

# A Spreadsheet Approach to Diverter Design Calculations

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## ABSTRACT

Diverter Systems must be designed to provide back pressures which will not result in fracture at the conductor casing seat. The system design loads are generally based on a shallow gas flow encountered prior to setting surface casing. Calculation of the pressure at various points in a diverter system is complicated by sonic flow at the exit, by unusually rapid fluid acceleration in some parts of the system, by temperature changes, and by the possible presence of more than one phase. A recent paper presented at the European Well Control Conference (Bourgoyne, 1992) presented a new empirical correlation for predicting sonic exit pressures during multi-phase flow. This correlation was based on experimental data carried out in 8 inch (0.203 m) and 10 inch (0.254 m) model diverter systems. The practical use of the calculation methods presented in this previous paper is now illustrated using a spreadsheet approach.

## INTRODUCTION

A key element of shallow gas well control is the selection of appropriate conductor casing setting depth that works well with the rig diverter system for the maximum likely formation pressure and productivity in the area of interest. Beck, Langlinais, and Bourgoyne (1987) recommended that the diverter and casing should be designed using a systems analysis approach that considers the gas reservoir, borehole, casing, and diverter linked together as a single hydraulic system. A systems analysis procedure (Brown and Beggs, (1977), Crouch and Pack, (1980), and Clark and Perkins, (1980) permits the simultaneous calculation of steady state pressures throughout the well and diverter system. A similar approach was recently presented in detail in API RP 64 (1991).

One of the problems encountered when using a systems analysis procedure is the need for an accurate prediction of the pressures occurring in the diverter system at potentially high gas flow rates. Calculation of the pressure at various points in a diverter system is complicated by sonic flow at the exit, by unusually rapid fluid acceleration in some parts of the system, by temperature changes, and by the possible presence of more than one phase. Conventional equations and computer algorithms used by petroleum engineers to analyze producing wells cannot be applied with any confidence. Recently, experiments involving two-phase (gas-water) flow were carried out in 8 inch (0.203 m) and 10 inch (0.254 m) model diverter systems at rates sufficient to achieve sonic flow (Bourgoyne, 1992). An improved algorithm for calculating pressures and fluid velocities at various points in a diverter system was developed based on this experimental study.

## RECOMMENDED ALGORITHM

The recommended diverter design calculations require the use of equations describing (1) sonic exit pressure, (2) flowing pressure gradients in the diverter and well, (3) formation productivity, (4) formation fracture gradient, and (5) erosion.

### Sonic Exit Conditions

The limiting (sonic) velocity at the vent line exit,  $v_e$ , can be computed for any fluid using

$$v_e = \frac{1}{\sqrt{\rho c}} \quad (1)$$

where  $\rho$  is the density of the fluid, and  $c$  is the compressibility of the fluid. For liquids, the density,  $\rho$ , and compressibility,  $c$ , can be assumed constant and are easily defined. For gases, the density can be determined from the real-gas equation, and is given by

$$\rho_g = \frac{p\bar{M}}{zRT} \quad (2)$$

for any given pressure,  $p$ , gas molecular weight,  $\bar{M}$ , gas deviation factor,  $z$ , and temperature,  $T$ , at the diverter exit. The coefficient,  $R$ , is the universal gas constant for the system of units being used. For most accurate results, the gas compressibility at the exit should be computed assuming a polytropic process. This assumption gives