DELIQUIFICATION & REVIVAL
OF OIL AND GAS WELLS
USING SURFACE JET PUMPS
Recent applications and experience

By: Sacha Sarshar, Caltec
CONTENTS;

• CAUSES OF LIQUID LOADING
• CHARACTERISTICS OF FLOW THROUGH WELL BORE-FLOW REGIME MAP
• SOLUTIONS TO DELIQUIFY OIL OR GAS WELLS
• IMPACT OF REDUCING THE FWHP
• INTRODUCTION TO SURFACE JET PUMP (SJP)
• PERFORMANCE OF JET PUMP
• EFFECT OF LIQUIDS IN LP AND HP GAS, AND HOW TO COPE WITH IT
• BEST LOCATION FOR SJPS, ONSHORE AND OFFSHORE
• OPERATION AND CONTROL/INSTRUMENTATION
• HOW TO ASSESS THE PERFORMANCE OF THE SJP
CONTENTS CONTINUED....

• HOW TO COPE WITH CHANGES IN HP OR LP PRODUCTION AND FLOW RATES
• HOW TO PREDICT PRODUCTION RATE AND INCREASE IN PRODUCTION
• DESIGN ISSUES; CODES, MATERIAL
• OPERATION ISSUES; - NOISE, TEMPERATURE, EROSION, CORROSION
• FIELD EXAMPLES
• ECONOMICS
• QUESTIONS AND ANSWERS
EFFECT OF FIELD DEPLETION ON WELL BORE PRESSURE

Inflow Parameters will change as the field depletes and the shape of the inflow performance curve will change, potentially due to factors like:

✓ Changes in relative permeabilities over time
  ▪ Increase in water production

✓ Reservoir compaction
  ▪ Closure of natural fractures

✓ Production below saturation pressures
  ▪ Gas is released from oil resulting an increase of GOR
  ▪ Condensate is dropping in the reservoir resulting a decrease of LGR – condensate banking.
Effect of field depletion on well bore pressure and production

- Increase of Non Darcy effect due to added turbulence
- Increase of effective stress (difference between the overburden and fluid pressures)
  - Closure of near well bore micro fractures
  - Closure of induced fractures (fracture conductivity reduction)
- Near wellbore damage
  - Fines migration build-up, Screen plugging
  - Sand production and build-up in well sump
  - Scale build-up / salt deposition
WELL FLOW PERFORMANCE PARAMETERS

• The well inflow rate is driven by:
  ✓ Reservoir pressure/pressure maintenance
  ✓ Well mechanical constraints (solid production, erosion, completion envelope, screen integrity, water / gas coning
  ✓ Back pressure on well (FWHP &FBHP)
  ✓ Flow regime within the well bore
  ✓ Phase envelope
  ✓ Mechanical skin (near wellbore damage, perforation skin, partial penetration skin, completion skin, sand control
  ✓ Non Darcy skin
  ✓ Well architecture (tubing size, well depth, profile ...)
  ✓ Facilities constraints (e.g. Water production capacity)
MAIN CAUSES OF LIQUID BUILD UP IN WELLS

• Low velocity of gas
• High FWHP, dictated by downstream process system
• Multiphase flow through well bore, leads to flow regimes such as Churn flow, slugging etc, which affect both the hydrostatic head and frictional losses
• Effect of viscosity & density of liquids and gas
• Inclined & horizontal profile of wells contribute to G-L separation within the well bore and generation of slugs;
• Liquid build up in pipelines could also aggravate the problem, increasing FWHP
• The flowing bottom hole pressure (FBHP) is the main factor affecting production, but FWHP is also a useful guide
COMPARISON OF FLOW REGIMES IN HORIZONTAL AND VERTICAL PIPES

- **Intermittent**
- **Dispersed Bubble**
- **Annular Mist**
- **Wavy**
- **Stratified**

**Superficial Liquid Velocity (m/s)**

- **Slug**
- **Annular Mist**
- **Froth**
- **Bubble**

**Superficial Gas Velocity (m/s)**

**V ≥ 5 m/s**
TYPICAL INSTANTANEOUS FLOW REGIME ASSOCIATED WITH MULTIPHASE FLOW

TYPICAL TWO-PHASE FLOW REGIME IN A PIPE
SEVERITY AND EXTENT OF LIQUID BUILD-UP

HOW SICK IS THE PATIENT?! 

- CASES WHEN LOWERING THE FWHP OR REGULAR SHUT-DOWN IS SUFFICIENT TO REVIVE THE WELL - EFFECTIVENESS AT WHAT FWHP/ FBHP?

- CASES WHEN AN INITIAL DELIQUIFICATION IS NEEDED, FOLLOWED BY OPERATION UNDER A LOWER FWHP, USING SURFACE JET PUMPS.
  - SEVERAL OPTIONS EXIST FOR THE INITIAL DELIQUIFICATION SUCH AS USE OF FOAMING AGENTS OR USE OF DOWNHOLE SYSTEMS.

- CASES WHERE A DOWNHOLE SYSTEM /SOLUTION IS NEEDED, BUT REDUCING FWHP WILL ENHANCE PRODUCTION
SELECTION OF SUITABLE SOLUTION DEPENDS ON;

• SEVERITY OF LIQUID LOADING
• RESERVOIR PRESSURE
• WELL INFLOW CHARACTERISTICS
• AVAILABILITY OF HP FLUIDS IF SJP IS USED
• PLATFORM OR SITE CONSTRAINTS
• ECNOMICS

Use of surface jet pumps is the simplest technique, provided there is sufficient source of motive flow
SELECTION PROCESS FOR WELL DELIQUIFICATION

Case 1 (Mild):
Lowering the FWHP by SJP is sufficient

Case 2 (Medium):
Well loaded, initial offloading is needed
Lower FWHP by SJP after initial offloading
Use SJP plus intermittent offloading

Case 3 (Severe):
Downhole system needed
SJP could enhance downhole system
COMMON REMEDIAL SOLUTIONS TO WELL DE-QUEIFICATION

- Regular gas blow down to atmosphere
- Lower flowing wellhead pressure (use of jet pump technology or other methods)
- Well shut-in Intermittently
- Use of foaming agents/intermittent or continuous
- Tubing size modification/velocity string
- Artificial lift systems (Downhole) including downhole jet pumps
- Best solution is dictated by well status, reservoir characteristics, available source of energy, platform constraints and economic consideration
INTRODUCTION TO SURFACE JET PUMPS
Surface Jet Pump Technology

Some possible HP sources:
- HP WELLS (oil or gas wells)
- HP GAS FROM PROCESS SYSTEM
- HP LIQUID (OIL, WATER)
- COMPRESSOR RECYCLED GAS
- A SINGLE PHASE (LIQUID) PUMP
Jet Pump Flow Dynamics

- HP Flow
- LP Flow
- Combined Flow

Diagram showing the flow dynamics with velocity and pressure graphs.

- HP
- LP
- Discharge

- Nozzle
- Mixing tube
- Diffuser

Diagram labels:
- Velocity
- Pressure

Diagram areas:
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
MAIN FACTORS AFFECTING THE PERFORMANCE

~ HP/LP PRESSURE RATIO
~ HP/LP FLOW RATIO
~ GAS/LIQUID RATIO (LP FLOW)

Secondary factors:
- Mol. weight
- Temperature
- Liquid in gas phase

Slide 17
EFFECT OF LIQUIDS PRESENT IN LP GAS

Gas as the motive flow
MULTIPHASE CHOKING IN JET PUMP:
A CRITICAL FACTOR NOT COMMONLY KNOWN
TYPES AND RANGES OF SJP APPLICATIONS

• Revival of dead wells (oil&gas wells)/ de-liquification
• Boost production from oil or gas wells
• Boost pressure of LP gas in a process system
• De-bottleneck compressors
• Eliminate intermediate compressors
• Prevent HP wells impose back pressure on LP wells
• Prevent flaring LP gas
• Others to meet process requirements
SOME FIELD EXAMPLES
WELL REVIVAL – SPILAMBERTO FIELD, ITALY

Source of HP flow; HP gas well

Benefits;

Gain in gas production by 23,000 sm3/d (0.812MMscfd) For almost two years
**BP Inde, UKCS**

**Solution:** Used HP recycled gas to power SJP, to draw-in low pressure satellite Shell wells

**Benefits**

- Used 68 MMscfd of gas from LP Shell wells into the exiting facilities.
- Production increased by 25%
- Increased intake capacity of compressor
- De- bottlenecked exiting compressor
- Removed liquids from LP wells and the pipeline

**Award winning solution**
**Solution**: HP gas from the existing compressor on recycle used to power the jet pump

**Benefits**
- Lowered arrival pressure at the platform by 200 psi
- Increased gas velocity and improved flow regime in wells
- Removed bulk of liquids in the pipeline, causing a further 140 psi drop at the wellhead (340 psi total pressure drop).
- Production increased by 24%.
- 2.5 Bscf of otherwise lost reserves recovered.
- Flow delivered at higher pressure to compressor suction increased compressor throughput.

\[
\text{Php/Plp=4.9, Qhp/Qlp= 2.11, Pd/Plp=2}
\]
Groet field surface jet pump

At eductor:
Pressure ratio HP/LP = 5
Flow ratio HP/LP = 3
Gas liquid ratio (m3 liquid per 1 million m3 gas)
HP well 65
LP well 30
Bergen Drying Facility surface jet pump

Case 1 At eductor:
Pressure ratio HP/LP = 4
Flow ratio HP/LP = 2.3

Case 2 At eductor:
Pressure ratio HP/LP = 10
Flow ratio HP/LP = 7
Production optimisation by surface jet pump

After ten months maximum stable flow reached using SJP

Re-start of the well after a closed-in period of two years, with reduced FTHP from 40 to 26 bar using SJP.
Alaska, USA

Solution; Used HP gas from long-string to off-load the well via surface jet pump

Benefits:

- Used available wasted energy to off-load the well.
- Total production from well raised to 7 MMscfd from 2.5 MMscfd. Production increased by 180%.
- Liquid loading cycle was reduced, hence more sustainable production gain.
ANGSI FIELD MALAYSIA
REVIVAL OF 16 GAS WELLS
OIL PRODUCTION - WELLCOM BOOST SYSTEM

HIGH PRESSURE GAS

JET PUMP

GAS

TO PIPELINE

Commingler

LOW PRESSURE OIL WELLS

I-SEP

GAS

LIQUID

COMMINGLER

BOOSTER PUMP

LIQUID

Php/Plp=7.9

Qhp/Qlp=3.23

Pd/Plp=1.46
WELLCOM SYSTEM ; OFFSHORE MALAYSIA

Lift gas as the motive flow + A booster pump to boost the liquid phase
COMPACT SEPARATOR TO SEPARATE GAS FROM LIQUIDS

I-SEP
SIZE MATTERS!
On-Shore, Italy
HP oil well as the source of motive flow

Benefits

• Backpressure reduction on the wells of up to 11 bar was achieved.

• Simple to operate with no rotating parts

• Net extra oil gain of 350 bbl/d with additional 1.5 MMscfd of gas was achieved.

Multi Awards winning solution
WELLCOM APPLICATION: Cendor, Malaysia

WELLCOM BOOSTING SYSTEM

Wellcom oil system; multiphase HP wells were used to bring in closed low pressure oil wells.

Benefits

• Used available energy from HP well
• 20% pressure boost for LP wells.
• Increased production by over 35% (150 b/d)
• Improved flow regime in well bore, stabilising production.

FTHP 360 psia

FROM HP WELL

3612 b/d

I-SEP

LIQUID

JET PUMP

TO PROCESS SYSTEM

87 psia

Dp FWHP; 17.4 psi

FTHP 69.6 PSIA

FROM LP WELL

450 b/d+0.138 MMSCFD
Record of flowing bottomhole pressure before and after installing the jet pump system

Flowing bottomhole pressure (FBHP)

Dp at wellhead = 17.4 psi

FBHP Dp = 140 psi
USES OF THE TEST SEPARATOR

• Well testing
• Well testing/metering at reduced FTHP
• Well revival
WELL REVIVAL USING THE TEST SEPARATOR

APPLIES TO BOTH GAS AND OIL WELLS

- HP Gas
- Gas Jet Pump
- To vent or flare (option 3)
- Liquid Jet PUMP
- Option 2
- Closed drain (option 1)

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EFFECT OF SJP COMBINED WITH GAS LIFT INCREASED PRODUCTION

- Gaslift injection system
- Pay zone
- Production via Tubing
- Lift gas
- Wellproduction
- Produced Oil Flow rate
- Gaslift Injection Flow rate
- To downstream process
- Additional production
- Wellcom system & Gaslift injection
- Gaslift injection

SJP

HP

# EFFECT OF COMBINED GAS LIFT AND SJP

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<td>S.P. Turbulent</td>
<td>Slug</td>
<td>Slug</td>
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<th>FWHP (psig)</th>
<th>300</th>
<th>150</th>
<th>300</th>
<th>150</th>
<th>300</th>
<th>150</th>
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<td>3714</td>
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<td>Oil flow rate (bbl/d)</td>
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<td>3642</td>
<td>3875</td>
<td>3845</td>
<td>3998</td>
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<tr>
<td>dQ (bbl/d)</td>
<td>-</td>
<td>571</td>
<td>773</td>
<td>1006 **</td>
<td>976 **</td>
<td>1129</td>
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<td>Water flow rate (bbl/d)</td>
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<td>5137</td>
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<td>5300</td>
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<td>Gas flow rate (MMscfd)</td>
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<td>3.1</td>
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Comparison of Gas Lift and use of SJP's and Effect on Production Increase
USE OF SJP TO RAISE THE PRESSURE OF LIFT GAS FOR INCREASING GAS INJECTION DEPTH
SOME ISSUES RELATED TO DOWNHOLE JET PUMPS
Effectiveness of downhole jet pumps for well revival

• Traditionally liquid has been the motive flow. Effective mainly for maintaining production from shallow oil wells with low GOR

• Effective in lifting heavy oil using a diluent fluid to reduce viscosity (Vega field- Agip)

• Limited experience in using gas as the motive flow. HP gas is not effective in boosting the bottomhole pressure

• Gas can be injected at bottomhole as lift gas via a number of specially designed nozzles to generate a good mixture.
### PDVSA EXPERIENCE OF DOWNHOLE JET PUMPS

#### TABLE 1 - FIELD TESTS RESULTS

<table>
<thead>
<tr>
<th>Well</th>
<th>Qg (Mscfd)</th>
<th>Qo (bopd)</th>
<th>Preservoir (psi)</th>
<th>Datum (feet)</th>
<th>Throat (inch)</th>
<th>Nozzle (inch)</th>
<th>GOR (scf/bbl)</th>
<th>Watercut (%)</th>
<th>Oil Increase (bopd)</th>
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<tr>
<td>1</td>
<td>997</td>
<td>215</td>
<td>1300</td>
<td>11000</td>
<td>3/4</td>
<td>10/64</td>
<td>2300</td>
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<td>5</td>
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<tr>
<td>2</td>
<td>1457</td>
<td>290</td>
<td>1300</td>
<td>11000</td>
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<td>12/64</td>
<td>400</td>
<td>3</td>
<td>120</td>
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<td>479</td>
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<td>9000</td>
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<td>12</td>
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<td>6</td>
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<td>1100</td>
<td>7000</td>
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<td>945</td>
<td>11750</td>
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<td>6500</td>
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<td>10/64</td>
<td>2000</td>
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*Autolift
FACTORS TO CONSIDER FOR USE OF DOWNHOLE JET PUMPS

• PRODUCTION (OIL OR GAS)
• GOR AND GVF
• WELL DEPTH AND PROFILE
• WELL FLUIDS STATUS AT BOTTOMHOLE (GVF)
• FOR OIL WELLS USE OF JET PUMP AND HP GAS AS THE MOTIVE FLOW WILL BE BENEFICIAL - IN THIS CASE ALSO CONSIDER USE OF MULTI-NOZZLE GAS INJECTION
DESIGN & OPERATION ISSUES

• NOISE
• JT EFFECT
• INSTRUMENTATION
• CONTROL
• CHANGE OF INTERNALS
• PERFORMANCE MONITORING/ACCEPTANCE
• MATERIALS/CODES
In-line Acoustic silencers for LP and Discharge Side Streams
RECOMMENDED INSTRUMENTATION FOR SURFACE JET PUMP SYSTEM

Recommended Instrumentation for Jet Pump System

MEASURING THE LP GAS FLOW RATE IS RECOMMENDED
PERFORMANCE OF THE SJP AND EFFECT OF HP AND LP PRESSURE AND FLOW RATE

• Nozzle performance
• SJP response to LP flow rate
• Well performance VS SJP performance
Angsi Jet Pump HP Base Case Nozzle Performance

HP Nozzle Design conditions
Pressure = 100 barg
Flowrate = 60 MMscfd

Inlet HP Pressure (barg)

Inlet HP Gas Flowrate (MMscfd)

Operating point 1
Operating point 2
Operating point 3

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Base Case Surface Jet Pump (SJP) Performance

LP pressures vs. LP intake flow rates and the effect of liquid on SJP performance

SJP Discharge Pressure = 50 barg

Operating curve 1

Double LP liquid flow rate:
LP = 24.65 MMscfd @ 46.8 barg
+ 4432 bbl/d liquid

SJP design point:
HP = 60 MMscfd @ 100 barg
LP = 24.65 MMscfd @ 41.8 barg
+ 2216 bbl/d liquid
Discharge = 50 barg

No LP liquid flow rate:
LP = 24.65 MMscfd @ 36.8 barg
+ 0 bbl/d liquid

Maximum flow through SJP before choking

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CHANGES TO PI AT DIFFERENT FWHPs

HOW THE PERFORMANCE OF THE WELL AND THE SJP MATCH

KEY; DD1 & DD2; DRAWDOWN 1&2
MATERIALS/CODES/ORIENTATION/LOCATION

• MATERIALS BASED ON FLUIDS COMPOSITION AND COMPATIBILITY WITH PIPE WORK (CS, STAINLESS STEEL, DUPLEX..)
• CODES; PIPELINE CODE (B31.3), PED, LOCAL/CLIENT REGULATIONS.
• ORIENTATION; HORIZONTAL, VERTICAL, INCLINED
• LOCATION; DICTATED BY SITE CONDITIONS
Gas Jet Pump System

Skid availability: 4 to 6 weeks from order

Motive fluid: HP Gas

HP Inlet pressure: 50 - 140 bar (*)

LP Pressure boost: 5 - 20 bar (*)

Pressure rating: ANSI 1500#

Material: LTCS NACE

CTP sizes (Jp-6): HP 3", LP 4", Discharge 6"

CTP sizes (Jp-10): HP 6", LP 8", Discharge 10"

CTP sizes (Jp-16): HP 8", LP 12", Discharge 16"
ECONOMICS; USE OF SURFACE JET PUMPS

• Low capital cost
• Capital recovery within a few weeks to a few months
• Short delivery period; 8 to 14 weeks
• Practically no operation cost /passive operation
• Practically no maintenance cost
• Alternative solutions more complex and costlier
• Rental option available to minimise capital cost
• Short life period is economically acceptable
• Could enhance what is achieved by other deliquification systems
CLOSING REMARKS

• Simplicity & cost effectiveness makes jet pump solutions very attractive & economical
• A good tool for initial well deliquification before the situation worsens
• In addition to economic benefits, eliminating intermediate compressors, deferring compressor upgrading or reducing liquid hold up in pipelines are additional benefits
• The system can work well with other deliquification solutions
• Installing tie-in points during shut downs simplifies installation
• Rental option justifies very short operation life
THANK YOU
QUESTIONS WELLCOME