



Future of Intelligent Completions

Oil Recovery



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OVERVIEW



- Introduction
- Background
- Conventional Completion Vs. Intelligent Completion
- Objectives of the Project
- Well and Technology Selection
- Real Time Monitoring
- Results
- Conclusions



OVERVIEW

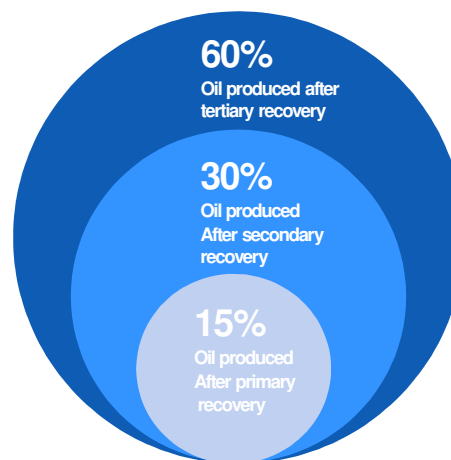
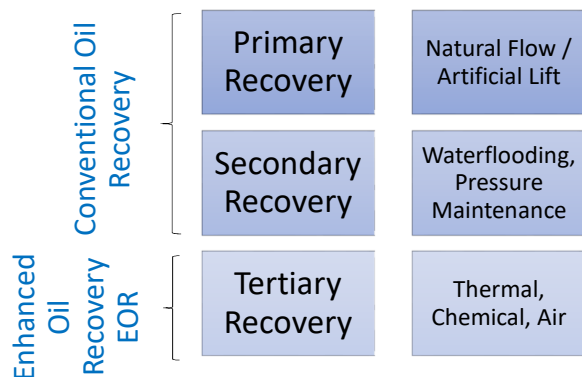


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There are 3 types of conventional oil recovery: Primary, Secondary and Tertiary (Known as EOR).

After secondary recovery, only around 30% of the oil in the reservoir is recovered.



Source: International Energy Agency, 2021

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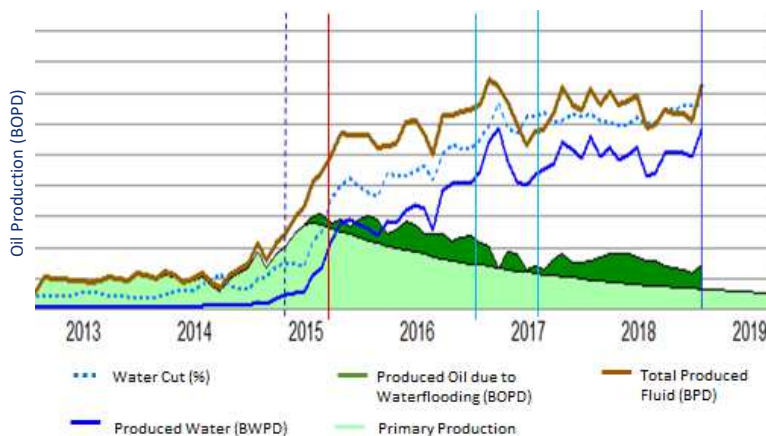
Colombia Chichimene Field: Declining oil production is one of the field most difficult challenges

Field Description:

- Location: Colombian Llanos Basin.
- Type of production: Heavy Oil.
- Recovery method: Waterflooding
Pilot start date: 2014.

Field Challenges:

- High Net-Pay (+250 ft).
- High differences in vertical permeability. (5D – 5mD in few ft).
- Distribution of existing Wells.
- Operational complexity in existing Wells.
- Declining oil production



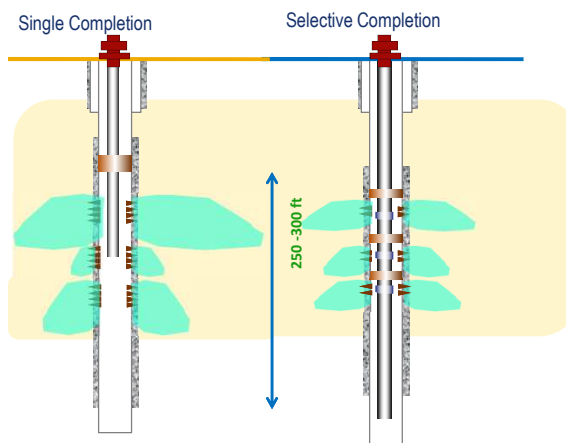
Source: Ecopetrol. Chichimene Field, historical production

Chichimene Waterflooding Pilot finished in 2019 with 37 injector wells.



- **2014** – Waterflooding pilot. 13 patterns (3 new wells and 10 converted to injector)
 - Single completion increased in 3% the Recovery Factor (RF).
 - Selective Completion increased 10% RF.
- **2018** – Technology expansion.
- **2021** - Total 37 injector wells with Good results in production and reserves.

Source: Solorzano, 2018 – SPE-191170-MS



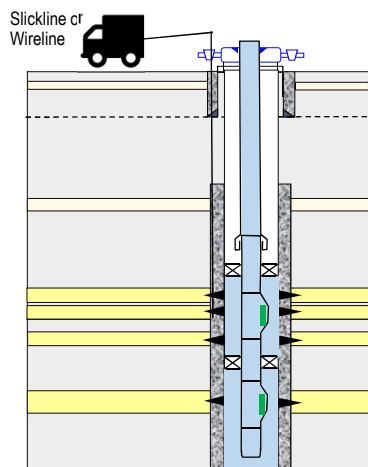
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Conventional Completion: Between 4-6 weeks to reach the injection targets rates per zone.



Completion Design:

- Hydraulic packers.
- Injection mandrels and dummies.
- Flow Regulator Valves. FRV.

Well Monitoring (SL, WL, CT):

- FRVs and Dummies with Slickline.
- Injection Log Tests (ILT) with Wireline + Fiber Optics.
- **Repeat, Repeat, Repeat.**

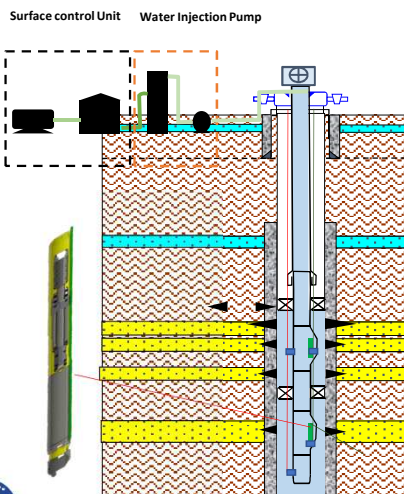
Time to Reach injection Targets:

- 4-6 Weeks.
- 2-3 FRV changes and ILTs.

With manual calibration and monitoring:

- Canalizations.
- Lack of data on time.
- Low injection swapping efficiency
- Operational incidents during Rig-less operations with.
- FRV Plugging.

Intelligent completion reduced calibration times, increased production, reduced Opex and CO2 footprint



Completion Design:

- Feedthrough Hydraulic packers.
- 4 Electric Intelligent control valves ICV

Well Monitoring (SL, WL, CT):

- Permanent Fiber Optics with DAS* and DTS**.
- Remote Valve actuation

Time to Reach injection Targets:

- Less than 6 hours
- 1 ICV actuation

*DAS: Distributed Acoustic Sensing

**DTS: Distributed Temperature Sensing

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Three strategic objectives were defined



Objectives of the Project

- Prove that an intelligent well completion:
1. Works for mature Wells with heavy oil.
 2. Can optimize the Water Flow regulation and effectively monitor the injection.
 3. Prove the Cycle Water Injection Technique to improve the swapping efficiency in the injection pattern.



Key Performance Indicators

- Difference between target flow per zone vs actual flow injected Target (**Target flow/Actual Flow. %**)
- Difference between FO Calculation versus ILTs. (**ILT Flow calculation / FO Flow Calculation. %**)

Others:

- % Increase in production.



OVERVIEW



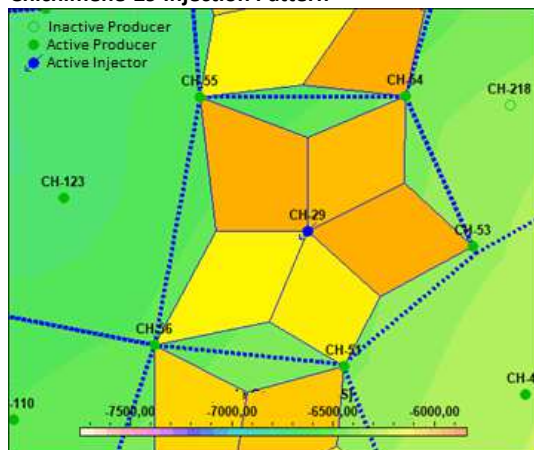
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CH29 well was selected among 10 wells based on 6 key parameters



Chichimene-29 Injection Pattern



- CH29 Well:
 - Drilled in 2008.
 - 9-5/8" Casing y 7" liner.
 - 3 zones Injector Well.
 - Target formation @ 8570 ft.
- Key parameters defined:
 1. Existing Well.
 2. Solid Injection baseline and performance.
 3. Good reservoir connectivity.
 4. Good pattern production.
 5. Well Integrity.
 6. Well Geometry and construction.

CH29 HAD ADDITIONAL CHALLENGES



- **Short distance between injection zones**
 - As short as 30ft between packers, resulting in a rigid assembly to install.
- **Existing perforations**
 - Zones with 8ft space to set packers, which could cause integrity issues.
- **Low formation Pressure**
 - High differential pressure (1,200 psi) during completion installation and valves operation compromised completion operation
- **Well Integrity**
 - Higher risk than other candidates.
 - 11 years since drilled
 - 29 well services (13 WO and 16 Rig-less).
- **Operational Risks**
 - Returns and circulation @ +10 BPM.



6 KEY PARAMETERS WERE DEFINED FOR THE PROJECT



Ranking of parameters for the project

Item	Parameter	Category	Score
1	Technology Readiness level (TRL) and associated risks during completion installation and well life	Technology	10
2	Compliance with operating parameters such as injection flow per zone and total injection flow. Ability to respond to changes in parameters in the future.	Completion equipment	8
3	Quality and precision of the information delivered by the intelligent injection control monitoring system (Temperature, Rate, Injection profile per perforation).	Information	7
4	Manufacturing and delivery time of the technology	Time and cost	6
5	Initial investment cost (CAPEX) and operating costs (OPEX)	Time and cost	3
6	Time to receive the information of the calculated injection flows by zone and the time to actuate the valves.	Completion equipment	2



OPERATIONAL REQUIREMENTS WERE COMPARED TO AVAILABLE TECHNOLOGIES



Technology Screening

Item	Equipment	Operational Parameters	Available Technologies
1	Packers	Required - Withstand tubing loads @ 2K psi and 6K BWPD and stimulation @ 3K psi and 0.5 BPM. - Have a feed-through feature to pass the cables	- Permanent hydraulic. - Semi-permanent hydraulic (cut to release or shift to release). - Tension Release Hydraulic
2	Intelligent Valves	Required - Ranges between 200 BWPD and 6K BWPD. - Unloading pressure greater than downhole pressure differentials. Desired Have the fewest cables for actuation	- Hydraulically actuated. - Electrically actuated. - Electro-hydraulic.
3	Valve regulation system (Chokes)	Required Enough positions to meet operating pressure and flow ranges. Desired Allow the least tortuosity and pressure losses	- Sliding sleeve type choke - Helical type choke - Flow Regulation valve actuated from surface.
4	Flow calculation system by zone	Required Allow the calculation of flow per zone in real time (without stopping the injection) with an accuracy of 90%. Allow calculation of injected fluid per perforate.	- Flowmeter with direct downhole flow measurement. - Pressure and temperature gauges. - Permanent fiber optic - Distributed Temperature Sensing (DTS) and Distributed Acoustic Sensing (DAS).



The Selected Configuration was: 100% electric valves and permanent fiber optics monitoring for flow calculation



Ranking and Selection of Technology Options

	Option	PR #1	PR #2	PR #3	PR #4	PR #5	PR #6	Score	Ranking	Result
1	Electric valves and permanent fiber optics (DTS & DAS) for flow calculation	3	3	3	2	2	3	2.71	1	Selected
2	Hydraulic valves with pressure and temperature (P/T) gauges for flow calculation	3	3	1	3	2	2	2.69	2	Optional
3	Electric valves with pressure and temperature gauges (P/T) for flow calculation	3	3	1	3	2	2	2.69	3	Optional
4	Hydraulic valves and permanent fiber optics for flow calculation	3	3	3	2	2	2	2.66	4	Discard

Key advantages of selected system:

- Electric Valves - 1 single cable.
- Helicoidal choke.
- Calculation of Rates per zone with DAS and rates por perforation with DTS.



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6 TEST WERE PERFORMED TO CHECK DAS PERFORMANCE



Comparison Between DAS and ILT

Test Number	Date	Choque position	ILT (Allocation)	ILT (BWPD)	DAS (Allocation)	DAS (BPD)	DAS vs ILT (%)
1	6/08/2019	Valve Zone 4	0%	0	5%	266	-5%
		Valve Zone 3	20%	1190	11%	631	9%
		Valve Zone 2	71%	4262	68%	3994	3%
		Valve Zone 1	9%	548	17%	1009	-8%
2	23/08/2019	Valve Zone 4	0%	0	11%	599	-11%
		Valve Zone 3	30%	1598	20%	1055	10%
		Valve Zone 2	59%	3117	40%	2136	19%
		Valve Zone 1	11%	585	28%	1505	-17%
3	29/08/2019	Valve Zone 4	0%	0	9%	509	-9%
		Valve Zone 3	31%	1629	24%	1277	7%
		Valve Zone 2	54%	2859	55%	2970	-1%
		Valve Zone 1	15%	813	12%	655	3%
4	30/08/2019	Valve Zone 4	0%	0	12%	518	-12%
		Valve Zone 3	30%	1359	25%	1125	5%
		Valve Zone 2	52%	2334	48%	2151	4%
		Valve Zone 1	18%	807	16%	702	2%
5	30/08/2019	Valve Zone 4	0%	0	11%	572	-11%
		Valve Zone 3	36%	1944	24%	1296	12%
		Valve Zone 2	43%	2322	53%	2862	-10%
		Valve Zone 1	21%	1134	13%	675	9%
6	30/08/2019	Valve Zone 4	0%	0	11%	605	-11%
		Valve Zone 3	36%	1947	26%	1377	11%
		Valve Zone 2	52%	2831	50%	2689	3%
		Valve Zone 1	12%	622	14%	7229	-2%



Comparison Between DAS and Target Rates per Zone

Calculated DAS Allocation	Calculated DAS Rate (BWPD)	Target Allocation	Target rate (BWPD)	Allocation Difference (DAS vs Target)
5%	266	12%	781	-8%
11%	631	23%	1491	-13%
68%	3994	50%	3168	18%
17%	1009	15%	954	2%
11%	599	12%	781	-1%
20%	1055	23%	1491	-3%
40%	2136	50%	3168	-9%
28%	1505	15%	954	13%
9%	509	12%	781	-3%
24%	1277	23%	1491	0%
55%	2970	50%	3168	5%
12%	655	15%	954	-3%
12%	518	12%	781	-1%
25%	1125	23%	1491	2%
48%	2151	50%	3168	-2%
16%	702	15%	954	1%
11%	572	12%	781	-2%
24%	1296	23%	1491	1%
53%	2862	50%	3168	3%
13%	675	15%	954	-2%
11%	605	12%	781	-1%
26%	1377	23%	1491	2%
50%	2689	50%	3168	0%
14%	7229	15%	954	-1%

The system delivers 1 datum per day (compared to 1 datum each 3 months with conventional completion)



Measure and Control Surface System

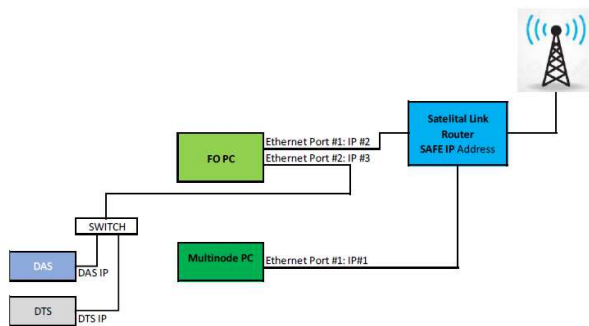


Figure 10 - Schematic of Surface Control and Surveillance Systems.



Visualization

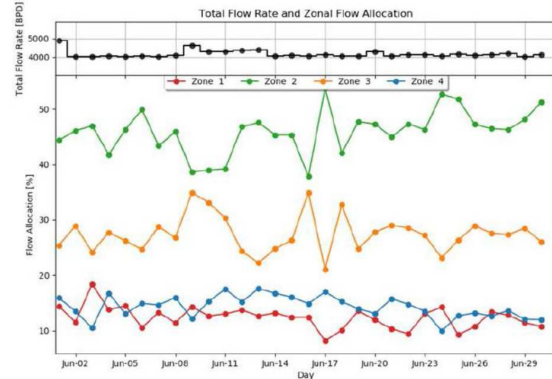


Figure 11 - Zonal Flow Allocation for one month

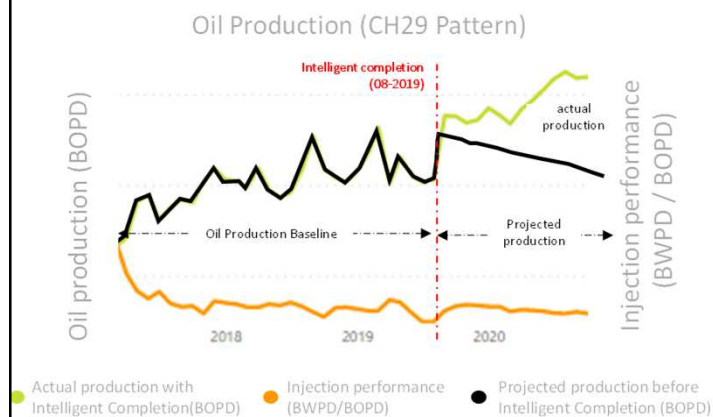
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The system increased the oil production +60%



60%

Increase of pattern production

Compared with the baseline production before completion

34 Months

After Installation

100% reliability in valve actuation and well integrity

30%

Savings in Opex/year

Compared with the cost of interventions in 2017.

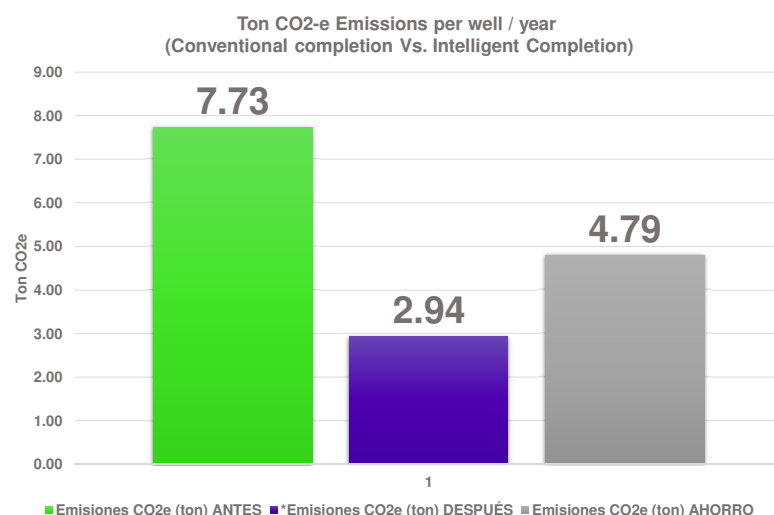
80%

Reduction in Carbon Footprint

Elimination of well interventions.



One intelligent completion reduces 62% of carbon footprint



62%

CO₂e Reduction

4,79

Ton CO₂e/well



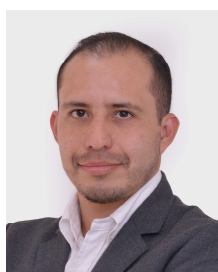
Conclusions



- Real-time monitoring and remote well actuation systems brings valuable benefits in terms of production, injection performance, and reduction of operational costs. This consequently accelerates the return on investment and optimize enhanced oil recovery processes.
- An intelligent completion can operate adequately in conditions of variable permeability and mobility, heavy oil, and high reservoir thicknesses. Such a system can also improve the sweeping efficiency and the recovery factor.
- DAS fiber optics delivered enough information to make on-time decisions for this project. DAS results provided an accuracy of 90% in the flow calculation per zone. If a greater accuracy is required, other technologies must be evaluated.
- The process of selecting the well and identifying the appropriate technology for this application, allowed the completion to be installed without complications in a complex injector well and to maintain its reliability and integrity to date.



Thank you



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