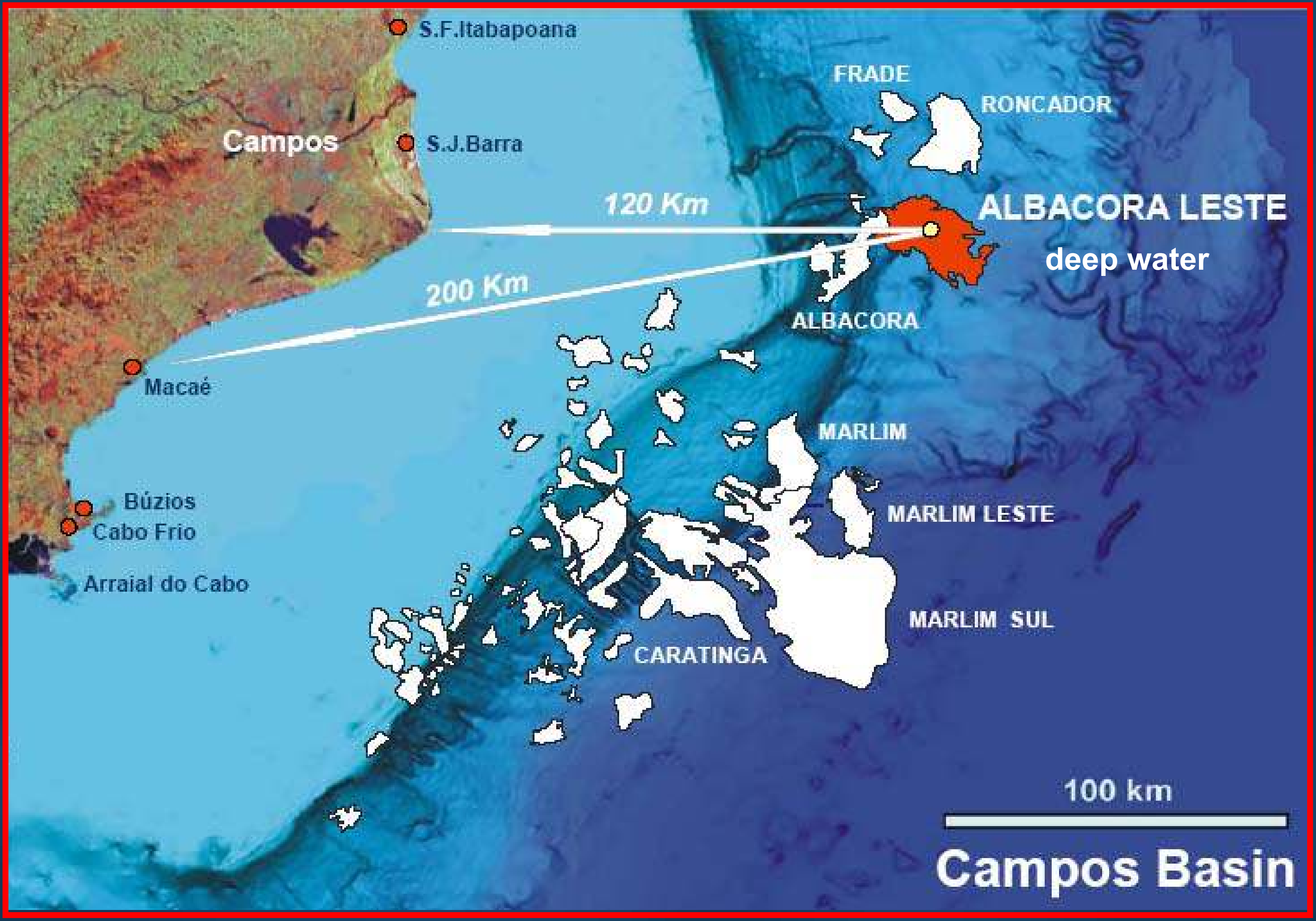
il densities range: 15 to 21 ºAPI (916 – 962 Kg/m^3)

umber of wells: 17 horizontal production wells
15 horizontal injection wells

oating platform: FPSO P-50 (4,035 ft water depth)
novative Differential Compliance Anchoring System (DICAS).

l lines and risers are flexibles and all production flowlines therm
sulated

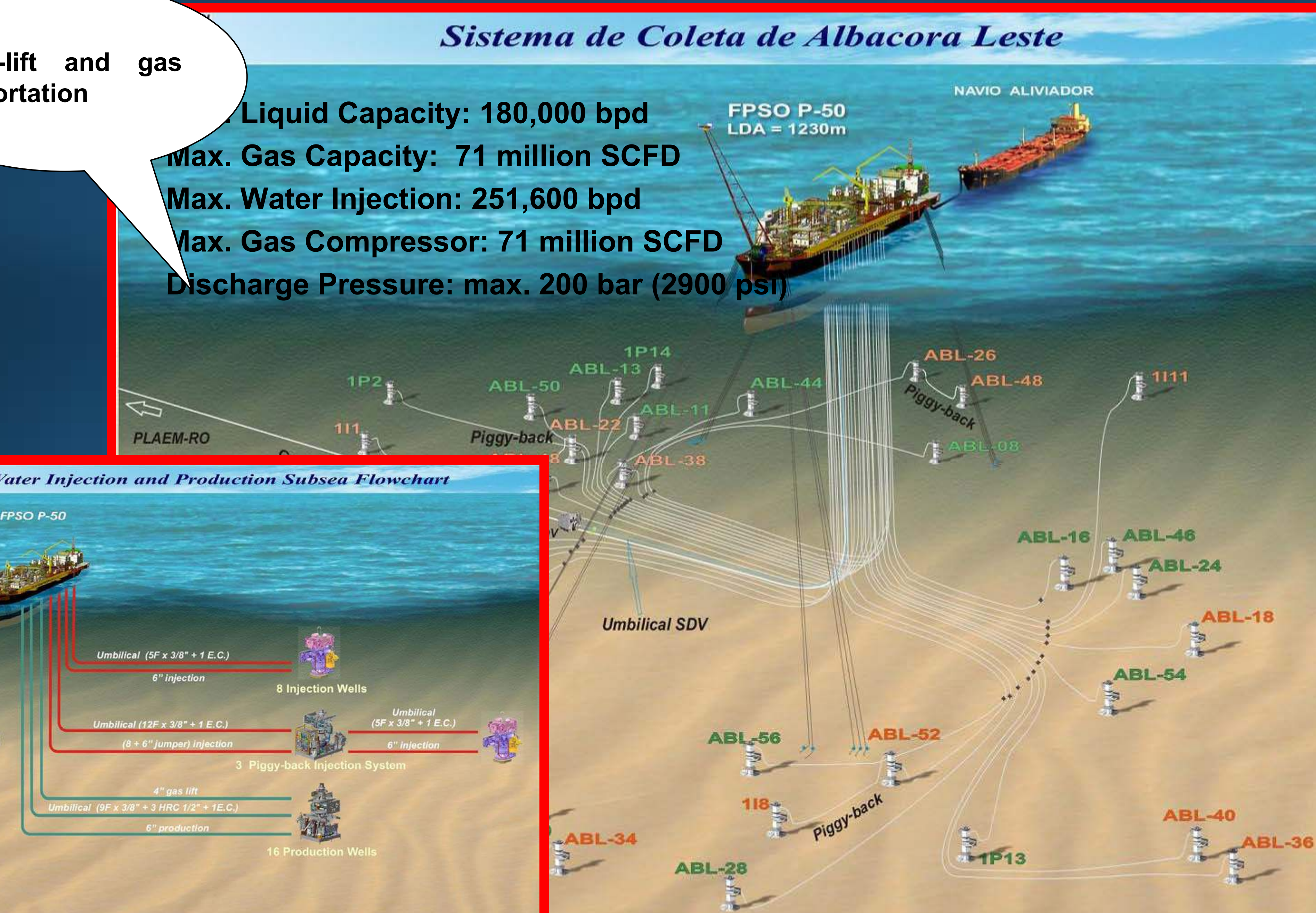
Field Location M



Albacora Leste Subsea Arrangem

-lift and gas
ortation

Liquid Capacity: 180,000 bpd
Max. Gas Capacity: 71 million SCFD
Max. Water Injection: 251,600 bpd
Max. Gas Compressor: 71 million SCFD
Discharge Pressure: max. 200 bar (2900 psi)



Selection of the Artificial Lift Met

alysis during the Design Phase selected two methods tential candidates for the field artificial lift: Electrical Submers mps (ESP) and Gas Lift.

espite ESP to be an approved technology for deep waters at time of the design phase was not still available to attend gh expect liquid flowrates.

ncertainty regarding reservoir parameters, including GOR, other main reason to eliminate ESP installation.

r technical reasons, gas Lift has been selected as the artif ethod to be applied to all production wells of the field.

as-Lift: uncertainty regarding the effect of low mixing of ga avy oils.

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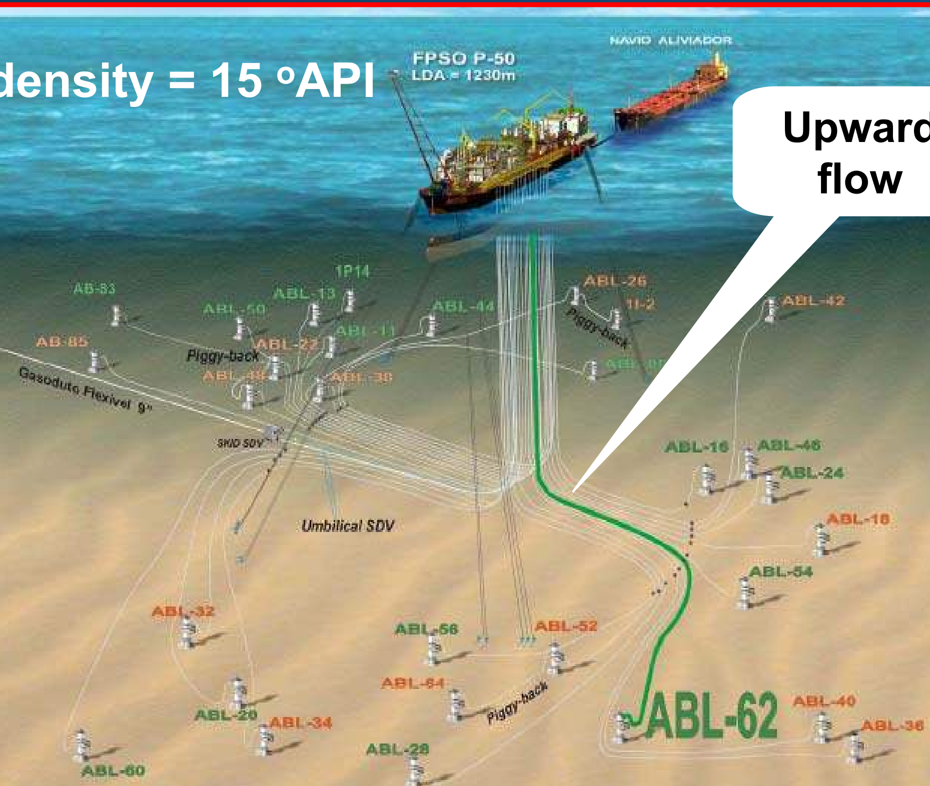
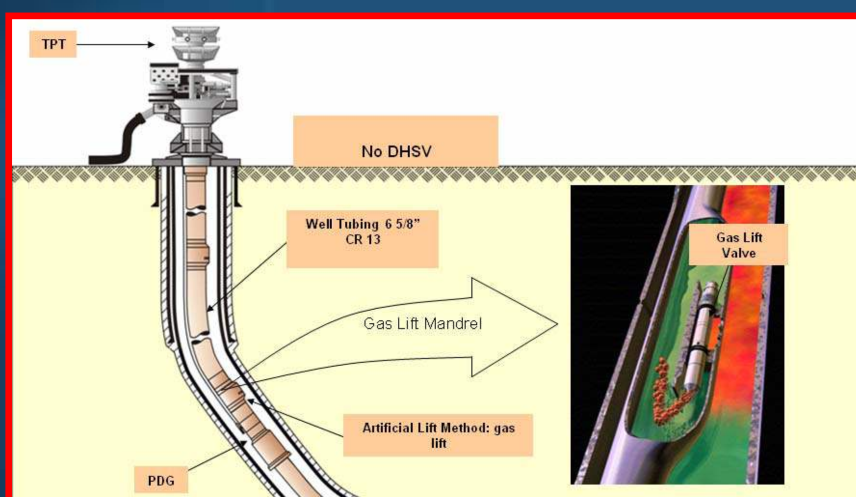
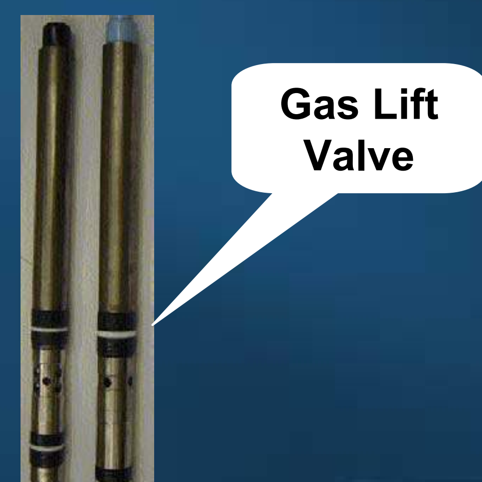
ABL-62 Well Da



Well	Horizontal
TVD	8333 ft (2540 m)
Reservoir Interval	8517/11811 ft
Well Xmas Tree	4626 ft (1410 m)
Well String	6 5/8" vam top cr 13
Production Line	6" (11407 ft)
Gas-Lift Line	4" (11407 ft)
Riser Catenary	5742 ft (1750 m)
Thermal Insulation (TEC)	2,86 w/m.oK
Gas-Lift Mandrel (tvd)	-7572 ft (-2308 m)
Gas-Lift Valve	RDO 5/16" x 1 ½"
PDG Mandrel (tvd)	-7621 ft (-2323 m)
IPR	19 $m^3/d/kgf/cm^2$ 8.402 bpd/psi
Reservoir Pressure @ -8333 ft	3211 psi





Artificial Lift Design Strate

Method: continuous gas-lift injection.

No pressure operated gas-lift valves installed along the we production tubing.

A very simple and reliable well completion comprising the installation of only one conventional gas-lift mandrel hostin an conventional orifice gas-lift valve.

Gas compressors installed topsides aiming to guarantee well kick off, continuous gas injection and gas exportation along all field production lifetime.

Flow Assurance Design Strate

- Thermal insulation applied to most of the well produ flowlines, aiming flowing arrival temperatures above the Appearance Temperature (WAT) and cooldown times allowi blowdown the critical flowlines when shutdowns occur.

- When pipe cleaning is required, the system was designed t a round-trip pig loop (foam pig) via the gas-lift line, pig-c over valve, back to the production line using high pressure g

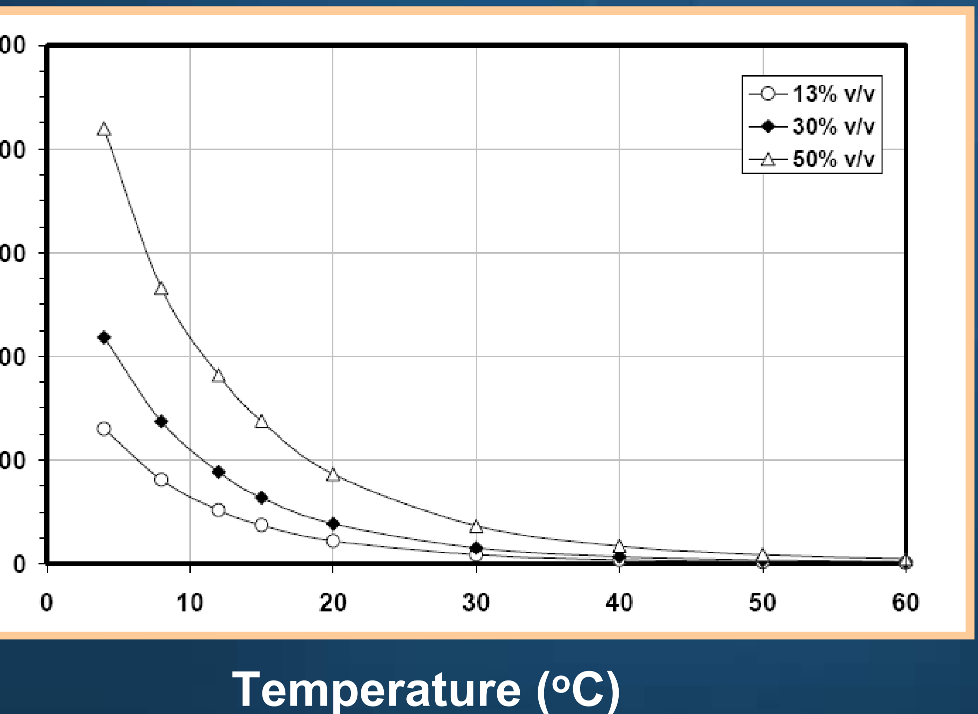
- A coiling-tubing technology was designed as contingenc allow wax removal or even hydrate blockage in c operating situations.

Fluid Proper

ad Oil Viscosity

(°F)	41	50	59	68	86	104	122
sc (cP)	24570	12742	6914	3750	1498	656	320

Rheological Characterization: high stable water in oil emulsion up to 7 ercut (high viscous emulsions behave as pseudo-plastic fluid).



Analysis Too

PI ProcessBook (OSI Software): graphical user interface to monitor real-time data on well flow and gas lift injection parameters.

Marlim (Petrobras code), Pipesim® and Olga® codes for stea state and transient multiphase simulations, gas-lift design, ga allocation and gas-lift optimization.

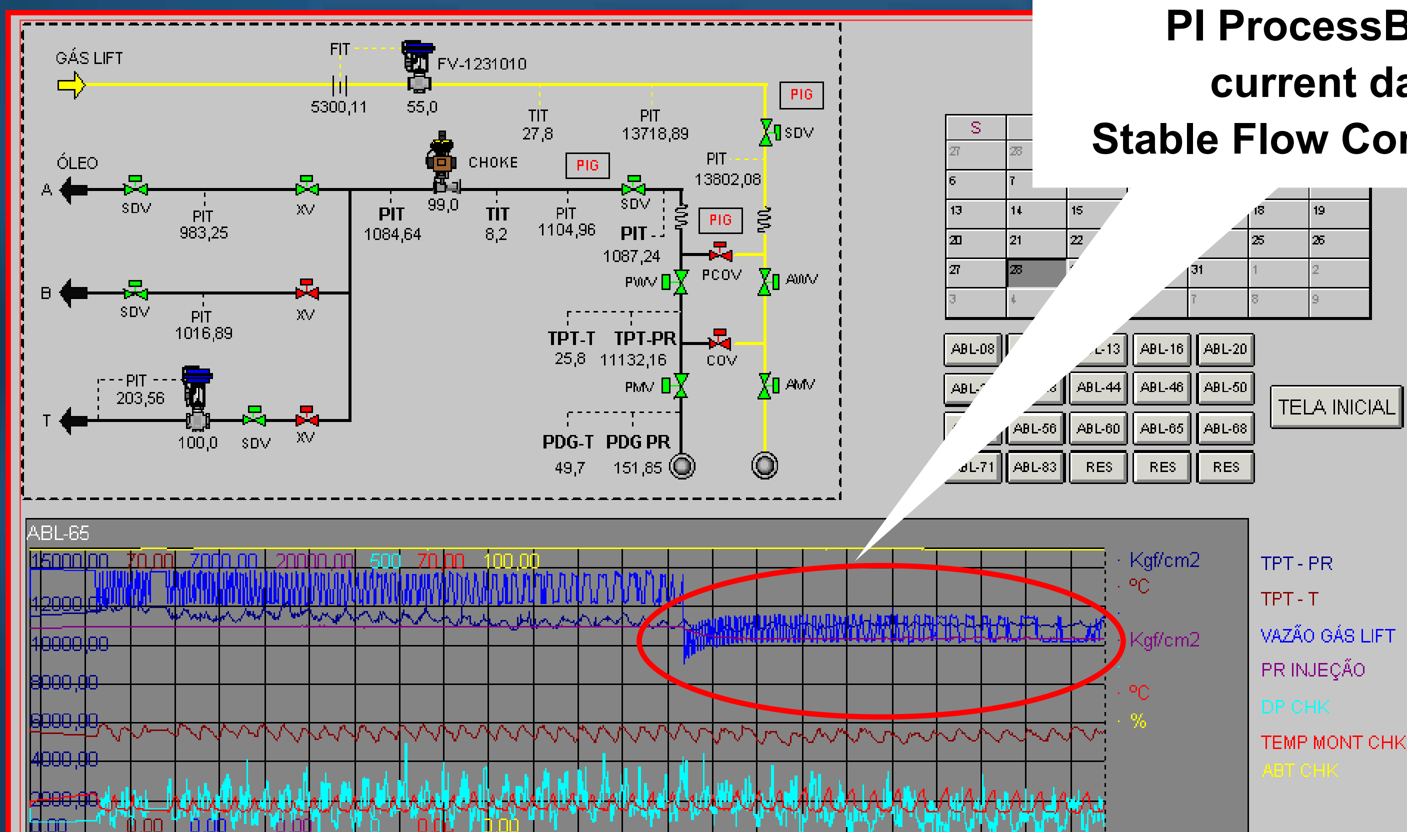
Well Production Test data (fluid flowrates, GOR, watercuts, e

Laboratory: PVT analysis and Oil Rheological Characterizatio

Well Production Tes

Production Test	Qoil BPD	Qwater BPD	Qgas 10^6 SCFD	Qgas lift MM SCFD	GOR SCF/STB	Watercut %	Flowing Conditions
2007/2/1	9240	266	6.90	0	746	2.8	Stable
2007/2/17	5013	465	1.31	6.52	261	8.5	Stable
2007/3/1	4258	535	1.22	7.07	286	11.2	Stable
2007/3/9	3428	704	1.11	7.03	323	17.0	Stable
2007/3/17	3277	799	0.92	7.42	280	19.6	Stable
2007/4/17	2359	1239	0.50	7.45	212	34.4	Stable
2007/6/14	2560	1352	1.15	7.63	449	34.6	Stable
2007/8/27	881	1340	1.47	5.19	1668	60.0	Stable
2007/9/5	843	1591	1.59	5.94	1886	65.4	Stable

PI ProcessBook current data
Stable Flow Conditions



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Predicted x Measur

uction Test: 2007/3/17 =280 scf/stb and BSW=19.6%	Predicted	Production Test
owrate (BPD)	3560	3277
Lift Injection (10^6 SCFD)	7.0	7.42
s-lift (PSI)	2538	2532
val (°F)	45.9	44.2
P (PSI)	1330	1349
T (°F)	107	not available
P (PSI)	1929	1958
T (°F)	119	121

Predicted x Measur

uction Test: 2007/3/17 =1886 scf/stb and BSW=56%	Predicted	Production Test
owrate (BPD)	1446	843
Lift Injection (10^6 SCFD)	4.41	5.94
s-lift (PSI)	1929	2205
val (°F)	66	60
P (PSI)	1494	1550
T (°F)	80	74
P (PSI)	2190	2219
T (°F)	122	121

As watercut increases and a viscous emulsion is formed, it is not easy to adjust the code to match the predicted parameters against measured data

Performance of the artificial lift method

t was expect to occur?	Good performance of the continuous ga method for heavy oil as predicted by previous multiphase simulation analysis.
t really happened?	Prediction confirmed. So far, the gas-lift me is doing a good job even for high meas watercuts.
t lessons were ned?	Gas-lift method can be applied for the field heavy oil (°15 API lower limit).

What happened during the well start-up?

at was expect to occur at well start-up?	The predicted parameters was suppo to agree with the measured data from ProcessBook and Production Test continuous gas-lift injection expected.
at really happened?	Prediction x Actual behavior (different) Natural flowing from reservoir occurre (No gas lift injection was required for days)
at may have caused the erence?	Reservoir parameters (transient)

Specification of the gas-lift orifice diameter.

/hat was expect to occur ?	Pressure drop through the 5/16" gas-lif orifice valve as predicted by simulation.
/hat really happened?	A high pressure drop through the gas lift orifice valve occurred.
/hat may have caused the ifference?	More gas injection required for gas lift.

Stable flow condition with gas-lift

hat was expect to occur ?	Not expected any difficult to keep th well flowing under stable flo condition.
hat really happened?	Stable flow condition only happene with higher gas-lift injection volume than predicted.
hat may have caused the fference?	Reservoir parameters changed, fluid behavior and low mixing of gas lift in heavy oil.

Lessons Learne

What was expect to occur ?	Actual gas lift injection flowrates match the predicted one.
What really happened?	Measured gas lift flowrates for sta flow conditions were higher th predicted.
What may have caused the difference?	Difficult mixing of gas into heavy oil and fluid flow behavior.

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Lessons Learned

at was expect to occur ?	Difficult to adjust the code flow parame predictions against the measured data higher watercuts.
at really happened?	Confirmed.
at may have caused the erence?	Despite the current improvement, more efforts are required to model the complex fluid behavior and multiphase flow of hea oil in pipes.

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Conclusion and Recommendat

So far, having the selected well experienced modifications o reservoir parameters (GOR, watercut, IPR, reservoir pressure), maximum 65% watercut was reached. The produced oil is st forming a stable high viscous water in oil emulsion and th practical results have shown that gas-lift is performing successfully keeping stable the well production to the platform and the gas li njection parameters.

n order to obtain good predictions, more efforts are require o model the complex fluid behavior and complex multiphas flow for heavy oil gas lift. In addition to that, a representativ oil characterization must be provided from lab. This includ he PVT analisys and rheologycal characterization of th complex emulsions formed.

Conclusion and Recommendati

Attention should be given to the high required kick-off pressure t
art-up the well after long shutdowns. Eventually, it may b
cessary to previously remove the high viscous emulsion from th
oduction line before the start-up begins.

In terms of gas-lift orifice valve specification, attention should b
ven to an eventual increase of gas injection volume to improv
xing of gas in heavy oil. An orifice diameter under estimated ma
use a very high pressure drop through the gas lift valve and henc
gh gas discharge pressures are required. In this case, using a
ge orifice diameter or even a venture orifice configuration shoul
considered.


Thank You
Obrigado!