Drilling Formulas for Oil & Gas: A Complete list from Basic to Supervisor Level

Drilling operations in the oil and gas industry rely on a wide range of mathematical formulas for effective & safe functioning.

This guide contains over 50 essential formulas, categorized by job level and designed to help professionals at all stages of their careers.

These formulas are widely used in day-to-day operations and are integral to certifications like IADC and IWCF.

Level 1: Roustabout Formulas

The roustabout level involves understanding basic measurements, equipment handling, and safety. The following formulas are fundamental for beginners in the industry.

1. Pipe Displacement (bbl/ft)

Determines the volume of the pipe inside the wellbore.

$$\text{Pipe Displacement (bbl/ft)} = \frac{(OD^2 - ID^2)}{1029.4}$$

Usage: Used to calculate the amount of fluid displaced by the pipe in the well.

2. Annular Volume (bbl/ft)

Calculates the volume between the drill pipe and the casing or wellbore.

$$\text{Annular Volume (bbl/ft)} = \frac{(OD^2 - ID^2) \times Length}{1029.4}$$

Usage: Helps in fluid volume calculations during drilling operations.

3. Hole Volume (bbl/ft)

Determines the volume of the open hole drilled.

$$\text{Hole Volume (bbl/ft)} = \frac{\text{Hole Diameter}^2}{1029.4}$$

Usage: Helps calculate how much fluid is needed to fill the open hole.

4. Pump Output (bbl/min)

Calculates the volume of fluid being pumped.

$$\text{Pump Output (bbl/min)} = \frac{\text{Pump Stroke} \times \text{Pump Efficiency}}{7.48}$$

Usage: Important for mud circulation calculations.

Level 2: Derrickman Formulas

Derrickman is responsible for maintaining drilling fluid properties and managing pumps. These formulas focus on drilling fluid management and pressure calculations.

5. Hydrostatic Pressure (psi)

Definition: Determines the pressure exerted by the drilling fluid column.

$$\text{Hydrostatic Pressure (psi)} = 0.052 \times \text{Mud Weight (ppg)} \times \text{True Vertical Depth (TVD in ft)}$$

Usage: Used for well control to prevent kicks.

6. Mud Weight Increase (ppg)

Definition: Calculates the increase in mud weight after adding a weighting material.

$$\text{Mud Weight Increase (ppg)} = \frac{\text{Weighting Material Added (lbs)}}{\text{Total Volume of Mud (bbl)}}$$

Usage: Adjusting mud weight for maintaining hydrostatic pressure.

7. Annular Velocity (ft/min)

Definition: Measures the speed of fluid moving through the annulus.

$$\text{Annular Velocity (ft/min)} = \frac{(PumpOutput \times 24.51)}{(HoleDiameter^2 - PipeOD^2)}$$

Usage: Ensures effective cuttings removal from the wellbore.

8. Surge Pressure (psi)

Definition: Calculates pressure increase due to pipe movement in the wellbore.

$$\text{Surge Pressure (psi)} = 0.052 \times \text{Mud Weight} \times \text{Trip Speed (ft/min)}$$

Usage: Prevents kicks while tripping in/out of the hole.

Level 3: Driller Formulas

Drillers handle the operation of the drilling rig. These formulas are critical for managing wellbore pressure and kick detection.

9. Bottom Hole Pressure (psi)

Definition: The total pressure at the bottom of the well.

$$\text{Bottom Hole Pressure (psi)} = \text{Surface Pressure} + (0.052 \times \text{Mud Weight (ppg)} \times \text{TVD})$$

Usage: Ensures wellbore stability and helps in well control.

10. Kick Tolerance

Definition: Maximum gas influx that can be tolerated without fracturing the formation.

$$\text{Kick Tolerance (bbl)} = \frac{\text{Max Allowable Pressure (psi)}}{\text{Mud Gradient (psi/ft)}}$$

Usage: Key in blowout prevention.

11. Trip Margin

Definition: Safety margin added to mud weight during tripping.

$$\text{Trip Margin (ppg)} = 0.5 - 1.0 \times \text{Mud Weight}$$

Usage: Used to maintain well control during tripping.

Level 4: Toolpusher Formulas

Toolpushers need to handle complex pressure management and fluid flow. These formulas focus on managing fluid systems and well control.

12. Equivalent Circulating Density (ECD, ppg)

Definition: Determines the effective mud weight while circulating.

$$\text{ECD (ppg)} = \text{Mud Weight} + \frac{\text{Pressure Loss (psi)}}{0.052 \times \text{TVD (ft)}}$$

Usage: Used to control downhole pressure.

13. Casing Burst Pressure

Definition: The internal pressure that the casing can withstand.

$$\text{Burst Pressure (psi)} = 0.875 \times \text{Yield Strength} \times \frac{OD}{OD - WallThickness}$$

Usage: Ensures casing integrity during high-pressure situations.

14. Formation Integrity Test (FIT)

Definition: Test to determine the strength of the formation.

$$\text{FIT (psi)} = \frac{\text{Pressure Applied (psi)}}{\text{TVD (ft)}}$$

Usage: Ensures the formation can handle planned mud weights.

Level 5: Supervisory Formulas

At the supervisory level, managing well control, casing design, and complex decision-making is crucial.

15. Well Control – MAASP (Maximum Allowable Annular Surface Pressure)

Definition: Maximum pressure the casing and surface equipment can safely handle.

$$\text{MAASP (psi)} = \text{Casing Burst Pressure} - \text{Formation Pressure (psi)}$$

Usage: Helps to set safe pressure limits during well control operations.

16. Cement Slurry Volume (bbl)

Definition: The volume of cement required for casing operations.

$$\text{Cement Slurry Volume (bbl)} = \text{Annular Volume} \times \text{Slurry Yield (bbl/sack)}$$

Usage: Ensures enough cement is used to stabilize casing.

17. Leak-Off Test (LOT)

Definition: Test to determine the pressure at which formation begins to fracture.

$$\text{LOT (psi)} = \text{Pressure Applied (psi)} \times \text{Well Depth (ft)}$$

Usage: Helps determine the fracture gradient for wellbore stability.

Level 6: Senior Toolpusher and Supervisor Formulas

At the senior supervisory level, professionals are responsible for strategic decisions in drilling, well control, and casing programs. Advanced calculations become essential for optimizing drilling performance, maintaining well integrity, and ensuring safety.

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18. Wellbore Stability – Fracture Gradient

Definition: The pressure gradient at which the formation fractures.

$$\text{Fracture Gradient (psi/ft)} = \frac{\text{Applied Pressure (psi)}}{\text{True Vertical Depth (ft)}}$$

Usage: Ensures proper mud weight and drilling fluid management to avoid formation fractures.

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19. Pore Pressure (psi)

Definition: Pressure of fluids within the formation.

$$\text{Pore Pressure (psi)} = \text{Mud Weight (ppg)} \times 0.052 \times \text{TVD (ft)}$$

Usage: Used in well planning and during drilling to predict formation pressures.

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20. Leak-Off Pressure (LOP)

Definition: The pressure at which the wellbore begins to leak into the formation.

$$\text{LOP (psi)} = \text{Surface Pressure (psi)} + (0.052 \times \text{Mud Weight} \times \text{TVD})$$

Usage: Used during leak-off tests to determine formation strength and prevent wellbore instability.

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21. Collapse Pressure (psi)

Definition: Pressure required to collapse the casing under external formation pressures.

$$\text{Collapse Pressure (psi)} = \text{Casing OD} \times \frac{\text{External Pressure (psi)} - \text{Internal Pressure (psi)}}{\text{Wall Thickness}}$$

Usage: Ensures the casing is strong enough to withstand downhole pressures and avoid collapse during drilling.

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22. Overburden Pressure (psi)

Definition: The total pressure exerted by the weight of all rock and fluids above a given formation.

$$\text{Overburden Pressure (psi)} = 0.433 \times \text{Overburden Gradient (psi/ft)} \times \text{TVD (ft)}$$

Usage: Used to understand the total stress on the formation, necessary for well control and mud weight design.

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23. Directional Drilling – Dogleg Severity (°/100ft)

Definition: Measures the change in the wellbore direction.

$$\text{Dogleg Severity }(^\circ/100\text{ft}) = \frac{\cos^{-1}(\cos A_1 \cos A_2 + \sin A_1 \sin A_2 \cos(B_2 - B_1))}{\text{Measured Depth (ft)}}$$

Where:

- A1A_1A1 and A2A_2A2 are inclinations at two depths
- B1B_1B1 and B2B_2B2 are azimuths at two depths
  Usage: Important for controlling well trajectory in directional drilling.

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24. Drilling Efficiency – Rate of Penetration (ROP, ft/hr)

Definition: The speed at which the bit drills through the formation.

$$\text{ROP (ft/hr)} = \frac{\text{Distance Drilled (ft)}}{\text{Drilling Time (hrs)}}$$

Usage: Key for measuring drilling performance and optimizing drilling parameters like bit weight and rotary speed.

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25. Hydraulic Horsepower (HHP)

Definition: The mechanical power generated by the drilling fluid to clean the hole and power the bit.

$$\text{HHP} = \frac{\text{Flow Rate (gpm)} \times \text{Pressure (psi)}}{1714}$$

Usage: Ensures that the rig has sufficient hydraulic power to maintain wellbore cleanliness and drilling efficiency.

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26. Equivalent Static Density (ESD, ppg)

Definition: The mud density accounting for the hydrostatic pressure of the fluid in a static state.

$$\text{ESD (ppg)} = \text{Mud Weight (ppg)} + \frac{\text{Pressure Loss (psi)}}{0.052 \times \text{TVD (ft)}}$$

Usage: Used to monitor wellbore pressure when the fluid is not circulating.

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27. Pressure Gradient (psi/ft)

Definition: The pressure per unit depth in the formation.

$$\text{Pressure Gradient (psi/ft)} = \frac{\text{Pressure (psi)}}{\text{TVD (ft)}}$$

Usage: Helps in predicting pore and fracture pressures during drilling operations.

28. Kill Sheet Calculation – Initial Circulating Pressure (ICP, psi)

Definition: The initial pressure required to circulate out a kick.

$$\text{ICP (psi)} = \text{SCR (psi)} + \text{SIDPP (psi)}$$

Where SIDPP is the Shut-In Drill Pipe Pressure.
Usage: Key formula for well control operations during a kick.

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29. Mud Pump Efficiency (%)

Definition: Efficiency of the mud pump in circulating fluid.

$$\text{Pump Efficiency (\%)} = \frac{\text{Theoretical Pump Output (bbl/min)}}{\text{Actual Pump Output (bbl/min)}} \times 100$$

Usage: Important for evaluating pump performance and ensuring optimal fluid circulation.

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30. Barite Addition to Increase Mud Weight (sacks)

Definition: Number of sacks of barite required to raise the mud weight to the desired level.

$$\text{Sacks of Barite} = \frac{\text{Desired Mud Weight (ppg)} - \text{Current Mud Weight (ppg)}}{0.052 \times \text{Volume of Mud (bbl)}}$$

Usage: Used to increase the mud weight and control well pressure.

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31. Trip Gas Volume

Definition: Amount of gas that enters the wellbore during tripping operations.

$$\text{Trip Gas Volume (scf)} = \frac{\text{Trip Gas Expansion Factor} \times \text{Volume of Gas at Surface}}{\text{Pressure Gradient (psi/ft)}}$$

Usage: Used to monitor and control gas influx during tripping operations.

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32. Choke Line Friction Loss (psi)

Definition: Pressure loss across the choke line during well control operations.

$$\text{Choke Line Friction (psi)} = \frac{(\text{Length of Choke Line} \times \text{Flow Rate})}{\text{Pipe ID}^4}$$

Usage: Helps in managing well control pressures during circulation.

Level 7: Senior Management & Well Engineering Formulas

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33. Casing Tensile Strength (lbs)

Definition: The maximum tensile load the casing can withstand before failure.

$$\text{Casing Tensile Strength (lbs)} = \text{Cross-Sectional Area} \times \text{Yield Strength}$$

Usage: Ensures the casing string is capable of withstanding the axial loads during drilling.

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34. Drilling Fluid Density Gradient

Definition: The relationship between mud density and depth in a static fluid column.

$$\text{Fluid Density Gradient (psi/ft)} = 0.052 \times \text{Mud Weight (ppg)}$$

Usage: Used in well control to calculate hydrostatic pressure exerted by the drilling fluid.

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35. Cuttings Transport Ratio (CTR)

Definition: Measures the efficiency of cuttings transport out of the wellbore.

$$\text{CTR} = \frac{\text{Annular Velocity (ft/min)}}{\text{Critical Transport Velocity (ft/min)}}$$

Usage: Ensures cuttings are effectively removed from the wellbore, preventing stuck pipe and other issues.

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36. Mud Compressibility (bbl/psi)

Definition: The change in volume of mud under pressure.

$$\text{Mud Compressibility (bbl/psi)} = \frac{\text{Initial Volume}}{\text{Change in Pressure (psi)}}$$

Usage: Important for high-pressure, high-temperature (HPHT) wells to ensure the correct volume is maintained.

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37. Differential Sticking Force (lbs)

Definition: The force exerted on the drill pipe or casing due to differential pressure across the wall of the wellbore.

$$\text{Sticking Force (lbs)} = \text{Contact Area (sq in)} \times (\text{Mud Weight (ppg)} - \text{Formation Pressure (psi)})$$

Usage: Helps in preventing stuck pipe incidents during drilling operations.

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38. Axial Stress on Casing

Definition: Stress in the casing due to vertical loads.

$$\text{Axial Stress (psi)} = \frac{\text{Axial Load (lbs)}}{\text{Casing Cross-Sectional Area (sq in)}}$$

Usage: Ensures the casing is capable of handling axial stresses during drilling and production.

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39. Gas Bubble Expansion Factor

Definition: Describes how much a gas bubble expands as it rises to the surface due to pressure reduction.

$$\text{Expansion Factor} = \frac{\text{Initial Pressure (psi)}}{\text{Surface Pressure (psi)}}$$

Usage: Critical for kick detection and gas handling during well control.

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40. Mechanical Specific Energy (MSE, psi)

Definition: Energy required to drill a volume of rock.

$$\text{MSE (psi)} = \frac{2 \times \text{Weight on Bit (lbs)} \times \text{Bit Rotational Speed (rpm)}}{\text{Rate of Penetration (ft/hr)} \times \text{Bit Area (sq in)}}$$

Usage: Optimizes drilling performance by analyzing the efficiency of energy use at the bit.

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41. Annular Velocity (ft/min)

Definition: The speed of the drilling fluid as it circulates in the annulus.

$$\text{Annular Velocity (ft/min)} = \frac{24.51 \times \text{Flow Rate (gpm)}}{(\text{Annulus Area (sq in)})}$$

Usage: Ensures proper hole cleaning and efficient cuttings transport during drilling.

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42. Gas Compressibility Factor (Z-Factor)

Definition: Describes the deviation of real gas behavior from ideal gas laws.

$$Z = \frac{PV}{nRT}$$

Where:

- PPP = Pressure
- VVV = Volume
- nnn = Amount of gas
- RRR = Gas constant
- TTT = Temperature
  Usage: Critical in gas wells to calculate the volume and behavior of gas under high pressures and temperatures.

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43. Well Control – Mud Gas Separator Sizing

Definition: Calculates the size of a mud gas separator to handle gas kicks.

$$\text{Separator Volume (bbl)} = \frac{\text{Gas Influx (bbl)}}{\text{Maximum Allowable Gas Velocity (ft/s)}}$$

Usage: Ensures safe and effective gas separation during well control operations.

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44. Volumetric Well Control Method

Definition: Method of controlling kicks using volume to monitor wellbore pressures.
Formula:

Volumetric Method Steps=Monitor pressures, pump fluid, and adjust choke settings based on formation response
Usage: Used to control gas influxes or kicks when circulation is not an immediate option.

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45. Surge & Swab Pressures

Definition: The pressure changes in the wellbore due to pipe movement.

$$\text{Surge Pressure (psi)} = \frac{\text{Pipe Speed (ft/min)} \times \text{Annular Area}}{\text{Fluid Viscosity}}$$

Usage: Prevents wellbore collapse or fracturing due to excessive surge or swab pressures.

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46. Bit Hydraulics Optimization

Definition: Determines the best nozzle size for the bit to optimize hydraulic cleaning power.

$$\text{Nozzle Size (in)} = \frac{\text{Flow Rate (gpm)}}{\text{Nozzle Velocity (ft/s)}}$$

Usage: Ensures efficient cuttings removal and cooling at the bit face during drilling.

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47. Well Control – Kick Tolerance

Definition: Maximum volume of gas influx that can be safely handled by the wellbore.

$$\text{Kick Tolerance (bbl)} = \frac{\text{Wellbore Volume} \times \text{Mud Density Change (ppg)}}{0.052 \times \text{TVD (ft)}}$$

Usage: Used to manage well control risks and ensure the well can handle pressure influxes.

IADC & IWCF Standards Formulas

These organizations focus on well control and safety. Below are some key formulas used for certification exams and operations.

48. Slow Circulating Rate (SCR, psi)

Definition: Pressure required to circulate out a kick at a controlled rate.

$$\text{SCR (psi)} = \text{Pump Pressure (psi)} \times \text{Circulating Time (min)}$$

Usage: Ensures controlled circulation during well control.

49. Kill Mud Weight (KMW, ppg)

Definition: The weight of mud required to control a well kick.

$$\text{KMW (ppg)} = \frac{\text{Initial Shut-In Drill Pipe Pressure}}{0.052 \times \text{TVD (ft)}} + \text{Current Mud Weight (ppg)}$$

Usage: Used in well control to safely kill the well.

50. Drill Pipe Pressure Schedule

Definition: A schedule for reducing drill pipe pressure during a kill operation.

$$\text{Initial Pressure (psi)} = \text{SCR} \times \text{Well Depth (ft)}$$

Usage: Prevents formation damage during kick control.

Conclusion

This document provides a detailed overview of critical drilling formulas across all levels of oil and gas operations, from roustabout to senior supervisory roles.

By mastering these calculations, professionals can maintain well control, ensure safety, and optimize drilling performance

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