Packers

A packer is defined as any device that seals or "packs off" the wellbore to redirect the flow path of fluids in the well. The packer consists of pipe which fluids flow, gripping elements called "slips" that grip the wall of the casing to anchor the packer, and a sealing element that can be all rubber, all metal or some combination of the two.
Obviously sealing is crucial since the role of the packer is to force reservoir fluids into the tubing and keep them out of the annulus between the tubing and casing. This also applies to injected fluids, such as treating fluids and injection water, forcing them into the reservoir and not the annulus. So the key to the ability of the packer to perform as it should is its sealing ability. When the sealing element of a packer is expanded, it should provide a pressure tight seal in the casing-tubing annulus.

Type of packers

1) Retrievable packers – can be retrieved on the production tubing or on a work string. This packer is usual run on the tubing and set using the tubing. This is the type of packer used in treating wells, acid or frac jobs. Also as production packers when needed.
2) Permanent packers – the tubing and work string can detach from the packer after it is set. To retrieve these packers a special retrieving tool must be run on the workstring. Can be set using mechanical, wireline or hydraulic means. Very precise setting can be obtain using wireline setting procedures. Other tools such as sliding sleeve valves and seating nipples can be used with these packers.

Setting configurations

1) Compression – the weight of the tubing string is set down on the packer after is set. Used in deeper wells and when the pressure below the packer will be less than the pressure in the annulus.
2) Tension – the tubing is pulled in tension when the packer is set. Used in shallower wells when the weight of the tubing is not sufficient to set the packer in compression. Also for treating wells where the pressure below the packer well be greater than the pressure in the annulus.

3) Neutral – common in the permanent packers, it is the only way when using the wireline method of setting the packer. Primarily these are used in production packer systems.

Bridge Plugs

Used to seal the wellbore, like packers but without the pipe that allows flow. Two main types, the retrievable and permanent. The retrievable can be set several times and is used in isolating zones for testing and treating in conjunction with a packer. The permanent plugs (known as cast iron plugs) are used to shut off zones permanently and can only be removed by drilling them out.

Both types of bridge plugs can be set by mechanical or wireline methods.

Effects of Pressure and Temperature

Hooke's Law

$$\Delta L = L\Delta F \Big/ EA_s \tag{P1}$$

$$\Delta F = \left(A_p - A_i\right)\Delta P_t - \left(A_p - A_o\right)\Delta P_A \tag{P2}$$

L = Length of tubing inchs
F = Force acting on bottom of tubing lbs
A_s= cross section area of tubing in^2
A_I= area based on ID of tubing in^2
A_p= area of packer seal in^2
A_o= area based on OD of tubing in^2
P_t= Pressure at packer seal in tubing psi
P_A= Pressure at packer seal in annulus

Helical Buckling

$$\Delta L_2 = \frac{r^2 A_p \left[\Delta P_t - \Delta P_A\right]^2}{8EI\left(w_s + w_t - w_A\right)} \tag{P3}$$

$$I = \frac{\pi}{64}\left(D - d^4\right) \qquad F_f = A_p\left(\Delta P_t - \Delta P_A\right) \tag{P4}$$

r = radial clearance between tubing and casing in
w_s= weight of tubing lb/in
w_t= weight of fluid in tubing lb/in
w_A= weight of fluid in annulus displaced by the tubing lb/in
D = tubing OD in
d = tubing ID in

$$n = \frac{F_f}{\left(w_s + w_t - w_A\right)}$$ length of tubing buckled

Ballooning Effect

$$\Delta L_3 = \frac{\mu L^2}{E}\left(\frac{\Delta\rho_t - R^2\Delta\rho_A - \frac{1+2\mu}{2\mu}\delta}{R^2-1}\right) + \frac{2\mu L}{E}\left(\frac{\Delta P_t - R^2\Delta P_A}{R^2-1}\right) \qquad \text{(P5)}$$

(Density effect) (Surface pressure effect)

R = tubing OD/ID
P_t = surface tubing pressure psi
P_A = surface annulus pressure psi
δ = 0 for most cases

Temperature Effects

$$\Delta L = LC\Delta T \qquad \text{(P6)}$$

C = 6.9×10^{-6} steel coefficient of expansion / ^{o}F

Packer Setting Force

$$\Delta L = \frac{LF}{EA_s} + \frac{r^2F^2}{8EI\left(w_s + w_t - w_A\right)} \qquad \text{(P7)}$$

Permanent Buckling

$$S_o = \frac{F}{A_s} + \frac{DrF}{4I} \qquad \text{(P8)}$$

If S_o is greater than the yield strength of the tubing then permanent damage will occur.

For Subsequent Operations

For the inside wall of the tubing

$$S_i = \sqrt{3\left(\frac{R^2\left(P_t - P_A\right)}{R^2 - 1}\right)^2 + \left(\frac{P_t - R^2 P_A}{R^2 - 1} + \sigma_a \pm \frac{\sigma_b}{R}\right)2} \qquad \text{(P9)}$$

For the outside wall of the tubing

$$S_i = \sqrt{3\left(\frac{\left(P_t - P_A\right)}{R^2 - 1}\right)^2 + \left(\frac{P_t - R^2 P_A}{R^2 - 1} + \sigma_a \pm \sigma_b\right)^2} \qquad \text{(P10)}$$

For Free Motion Packer

$$\sigma_a = \frac{F_a}{A_s} \qquad F_a = \left[A_p - A_i\right]P_t - \left(A_p - A_i\right)P_A \qquad \text{(P11)}$$

$$\sigma_b = \frac{Dr}{4I}F_f \qquad F_f = A_p\left(\Delta P_t - \Delta P_A\right)$$