$$Power = \left\{ \frac{(-W)_{actual}\, w}{3,600} \right\}, \text{ kW} \quad (42)$$

Adiabatic compressor. Performance of reciprocating (piston) compressors with large valve area, or where valve losses are evaluated, is considered as close to adiabatic behavior as can be measured. The thermodynamic definition of an adiabatic process requires that no heat be added or removed from a system in which a change of state occurs. The adiabatic head produces the following equation, which is similar to the polytropic head of Eq. 33. This is expressed as:

$$H_{ad} = \left(\frac{Z_{avg} RT_1}{M_w} \right) \left(\frac{k}{k-1} \right) \left(R_c^{\frac{k-1}{k}} - 1 \right), \ \frac{\text{kJ}}{\text{kg}} \quad (43)$$

This can also be given by:

$$H_{ad} = \left(\frac{8.314\, Z_{avg}\, T_1}{M_w} \right) \left(\frac{k}{k-1} \right) \left(R_c^{\frac{k-1}{k}} - 1 \right), \ \frac{\text{kJ}}{\text{kg}} \quad (44)$$

The discharge temperature is:

$$T_2 = T_1 R_c^{\frac{k-1}{k}}, \text{ K} \quad (45)$$

The adiabatic work required is:

$$(-W)_{ad} = \frac{k}{k-1} \left(\frac{Z_1 RT_1}{M_w} \right) \left(R_c^{\frac{k-1}{k}} - 1 \right), \text{ kJ/kg} \quad (46)$$

The actual adiabatic work required is:

$$(-W_{actual})_{ad} = \frac{(-W)_{ad}}{E_{ad}}, \text{ kJ/kg} \quad (47)$$

The adiabatic power required by the compressor is:

$$Power_{ad} = \left\{ \frac{(-W_{actual})_{ad}\, w}{3,600} \right\}, \ kW \quad (48)$$

Efficiency. The adiabatic efficiency, E_{ad}, assumes that work done in compressing the gas is reversible (that is, there is no heat loss or gain, and on re-expansion to the original pressure, volume and temperature will remain the same as the original).

The adiabatic efficiency, E_{ad}, is defined by:

$$E_{ad} = \frac{R_c^{\left(\frac{k-1}{k}\right)} - 1}{R_c^{\left(\frac{n-1}{n}\right)} - 1} \quad (49)$$

where:

$$k = \frac{M_w\, C_p}{M_w\, C_p - 8.314} \quad (50)$$

The polytropic efficiency, E_p, is used to compare adiabatic with polytropic performance. This is defined by

$$\frac{n}{n-1} = \left(\frac{k}{k-1} \right) E_p \quad (51)$$

The polytropic efficiency assumes that heat is lost (radiation or conduction) or gained by friction during an actual compression process. Both polytropic and adiabatic efficiencies represent the difference in theoretical energy required in compressing a gas and the actual energy required. However, the adiabatic efficiency closely represents the power absorbed. The polytropic efficiency gives a better estimate of the temperature rise. Generally, polytropic efficiency is used in all centrifugal compressor computations. Table 1 gives some typical polytropic efficiencies for different types of machines.

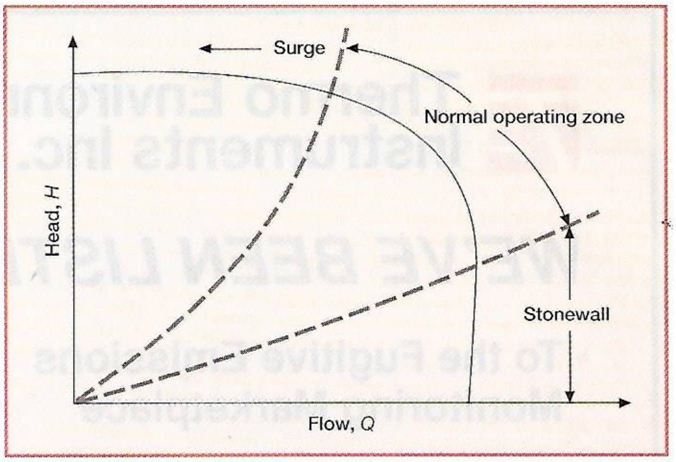

Fig. 5. Compressor generalized flow characteristics.

Fig. 4 shows the relationship between the polytropic efficiency and adiabatic (isentropic) efficiency of a perfect gas.

The mass flowrate, w, *kg/h*, can be determined from the volumetric rate, Q, m^3/h, as:

$$w = Q\rho \quad (52)$$

where:

$$\rho = \frac{weight}{volume} = \frac{PM_w}{ZRT} \quad (53)$$

substituting Eq. 53 into Eq. 52, w becomes:

$$w = Q\left(\frac{P_1 M_w}{Z_1 RT_1} \right) \quad (54)$$

$$= Q\left(\frac{12.0279\, P_1 M_w}{Z_1 T_1} \right) \quad (55)$$

The discharge volumetric flowrate, Q_d, is defined by:

$$Q_d = Q\left(\frac{P_1}{P_2} \right)\left(\frac{T_2}{T_1} \right)\left(\frac{Z_2}{Z_1} \right), \ \frac{\text{m}^3}{\text{h}} \quad (56)$$

The actual intake volume, Q_s, is the volume aspirated into a reciprocating compressor cylinder during the suction stroke, or drawn into the inlet of a centrifugal compressor impeller. Q_s is defined by:

$$Q_s = Q_{s(st)} \left(\frac{1.01325}{P_1} \right)\left(\frac{T_1}{288.15} \right)(Z_1), \text{ m}^3/\text{s} \quad (57)$$

Generally, if the compression ratio for piston machines is less than 5 or 6, single-stage compression is used. If the total compression ratio is between 6 and 36, two-stage compression will be required. Three or more stages may be required for compression ratios greater than 36. For a two-stage com-