PETROCHEM

PRESSURE CALCULATION

The pressure at any point in the well bore is the sum of the hydrostatic pressure and the frictional pressure. The hydrostatic pressure exerted on the formations, casing, and down-hole equipment by the weight of the fluid or fluids above them. Friction pressure is generated by the resistance of the fluids to the movement.

$$P=P_h+P_f$$

Where
- P =Total pressure any point in the well bore
- P_h= hydrostatic pressure
- P_f = friction pressure

The hydrostatic pressure is easily calculated for the density of the fluids above the given point and the length of the column of the given fluid. Thus:

$$\mathbf{P_h=0.052\ pL}$$

P_h = hydrostatic pressure, psi p
p = fluid density, lb/gal
L = length of the fluid column, ft

The friction pressure is not as easy to calculate since in depends on the rheological behavior of the fluid, as it is exposed to shear caused by pumping. A detailed discussion of this complex topic is beyond the scope of this article. At this point, we need only to say that different cement slurries behave differently when exposed to shear. For general purposes, the following calculational approach to friction is perhaps appropriate. It assumes that the cement slurry behaves as a power-law fluid. Determine flow characteristics using the Faun VG meter. Obtain the dial readings at 600 and 300 rpm. Calculate the flow-characteristic parameters by using the equations:

$n = (3.32) \log_{10}$ (600-rpm reading/300-rpm reading)
$K = (N)(1.066)$ (300-rpm reading)/$(100)(511)^n$
N = Range extension factor of the torque spring of the VG meter

To determine friction pressure, calculate the Reynolds number, N_{Re} from the following equations:

For casing:

$$N_{Re} = (547)(Q)^{2-n}(p) / (1{,}647)^n (d_i)^{4-3n} (K)$$

For annulus:

$$N_{Re} = (547)\ (d_w - d_o)^n\ (Q)^{2-n}\ (p)\ /\ (1{,}647^n)\ (d_w{}^2 - d_o{}^2)^{2-n}\ (K)$$

Where:

N_{Re}	= Reynolds number, dimensionless
Q	= Pumping rate, bbl/min
p	= Fluid density, lb/gal
d_i	= Casing ID, in.
d_w	= Hole diameter, in.
d_o	= Casing OD, inc.

Using the n-value and Reynolds number, estimate a friction factor form Fig 1. Friction pressure is then determined by:

For casing:

$$P_{fc}\ \_\ (11.5)\ (L)\ (p)\ (Q^2)\ (f)\ /\ d_i{}^5$$

For annulus:

$$P_{fa} = (11.5)\ (L)\ (p)\ (Q^2)\ (f)\ /\ (d_w - d_o)\ (d_w{}^2 - d_o{}^2)^2$$

Where:

f	= Friction factor, dimensionless
P_{fc}	= Friction pressure in casing, psi
P_{fa}	= Friction pressure in annulus, psi

Notice that the above calculation must be performed for every fluid using the corresponding n , K, and p. Also, the L's will be different for each fluid both inside and outside the casing.

Pressures. Once all the individual hydrostatic and friction pressure are calculated for each fluid in the casing and annulus, the total hydrostatic and frictional pressures for the casing and annulus can be calculated by simple addition. Next, the surface and bottom-hole pressures can be calculated:

$$P_s = P_f + P_a - P_C$$
$$P_B = P_{fa} + P_a$$

Where:

P_s	= Surface pumping pressure, psi
P_B	= Bottom hole, circulating pressure, psi
P_a	= Total hydrostatic pressure in annulus, psi
P_c	= Total hydrostatic pressure in casing, psi
P_f	= Total friction pressure (casing and annulus), psi

Hydraulic horsepower. The following equation can be used to calculate the hydraulic horsepower needed to circulate the well at the given rate:

$$Hhp = 0.0245\ (P_s)(Q)$$

Where:

Hhp = Hydraulic horsepower
P_s = Surface pumping pressure, psi
Q = Pump rate, bbl/min

Turbulent flow rate. Cement placement under turbulent flow condition is an effective technique for achieving a good cement job. The pumping rate for turbulent flow may be determined from the following procedure. First, determine n and k for the cement slurry as o outlined above. Then determine the upper critical Reynolds number for turbulent flow, from the friction-factor chart (notice that the upper critical Reynolds number for turbulent flow, from the friction-factor chart (notice that the upper critical Reynolds number changes with n, and varies from about 2,900 to 3,500. A good average number is 3,000).

Calculate the turbulent flow rate from the equation:

$$Q^{2-n} = (N_{Re})\ (1\ ,\ 647)_n\ (d_w^{\,2} - d_o^{\,2})^{2-n}\ (K)\ /\ (547)\ (d_w - d_o)^n\ (p)$$

Where:

Q = Flow rate, bbl/min
N_{Re} = Reynolds number, dimensionless
n = Fluid-flow behavior index, dimensionless
K = Fluid-consistency index, lb-sec/sq ft
d_w = Diameter of well bore, in.
d_o = OD of casing, in.

The value obtained for Q is the minimum rate at which the cement must be pumped to achieve turbulent flow. Experience has shown that the cement in turbulence must be in contact with the zone of interest for a least 10 min. This length of time of contact is necessary to achieve mud removal.