Ariel Calculation Method

The Ariel Performance Software includes calculations for predicting the flow, power, temperatures, pressures, gas rod loads, crosshead pin load reversals as well as other values for the predictions and limitations of the compressor applications. The following outlines the general methods and some of the equations applied for Ariel reciprocating compressors.

Pressures:

Operating pressures are calculated allowing user input pressure losses prior to, after and between stages of compression. Ariel includes a typical pressure loss for the interstage and final discharge pressure losses. Typical values are:

Flange Pressure	Pressure Loss	Not To Exceed
35 psia and below	5%	1 psi
36 psia to 250 psia	3%	5 psi
251 psia to 1000 psia	2%	10 psi
1001 psia and above	1%	

Operating pressures at each stage are expressed in the term Compression Ratio. Depending upon the use of this term, it may be defined at the cylinder flange pressures or the internal pressures. Compression ratio is the discharge pressure divided by the suction pressure (in absolute pressure units).

Interstage flange pressures are determined by balancing the flow of gas through each stage (expressed in standard, not actual volume). Gas added through side streams or removed through side streams or condensate from each stage is considered.

Pressures inside the cylinder consider pressure losses through the cylinder gas passages and valves. Many of the calculations apply the use if internal pressures rather than flange to flange pressures. Cylinder and valve pressure losses are a function of the gas density and gas velocity through the cylinder gas passages and valves.

Temperatures:

Discharge temperature after each stage of compression is a function of the gas properties (k-value, or N-value), internal compression ratio and suction temperature. Suction temperature at each stage is user defined. The internal suction temperature may include a preheat value, depending upon the inlet gas temperature and discharge gas temperature.

Discharge Temperature (initial estimate using flange ratio): $Tdi = Tsi\ (Ri)^{\frac{k-1}{k}}$

Suction Temperature Preheat: Tsph = Ts + [(0.02 + (0.002 x Cyl bore)) x (Tdi - Ts)]

Discharge Temperature: Td = Tsph x (Rinternal)^((k-1)/k)

Flow:

Flow is a function of the piston displacement and the volumetric efficiency. The piston displacement is the piston area times the length of stroke times the rpm. Both ends of a double acting cylinder are included in this calculations, with the crank end considering the loss of piston area due to the piston rod. Flow is calculated on a per end basis.

$$Q = VE \text{ x } PD \text{ x } \left(\frac{Ps}{Zs} \right) \text{ x number of cylinders x } 10^{-6}$$

As Q is actual flow, it is often converted to be expressed in standard flow units.

Volumetric Efficiency:

Volumetric efficiency includes many factors that help explain the differences between ideal gas behavior and real gas behavior. In general, volumetric efficiency depends upon compression ratio, cylinder clearances, gas compressibility values and the ratio of specific heats (k or N value). A common representation of volumetric efficiency is:

$$VE = \frac{98 - R}{100} - CL\left[\left(\frac{Z_s}{Z_d}\right)R^{\frac{1}{n}} - 1\right]$$

Power:

Power is calculated through a power per unit flow equation, multiplied by the flow. Calculated power will include the power of compression, plus mechanical inefficiencies, plus frame friction power. Internal power of compression equations include:

$$IHP / MM = 43.6\left(\frac{k}{k-1}\right)\left(Rint^{\frac{k-1}{k}} - 1\right) \text{ x } Za$$

CHP = Q x (IHP/MM)/ Mech Eff + Friction power.

Mechanical Efficiency is near 0.95, offering a 5% loss for mechanical inefficiencies of the cylinders. Friction power loss is dependent upon the frame size.

Gas Rod Load:

Ariel calculates gas rod load based upon internal cylinder pressures. The equations below are based upon pressures in gauge units. If absolute units are applied, then additional terms for Patm being applied on the piston rod diameter must be included.

Double Acting Cylinders

RLc = Ahe x Pdi - Ace x Psi

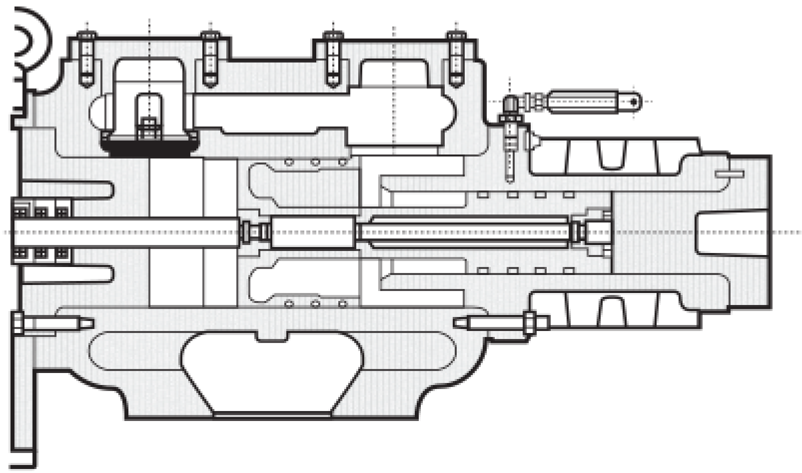
RLt = Ace x Pdi - Ahe x Psi

Single Acting Crank-End Cylinders

RLc = Ahe x Pdihe - Ace x Psi

RLt = Ace x Pdi - Ahe x Psihe

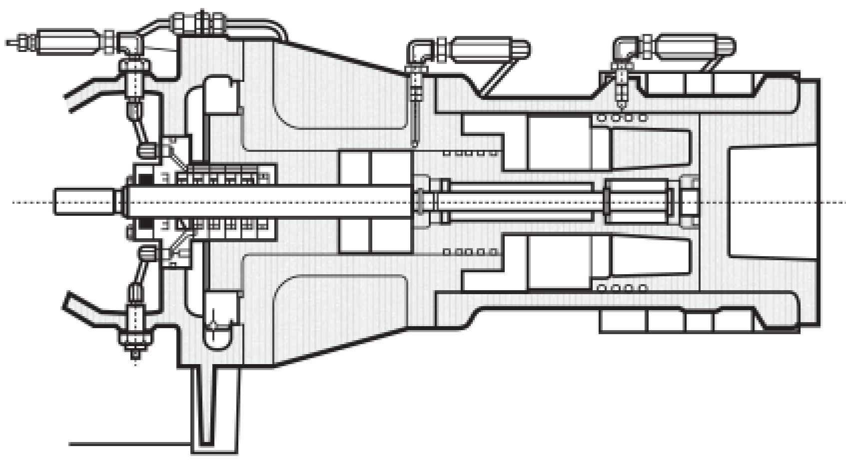
Tandem Cylinders - (High Pressure Cylinder Outboard)



RLc = Ahe(HP) x Pdi(HP) +[Ahe((LP) - Ahe(HP)] x Psflg(LP) - Ace(LP) x Psi(LP)

RLt = Ace(LP) x Pdi(LP) - [Ahe(LP) - Ahe(HP)] x Psflg(LP) - Ahe(HP) x Psi(HP)

Tandem Cylinders - (High Pressure Cylinder Inboard)



RLc = Ahe(LP) x Pdi(LP) - [Ahe(LP) - Ahe(HP)] x Psflg(LP) - Ace(HP) x Psi(HP)

RLt = Ace(HP) x Pdi(HP) + [Ahe(LP) - Ahe(HP)] x Psflg(LP) - Ahe(LP) x Psi(LP)

Since Gas Rod Load is calculated using internal pressures, the pressure losses through the cylinder gas passages and valves must be applied to the cylinder flange pressures. Pressure losses are calculated using the gas velocity at the suction and discharge. Gas velocities are calculated based upon the flow areas of the gas passages and valves. Flow areas are available through the Performance Software cylinder data sheets.

Psi = Psflg x ((100 - PLs)/100)

Pdi = Pdflg x ((100 + PLd)/100)

Rint = Pdi / Psi

$$PLs = \left[\frac{(GVs)^2}{6.55 \times 10^6}\right] \times \frac{SG}{Zsi} \times \frac{520}{Tsi}$$

$$PLd = \left[\frac{(GVd)^2}{4.55 \times 10^6}\right] \times \frac{SG}{Zd} \times \frac{520}{Td}$$

$$Avc = \left[\frac{1}{(AV)^2} + \frac{1}{(AC)^2}\right]^{-\frac{1}{2}} \text{ (HE or CE Suction or Discharge)}$$

$$GVs \text{ or } GVd = \frac{\text{Piston Area, in}^2 \text{ (HE or CE)} \times \text{Piston Speed, fpm}}{\text{Avc, in}^2 \text{ (HE or CE) Suction or Discharge /Corner}}$$

Definitions / Units

Area units are in square inches.

Diameter and stroke units are in inches.

Gas velocity units are in feet per minute

Pressure units are in psia for ratio calculations and psig for rod load calculations.

Temperature units are in Rankine.

Power units are in hp.

Flow units are in MMCFD, actual for Q and standard for Flow.

Clearance values are in percent.

Pressure loss is expressed in percent.