Lecture Seven

Horizontal Gradient Curves

7.1 Practical application of horizontal multiphase flow

The principal application of horizontal multiphase flow correlations for the flowing or artificial lift wells is to determine the necessary flowing well - head pressure to move the fluids to the separator or to determine the optimum surface flow line size. One of the most serious problems for any flow system has to produce a well into excessive well - head pressure. In many instances the surface flow line must, by necessity, be anywhere from 1500 ft to several miles long. If this line is too small, then a high wellhead pressure is necessary to move the fluids over to the separator. By using a good horizontal multiphase flow correlation the optimum line size can be selected. For example, the use of a 4 in, Flow line in comparison to a 2 in, Flowline can mean several hundred bPD more production.

As is true for vertical flow, we may have two choices in making use of horizontal multiphase flow correlations. The calculations can be made by computer or "working curves" can be used. Most companies have at least one horizontal flow line computer program available. It is recommended that either the Dukler Case II or the Eaton correlation be used. There is only one published set of working curves available for horizontal flow and those are found in Brown's these are prepared from the Eaton correlation and have proven to be very good except in the very low pressure, low rate, and low gas - oil ratio range.

7.2 Effect of variables

In general, the effects of variables such as pipe size and viscosity have the same effect in horizontal multi phase flow as they did in vertical flow. The one variable that differs completely in its effect is the gas - liquid ratio.

The effect of gas - liquid ratio on horizontal pressure losses is shown in Figure. 7.1.

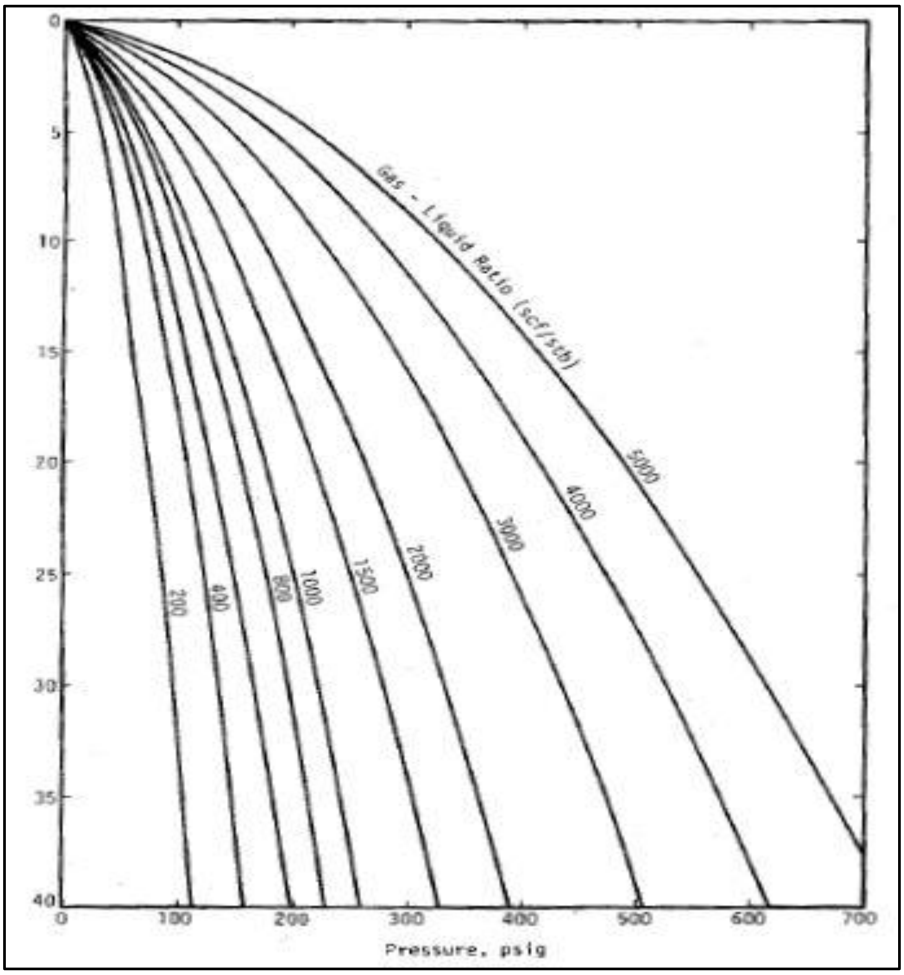

Figure 7.1: The effect of gas - liquid ratio

For vertical flow we recall an increased gas-oil ratio causes a decrease in pressure for a certain set of conditions until the minimum gradient is reached. This is because the increased as lightens the static gradient and causes a decreased pressure traverse. The opposite effect takes place for horizontal flow, where no fluids are being lifted vertically and therefore the gas merely represents additional fluids to be moved in the horizontal line.

Example 7.1: How to determine the necessary wellhead pressure.

For surface flow-lines, it is likely that the separator pressure is the only known constant. This is generally a constant for a particular well or lease and is predetermined due to gas sales line pressure, required liquid dump pressure, or composition of the fluids with reference to a required back pressure to give the most economical separation. The necessary wellhead pressure to move a certain fluid rate through a set flow line size and length can then be determined. This can be illustrated through an example as follows:

Given:

Flow line size = 2 in (I.D).

Separator pressure = 100 psig = P_{sep}

Flow line length = 5,000 ft = L

Gas - liquid ratio = 1,000 scf/bbl (SP.GR = 0.65)

q = 1,000 bpd (95% water)

Determine the wellhead pressure necessary to move these fluids through the 5000 ft of horizontal flow line into a separator pressure of 100 psig.

Solution:

The following solution is given:

1. The solution can be made by long hand, or, preferably, by machine computation by starting with the separator pressure. Pressure increments are assumed and the wellhead pressure determined.

2. The solution can be easily obtained by referring to a set of working curves such as those of Brown

Refer to Fig.D.103 for the solution to this problem. Although these curves are for 100% water, they may also be used for 100% oil with fair accuracy since no vertical lift is involved in the horizontal flow problem.

(a) Find the equivalent length due to separator pressure by following a line vertically downwards on Fig. D.103 to the 1,000 scf / bbl line from the separator pressure of 100 psig at zero length. This length is found to be 200 ft.

(b) Add this length equivalent of 200 ft to the total length of 5,000 ft and find 200+ 5,000= 5.200 ft.

(c) From a length of 5200 ft on the ordinate, proceed horizontally to the right until intersecting the 1.000 scf/bbl line. Read the pressure at this intersection to be approximately 545 psig. This is the required wellhead pressure.

Example 7.2: How to find the separator pressure.

Given data:

L = 6000 ft

P_{wh} = 800 psi

q_L = 4000 bpd

d = 3 in.

G/L = 600 scf / bbl

Find the pressure on the separator.

Solution:

1. Disregarding the length of the line of 6000 ft. find the arbitrary length where the pressure of 800 psi on the 600 scf / bbl gas-liquid ratio line. This is found to be at 8400 ft (Fig.D.1016).

2. Subtract the length of the line of 6000ft from 8400ft = 2400 ft.

3. At 2400 ft on the ordinate, read the pressure on the 600 scf/bbl line. This is found to be 415 psi which the separator pressure.