EnSys Yocum
MULTIPHASE FLOW TECHNOLOGY

WELLSIM– Technical Description

Horizontal well simulation model

Sections to this technical paper include an Overview and Application example.

I. Overview

The EnSys Yocum WELLSIM Model has the following capabilities:

- handles a large number of stublines and laterals flowing into vertical or inclined wells
- balances pressure flow and converges to specified wellhead or surface line terminus pressure.
- blends different reservoir pay GOR, water fraction and other physical properties.
- well technology and surface line technology items can be invoked – including submerged pumps, GOSPs, gas injection and chokes.
- predicts flow regimes, slug sizes and frequency in laterals
- predicts wellbore flow regimes
- predicts sand settling velocities
- predicts cease flow conditions. these may result from low pi, sand and/or drilling mud plugging and sand settling.

II. Example of Horizontal Well Simulation

The EXCEL spreadsheet pictorial sketch attachments illustrate the simulation of two horizontal well laterals flowing into a vertical oil well tubing using our WELLSIM model. The inputs are based on an actual field case where cease flow conditions were observed in one of the horizontal well laterals, the lower PI lateral.

As shown, these are low PI reservoirs flowing in at a depth of approximately 7500 feet depth, with a water content of 45 to 50%. The vertical well is predicted to be in slug flow near the bottom, becoming froth flow at the top as associated gas evolves.

The lateral physical properties are somewhat different as to free gas and water content. WELLSIM blends lateral physical properties from multiple laterals as they enter the vertical well section.

WELLSIM incorporates components of our PRODSIM, TRUNKSIM and GOSPSIM models. As a consequence:

- Up to 100 perforation flows into multiple laterals can be represented. Based on PI, reservoir pressure and lateral dimensions, WELLSIM solves the pressure flow network and converges all flows to meet a specified well head pressure. The model can also converge to a surface line terminus.

- All of the well technology options available in WELLSIM can be invoked, including submergible pumps, gas injection, well chokes, inclined wells and others. A method developed by Gouvier, Radford and Dunn is programmed to predict vertical upflow well flow regimes (bubble, slug, froth, ripple and film) as a function of gas to liquid ratio and superficial liquid velocity

- The lateral flow lines can be modeled using the full capabilities of PRODSIM. These include elevation variations, flowline and riser slug flow prediction (with estimates of slug size and frequency), calculation of sand settling velocities, pumps and others. Downhole lateral gas-oil-water separation options can be represented, using the capabilities of GOSPSIM.
  Surface line facilities from the wellhead can be modeled in detail.

Cease flow in Laterals

Experience with horizontal/lateral wells has shown that sufficiently low flowing pressures in the laterals can cause critically low fluid flow velocities which initiate cease flow in the laterals (during the time period before the well flow ceases, slug flow begins to evidence increasing pressure fluctuations and frequencies).

There are several reasons why critical low flowing pressures have occurred in wells:

- the inflow performance from the reservoir into the lateral through the open formation or pay zone (whether one or several, whether flowing through perforated liners or open hole production) has the high pressure drop associated with low PI. This reduces flow velocities in the lateral. Factors causing this flow behavior are:

    - sand or other particles flowing into the wellbore mechanically plug off pores resulting in high pressure drop

    - during the drilling of the well the mud may have been forced into the open formation by the positive pressures relative to formation pressures, thus plugging up pores and causing high pressure drop skin effects. This again reduces PI.

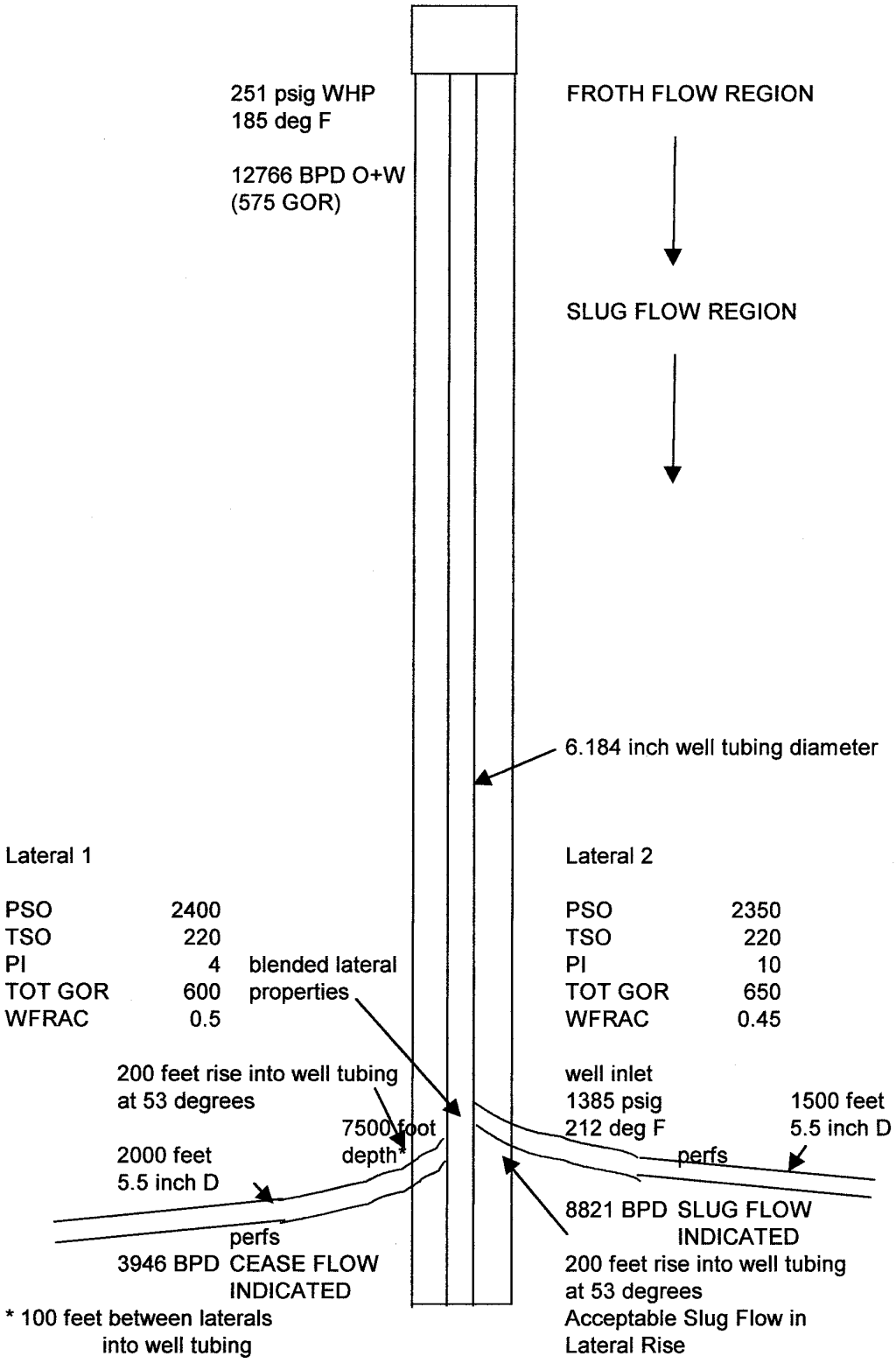
    - during the flowing time of the well, the flow velocities in the lateral section may not be able to carry the sand or other particles in the flowing stream out through of the lateral or vertical well. Below the critical sand deposition velocity, sand particles (with a range of particle sizes) deposit on the bottom of the lateral. The accumulation effects over flowing time may reduce the flowing cross section area sufficiently to increase pressure drop across the lateral, thereby reducing volume flow rates helping to initiate cease flow.

Experience shows that some well formations, especially those producing fractured zones may have rapid reservoir pressure declines. The flow velocities may be reduced (unless GOR increases at the lower reservoir pressures) and cease flow may ensue. If water cuts increase, this in turn increases elevation pressure drops which interacts with the other factors to reduce flow velocities.

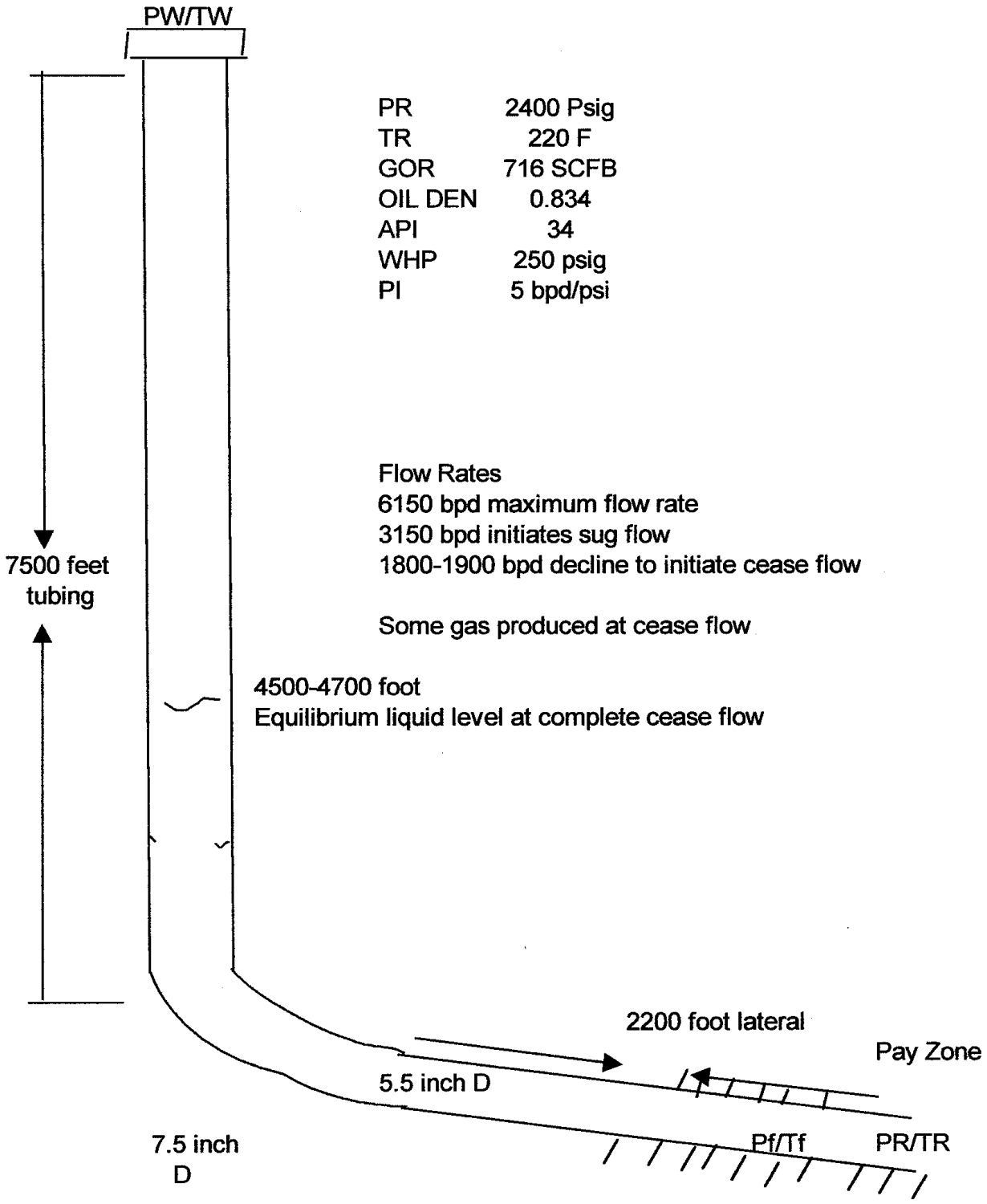
In our review of 100 horizontal/inclined lateral wells, about 20 wells had ceased flow. Our wellbore/reservoir hydraulic simulator employs available data inputs to evaluate the performance of these wells. The options available to correct the situation can then be subject to an economic evaluation. Production can be restored in many wells.

Wells do not have to in cease flow to benefit from an analysis employing WELLSIM. Options can be studied for horizontal wells at different points in their production history.

SIMULATION OF HORIZONTAL WELL LATERALS FLOWING INTO VERTICAL WELL



HORIZONTAL/INCLINED WELLS
MULTIPHASE WELL/LATERAL HYDRAULICS



PR	2400 Psig
TR	220 F
GOR	716 SCFB
OIL DEN	0.834
API	34
WHP	250 psig
PI	5 bpd/psi

Flow Rates
6150 bpd maximum flow rate
3150 bpd initiates sug flow
1800-1900 bpd decline to initiate cease flow

Some gas produced at cease flow

EnSys Yocum Incorporated

PO Box 2320 Flemington NJ 08822
Tel: (908) 788 7332, (281) 788 7880
Email: info@ensysyocum.com
Website: www.ensysyocum .com