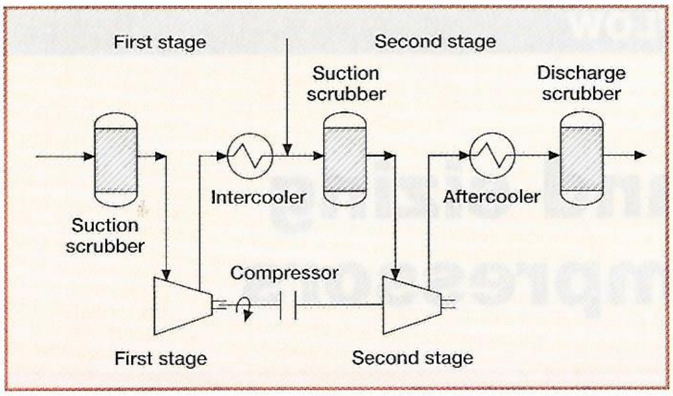

Fig. 3. Two-stage compressor flow diagram.

per stage is limited by the discharge temperature and does not exceed four.[2]

Multistage compressors are provided with intercoolers between stages and with an aftercooler at the compressor discharge. These are heat exchangers that remove the heat of compression from the gas and reduce its temperature to approximately that at the compressor intake. In certain cases, aftercooling and interstage cooling are not always beneficial. If the gas must be heated before entering a reactor, downstream heaters can be designed for a lower duty if the heat of compression is not removed. Multistage compressors are intercooled when the inlet temperature of the gas and the required compression ratio are such that the discharge temperature of the gas exceeds 150°C. The coolers reduce the actual volume of gas flowing to the high pressure cylinders, the power requirement, and, therefore, keep the temperature within safe operating limits. In instances where a compressor with intercoolers is used to compress gases with condensable vapors, the combined effect of compression and cooling can condense out the liquid. Therefore, the liquid condensate must be removed by installing a knockout pot after the intercooler. This will prevent damage to the downstream of the compressor. Fig. 3 illustrates a two-stage compressor with intercoolers.

Compressor equations. Compressors are rated in kJ/kg of compression head developed. This is the energy conveyed to a gas stream by a compressor. It is observed by the increase in gas pressure as the gas passes through the compressor. Centrifugal compressors more nearly follow polytropic operation and are widely used to handle large volumes of gas at pressure ranges of 7 bar to several thousand bar.

There are two ways to carry out the thermodynamic calculations for compression, namely by assuming:

(1) An adiabatic (isentropic) reversible path: A process during which there is no heat added or removed from the system. The entropy is constant. That is:

$$pV^k = constant \tag{1}$$

(2) A polytropic reversible path: A process in which changes in gas characteristics during compression are reviewed. That is:

$$pV^n = constant \tag{2}$$

The constant temperature process is a case when $n = 1$; which is equivalent to isothermal compression; the constant pressure process $n = 0$; and the constant volume process $n = \infty$. Generally, it is impractical to build sufficient heat transfer equipment into the design of most compressors to convey the bulk of the heat of compression. Therefore, most machines tend to operate along a polytropic path which approaches the adiabatic. Most compressor calculations are based on the adiabatic curve.[3]

Relationships may be developed between the temperature, pressure and volume for a polytropic process between state 1 and state 2. The ideal gas law states that:

$$pV = RT \tag{3}$$

that is:

$$p_1 V_1^n = p_2 V_2^n \tag{4}$$

$$p_1 = \frac{RT_1}{V_1}, \qquad p_2 = \frac{RT_2}{V_2} \tag{5}$$

Rearranging p_1 and p_2 in Eq. (5):

$$\frac{p_1}{p_2} = \left(\frac{T_1}{T_2}\right)\left(\frac{V_2}{V_1}\right) \tag{6}$$

For a polytropic process between states 1 and 2:

$$\frac{p_1}{p_2} = \left(\frac{V_2}{V_1}\right)^n \tag{7}$$

Substituting Eq. (6) into Eq. (7):

$$\left(\frac{T_1}{T_2}\right)\left(\frac{V_1}{V_2}\right) = \left(\frac{V_2}{V_1}\right)^n \tag{8}$$

Therefore:

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{n-1} \tag{9}$$

or:

$$\frac{V_2}{V_1} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{n-1}} \tag{10}$$

Substituting Eq. 10 into Eq. 7:

$$\frac{p_1}{p_2} = \left(\frac{T_1}{T_2}\right)^{\frac{n}{n-1}} \tag{11}$$

The compression work can be calculated from the pressure-volume relationship as follows:

$$W = \int_1^2 p\mathrm{d}V \tag{12}$$

and:

$$pV^n = C$$

for a polytropic process:

$$W = \int_1^2 C\frac{\mathrm{d}V}{V^n} \tag{13}$$

Integrating Eq. 13: