Easy Kick Tolerance Calculations By Hand

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Think of MAASP as a budget for kick tolerance. You have $500 to spend on food and drink. The more you spend on food, the less you can spend on drink. While you can spend less than you have, you cannot spend more as Nature doesn't allow you to borrow. Food = kick intensity, drink = loss of hydrostatic due to gas replacing mud.

You can also spend a bit on chocolate (choke margin) but this reduces how much you can spend on food and drink. I don't usually apply a choke margin because there is already a hidden safety factor because a single gas bubble is assumed whereas it is a strung out column of gassified mud. The average expansion of the gas is less than if it was a single bubble when top gas reaches the shoe. The kick tolerance calculations are sensitive to this –reducing MAASP by a choke margin can significantly reduce maximum safe influx volume.

Kick tolerance must be expressed as both a kick intensity (zero if a swab kick) and a kick volume. Stating a volume or intensity alone is meaningless. For any well that drills into a new structure or unknown pressure regime, the kick intensity should not be less than 0.5 ppg. The required volume should be that volume that can be detected and closed in on with the equipment, crews and level of competence available. As a rule of thumb, kick volume by the time the BOP is closed is 3x the influx volume when detected.

The methodology is simple. Calculate the MAASP. If this is for a well design, use the fracture pressure profile and the shoe depth to calculate the MAASP. Subtract from this any choke margin you want to apply. What is left is your Total Kick Tolerance Budget. This budget pressure represents the addition of shut in drillpipe pressure (Pdp) and the loss of hydrostatic pressure caused by gas replacing mud in the annulus. With a higher kick intensity and therefore a higher Pdp, the maximum volume of gas that can be circulated out diminishes. Subtracting the Pdp from the Total KT Budget gives the Gas Budget. This is the pressure arising from a column of gas replacing an equal column of mud and the vertical height of this can be calculated. The annular capacity and hole inclination under the shoe then gives the gas volume at the shoe, V1.

Having calculated V1, then the Combined Gas Law is used to calculate the influx volume at TD, V2. This is the maximum influx that can be safely circulated out of the well.

We'll work through an example and summarise the formulae at the end.

Using easy figures;

Shoe at 5000', shoe strength gradient 0.6 psi/ft.

Hole at 8000', assume a kick intensity of 0.5 ppg (= 0.026 psi/ft) and a gas gradient of 0.05 psi/ft (reasonable for a natural gas at around 4000 psi).

Mud in hole is 0.5 psi/ft. Use zero choke margin and a vertical well.

56 C shoe temperature and 86 C bottom hole temperature.

Calcs

MAASP = (0.6 shoe strength – 0.5 mud gradient) x 5000 = **500 psi**.

Subtract choke margin, 0 psi, Total Kick Tolerance Budget = 500 – 0 = 500 psi.

From the Total KT Budget of 500 psi, subtract the shut in drillpipe pressure arising as a result of the kick intensity at section TD. With a kick intensity of 0.026 psi/ft at 8000 ft, Pdp = 0.026 x 8000 = 208 psi.

Gas Budget = 500 – 208 = 292 psi.

Assuming a gas gradient of 0.05 psi/ft, the loss of hydrostatic is the length of the gas column, multiplied by (mud gradient – gas gradient). Rearranging the equation, the length of the gas column is the Gas Budget divided by (mud gradient – gas gradient). Divide by cos Inclination and multiply by the annular capacity to get V1.

With a $12^1/_4$" hole and 5" pipe, the annular capacity is 0.1214 bbl/ft. Cos of 0 is 1.

$$V1 = \frac{Gas\ Budget\ x\ ann\ cap}{Cos\ I\ x\ (\rho mud - \rho gas)}$$

$$V1 = \frac{292\ x\ 0.1214}{1\ x\ (0.5 - 0.05)} = 79\ bbls$$

Use the combined gas law to calculate the initial influx volume.

T1 Temperature at the casing shoe = 56 C or 329K.

T2 Temperature at TD = 86 C or 359K.

P1 Pressure at the top of the gas column = shoe strength = (5000 x 0.6) = 3000 psi. Note that to be precise, we'd calculate the average pressure in the gas rather than the pressure at the top for P1 and bottom for P2. The result will be so similar that it's hardly worth the effort so we won't bother. If you did want to, then pressure halfway down the gas column (average gas pressure with the bubble at the shoe) =3000 + (length of gas 462' x 0.05) = 3000 + 23 = 3023 psi.

P2 = Gas bubble pressure on bottom = shut in bottom hole pressure

P2 = (8000 x (0.5 + 0.026)) = 4208 psi.

Using the combined gas law;

V2 = (P1 x V1 x T2) ÷ (T1 x P2) = (3000 x 79 x 359) ÷ (329 x 4208) = 61.5 bbls

Using average gas pressure rather than top and bottom yields 62 bbls.

Notes

1) Higher mudweight = lower MAASP = reduced kick tolerance gas volume for a particular kick intensity.
2) Bottom hole pressure **cannot possibly** be less than mud hydrostatic; this would be a negative kick intensity which the popular BP kick tolerance spreadsheet allows you to enter, but cannot be as this defies the laws of physics. As soon as you start to circulate, bottom hole pressure cannot be less than mud hydrostatic as the pipe is full of mud.

Kick tolerance calcs summary

$$\boldsymbol{MAASP = (shoe\ strength\ gradient - mud\ gradient)\ x\ shoe\ TVD}$$

$$\textit{Total Kick Tolerance Budget} = \textit{MAASP} - \textit{Choke Margin}$$

$$\boldsymbol{Gas\ Budget = Total\ KT\ Budget - (TVD\ well\ x\ kick\ intensity)}$$

$$\boldsymbol{Gas\ Vertical\ Length = \frac{Gas\ Budget}{Mud\ Gradient - Gas\ Gradient}}$$

$$\boldsymbol{Gas\ Volume = Gas\ Vertical\ Length\ x\ Annular\ Capacity} \div \textbf{Cos Incl}$$

$$\boldsymbol{P1 = (Shoe\ TVD\ x\ Shoe\ Strength\ Gradient)}$$

$$\boldsymbol{P2 = (Well\ TVD\ x\ [Mud\ Gradient + Kick\ Intensity)}$$

T1 = absolute geothermal temperature (Temperature C + 273) at the shoe.

T2 = absolute geothermal temperature at the bottom of the well.

$$\textit{V2 = (P1 x V1 x T2) ÷ (T1 x P2)}$$

There is an online kick tolerance calculator Mathcad worksheet on www.drillers.com. At the bottom right of the Home page, click Mathcad Worksheets then select Kick Tolerance from the list.

