Assisted Extra Heavy Oil Sampling by Electromagnetic Heating*

W. Acosta[1], J. Bermudez[1], L. Andarcia[1], and A. F. Suarez[1]

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[1]HOCOL, Bogota, Columbia (andres.suarez@hocol.com.co)

Abstract

Sampling extra heavy oil becomes a challenging operation when viscosities overcome 3000 cp at reservoir temperature. The acquisition of quality samples that allow obtaining accurate viscosity measurements and initial solution gas, among other fluid characterization measurements, is crucial, since they are key parameters to identify and select reservoir strategies. Samples that are commonly gathered from such reservoirs come from mud tanks during drilling, which bring uncertainty due to chemical contamination, and from preserved cores, which usually cannot provide sufficient volume for the required analysis.

A new sampling technique presented in this paper, involves an operation assisted by electromagnetic heating. This technology has been studied since the 70s, with some field trials in the 90s, and is currently subject of renewed interest due to better design and prediction methods. It consists of applying radiofrequency heating through use of an antenna positioned in front of the zone of interest. The target zone heats up due to the water molecules oscillation induced by the electromagnetic waves. The increment of reservoir temperature reduces the extra heavy oil (EHO) viscosity and allows such viscous fluid to flow. After heating a substantial fluid volume, the downhole sampling operation with a wireline tool can be started. Heated volume and temperature increment become key parameters to have a successful operation.

The heating process is simulated using a coupled reservoir and electromagnetic (EM) simulator. The thermal and electromagnetic models are created for a reservoir with standard conditions found in Colombian Llanos basin, which is the type of reservoir where this heating technology will be applied. Multiple simulations of the heating process using different radio frequencies (RF) power levels, frequencies and antenna lengths were performed to identify the optimum combination, which would allow fastest heating process.

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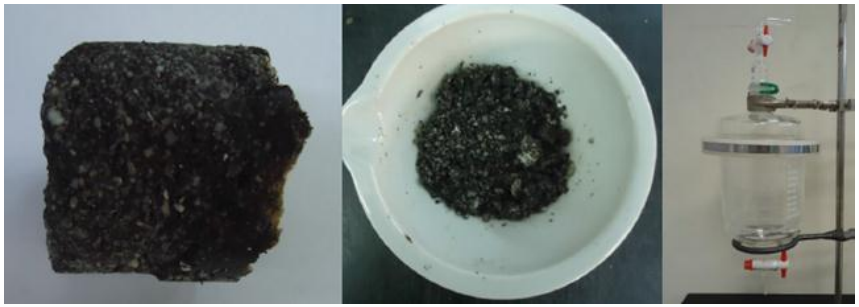
INTRODUCTION

To obtain representative fluid samples from heavy oil reservoir with very high viscosities is challenging

Current Colombian conditions:
Long time for exploration license approval
Restriction for testing stratigraphic wells

Fluid reservoir characterization is crucial in earliest stages

Current normal sampling methods for highly viscous heavy oil:



Core extraction

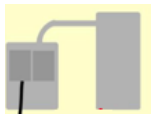
Drilling cuttings

Wireline sampling

Assisted Extra Heavy Oil Sampling Technologies

Options to improve oil mobility for downhole extra-heavy oil sampling?

- Chemical methods
  - Injection and soaking of diluents, nanofluids to improve oil mobility
- Thermal methods
  - By using not intrusive methods to heat the formation to a desire temperature
    - Circulating hot fluids
    - Resistive heating
    - RF-Heating



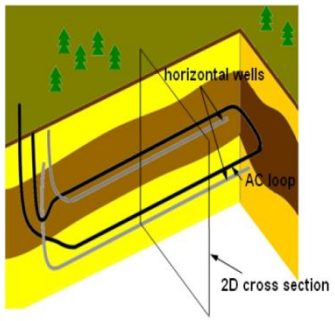
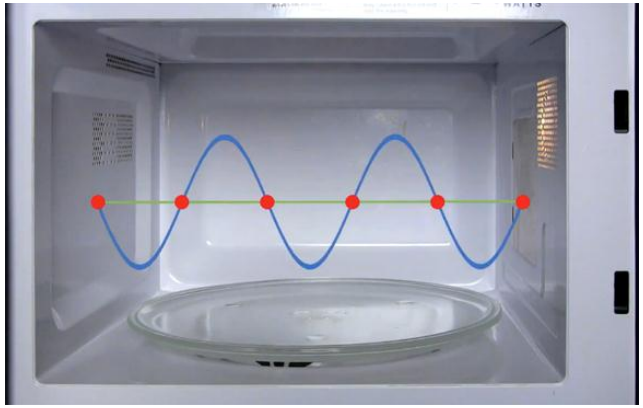


Figure 1: AC loop for reservoir inductive heating

Source: Mustafina, D et al SPE 165507

RADIO FREQUENCY HEATING

- The principle of microwave heating which resides in the property of the water molecules to vibrate and produce heat.
- The same basic principle works in the reservoir heating.
- All oil reservoirs have water and this water can be excited by RF waves. Therefore, the RF Heating technology, applied for heating oil reservoirs.
- All reservoirs contain water!!!



Motion **Friction** **Heat**

Source: University of Colorado, Physics Department

What Do We Have to Understand for Sampling Application?

- Volume (stimulated zone)
- Required time for heating
- Facility to be implemented
- Side applications
- Risks involved
- Operational restrictions

Sensitivity analysis of critical parameters "Initial – Design"

SIMULATION PROCESS

Mass conservation equation combined with the momentum equation

$$-\nabla \bullet \frac{\vec{V}_i}{B_i} - \frac{q_i}{\rho_i} = \frac{\partial}{\partial t}(\varphi \frac{S_i}{B_i})$$

Reservoir Simulator

Maxwell equations

$$\nabla \times \vec{H} = \vec{J} + \frac{d}{dt}\vec{D}$$

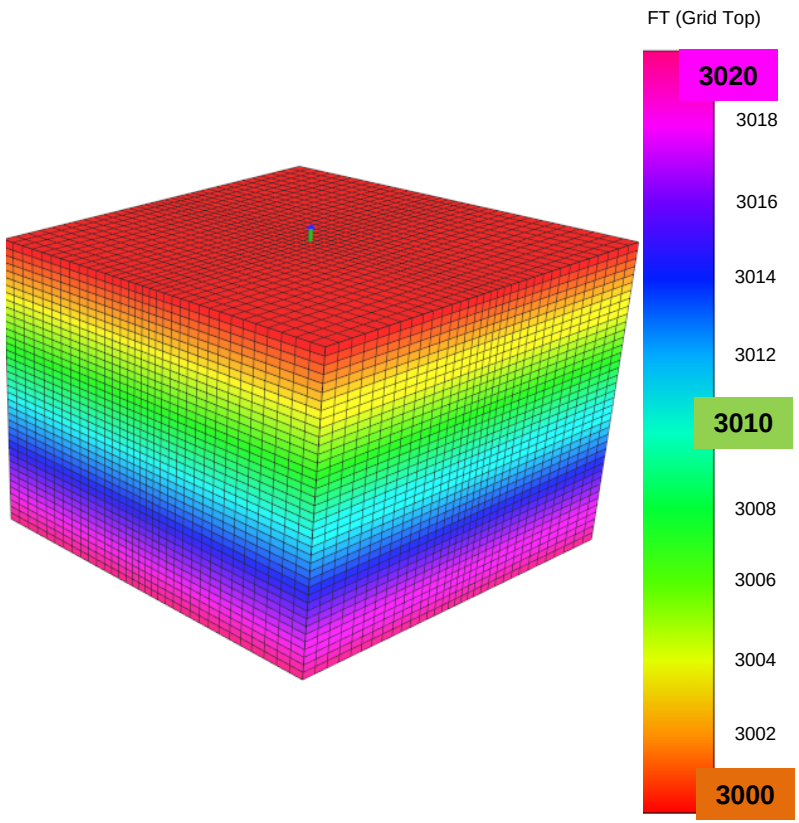
EM Simulator

Calculates Temp/Pres/Sat

Calculates EM field

Master Program
Comm. Interface
Calculates EM properties and heat source

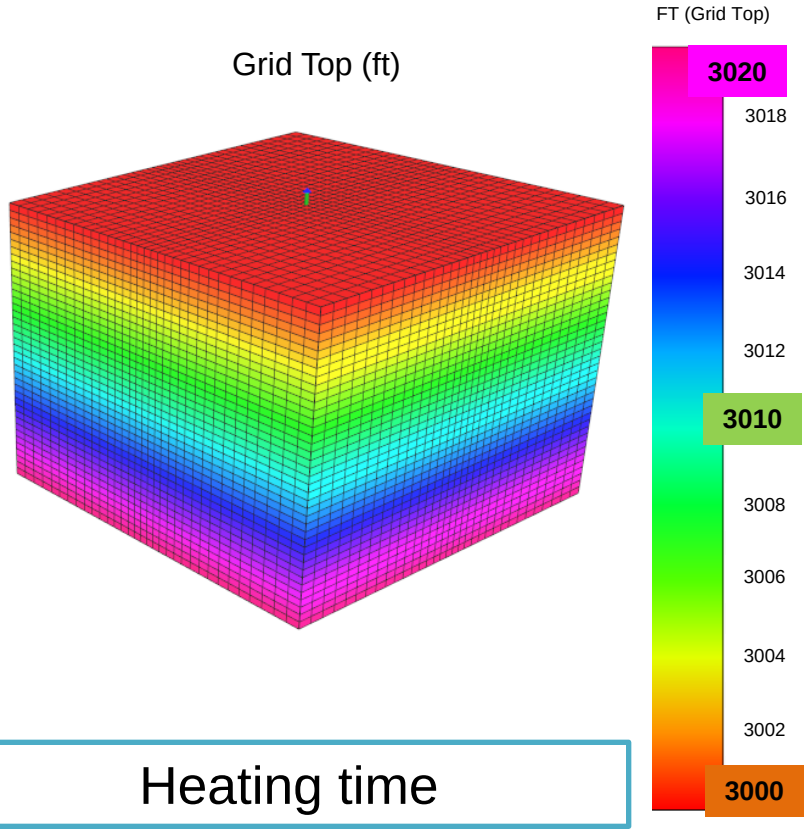
BASE CASE - PARAMETERS



RESERVOIR PROPERTIES

Initial pressure	1250 psia
Initial temperature	100 °F
Initial reservoir porosity	30%
Reservoir permeability	3000 md
Initial reservoir So	65%
Initial reservoir Sw	35%
Rock thermal conductivity	17.4 Btu/ft-d-°F
Oil thermal conductivity	3 Btu/ft-d-°F
Water thermal conductivity	8.6 Btu/ft-d-°F
Oil viscosity @ initial Temp.	10,000 cp

SENSITIVITIES



Power

- 1.2 Kw/ ft
- 2Kw/ft

Frequency

- 7 MHz
- 8 MHz
- 30 MHz
- 60 MHz

Antenna length

- 3 ft
- 5 ft
- 15ft

Materials

- Aluminum
- Ceramic
- Zirconium

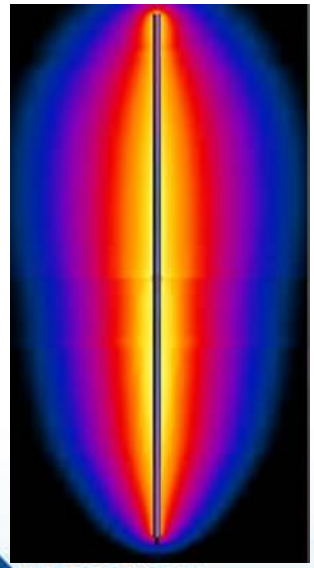
Heating time

Well fluid

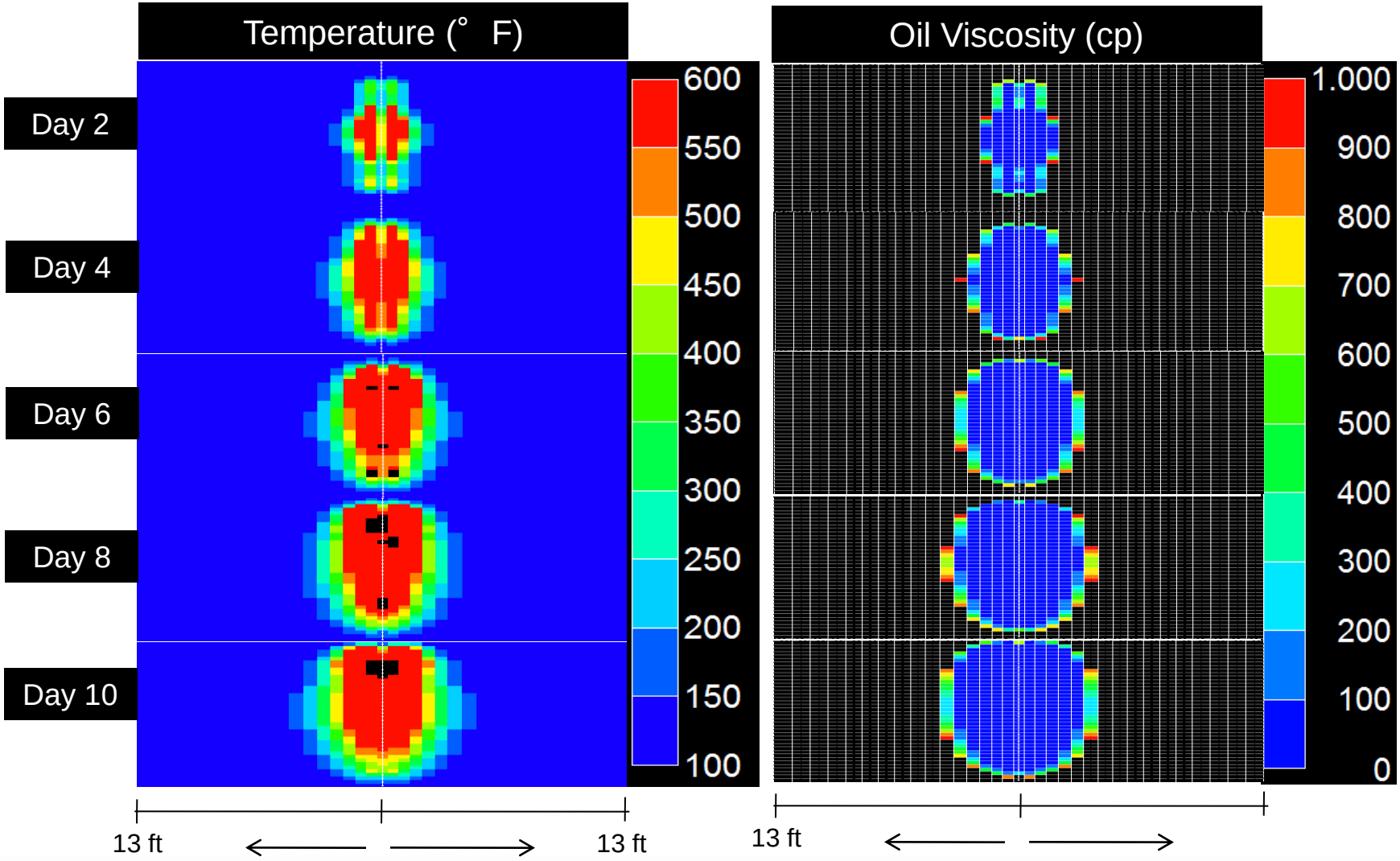
- Water based mud
- Oil based mud

Swc

- 15%
- 35%



RESULTS



Total oil volume heated of 3.5 bbl (556 Lt). If just 1% in recovered during sampling operation, it represents 5500 cc

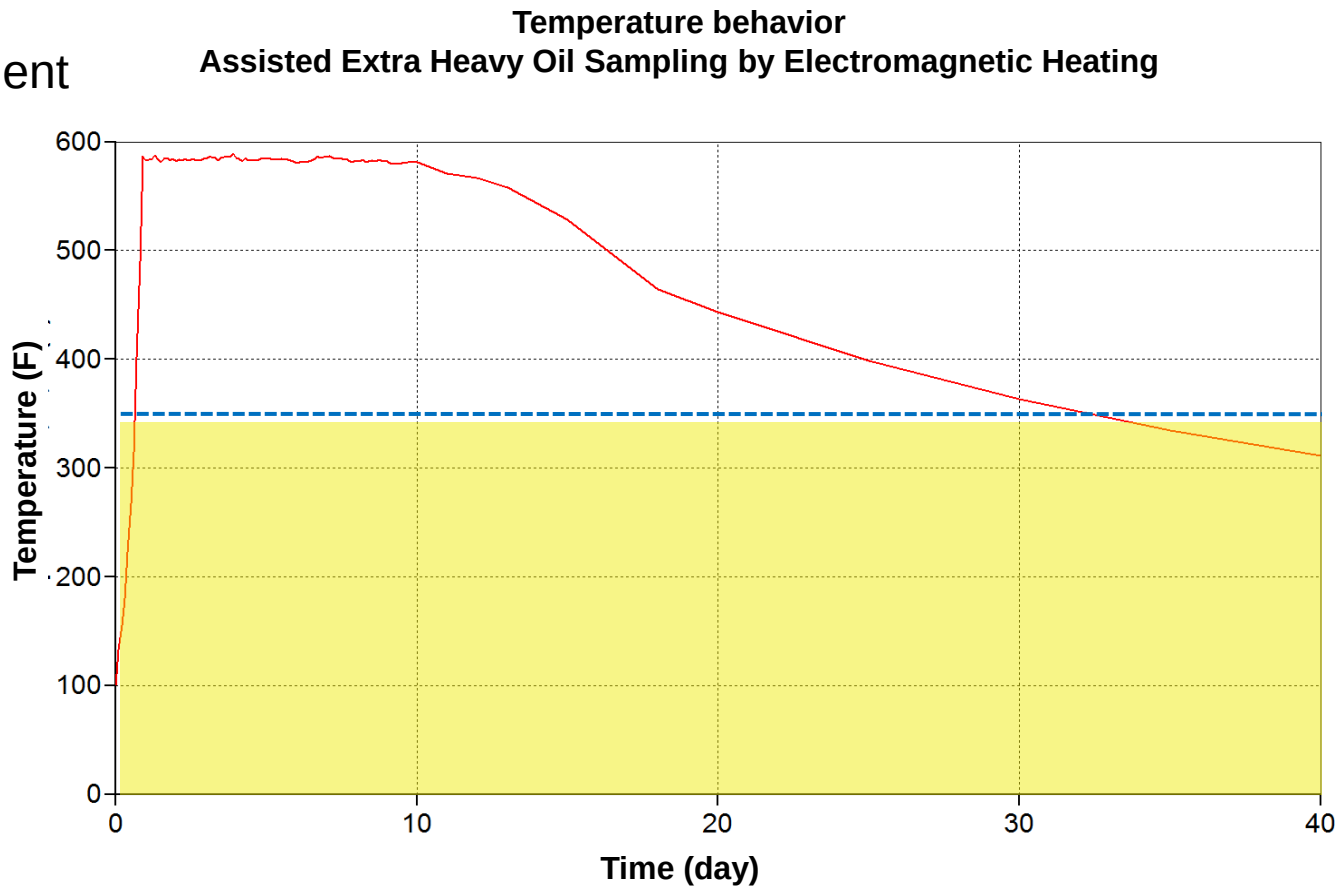
RESULTS

*Normal pressure gradient

Ts @ 3000 ft

Ts @ 1000 ft

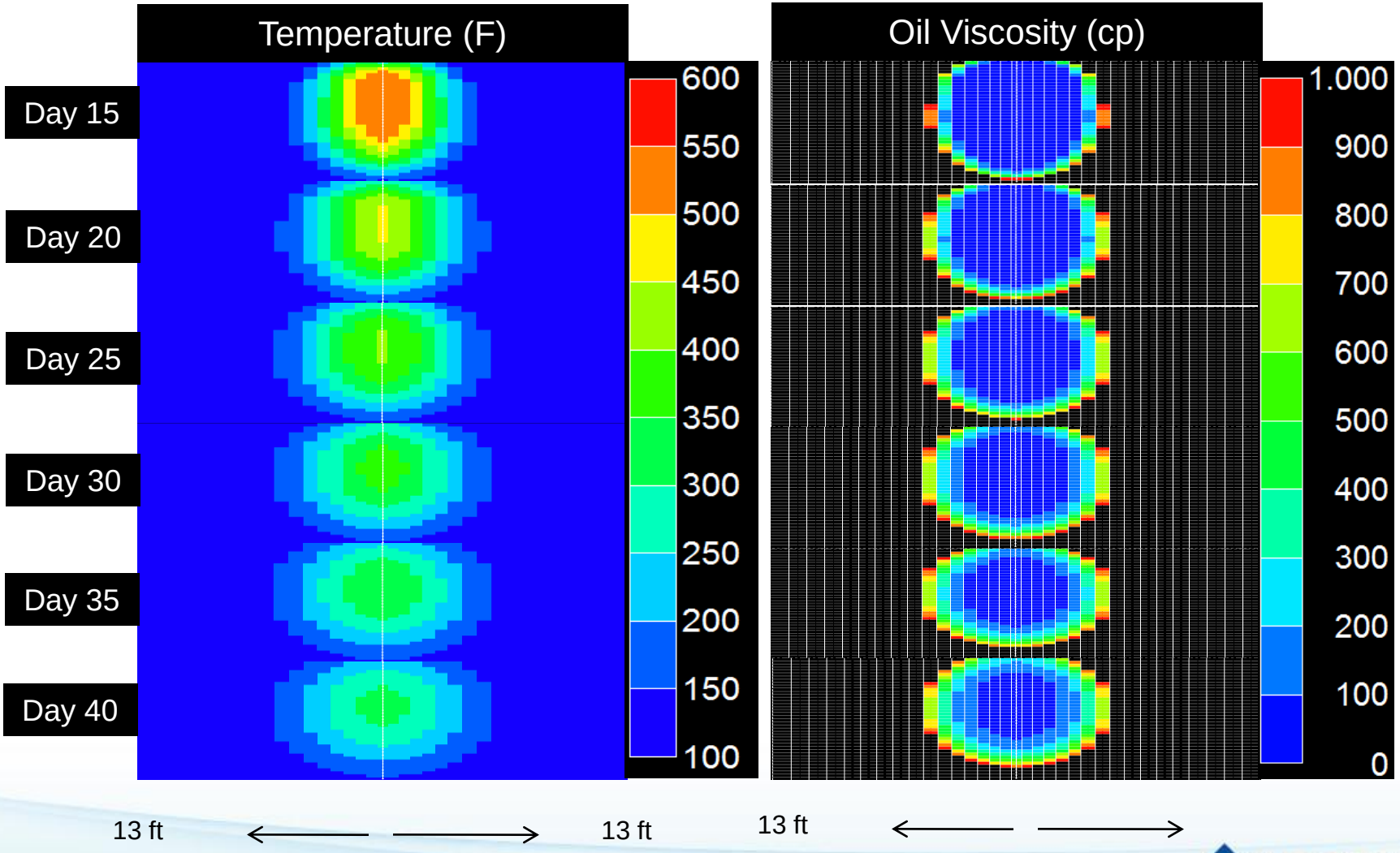
Ts @ 300 ft



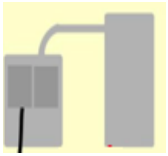
Zone where no heat dispassion will be required to start sampling operation «current constraint conditions»

RESULTS

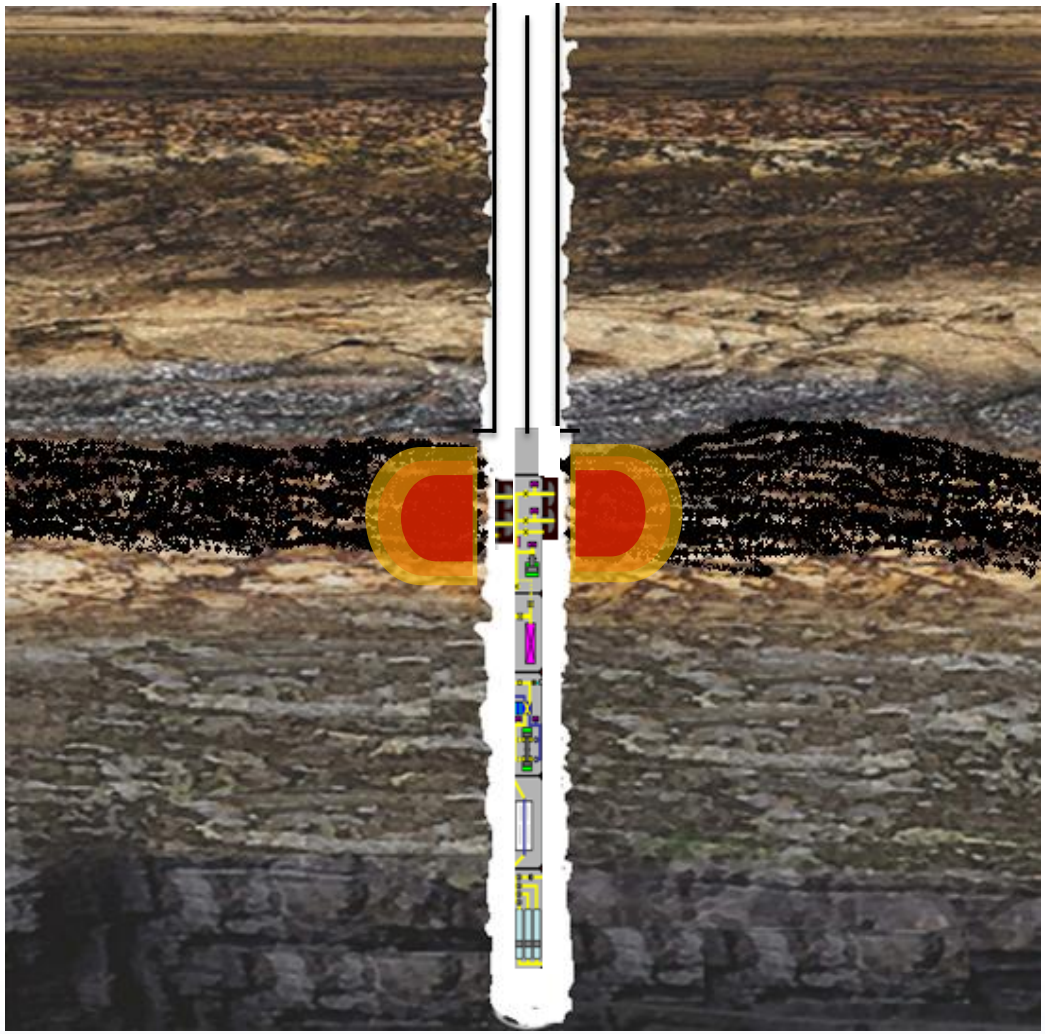
Temperature dissipation and viscosity behavior



General Operating Procedure



Surface Equipment



1. Antenna Deployment

2. Heating Time

3. Cooling Time

3. Sampling Operation

Source: Some graphs are taken from Halliburton, SLB and Weatherford wireline brochures and webpages and edited by the author

CONCLUSIONS

It is technically viable to sample highly viscous heavy oil by using radio frequency heating, to increase reservoir temperature around the wellbore and improving oil mobility conditions.

Sampling operation is limited by maximum temperature operation of wireline sampling tool. However, a cooling time for some cases (saturation temperature) is required before to start the downhole operation.

The methodology presented in this work is an option to obtain reservoir samples in highly viscous oil at early stages of exploration, where limitation exists due to current Colombian legal restrictions for stratigraphic wells and delays in exploration license approvals

ACKNOWLEDGEMENTS

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Thank You