DOCUMENT TITLE:

METHOD FOR ESTIMATING SLUG CATCHER FEED RATES DURING PIGGING OPERATIONS

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1.1 ESTIMATION METHOD

It is essential that multiphase feed rates be quantified and considered as part of the slug catcher's design process, inclusive of rates during both normal operation and slugging conditions. During normal operation, the slug catcher's multiphase feed rate is simply the sum of the individual gas and liquid feed rates for all pipelines feeding the slug catcher:

$$Q_{gn} = Q_{gn1} + Q_{gn2} \qquad Eq. 1$$

$$Q_{ln} = Q_{ln1} + Q_{ln2} \qquad Eq. 2$$

However, during pigging operation, the liquid component of the slug catcher's multiphase feed rate will increase substantially as the pig generated slug arrives at the slug catcher. Presented below is a calculation method for estimating feed conditions during a pig generated slugging event based on normal operating parameters — note that verifying the estimated slugging rates with rigorous software based dynamic models is always recommended.

By assuming that only one pipeline feeding the slug catcher is pigged at a time, and no gas bypasses the pig, the total liquid feed rate to the slug catcher a can be estimated with Equation 3:

$$Q_{lp} = \left[\frac{(469)(Q_{gn1})(MW)(LVF)(DF_1)(DF_2)}{(\rho_g)}\right] + Q_{ln1} + Q_{ln2} \qquad Eq. 3$$

During a pig generated slugging event there is a reduced amount of gas still being fed to the slug catcher in the form of bubbles entrained in the incoming slug, or auxiliary gas feed(s) provided by other pipelines. As such, the total gas feed rate to the slug catcher during a pig generated slugging event can be estimated with Equation 4:

$$Q_{gp} = (Q_{gn1})(DF_2)[1 - (LVF)(DF_1)] + Q_{gn2} \qquad Eq. 4$$

The liquid volume fraction of the pig generated slug can be estimated with the following correlation provided by Gregory [1] as a function of the slug's velocity, which in the case of pigging is the same as the pig's velocity:

$$LVF = 1/\left[1 + (V_p/28.4)^{1.39}\right] \qquad Eq. 5$$

By assuming that the pig is traveling at the same speed as the pipeline's fluid velocity during normal operation, Equation 6 can be used to estimate the pig velocity:

$$V_p = \left[\frac{(5.59)(Q_{gn1})(MW)}{(\rho_g)(D^2)}\right] + \left[\frac{(Q_{ln1})}{(83.9)(D^2)}\right] \qquad Eq. 6$$

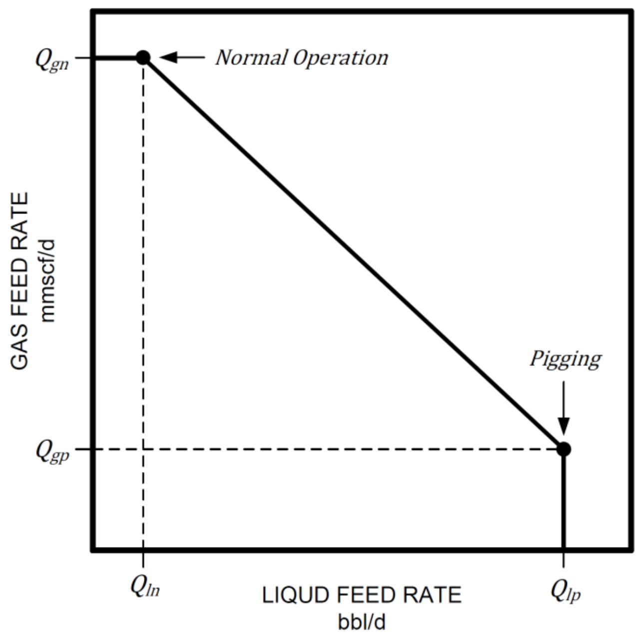
Note that the estimated pigging velocity should be checked for operational practicality. In the event that the pigging velocity is deemed to be excessive, the values of Q_{gn1} and Q_{ln1} used in the equations above should be reduced to reflect a production cutback to control the pigging speed.

Finally, design factors are used to account for estimation uncertainties with the liquid volume fraction calculation, and the potential for a temporary end-of-pigging rate spike due to pipeline pressurization during pigging (if applicable). These factors will vary depending on the nature and criticality of the application, but the following general limits are recommended:

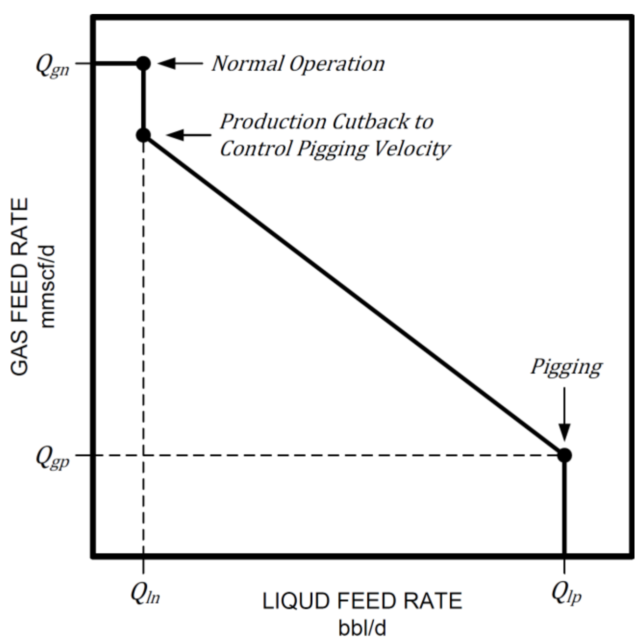
$$1.0 \le DF_1 \le \frac{1.0}{LVF} \qquad 1.0 \le DF_2 \le 1.5 \qquad (DF_1 \times DF_2) \le 2.0 \qquad Eq. 7,8,9$$

1.2 GRAPHICAL REPRESENTATIONS

If an end-of-pigging rate spike is not applicable (due to facility controls or other physical limitations), then the performance window of the slug catcher can be depicted graphically as a line of constant volumetric flowrate that intersects the feed conditions during normal operation and a pig generated slugging event



In the event of a production cut necessary to control pigging speed, the graphical representation would be as follows:



1.3 WORKED EXAMPLE #1

Two pipelines feed a slug catcher, one size 24" @ 230 mmscf/d and the other size 12" @ 70 mmscfd during normal operation. The slug catcher is located at a facility which is physically limited to 300 mmscfd max throughput, therefore end-of-pigging rate spiking is not of concern. Calculate the normal operating and pigging feed rates to the slug catcher given the following inputs:

Inputs:

$Q_{gn1} = 230\ mmscf/d$

$Q_{gn2} = 70\ mmscf/d$

$Q_{ln1} = 10{,}000\ bbl/d$

$Q_{ln2} = 2{,}500\ bbl/d$

$MW = 21.0\ lb/lbmol$

$\rho_g = 4.0\ lb/ft^3$

$D = 23.25\ in$

$DF_1 = 1.15$

$DF_2 = 1.00$

Solutions:

$Q_{gn} = 300\ mmscf/d$

$Q_{ln} = 12{,}500\ bbl/d$

$Q_{gp} = 101\ mmscf/d$

$Q_{lp} = 504{,}000\ bbl/d$

$LVF = 0.754\ ft/s$

$V_p = 12.7\ ft/s$

1.4 WORKED EXAMPLE #2:

One 30" pipeline feeds a slug catcher @ 1,100 mmscf/d during normal operating. Due to the possibility of excessive pig velocities at the normal flowrate, it is operationally planned to cut production by half during pigging. An end-of-pigging rate spike is expected. Calculate the normal operating and pigging feed rates to the slug catcher given the following inputs:

Inputs:

$Q_{gn1} = 1{,}100\ mmscf/d$

$Q_{gn2} = 0\ mmscf/d$

$Q_{ln1} = 60{,}000\ bbl/d$

$Q_{ln2} = 0\ bbl/d$

$MW = 19.0\ lb/lbmol$

$\rho_g = 3.0\ lb/ft^3$

$D = 29\ in$

$DF_1 = 1.30$

$DF_2 = 1.30$

Solutions:

$Q_{gn} = 1{,}100\ mmscf/d$

$Q_{ln} = 60{,}000\ bbl/d$

$Q_{gp} = 190\ mmscf/d$

$Q_{lp} = 1{,}588{,}000\ bbl/d$

$LVF = 0.564$

$V_p = 23.6\ ft/s$

1.5 UNITS AND SYMBOLOGY:

Q_{gp} = Combined instantaneous gas flowrate feeding slug catcher during pigging operation, $mmscf/d$

Q_{gn} = Combined steady state gas flowrate feeding slug catcher during of normal operation, $mmscf/d$

Q_{gn1} = Steady state gas flowrate of largest feeding pipeline during normal operation, $mmscf/d$

Q_{gn2} = Steady state gas flowrate of other feeding pipeline(s) during normal operation, $mmscf/d$

Q_{lp} = Combined instantaneous liquid flowrate feeding slug catcher during pigging operation, bbl/d

Q_{ln} = Combined steady state liquid flowrate feeding slug catcher during normal operation, bbl/d

Q_{ln1} = Steady state liquid flowrate of largest feeding pipeline during normal operation, bbl/d

Q_{ln2} = Steady state liquid flowrate of other feeding pipeline(s) during normal operation, bbl/d

ρ_g = Gas density, lb/ft^3

MW = Gas molecular weight, $lb/lbmol$

V_p = Travel velocity of pig in pigged pipeline, ft/s

D = Internal diameter of pigged pipeline, in

LVF = Liquid volume fraction of pig generated slug

DF_1 = Design factor for calculated liquid volume fraction

DF_2 = Design factor to account for temporary end-of-pigging rate spike (due to pipeline pressurization)

1.6 REFERENCES:

1. Gregory, G.A., et al.: "Correlation of the Liquid Volume Fraction in the Slug for Horizontal Gas-Liquid Flow," Int. J. Multiphase flow, 4., (1978), pp 33-39.

1.7 DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

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1.8 OTHER INFORMATION:

Holloman is a vendor of harp, hybrid, and multi-vessel slug catcher systems. To request a quotation, please provide as much of the following information as is available:

- Design code (typically B31.8, "F" factor = 0.5)
- Total storage capacity (LLLL to LLHH, bbl)
- Total gas and liquid feed rate during normal operation (mmscf/d, bbl/d)
- Total gas and liquid feed rate during slugging/pigging (mmscf/d, bbl/d)
- Maximum liquid draw-off rate (bbl/d)
- Size / rate of largest feeding pipeline (inches / mmscf/d)
- Size of gas inlet piping (inches)
- Size of gas outlet line (inches)
- Gas density, viscosity, and molecular weight or SG (lb/cuft, cP, lb/lbmol)
- Liquid density, viscosity, surface tension (lb/cuft, cP, dyne/cm)
- Liquid droplet separation criteria (microns)
- Operating pressure / temperature (psig / °F)
- Design pressure / temperature (psig / °F)
- Design MDMT (°F)
- Corrosion allowance (inches)
- Sour Service / NACE (yes or no)
- Paint specification (if not vendor standard)
- Manifold coating (supplied painted or primed only)
- Linepipe coating (supplied painted, primed, or mill varnish only)
- Plot space available (ft x ft)
- Project or plant name
- Delivery location
- Requested delivery timeframe
- Taxes applicable (yes or no)

1.9 CONTACT HOLLOMAN:

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