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CHOPS (Cold Heavy Oil Production with Sand) Trial in an Oilfield from Romania

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Abstract

Cold Heavy Oil Production with Sand (CHOPS) has been successfully applied in Canadian heavy oil fields for about 20 years, providing as much as 20% of Canadian crude oil output in 2001 – 2003. The major Canadian CHOPS field characteristics are unconsolidated sand, low oil qualities (API ~ 11°-14°, viscosities up to 20,000 cP), reservoir thicknesses (<15m) too thin to justify thermal recovery methods, and sufficient solution gas ratios (>7 m^3/m^3) to help drive oil and sand to the wellbore.

In 2009 it was established a program to achieve an evaluation of the potential of CHOPS in the field from Romania which will be called Field A. It was based on the collection of a great deal of relevant data (largely from Canadian experience) and from a four-day workshop (September 21-24, 2009). The CHOPS trial was proposed to start with the completion of the new wells X_1, X_2 and X_3. Based on similar fields (no mathematical model is available) - for a CHOPS trial with better oil qualities such as prevailing at Field A - a production rate increase of 2-4 times the regular gravel pack completion rate was expected.

Key words: *oil, heavy, sand, unconsolidated, production, reservoir.*

CHOPS – Cold Heavy Oil Production with Sand

CHOPS are now widely used as a "primary" production approach in unconsolidated sandstones and thousands of wells in Canada are steadily producing oil through CHOPS. Instead of blocking sand ingress by screens or gravel packs, sand flow into the wellbore is encouraged by aggressive perforation and swabbing strategies. Vertical or slightly inclined dipping wells (vertical to 35°) are operated with rotary progressive cavity pumps, rather than reciprocating pumps. Old fields continue to be equipped with higher-capacity progressive cavity pumps, giving production boosts to old wells. Note that if a screen is installed to keep out sand, oil production will drop to uneconomic levels in the high-viscosity Canadian unconsolidated sand deposits. Productivity increases over conventional primary production as high as 10 - 20 times have been achieved regularly (e.g. 100 bbl/d rather than 5-10 bbl/d), and a good CHOPS well in Canada can produce as much as 150-200 bbl/day for many years.

About 10-25% of OOIP can be recovered, rather than the 2-5% typical of primary production without sand in such cases. Also, because massive sand production creates a large disturbed zone of greater porosity and permeability, the reservoir may be positively affected for later implementation of thermal processes (CSS, SAGD). Lower viscosity reservoirs – such as in

Romania - tend to give better recovery in CHOPS applications, but may suffer more from increasing water cuts and gassy well behavior.

CHOPS increases well productivity for five reasons:

- if sand can move, the basic mobility of the flowing phase is enhanced;
- as more sand is produced, a growing zone of greater permeability is generated (30% behind and 36% to 45% after CHOPS – fig. 1), similar to a large-radius well which gives better production;
- gas ex-solution in viscous oil does not generate a continuous gas phase; rather, bubbles flow with the fluid (and sand) and do not coalesce, but expand down-gradient, generating an "internal" gas drive, referred to as "foamy flow". This also helps to locally destabilize the sand, sustaining the process;
- continuous sand production means that asphaltene or fines plugging of the near-wellbore zone cannot occur, so there is no possibility of a "positive skin" effect impairing productivity;
- as sand is removed, the overburden weight acts to shear and destabilize sand, helping to drive sand and oil toward the wellbore.

Typically, a producing by CHOPS technology will initially produce a high percentage of sand, greater than 20% by volume of liquids; however, this generally decays to 0.5% - 6% sand by volume (higher values for the lower API gravity oils, which are more viscous) after some weeks or months. For higher API gravities, such as in Field A, early and later stage sand volumes are expected to be substantially less in the order of 5-10% initially decreasing to less than 1% in steady state conditions. Often huge volumes of sand may be disposed of by slurry fracture injection or salt cavern placement or by sand placement in landfills.

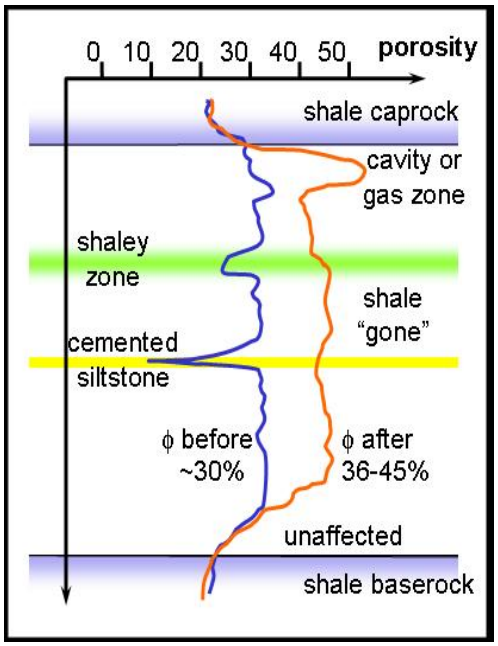

Fig. 1. Porosity before and after CHOPS

CHOPS production in Canada is now significant, approx. 25% of total Canadian crude output. CHOPS appears to be suitable for any unconsolidated sandstone where there are no active water legs and where there is sufficient gas in solution to sustain the foamy oil process. In Canada, the minimum thickness of zones for economic production appears to be about 3 m. The maximum

viscosity appears to be 15,000-20,000 cP, in higher viscosity cases, the sand cut remains too high, and there are associated problems with overburden destabilization.

CHOPS is most suited to reservoirs that are less than 15 m thick, therefore applicability covers the range of zonal thicknesses that are less than those suitable for SAGD. In Canada, economic success has been achieved in zones as thin as 2.5 m, and it is typical to reserve thick zones for thermal methods, including steam-assisted gravity drainage and horizontal well cyclic steaming. However, the high costs of steam and the issue of heat losses and thermal inefficiencies in thin zones have led to very few thermal applications in zones less than 15 m thick, and none in any zone less than 12 m thick. It is widely understood that of the technologies currently commercialized in Canada, only CHOPS is economically viable for zones less than 10 m thick. Figure 2 shows the effect of a conversion of a well to CHOPS production, although not all wells show such a dramatic increase.

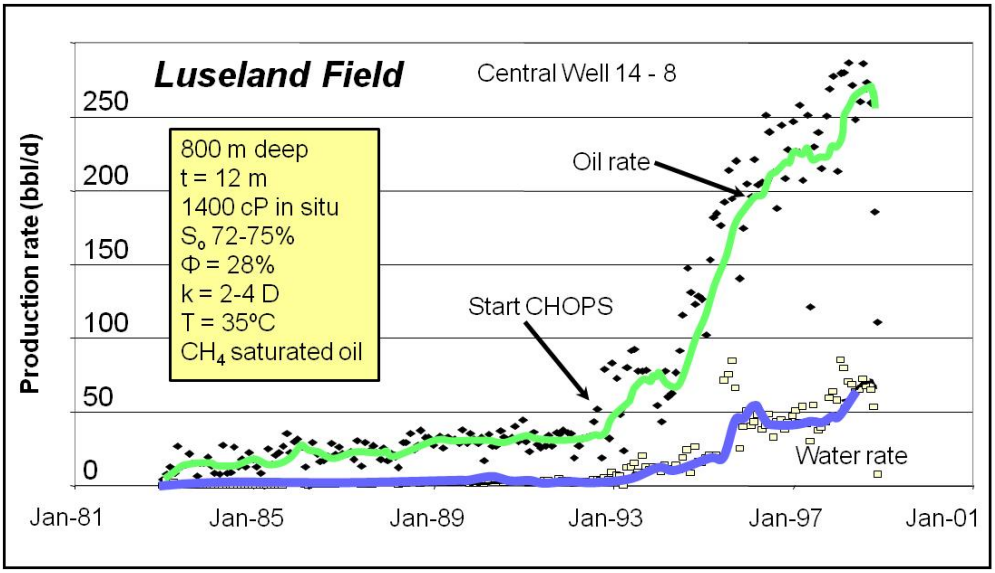

Fig. 2. Results of a well recompletion to CHOPS production

CHOPS are now seeing applications in other countries. In China, two small projects in the Nanyang and Jilin oilfields have achieved economic success, although in the former case a management change caused abandonment of CHOPS in favor of steam injection, and in the latter case lateral water invasion proved to be highly detrimental. Nevertheless, the CHOPS activity was deemed to be economical, and projects are underway in other heavy oil areas to assess and implement CHOPS in appropriate zones.

To Karazhanbasmunai field in Kazakhstan, the largest viscous oil field in the former Soviet Union, approval to implement was given CHOPS instead of steam injection. The development continues into new zones, and results in the first five years have been good, with far lower costs than steam stimulation (no water or heat needs). In the Kazakhstan case, the low viscosities (~300-450 cP) and unconsolidated sandstone nature give stable sand rates of 0.15-0.25%, a tenth of typical Canadian rates, but the improvements in well productivity are impressive. Typically, wells are about four times as productive on CHOPS, and well rates peaking at 100 cm/day are common. However, new ownership in 2007 is leading to a reversion to far less efficient steam injection approaches.

The greatest barriers to more wide-spread CHOPS applications in the petroleum industry is fear of sand influx, the poor profit margins historically associated with heavy oil exploitation and a general conservative attitude to asset development because of perceived risks. More realistically, CHOPS success has shown that these concerns are not justified, and that the

perceived issues have been successfully resolved in practice. In any new wells where suitable criteria are met, CHOPS can be tried initially, after well completion, at no risk. If it is found that CHOPS is not performing as well as hoped, the well is undamaged and suitable for the implementation of other approaches, therefore the asset risk is very low.

Romanian Applications

Romania has extensive unconsolidated sands, heavy oil deposits at depths similar to those in Canada. The deeper oils are less viscous than in Canada, but there are also issues with water ingress, and the reservoir properties are somewhat inferior to Canadian cases. If CHOPS can be demonstrated to be viable in reservoirs such as Field A, it may benefit the economics through increased oil rates, higher recovery factors, and no steam costs.

Furthermore, because CHOPS improves the reservoir transport properties by virtue of sand removal, it is possible that deposits that are marginally uneconomic for steam applications could be "improved" by a CHOPS phase before being steam stimulated. After a phase of learning the CHOPS concept and identifying the key actions, there are two strategies that must be evaluated:

(a) Converting suitable existing wells to CHOPS production;

(b) Using CHOPS from the beginning in the thin step-out flanks of the reservoir.

Anyway, the knowledge gained from the study and testing of CHOPS in Oteşti will be a corporate resource for use in other cases with heavy oil located in unconsolidated strata, where the reservoirs are suitable, yet unlikely to be suitable for thermal technologies.

It is recommended that CHOPS be assessed as a possible production technology in all Romanian cases where the following criteria are met:

- unconsolidated or weakly consolidated sands to sandstone so that sand influx will be sustained;
- absence of or adequate distance from aggressive free water or free gas zones because CHOPS is a high-drawdown process and water influx is anyway an issue;
- zone less than 15 m thick down to 2.5 m, with reasonable reservoir properties;
- some solutions for gas drive remaining to sustain CHOPS production.

Reservoir and Wells Selection

Geological settings

The Field A is among the largest in the Southern part of the Getic Depression and the Northern part of the Moesian Platform (19 x 6.2 km wide).

The target formation is Upper Meotian sands, with an average thickness of 10-15 m at depths of around 850 m (-600 m sub-sea). Hydrocarbon reservoirs are represented by mouth bars sands, possibly re-sedimented, accumulated in mixed shallow lacustrian/marine depositional environments, consisting of unconsolidated sands (medium - to fine-grained in size), including lateral facies changes.

Reservoirs characteristics

The Field A was brought on production in 1961. The Meoțian reservoir with 30% porosity, 90-300 mD permeability and 36% connate water saturation, contains heavy oil (20°API) with a viscosity of 50-80 cP at reservoir conditions (Pi = 80 bar, T = 35°C). The initial gas solution ratio was estimated to be 6 Sm^3/m^3. An original gas cap prevails in the north-western area of the field. A small secondary gas cap has developed in the central area of the field. Reservoir pressure has declined from initial normal hydrostatic conditions to 30-45 bar.

In this field natural drive mechanisms have been supported by water injection since 1963. Currently, only produced water after limited treatment is injected in 115 wells. The field currently produces 326 tons daily (2345 bbl/d) from 355 wells at 91% watercut. Actual recovery factor is estimated to be close to 20%.

For a Romanian CHOPS trial in Field A, were selected from literature two analogue fields, Provost from Canada and Karazhanbasmunai (KBM) from Kazakhstan (Table 1, highlighted in yellow). A major difference to CHOPS applications in Canadian fields is that CHOPS is generally used as primary exploitation method, i.e. not in reservoirs with water injection history.

Table 1. Comparison of reservoir parameters

Field	Zone	Depth (m)	Thick (m)	Initial Press., (MPa)	Por., (%)	Perm., (mD)	Oil Density (kg/m^3)	API Gravity, (°API)	Sw, (%)	Solution Gas Ratio, (m^3/m^3)	Abs. Visc @ 30°C (mPa-s)	R.F., (%)
Field A	Meotian	850	10	8	30	315	940	20	36	7	3450	20
Luseland	MbkknM_ss	739	12	6.3	31.5	3000	983	12.4	25	10	1400	11.4
KBM	n.m.	375	10	4.5	30	175	940	20	31	7	455	n.m.
Provost	Kdina	835	3	5.7	26	802	914	23.3	22	7	42	50

Well selection

Based on Canadian experience, Field characteristics and history the wells selection criteria mentioned in table 2 were established. Accordingly, three new wells for CHOPS trial were selected: X_1, X_2 and X_3.

Table 2. Well selection criteria

Well Selection Criteria	Value
Distance to gas cap	> 800 m
Well inside sand body acc. to facies model	Yes
Lowest clay content	< 20
Distance to OWC	> 800 m
Watercut	< 80%
Distance from the closest water injector	> 800 m
Casing diameter	at least 6 5/8"
Casing cementation integrity	Yes
Casing integrity	Yes
Well rat hole	30 m
Well location access	Yes
Distance to surface facilities	Close

Production Forecasts

No mathematical model is available to forecast production using industry standard simulators such as Eclipse or CMG. Therefore, the used production profile for oil, water and sand in this Report will be based on Canadian analogues.

Fluids Production: a major difference in CHOPS wells compared to regularly completed wells are the shapes of the production profiles, which increases for several months after put into production, then "peak" and decline thereafter (fig. 3).

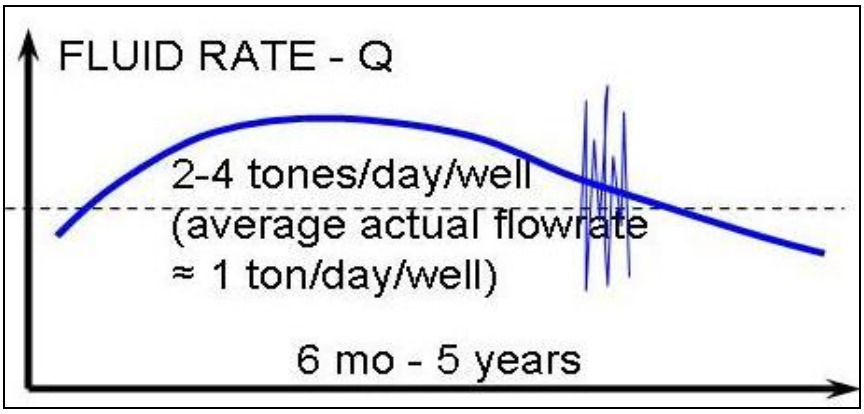

Fig. 3. Expected fluid rates in CHOPS production

For a preliminary economics assessment three different expected fluid production volumes have been agreed upon in the workshop: 2x for pessimistic case (P90), 3x for base case (P50) and 4x for optimistic case (P10) of current average production in a case of new well drilled (3 tons/day)

Based on (fig. 4), sand production is assumed to be about 5-10%, leveling out at around 0.5-2% under "steady-state" conditions as has been obtained in two analogues fields of Karazhanbasmunai - Kazakhstan and Amber Lake.

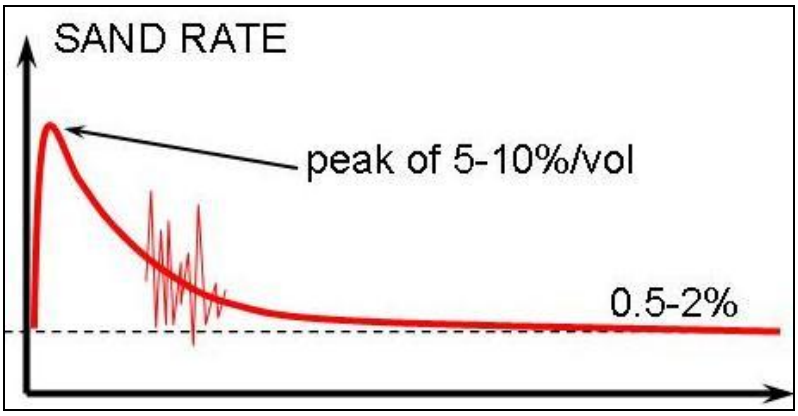

Fig. 4. CHOPS sand production forecasts

Note, both Canadian analogue production profiles (fig. 3 and 4) display a quite "spiky" shape. The expectation of these highly irregular rates needs to be communicated to the production department and operators to allow for fluctuating production volumes. Also note that peak rates do not coincide, i.e. the maximum sand volumes are reached shortly after CHOPS start-up whereas peal oil volumes should be achieved several months later.

CHOPS Trial Results

The first well produced in CHOPS was the new well X_1, which has perforated the interval 892 – 889 m in January 2010. The well produced 20 m^3/day during two months, after that being converted in an injector. The trial was considered inconclusive, because the well was situated close to other injector.

In March 2010, into the new well X_2 was perforated the interval 900 – 897 m, after that it was produced in CHOPS. In two months the liquid rate increases to 28 cm/day, 88 % watercut and 3.1 tons/day. The send percent reported initially was 1.5 – 12 % and decrease after one month to 0.5 – 2 %. It was taken the decision to complete the well in gravel – packing system, but after the best performances was obtained in October 2010, respectively 26 cm/day liquid, 94% watercut and 1.5 tons/day oil rate.

The new well X_3 was perforated the interval 960 – 957 m and produced in CHOPS one month with 30 cm/day and some oil tracers. After that it was taken the decision to be equipped in gravel – packing and in June 2010 was obtained the maximum production, respectively 23 cm/day, 48% watercut and 11 tons/day oil rate. The decline was observed in the well and after a KLA-STOP treatment in January 2011, the oil production increase from 1 ton/day to 3 – 4 tons/day. In September 2011 the well production were 28 cm/day liquid, 85% watercut, respectively 4 tons/day oil rate.

Conclusions

According to results observed in the trial well, we can assume in well Oteşti – 1154 the expected results in base case forecasted, because the initial rate was at least 3 times more than in the case of wells drilled in the last years (3 – 5 tons/day). This fact was assumed as effect of permeability modification close to wellbore due to CHOPS trial. Also, the well is located in the northern part of structure, which is not affected by water injection. The well was an appraisal one in an area with initial oil saturation.

Because the well Oteşti – 627 was close to an injector, we consider that the results are inconclusive. In case of Oteşti – 628 well, the result was as in pessimistic case forecasted. Both were infill wells and were located in the southern part of structure, affected by water injection and with considerable cumulative production, respectively lower actual oil saturation.

We can conclude is better to continue to drill into the northern part of structure, close production from Oteşti – 1154 and to check CHOPS trial in at least two new wells for more accuracy of results.

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Experimente CHOPS (Cold Heavy Oil Production with Sand) într-un zăcământ din România

Rezumat

Producția la rece a țițeiului greu împreuna cu nisipul - Cold Heavy Oil Production with Sand (CHOPS), a fost aplicată cu succes pe zăcăminte de țiței greu din Canada de aproape 20 de ani, furnizând nu mai puțin de 20% din producția brută de țiței în perioada 2001 – 2003. Principalele caracteristici ale zăcămintelor din Canada pe care s-a implementat tehnologia CHOPS sunt nisipuri neconsolidate, calități scăzute ale țițeiului (API ~ 11°-14°, viscozități de până la 20000 cP), grosimi mici (<15m), strate prea subțiri pentru a justifica metodele termice de recuperare, dar suficiente gaze în soluție (>7 Nm^3/m^3) pentru a ajuta curgerea țițeiului şi nisipului spre gaura de sondă.

În 2009 a fost stabilit un program de realizare a unei evaluări a potențialului aplicării tehnologiei CHOPS pe un zăcământ A din România. Acest program a avut la bază exemple relevante din experiența CHOPS aplicată în Canada şi a unui workshop desfăşurat pe 21-24 Septembrie 2009. Experimentele CHOPS au fost propuse a fi efectuate în sondele noi X_1, X_2 şi X_3. Pe baza zăcămintelor similare (un model matematic nu este disponibil încă) – pentru experimentele CHOPS cu mai bune calități ale țițeiului, aşa cum sunt preponderente pe zăcământul A – a fost aşteptată o creştere a producției de 2-4 ori, comparativ cu cazul sondelor echipate în sistemul gravel – packing.