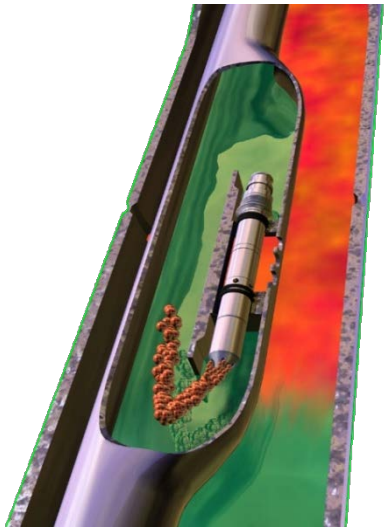
Weatherford®

Horizontal Production Solutions

Presented by Samuel Michaud

ICoTA 2011



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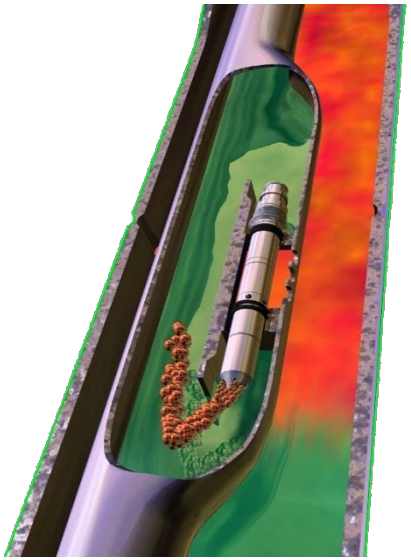
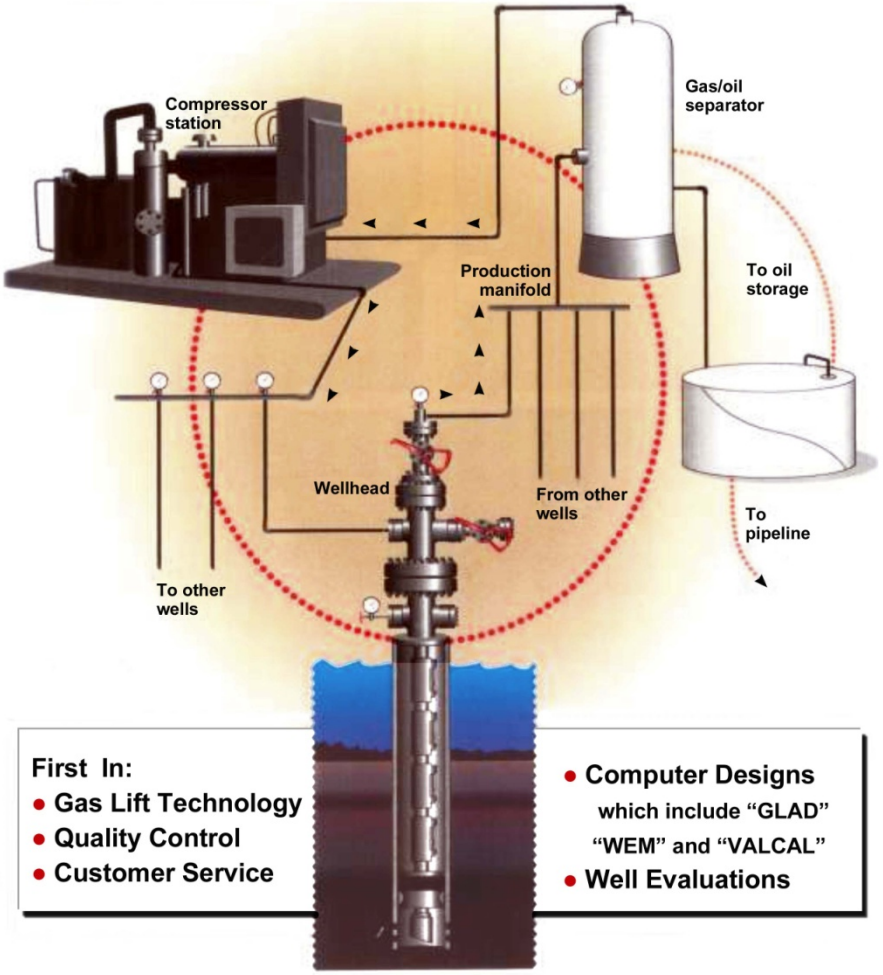
Gas Lift

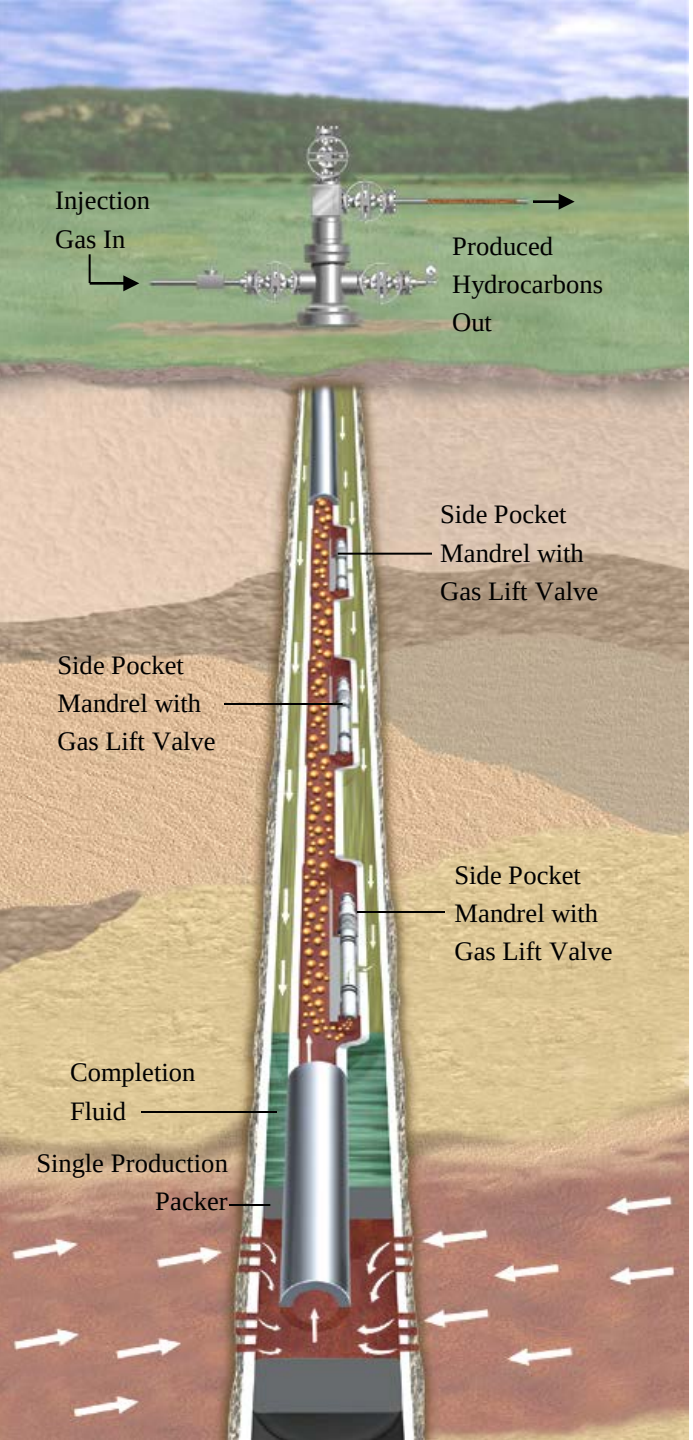


- Theory, Application, and Advantages
- Horizontal Production Challenges
- Solutions
- Coil Tubing Gas Lift
- Coil Tubing SAGD Gas Lift

Theory / Application - Gas Lift Objectives and Process

- To lift as deep as possible within constraints of production system
- Inject gas requirements through one single valve station





Applications

- Return dead or loaded wells back to production
- Increase production in flowing wells
- Wide range of production rates
- Remove or unload fluids from gas wells and/or keep gas well unloaded
- Good operation in high GOR wells
- Back flow salt water disposal or injection wells
- No moving parts
- Sand production not a major problem

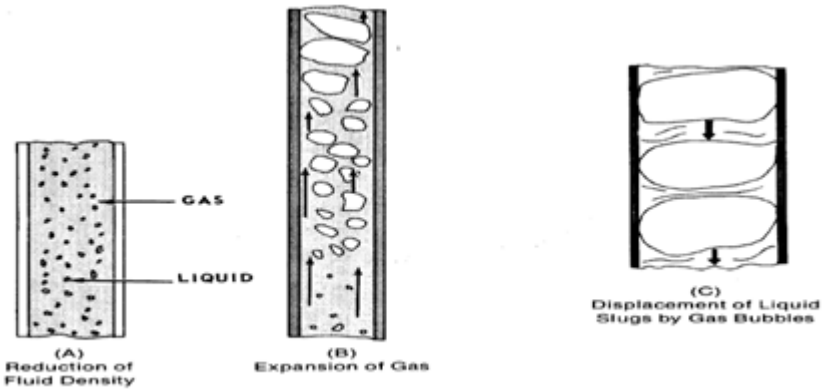
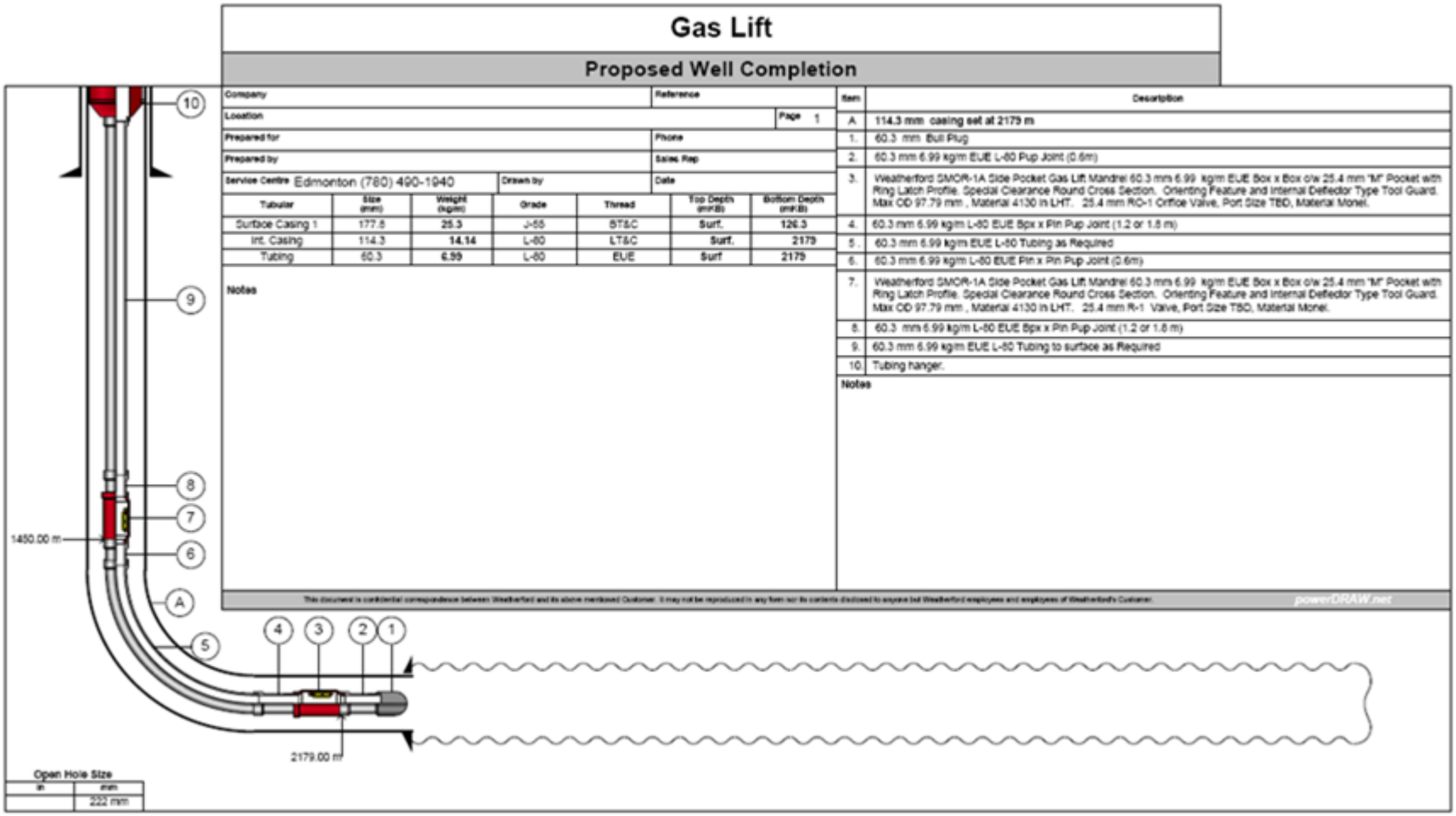


Fig. 1-4 — Three effects of gas in a gas lift well

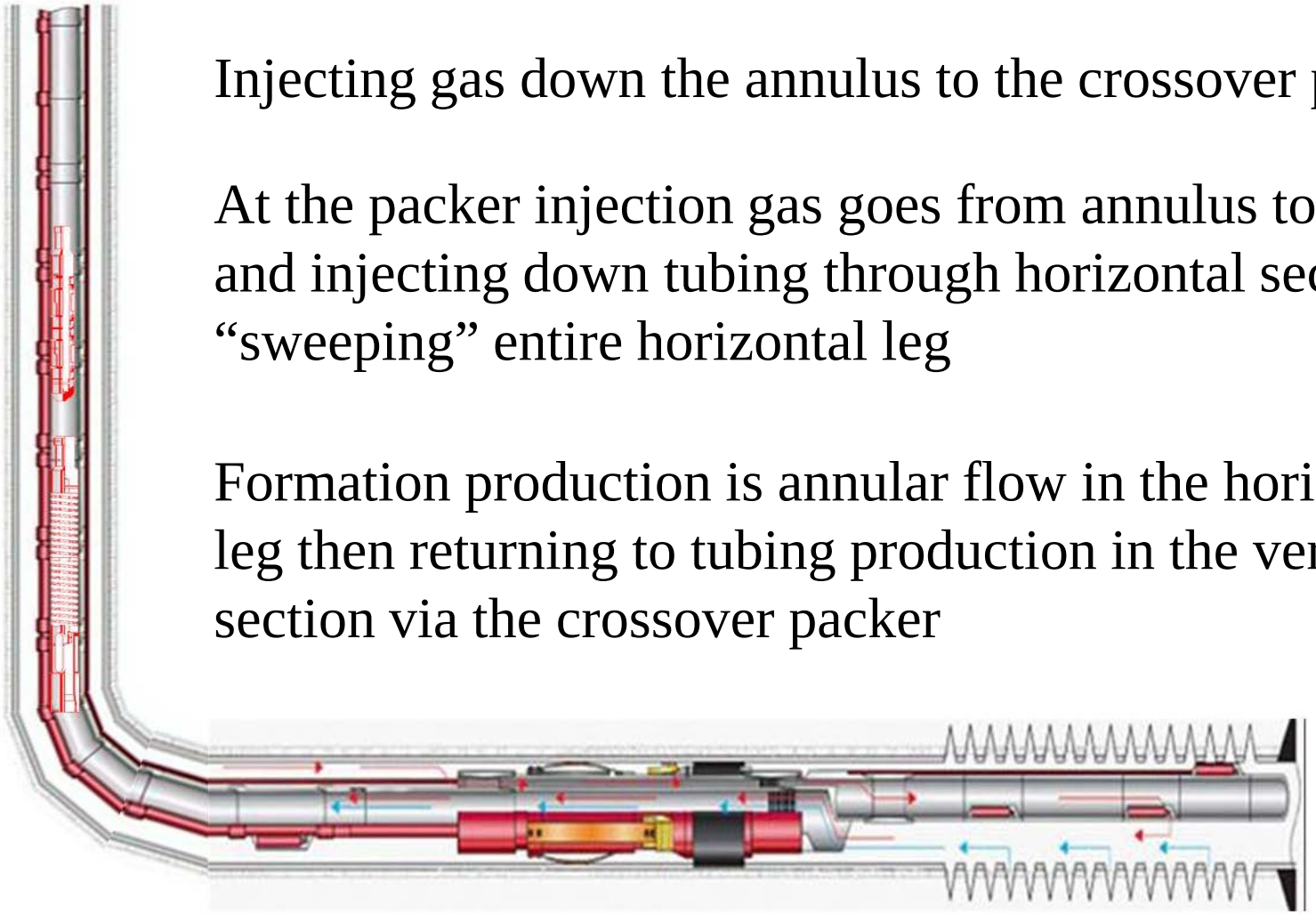
Horizontal Production Challenges

- Challenges with traditional methods of artificial lift providing lift from the HZ section
- Logistics of getting equipment down around the 90 degree heel
- Life span and maintenance of equipment run past 90 degrees
- Commonly a lot of sand build-up in HZ section

Horizontal Production– Gas Lift



Horizontal Production– Gas Lift



Injecting gas down the annulus to the crossover packer

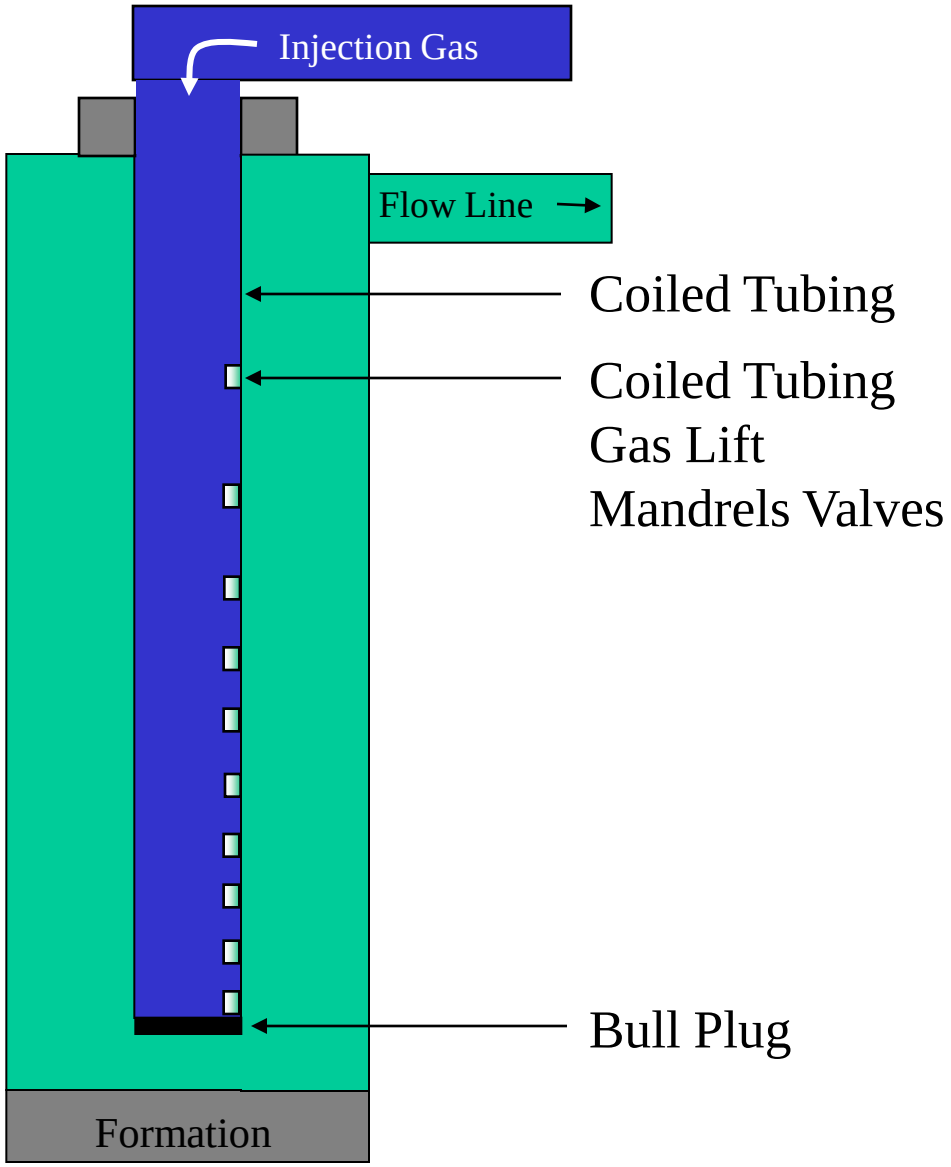
At the packer injection gas goes from annulus to tubing and injecting down tubing through horizontal section “sweeping” entire horizontal leg

Formation production is annular flow in the horizontal leg then returning to tubing production in the vertical section via the crossover packer

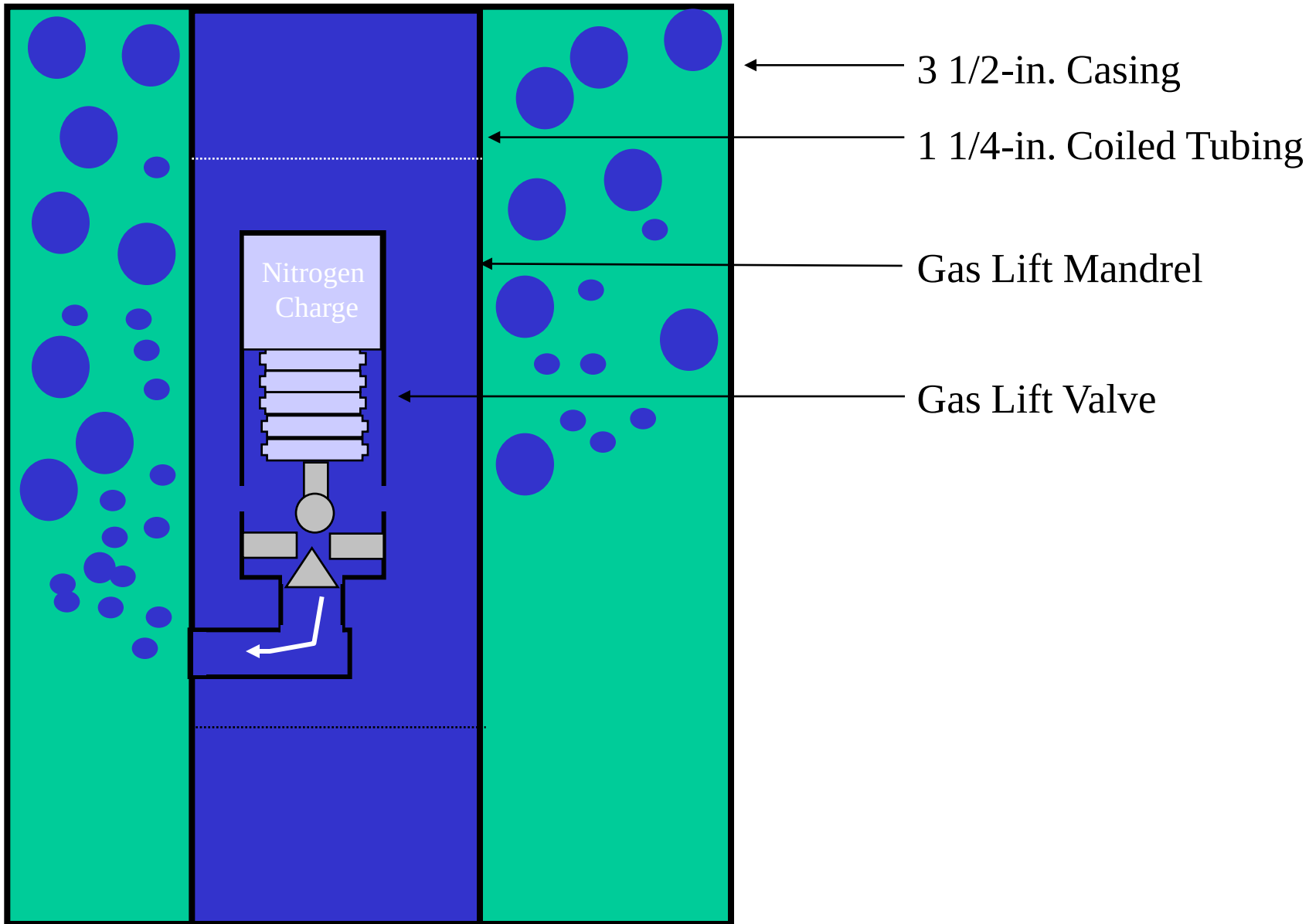
Coil Tubing Solutions – Gas Lift

- Coil tubing gas lift (bull plug / valve) can be run down into HZ section of tubing with ease
- Simple , reliable , minimal intervention to set up
- Unloading valves/mandrels can be spliced in to coil if required (low injection pressure)
- No moving parts - no rod wear - nothing to get jammed with sand
- No rig intervention required in most cases, can use existing tubing string
- Locked and packed into any profile nipple
- Low BHP wells , extended perforated intervals
- Below deviations where it is to risky to run packers

Coiled Tubing Gas Lift - Downhole Components



How A Gas Lift Valve Works



Coil Tubing Gas Lift Valves

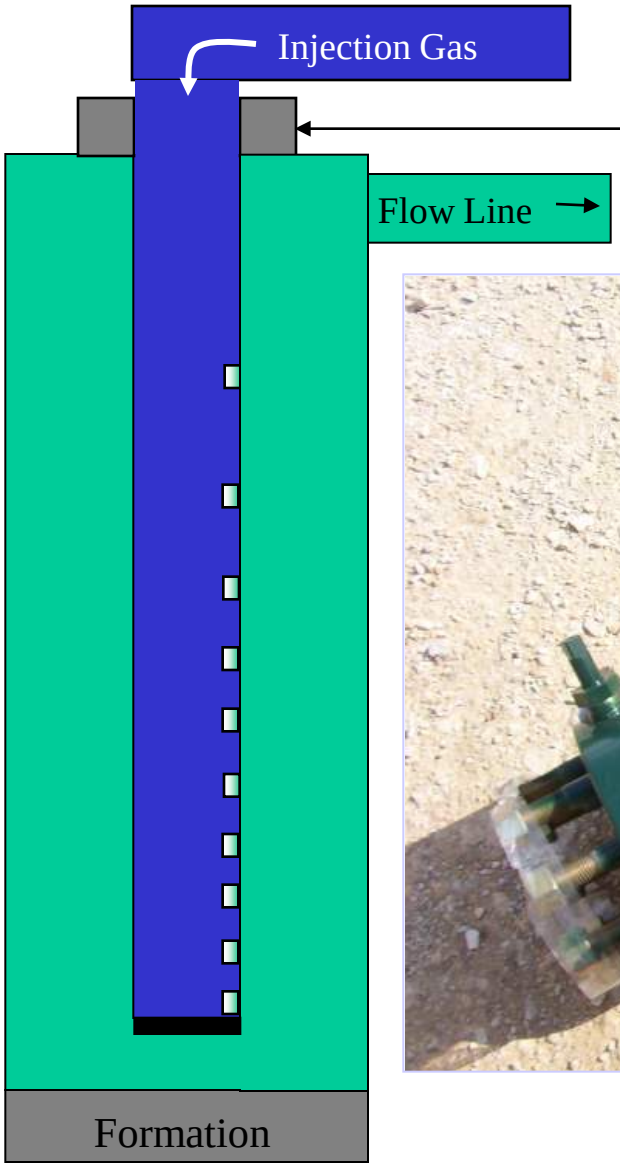
- Reduced running OD gas lift mandrels with internally mounted gas lift valves
- CT connectors are installed above and below each mandrel
- These special mandrels and valves are also used in pack-off and slim-hole, jointed pipe gas lift applications
- Provides gas lift applications without pulling well completion

Coiled Tubing Gas Lift Mandrels

Coiled Tubing Gas Lift Mandrels

Surgrip Coiled Tubing Connector Assembly

Coiled Tubing Gas Lift Surface Components

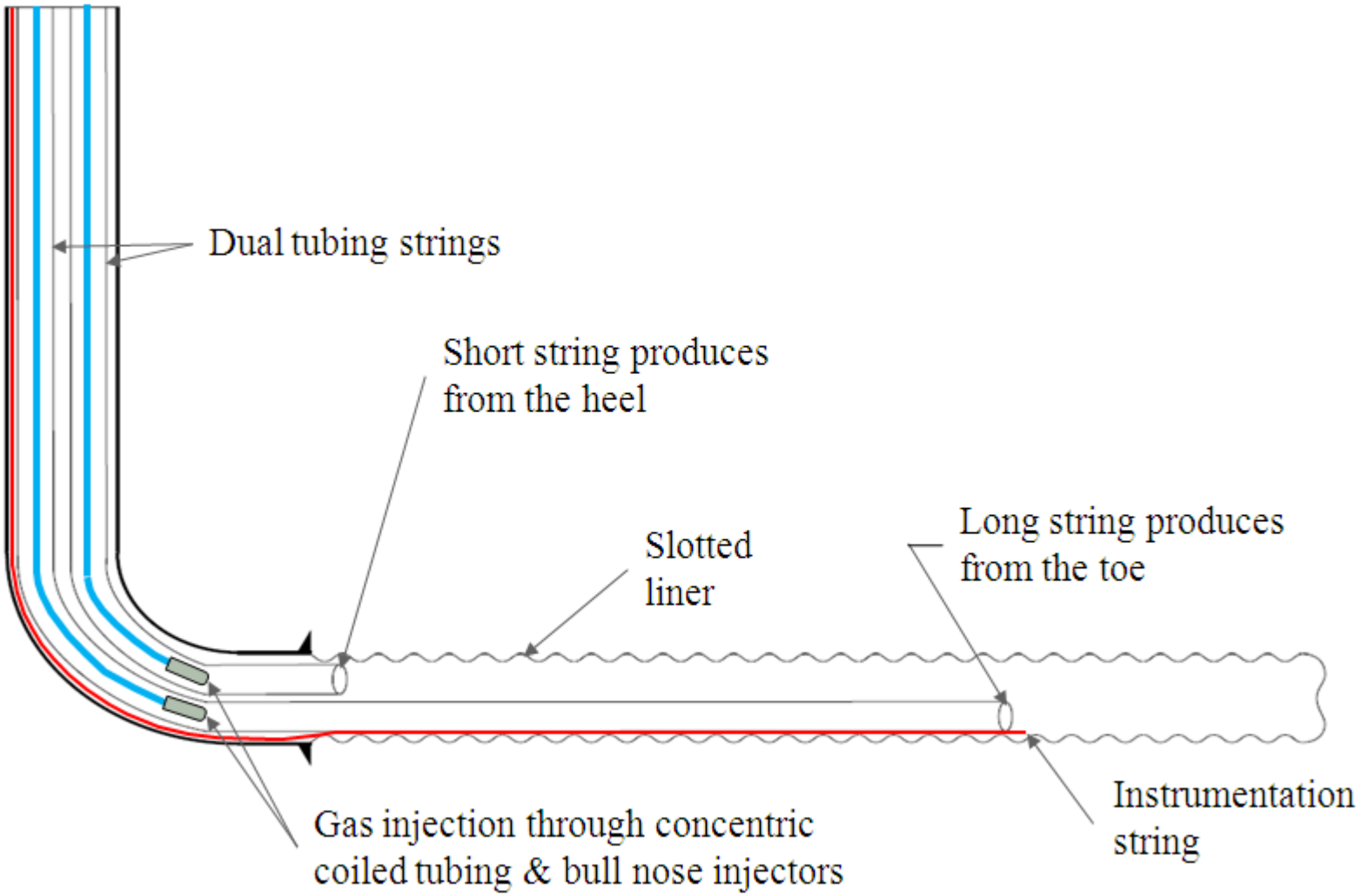


Coiled Tubing Gas Lift Installation

Gas Lift Theory / Application - SAGD

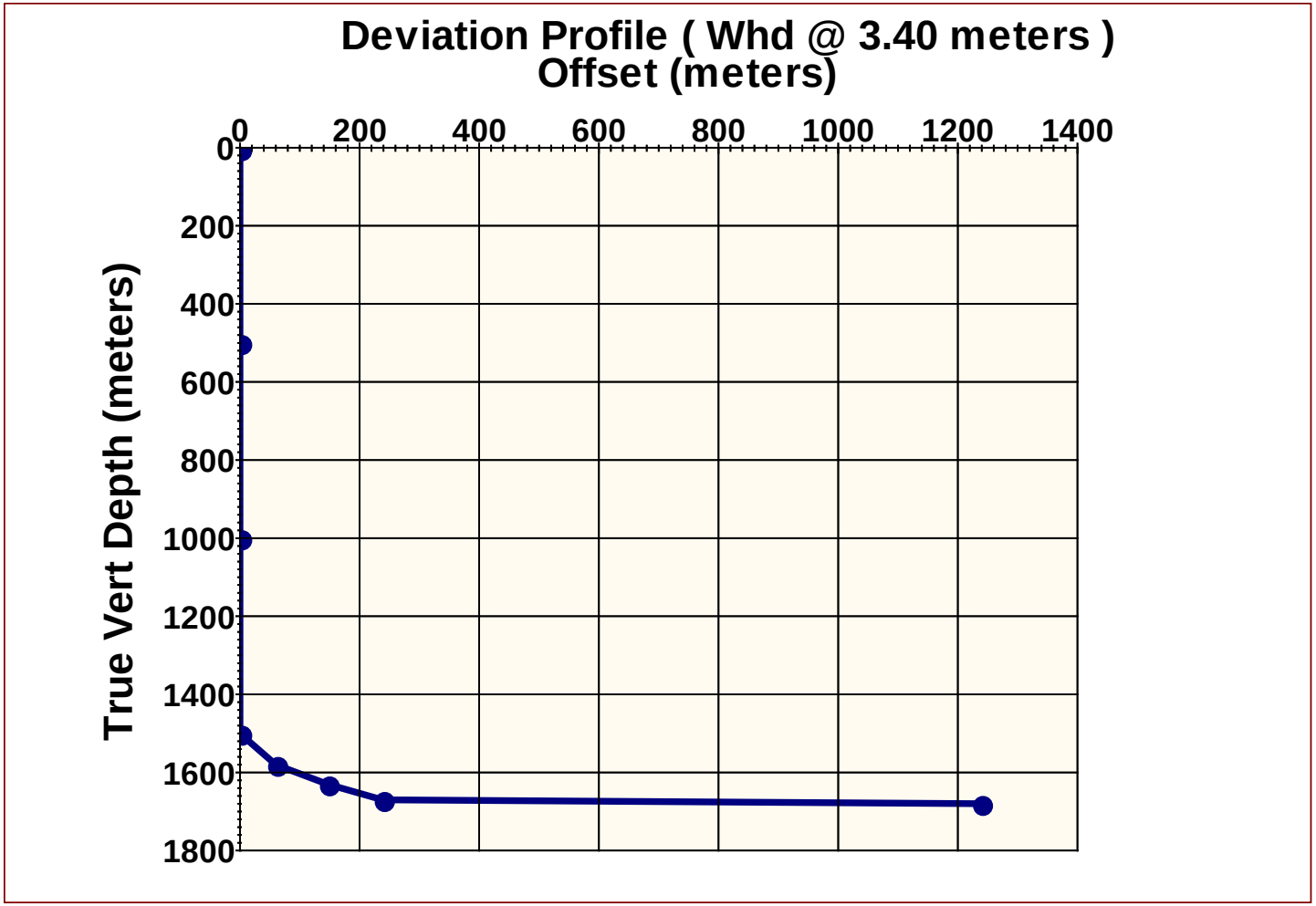
- Gas lift was one of the first artificial lift choices for SAGD operations. Gas Lift was chosen due to the low cost and its ability to accommodate the elevated temperature conditions and high fluid production rates.
- Gas lift deployed is a “poor boy” version which is simple completion consisting of production tubing landed in the producing interval – usually two strings one in heel and one near the toe. Coil tubing is run concentrically in the production tubing and gas is injected down the coil and production flows up the tubing (micro-annulus)
- Gas Lift currently accounts for ~ 45% of the market share in SAGD operations
- Inject gas into producing conduit to reduce fluid density , thus reducing the gradient
- Reduce the FBHP enough to allow fluids to flow to surface without mechanical interference
- Control injection volumes for optimal production
- Maintain a stable pressure drop across orifice valve to ensure stable inflow and consistent injection volumes which are commonly very low ~ 3-5 e3m3/day

Gas Lift Completion - SAGD



Gas Lift - SAGD - Equipment

Coil Tubing Gas Lift - Evaluation



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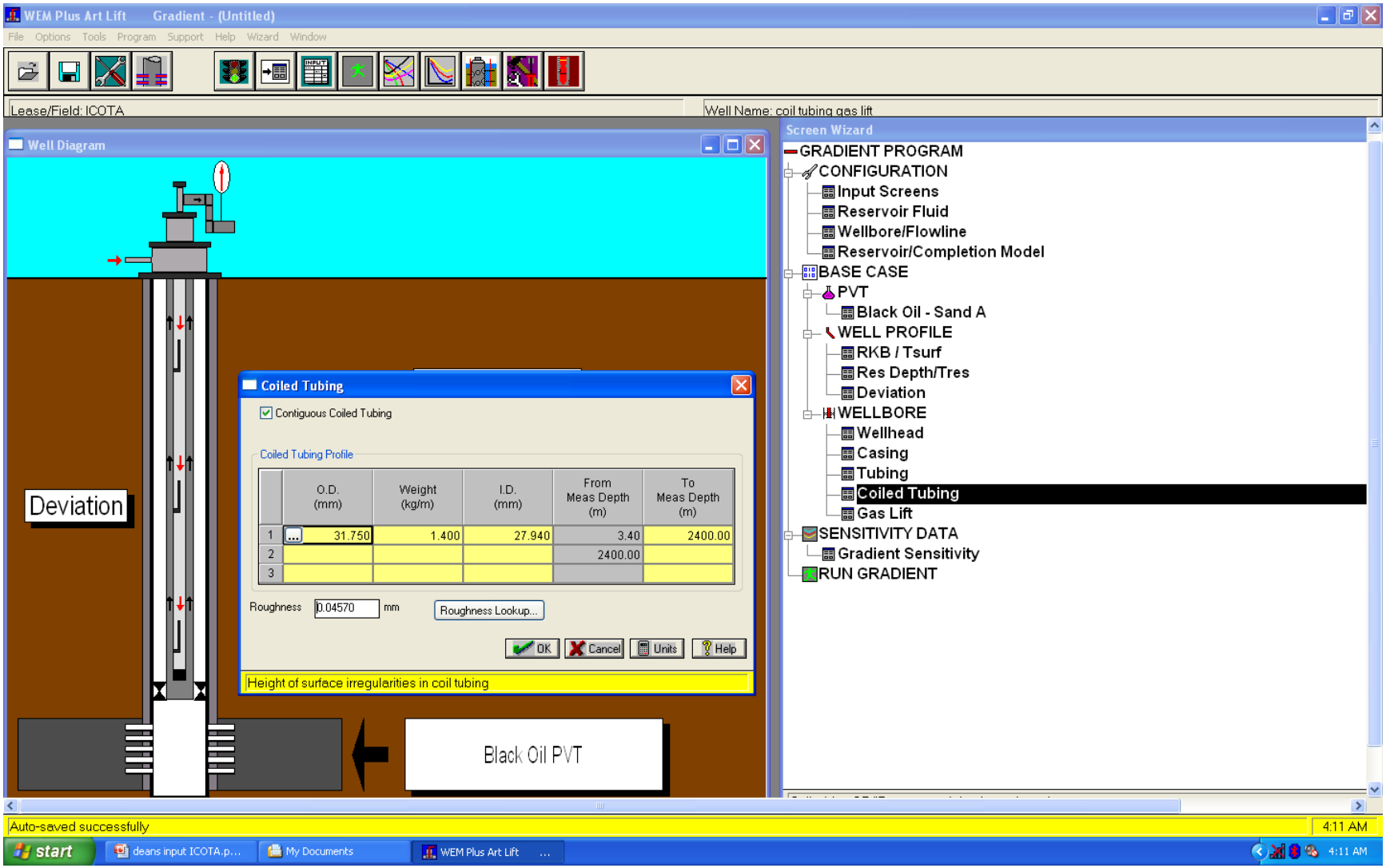

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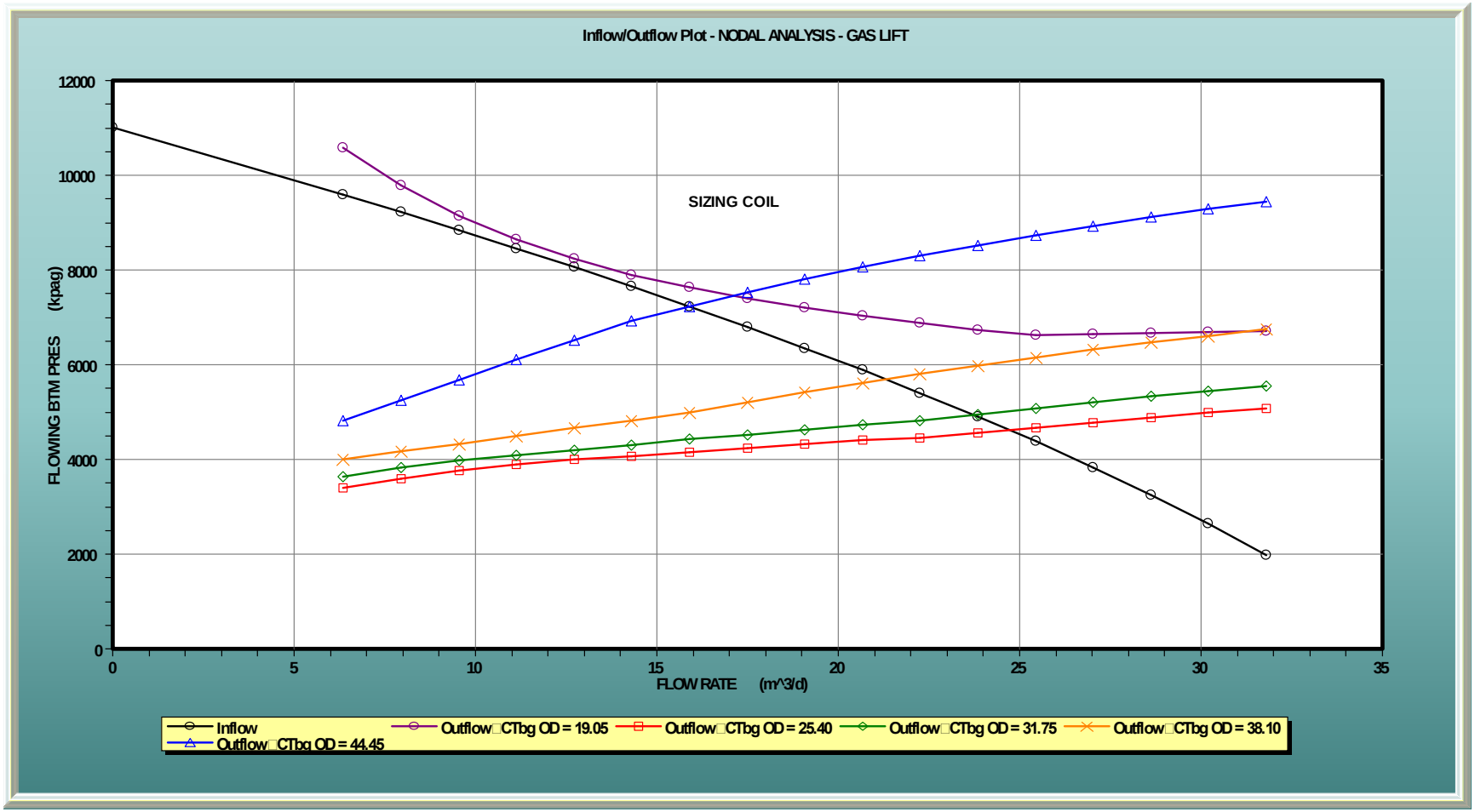

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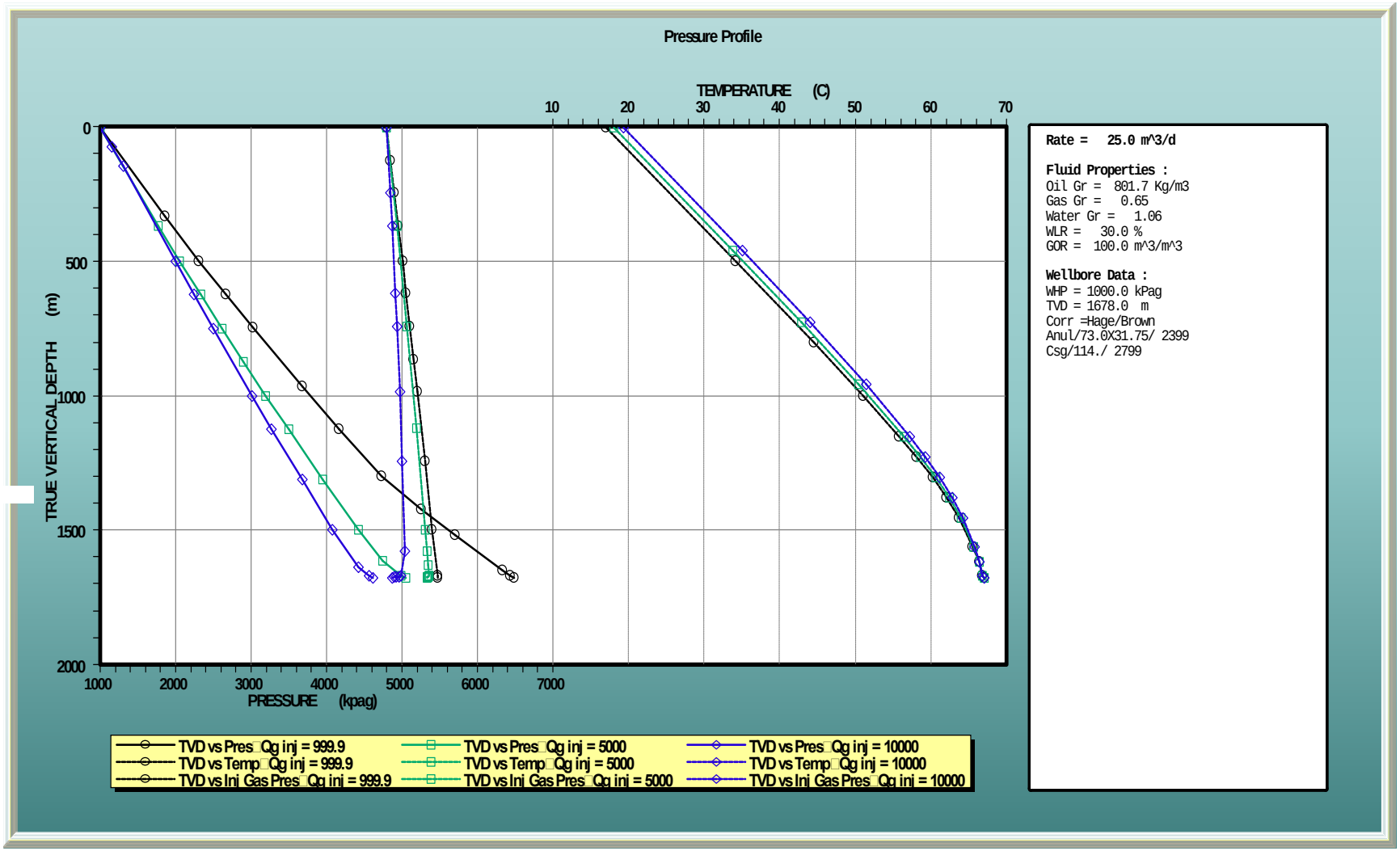

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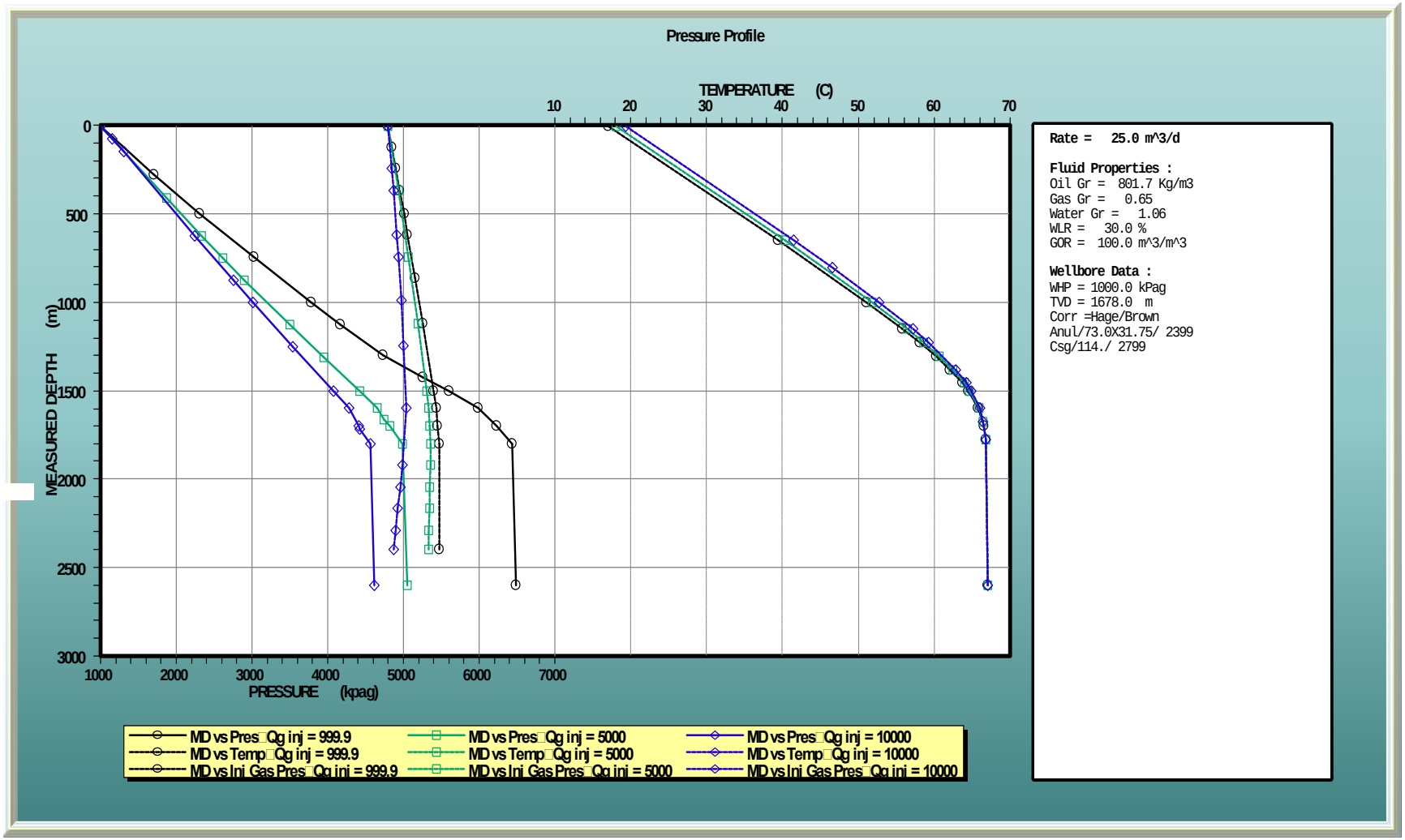
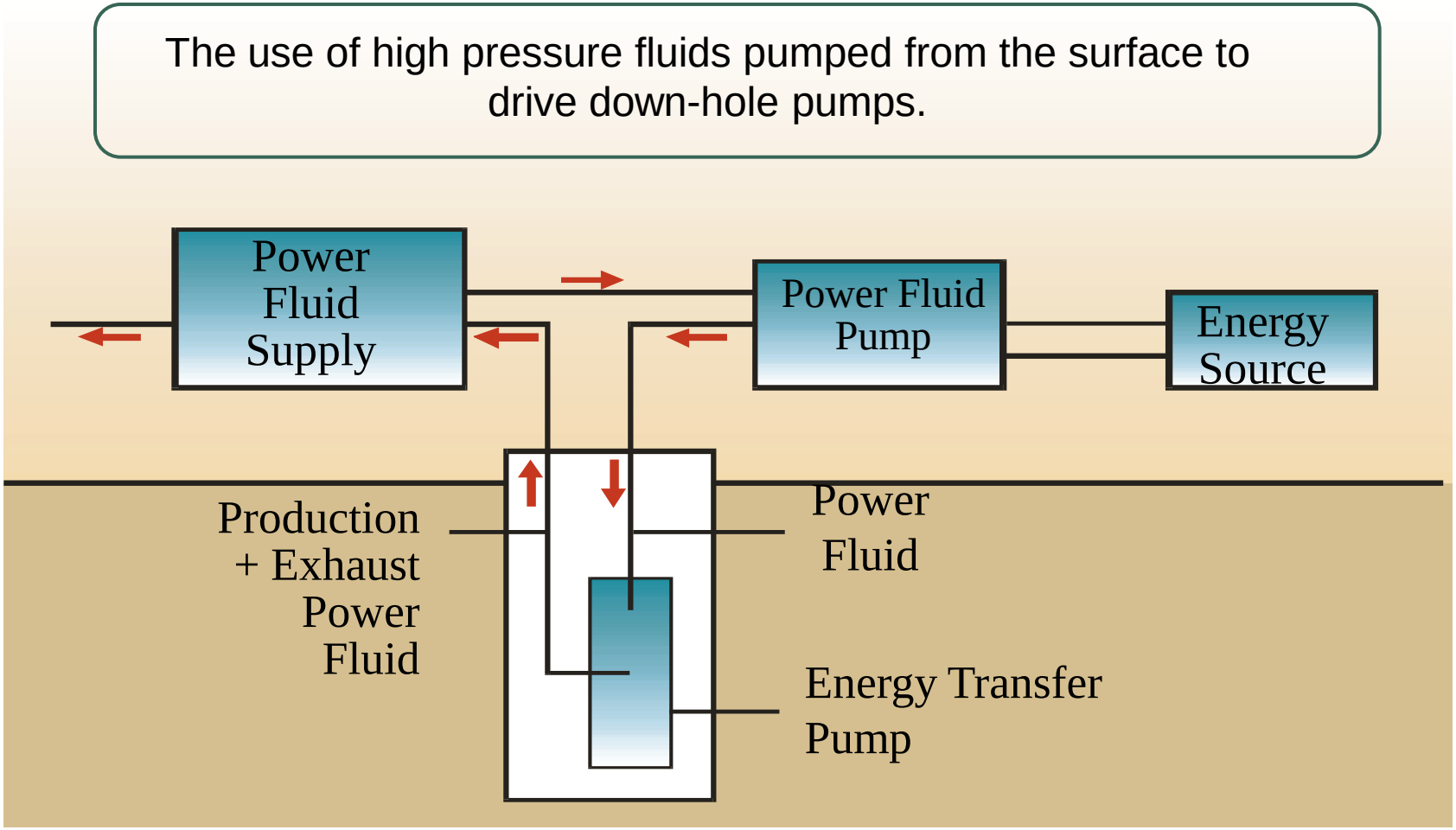


Hydraulic Jet Pump

- Theory – How They Work
- Applications – Where/Why They are Used
- Advantages
- Coil Tubing Jet Pumps

Theory – How They Work

The use of high pressure fluids pumped from the surface to drive down-hole pumps.



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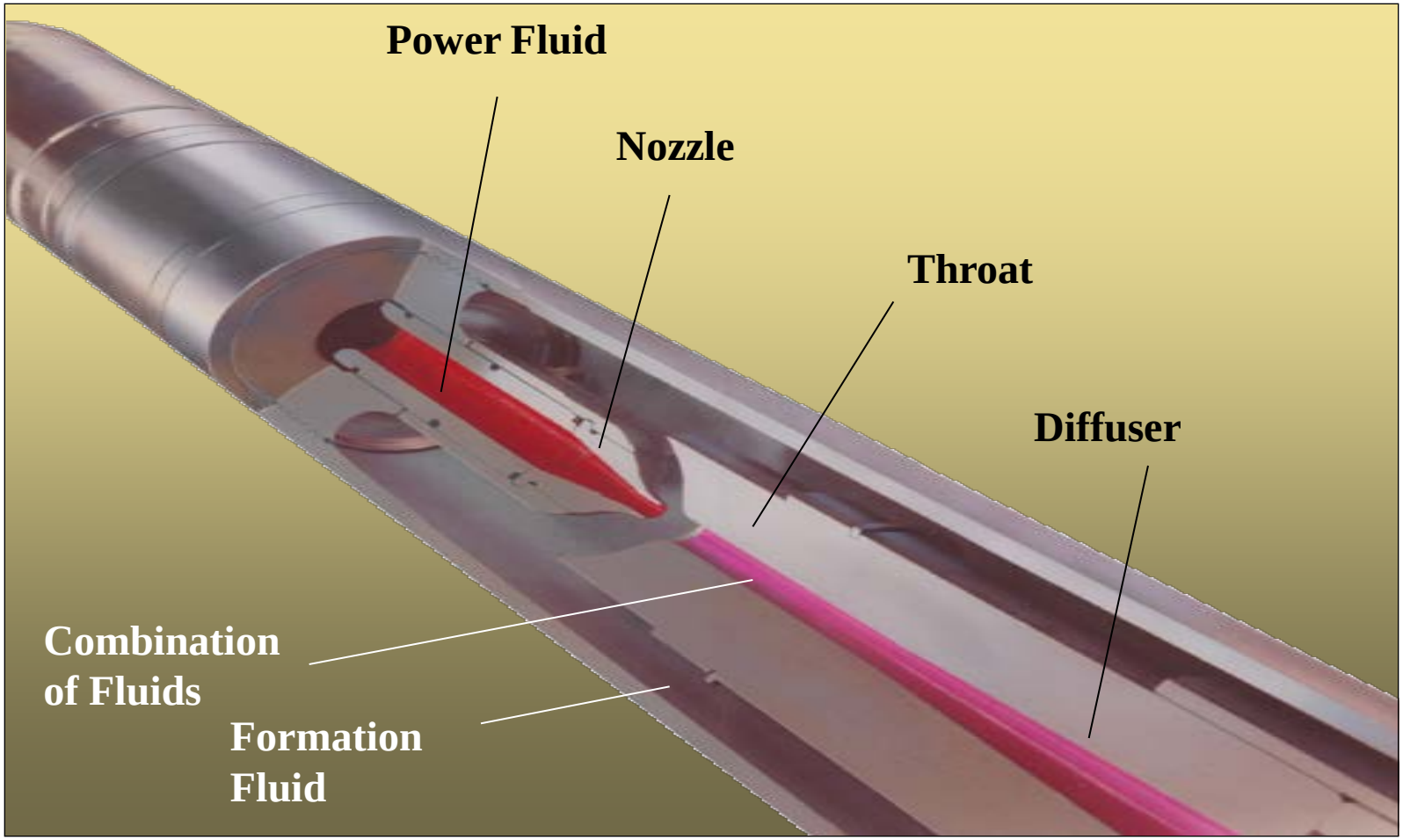

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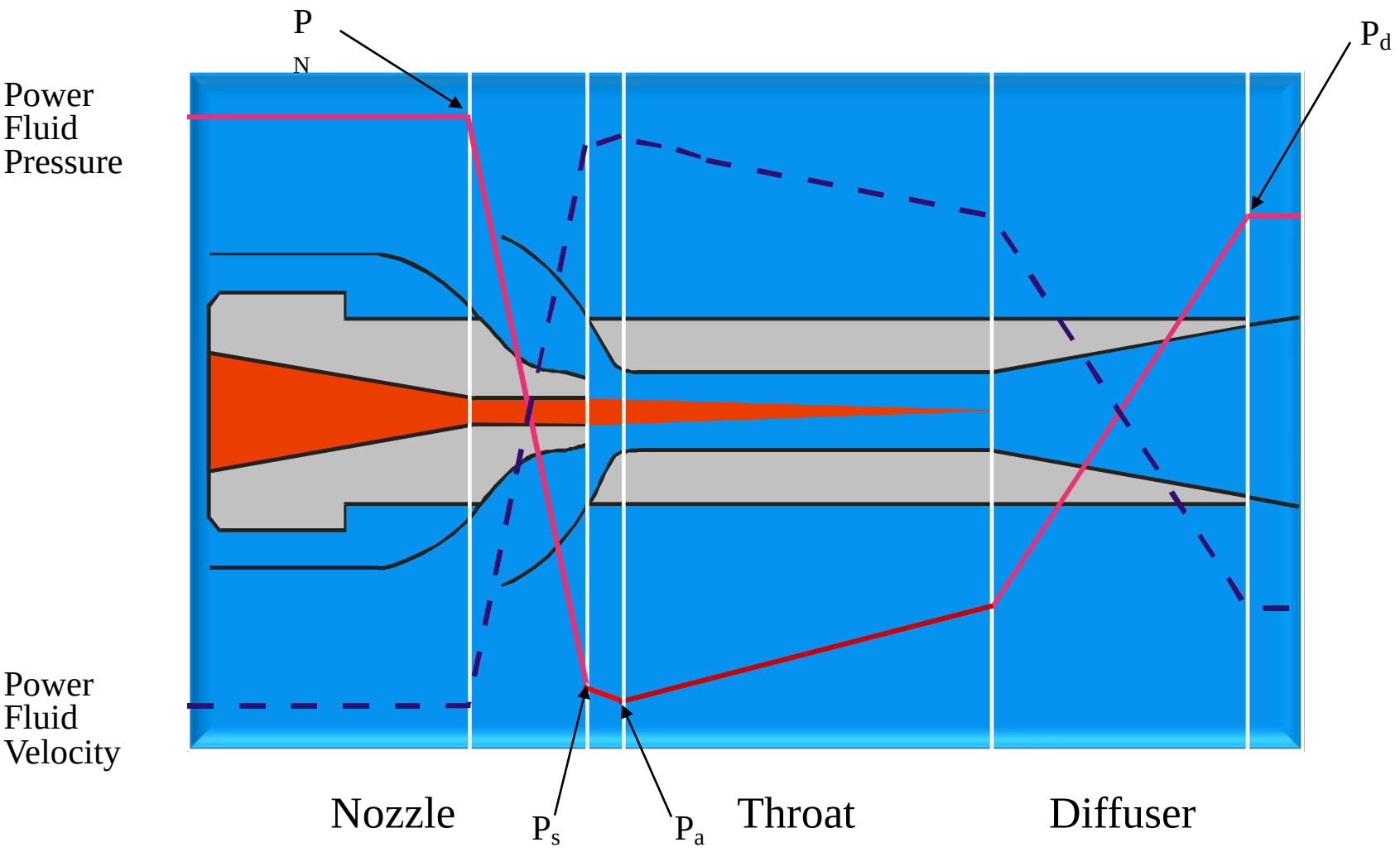
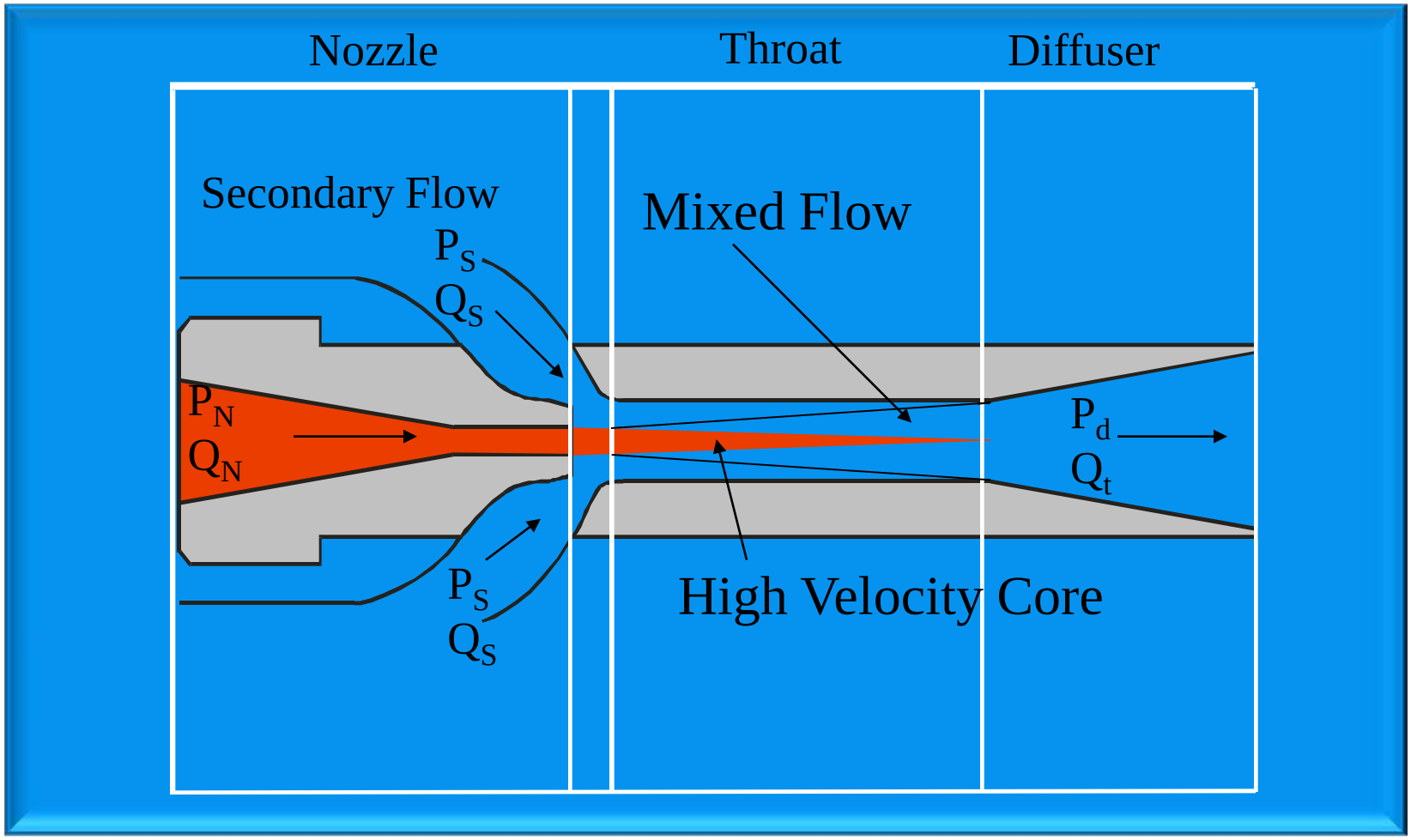


Theory – How They Work

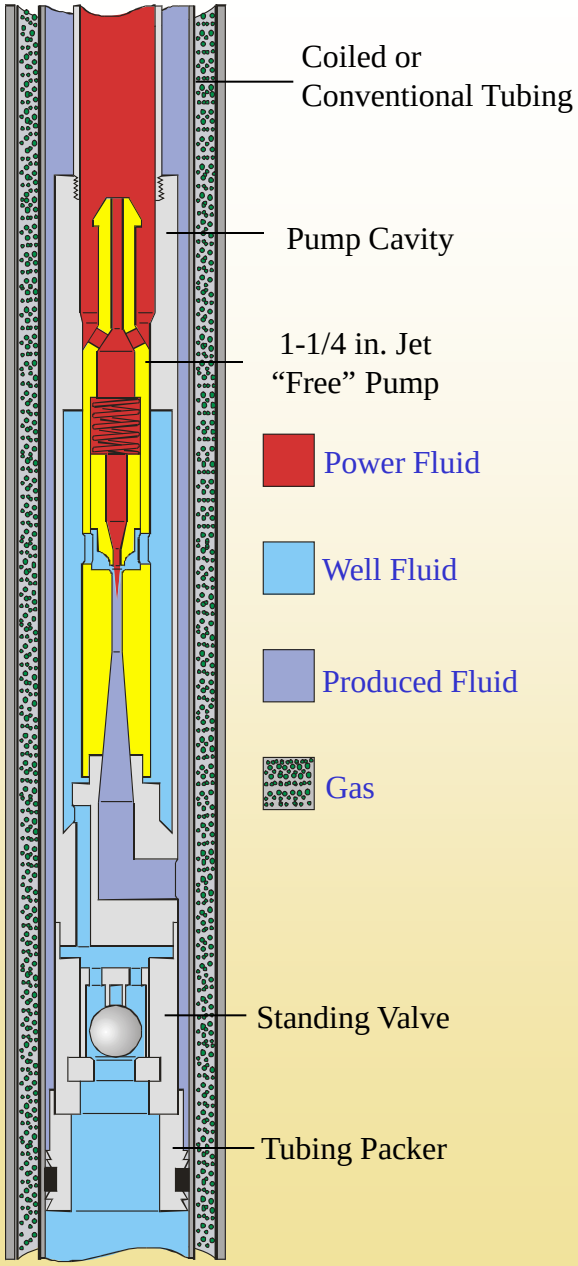


Applications – Where They Are Used

- Horizontal/Deviated Wells – Can be landed at 90°
- Sandy and Gassy Production – No Moving Parts Downhole
- FFR Frac Fluid Recovery – Highly Flexible
- Production Testing – Moveable Surface Assets
- Idle Well Revival – Can Land in Existing Tubing String
- Dewatering Gas/CBM Wells – Coil Jet Pump
- Backup for ESP & Gas Lift – Can Land in Sliding Sleeve
- Corrosive/Scaly/Waxy Wells – Power Fluid Additives
- Permanent Production – Low Maintenance
- Remote Locations – Pump Retrievable without Wireline/Service Rig

Hydraulic Jet Pump - Advantages

- No moving parts downhole
- High volume capability
- Run and retrieve via wireline or “free” circulation
- Deviated and horizontal wells
- No rods in tubing
- Tolerant of solids, corrosive fluids, gas
- Excellent for producing viscous crude
- Adaptable to existing BHA’s and sliding sleeves
- Repairable at well site
- Low pump maintenance, easy to repair

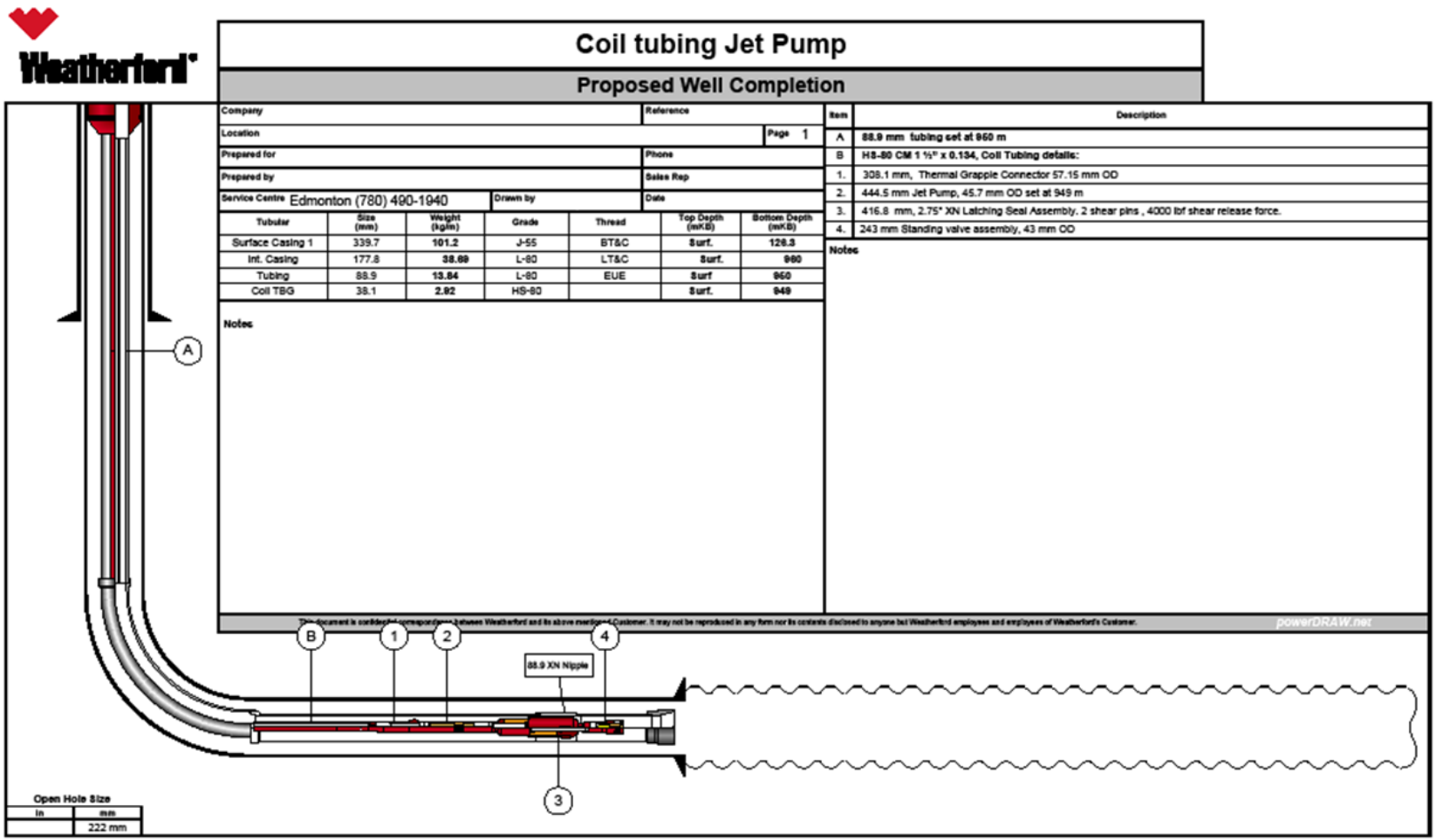


Coil Tubing Jet Pump

- Installs without pulling tubing
- Can be run in directional or horizontally completed wells
- Capable of “free pump” operation; circulates in and out hydraulically
- Jet pump design adaptable to a wide variety of well conditions and configurations

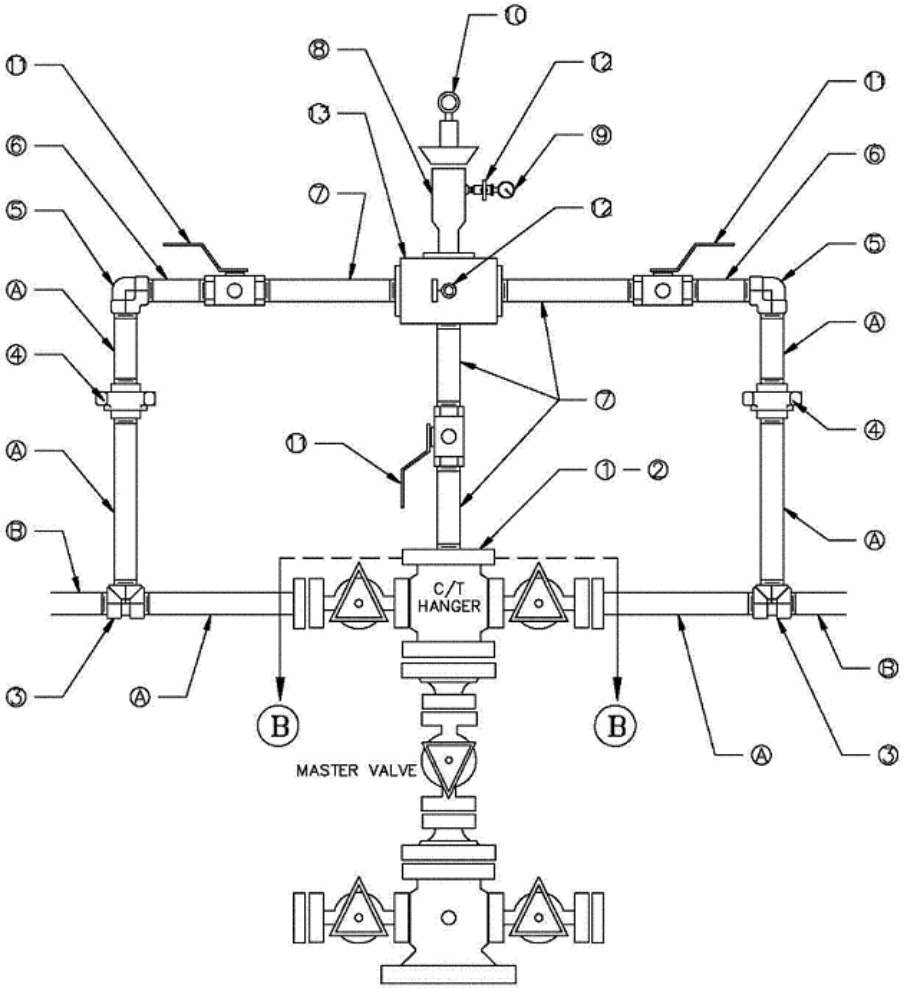
-Casing Used As Gas Vent for Liquid Wells or Gas Production for Gas Wells

Coil Tubing Jet Pump Completion

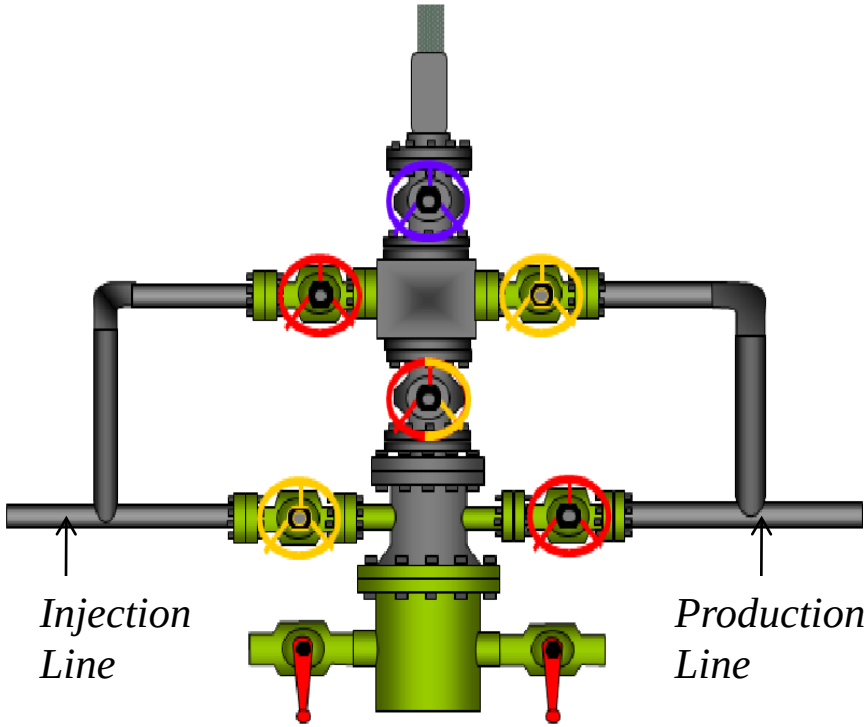


Coil Tubing Jet Pump Wellhead

Coil Wellhead



Standard Wellhead



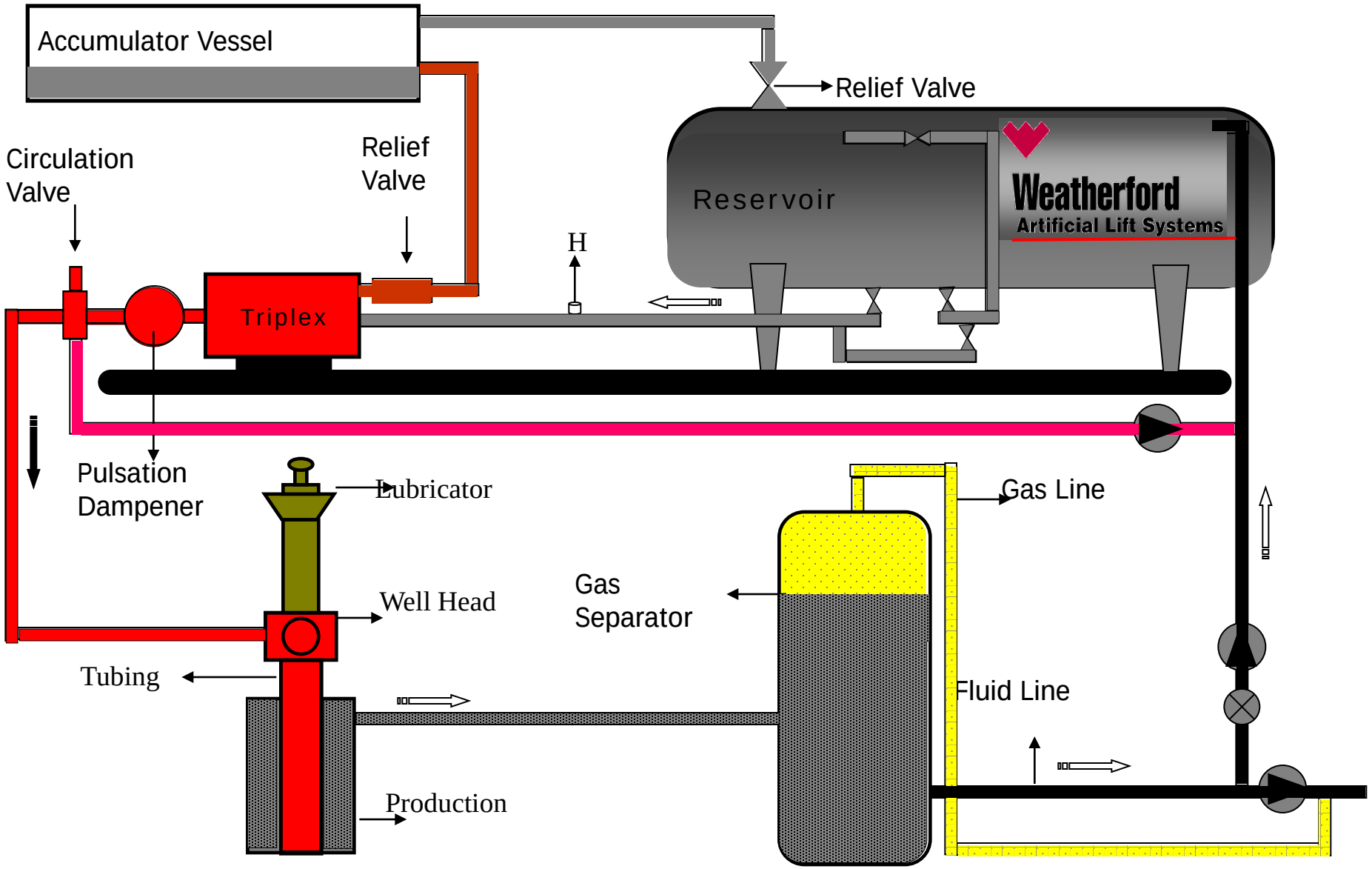
Jet Pumping – Surface Equipment

- Each jet pump application will have unique surface requirements.
- Essentially what is needed:

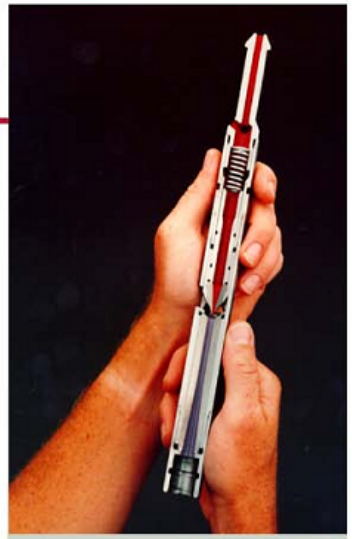
1. **Reservoir Vessel / Separator** – Stores produced fluid and power fluid, dumps to flowline or storage tank. Can act as a separator or be used in conjunction with another separation vessel, provides power fluid to Triplex.
2. **Multiplex or HPS Pump** – Provides power fluid to the jet pump. Can be fed either from a separation vessel or from water tanks.

Jet Pump Surface Setup - NW Alberta

Jet Pumping – Surface Equipment



Coil Jet Pump – Case Study



REAL RESULTS

Jet Pumps Installed "Free Style" Answer Need for Producing Highly Deviated Wells at Rates of 800 to 50 Bbl/d

Objectives

- Produce highly deviated wells of unknown capability with a single artificial lift method able to perform reliably over a wide range of production rates. The rate requirements and hole deviations eliminated rod pumps, progressing cavity pumps, and electric submersible pumps from consideration.

Results

- Weatherford's coiled tubing jet pumps produced at rates as high as 800 Bbl/d and as low as less than 50 Bbl/d simply by changing the nozzle and/or throat. This task was quickly accomplished, as the pump's "free style" operation capability meant it could be circulated in and out hydraulically.

Value to Client

- Enabled client to develop a productivity index/inflow performance relationship (PI/IPR) for each well to learn what the well was capable of producing and to size the downhole pump accordingly. The wells could be produced at different rates by varying the power fluid injection pressures and rates for each nozzle/throat combination.
- No operating expenses were incurred in the changing of nozzles or throats, as the "free style" pumps were installed/retrieved with power fluid and not a pulling unit.
- The pumps have operated without any incidents or downtime.

Client:
Major Operator

Location:
North Texas (Denton area)

Well type:
Gas

Casing/tubing:
6-in., 26-lb/ft, 2 7/8- and 1 1/4-in.

Depth in:
8,000 ft

Flow rate:
Dropped from 800 to 50 Bbl/d

BHA details:
Coiled tubing

Weatherford International Ltd.
515 Post Oak Blvd., Suite 600
Houston, Texas 77027 USA
Tel: 713-693-4000
www.weatherford.com

Weatherford
Toby Pugh, Regional Product Line Manager
972-243-1114 or 713-693-4895
Mobile: 972-768-4174

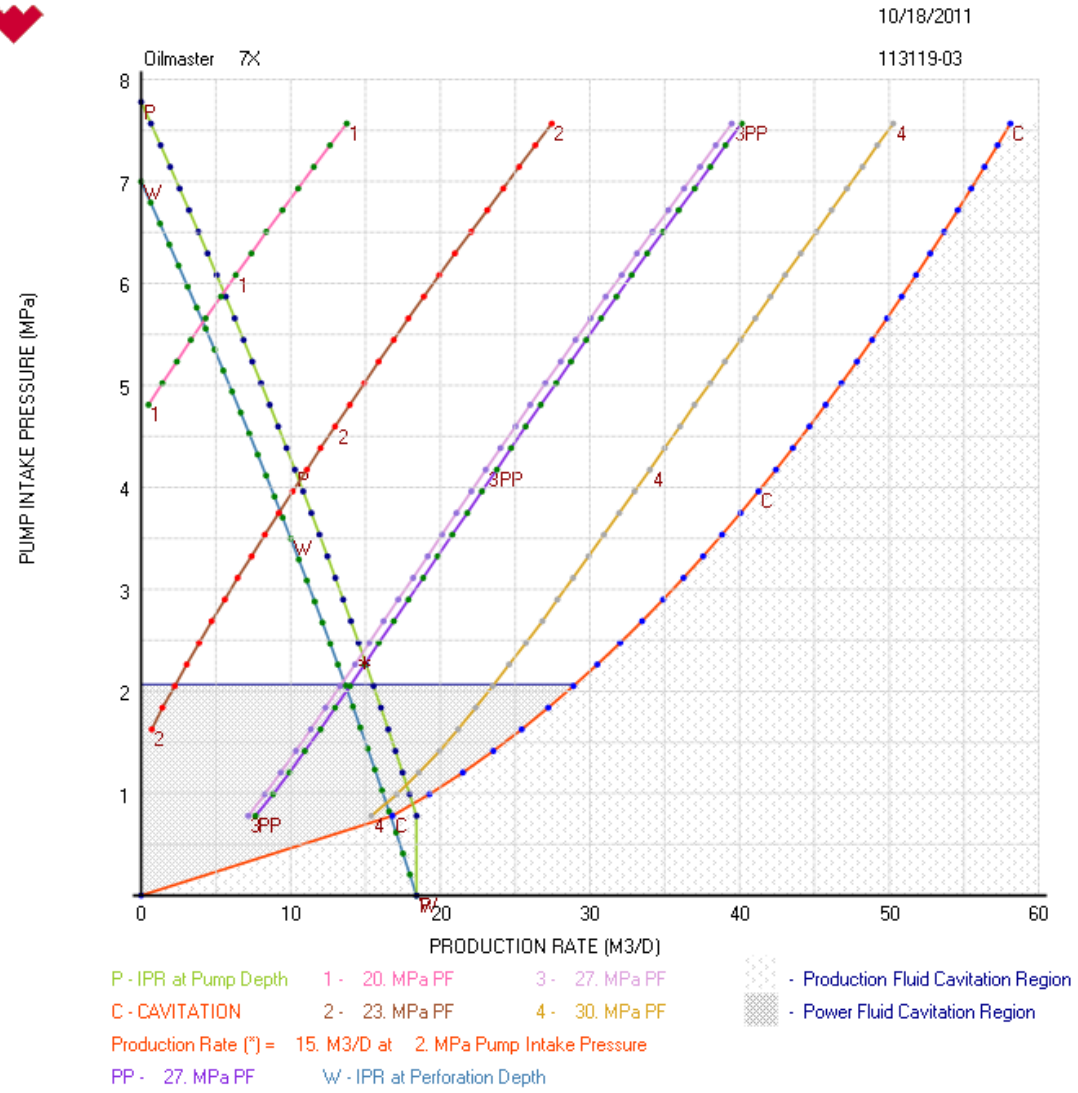
Issues With Production:

- Highly deviated wells
- Unknown well capability

Coil Jet Pump Solution:

- Produced variable rates from 8 – 130m^3/day
- Enabled client to develop PI/IPR's for each well
- No operating expenses were incurred to change the nozzles and throats as they were installed "free style"
- Pumps have operated with no incidents or downtime

Jet Pump – Design & Evaluation



Jet Pump – Design & Evaluation

WEATHERFORD ALS, INC.

W E L L D A T A S U M M A R Y

Customer :
Field & Well :
Location :

Date : 10/18/2011

Run ID: 113119-03

1. Perforation Depth	(m) :	2108.0	13.Producing GOR (s.m3/m3) :	104.0
2. Pump Vertical Depth	(m) :	2190.0	14.Gas Sp. Gravity (air=1.) :	0.650
3. Pump Instl (1) Standard Flow			15.Separator Press (KPa) :	828.0
(2)Rev. Flow (3)Parallel Flow:		1	16.Well Static BHP (MPa) :	7.00
4. Casing ID	(mm) :	62.0	17.Well Flowing BHP (MPa) :	1.50
5. Tubing OD	(mm) :	38.7	18.Well Test Flow Rate(m3/D):	15.0
6. Tubing ID	(mm) :	31.8	19.Well Head Temp (deg. C) :	15.0
7. Return Tubing ID	(mm) :	N/A	20.Bottom Hole Temp(deg. C) :	65.0
8. Tubing Length	(m) :	2265.0	21.(1)vented (2)unvented :	1
9. Pipe Cond (1)new(2)avg(3)old	:	2	22.Power Fld (1)oil (2)water:	2
10.Oil Gravity	(API) :	35.000	23.Power Fld API/Sp. Gravity:	1.050
11.Water Cut	(%) :	75.00	24.Bubble Point Press (MPa) :	20.82
12.Water Specific Gravity	:	1.050	25.Well Head Press (KPa) :	828.0

Oilmaster 7X Jet Pump Performance Summary for User Target Specified Production Rate of 15.0 m3/D at 2.28 MPa Pump Intake Pressure

Injection Pressure = 26.9 MPa
Injection Rate = 159.5 M3/D
Horsepower to Jet Pump = 76.4 HP
Pump Intake Pressure = 2.3 MPa
Discharge Pressure = 24.8 MPa
Cavitation Rate = 30.6 M3/D

Injection Pressure = 20.0 MPa
Production Rate = 5.5 M3/D
Injection Rate = 140.6 M3/D
Horsepower to Jet Pump = 50.2 HP
Pump Intake Pressure = 5.9 MPa
Discharge Pressure = 24.4 MPa
Cavitation Rate = 51.0 M3/D

Injection Pressure = 23.3 MPa
Production Rate = 10.6 M3/D
Injection Rate = 150.3 M3/D
Horsepower to Jet Pump = 62.5 HP
Pump Intake Pressure = 4.1 MPa
Discharge Pressure = 24.6 MPa
Cavitation Rate = 41.8 M3/D

Injection Pressure = 26.7 MPa
Production Rate = 14.8 M3/D
Injection Rate = 159.0 M3/D
Horsepower to Jet Pump = 75.6 HP
Pump Intake Pressure = 2.4 MPa
Discharge Pressure = 24.8 MPa
Cavitation Rate = 31.3 M3/D

Injection Pressure = 30.0 MPa
Production Rate = 17.7 M3/D
Injection Rate = 166.7 M3/D
Horsepower to Jet Pump = 89.2 HP
Pump Intake Pressure = 1.1 MPa
Discharge Pressure = 25.0 MPa
Cavitation Rate = 20.3 M3/D

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