Interpretation Theory

KAPPA

Module #7
Single Phase
Interpretation Theory

Single Phase Interpretation

The single phase case is the simplest PL situation.

In single phase production the only questions are;

1. How much fluid is flowing from/into which perforations ?

2. Is there any flow behind casing ?

3. Is there any crossflow?

Single Phase Interpretation

A simple **Flowmeter** answers the main question of single phase.

However...

- **Caliper** is essential for hole size changes
- **Temperature** is needed to look for flow behind casing
- **Density** can also be useful, even in single phase.
- **Temperature & Pressure** needed for PVT

Flowrate

Flowrate:
Given by the product of velocity, hold-up and pipe area.

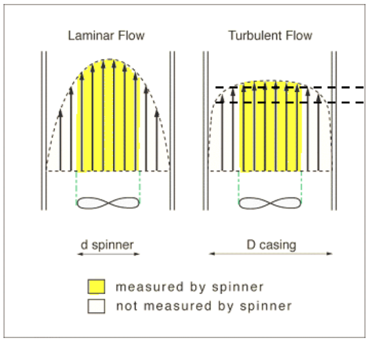
Velocity, v:
This is actual mean velocity of the phase of interest.

In single phase flow laminar flow is one in which the layers glide smoothly over adjacent layers.

In turbulent flow the fluid exhibits very erratic motion with a violent interchange of momentum across the pipe.

The nature of the flow - turbulent or laminar - and its relative position along a scale indicating the relative importance of turbulent to laminar tendencies - are indicated by the Reynold's number.

Flow in Pipes



VAPP – velocity as seen by the spinner

Vm – average mixture velocity in the pipe area needed for rate calculation

The spinner, centered in the borehole, sees only the middle part of this flow since the blade does not cover the full casing diameter

$$V_m = VPCF \, . \, Vapp$$

The velocity profile correction factor, VPCF, was historically taken as 0.83

The velocity profile correction factor actually depends on Reynolds number

N_{re} = Area.Velocity.Density/Viscosity

Reynolds Number

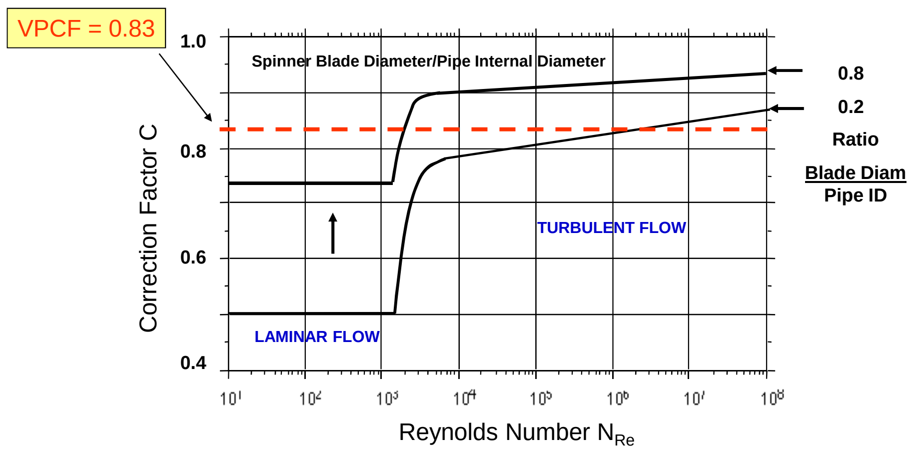
Reynolds number (N_{re}) is a dimensionless parameter that represents the ratio of intertial forces to viscous forces and is defined by:

ρ = fluid density g/cc
l = pipe diameter in
v = fluid velocity ft/s
μ = fluid viscosity cp

$$N_{re} = 7.742 \times 10^3 \frac{\rho l v}{\mu}$$

From experiments, the range of Reynolds numbers is:
Nre < 2000 - laminar flow (Reynolds lower critical pipe number)
2000 <Nre <4000 - transition from laminar to turbulent
Nre > 4000 - turbulent flow
The majority of flows encountered in vertical/deviated oil wells are turbulent

Flowmeters: Velocity Correction



The correction depends on whether there is laminar or turbulent flow, which is determined by the Reynolds number.

Vm calculation

V_m … the average velocity, is a function of the Reynolds number,

- **the fluid density***
- **the fluid viscosity**

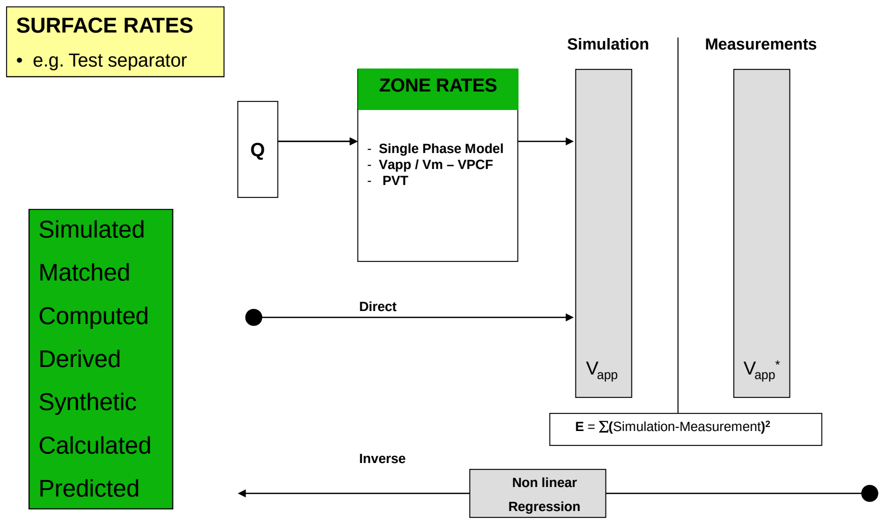
→ PVT

and…..

- **the velocity V_m** → Iterative solution

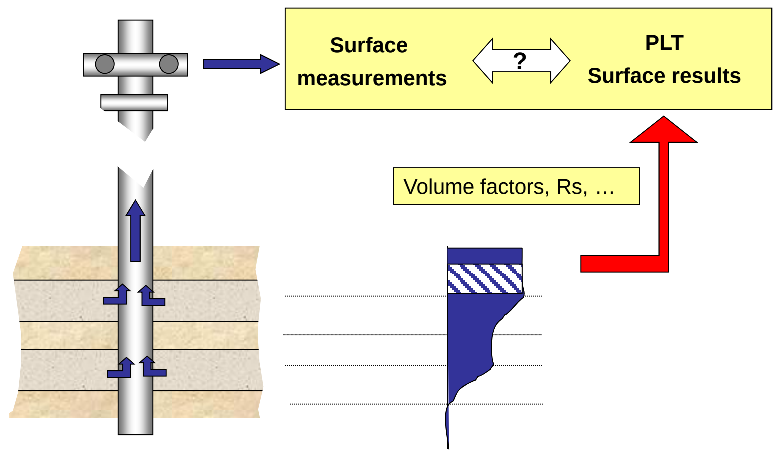
Density could be measured

Single Phase Emeraude Process



 9

Surface Rates



The Surface Rate measurements are the only benchmark we have to validate the quantitative results from EMERAUDE.

Beware of surface rate measurements !!

 10

Surface to downhole

SURFACE RATES

- Test separator
- Multiphase rate meter
- Chart readings
- Production history
- Flowline measurements

(preferably recorded during the actual time the PLT was logged)

Surface rates - Qw, Qo, Qg

↓

PVT – Bw, Bo, Bg

↓

Vmsc

Vm

EMERAUDE – calculated rates

QWZT, QOZT, QGZT → Vm

Vmsc/Vm = Vpcf_mult

Velocity Profile Correction

$$V_m = Vpcf.(\rho, V_m, \ldots.) x\ V_{app}$$

V_{pcf} = 0.83 is assumed by default, but a better estimate can be obtained by solving the equation

Emeraude solves the equation by using non linear regression in order to minimize the function

$$E(V_m) = [V_m / Vpcf.(\rho V_m, m, \ldots) - V_{app}]^2$$

$$\text{Error function} = [\ \text{synthetic } V_{app} \quad - V_{app}]^2$$

Realistic values for V_{pcf} range from about 0.75 to about 0.92

In monophasic the velocity is the only residual.
In multiphase, the velocity is one residual among others e.g. density

V_{pcf} Multiplier

The correlation for V_{pcf} is based on assumptions that may not be valid in practice

Hence an error will lead to error in V_m and total downhole rates

The V_{pcf} multiplier is introduced - V_{pcf_Mult}

$$V_m = V_{pcf\_Mult} \times V_{pcf}(\rho, V_m, \ldots) \times V_{app}$$

When surface rates are known: $V_{pcf\_Mult} = V_{mSC} / V_m$

(Where V_{mSC} is equivalent Vm calculated from surface rates)

Do you trust the Surface Rates – PVT – PLT …?????

"MATCH SURFACE" - BEWARE!

Emeraude Data Structure

Original file types Pre V2.50

*.Ke2 Document
*.Ker Recovery
*.eun Units
*.epv PVT

New file types V2.50

*.stg Settings
*.kvt Templates
*.kuf Mathpack