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Drilling Horizontal Wells for the Mine Assisted In-Situ Project

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Introduction

The Mine Assisted In-Situ Project, or MAISP, was initiated in 1977 to investigate Thermal Oil Mining with steam drive between horizontal wells. The five party consortium included Petro-Canada (as operator), Esso Resources, Husky, Gulf Canada and Canada Cities Service. Papers on MAISP were published in 1979, 1982, 1984 and 1985 that described the concept of thermal oil mining, post-pilot monitoring and reservoir engineering aspects of the technology. This presentation describes the challenges encountered while drilling and completing the original, thermally capable, long horizontal wells in the McMurray Oilsands.

Background

Oil mining is not new. Oil wells have been dug by hand for centuries in Asia Minor, Romania, Burma, and even in Canada (Petrolia,1858). Galleries were driven into an outcrop of bituminous sand, at Pechelbronn, Alsace, France starting in 1735. In 1916 vertical mine shafts & galleries were sunk to ~ 150 m to increase production. Mining operations for oil recovery at Wietze, Hannover, Germany were initiated in 1917. Production was initially by seepage from the reservoir into the mine galleries, but later changed to actual extraction of the oil-bearing sands. Mined sand was brought to the surface where it was washed to extract the oil (1).

The Yarega heavy-oil field was discovered in 1932, ~ 1100 km NE of Moscow. The field was initially drilled with vertical wells, then construction of an oil mine commenced in 1937. Oil drained into galleries, where is was collected and pumped to surface. “Thermal Oil Mining” experiments commenced in 1972 with horizontal steam injectors at the same elevation as the producers. Eventually, vertical steam injection wells were drilled to the top of the pay, with oil production via horizontal wells drilled from galleries (2). In 1976, a group of Canadians went to Yarega to observe a Soviet “oil mine”, which led to the formation of the MAISP consortium.

Drilling Horizontal Wells at MAISP.

The Mine Assisted In-Situ project envisioned recovering bitumen from the oilsands with steam drive via horizontal wells that would be drilled from mined galleries (drifts) located in limestone beneath the oilsands. To increase confidence in the project, the first step was to test drill horizontal wells at an outcrop, plus construct a bitumen treating facility. The outcrop test envisioned three long, thermally capable, horizontal wells drilled 6 m apart, plus six vertical observation wells. Site preparation involved contouring the hill above the drill site to promote slope stability, plus excavating of a large hole in the limestone into which we would locate the horizontal drilling rig.

Drilling horizontal wells from beneath the oilsands was new to all JIP participants, so we did a lot of brainstorming and decided to experiment with a number of different drilling techniques, including high frequency resonation of drill pipe and air-hammer drilling. In addition to investigating various drilling methods, a prime objective was to complete the wells in a configuration suitable for steam circulation & injection, plus hot bitumen/water production. The horizontal wells were drilled in the Spring of 1979 and were to be completed at ±310 m TD with 100 m of slotted liner in the oilsands. We also drilled a longer well to 543 m TD to test limits of equipment and technologies, and completed this well to 295 m.

We anticipated a number of drilling problems such as: hole cleaning, bitumen sticking to drill pipe, surveying and a whole bunch of unknowns. We expected hole collapse issues as there would be no hydrostatic pressure from drilling mud to hold back the unconsolidated formation, plus overburden stress was perpendicular to the horizontal borehole.

Figure 1 shows the drilling rig used for all MAISP wells. The rig had been modified to drill at inclinations of 0 to 98°, had a lengthened mast for longer pipe lengths, pulldown was increased from 4500 to 11000 daN, and torque increased from 2700 to 6200 N-m.

Figure 1: Hawker Siddeley Super Drill 150 in “The Pit”.

As can be expected when doing something for the first time, there were a lot of surprises and we certainly spent more time not drilling than making hole. The main challenge was the inclined beds in the Waterways argillaceous limestone beneath the McMurray oilsands. The formation dipped to the West at 12°, while we were attempting to drill upwards at +5°, for a difference of ±17°. The drilling assemblies wanted to follow the downward dipping bedding planes. By trial and error we eventually worked out a stabilization configuration that imparted an upwards force on the air hammer bits. Another problem was that the limestone was quite permeable, which led to lost circulation while cementing the production casing into place.

Rotary drilling the oilsands with mud proved to be challenging due to high circulating pressures, high torque and twist-offs on the first horizontal well. Drilling with the resonant driver did not improve rate of penetration (ROP), but the resonant driver was very useful for freeing stuck drill pipe. The well was successfully drilled to TD using a smaller air hammer with air-foam as the drilling fluid. The oilsands section of the first well took quite a while to drill, at 9 days to drill 120 m. Because the borehole had been open for so long, we then had trouble running the slotted liner through a collapsing borehole.

The second horizontal well was also drilled with an air hammer and foam to a TD of 543 m, then was completed with slotted liner and a circulating string to 295 m. The major challenge on the second horizontal well was that the magnetic survey tools no long functioned due the interference from the steel liner in the first horizontal well. Drilling the oilsands section of this 2nd well required only 2 ½ days to drill 330 m.

We built aggressive, wear resistant bits and stabilizers to drill the oilsands section of the third horizontal well. The 3rd well used rotary drilling with air-foam, and achieved an ROP of 110 m in 24 hours. The borehole was not open for long, so the slotted liner was easier to install compared to the first two wells.

On completion of the three horizontal wells, six observation wells were drilled into the pattern from above. Total cost to drill and complete three horizontal wells and six observation wells was $671,000, including rig modifications. Figure 2 illustrates the final configuration of the MAISP project.

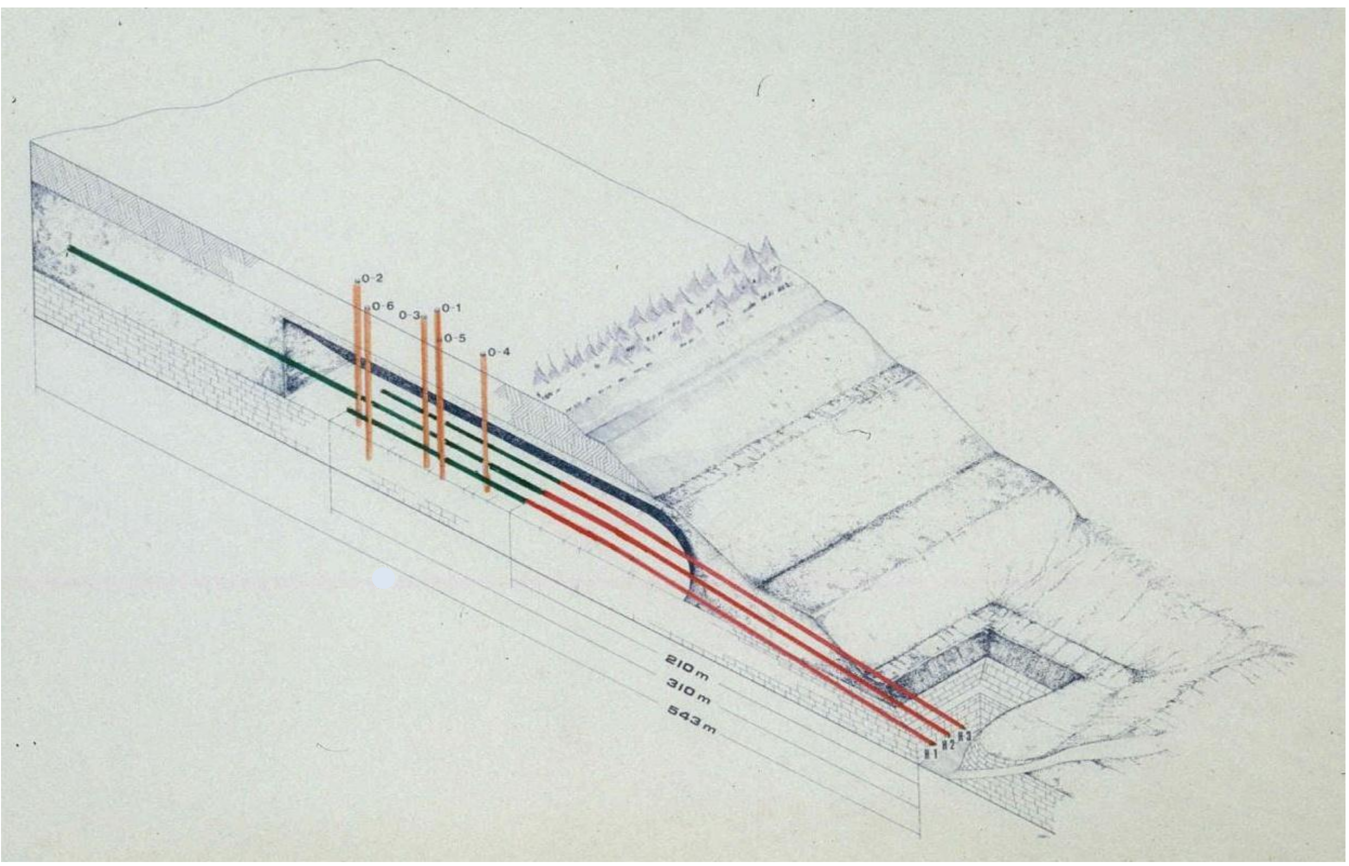

Figure 2: Layout of Thermally Capable Horizontal Wells and Vertical Observation Wells.

Production Results

The primary purpose of MAISP was to demonstrate drilling and completion of thermally capable horizontal wells from beneath the oilsands. Production results were also encouraging. Steam was circulated in the three horizontal wells for a few months, then the centre well was shut in. Steam was initially injected into the North well, which was 4 m. lower than the South well. After a number of months steam was injected into the higher South well while production was via the lower North well –

and bitumen production increased significantly. Over the short time that the pilot operated, total steam injection was 13,648 Sm3 CWE and bitumen production was 1297 m3. Oil rates were increasing and SORs were decreasing, but the pilot was shut down after only 16 months of steaming. Following cessation of steaming operations, 8 vertical boreholes were drilled and logged. The heat affected zone was found to be 21 m high (lower McMurray), 110 m long and greater than 20 m in width.

References:

(1) USBM-351, Mining Petroleum by Underground Methods, 1932
(2) The Yarega Heavy Oil Field – History, Experience and Future, JPT, Apr 2012