mined elsewhere,[7] where y_i = mole fraction of component i.

Compressor surge control. All dynamic compressors have a limited range of capacity for a given selection of impellers at a fixed speed. Below the minimum value of 50% to 70% of the rated flow, the compressor will surge, becoming unstable in operation. Excessive vibration and possibly sudden failure or shutdown may occur.

It is essential that all compressor systems be designed to avoid possible surge operation. This is done by incorporating some type of antisurge control system. This is to ensure that the flow into the compressor is sufficient to maintain stability at the required pressure drop across the compressor. The surge control system should be used only for surge control and must not be linked with other functions of the process control system, otherwise this could result in compressor damage.

Other surge control may be a blow off valve. This is automatically controlled to open and blow off excess capacity to the atmosphere if the process flow requirement is too low. In some cases, suction control valves are used. For gases that cannot be discharged to atmosphere, a bypass control is the common method. This action bypasses unwanted flow back to the suction source. However, since the gas has already been compressed, its temperature is increased, and, therefore, must be cooled before entering the compressor a second time. In this case, a bypass cooler may be installed. The cooler may be avoided where the suction source is large or far away such that the heat is dissipated by mixing or radiation.

Fig. 5 shows generalized flow characteristics of a compressor.[6] In this figure, as the system resistance decreases, the compressor-system operating point moves to the right with a corresponding increase in the volumetric gas flow. However, the gas flow through the compressor cannot increase without a limit. This limit is known as "stonewall" and is caused by choking of the gas as it exits from the compressor. These two operating limits are shown in Fig. 5. The designer should ensure that the system compressor curve-intersection point is well away from the surge or stonewall for efficient operation.

Compressor fluids treatment. The discharge from any compressor contains a dirty corrosive liquid. Removing the sludge from a compressor air system can effect the following:

- Reduce installation costs for drain traps, pipe and fittings, filters and regulators.
- Reduce drain trap maintenance and the failure rate of pneumatic equipment, which is caused by dirt and moisture in the supply line
- Increase the life of pneumatic equipment.

High performance equipment requires high quality clean and dry compressed air. Compressed air contains water, oil and dirt particles, which affect performance of pneumatic equipment. Compressed air dryers are used to remove water vapor and to dry the air. Two main types of dryers are used: refrigerant and desiccant. Desiccant dryers use an adsorbent material such as activated alumina or molecular sieves to remove moisture from the compressed air. Also, desiccant dryers are either heat regenerated or heatless. The main advantage of desiccant dryers is their ability to cool the air to a very low temperature. They are more expensive in both capital and running costs, but are important when higher quality air is required. These dryers are widely used in the offshore oil industry, where extreme ambient conditions are encountered. Design of desiccant dryers for removing water vapor from natural gas is given elsewhere.[8,9]

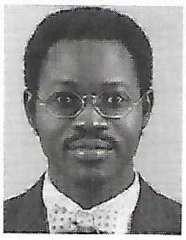
NOMENCLATURE

C = constant.
C_p = specific heat at constant pressure, J/kg K
C_v = specific heat at constant volume, J/kg K
E_{ad} = adiabatic efficiency
E_p = polytropic efficiency (try 0.75 for preliminary work)
G = gas flowrate, kg/hr
H = head, kJ/kg
H_{ad} = adiabatic head, kJ/kg
H_p = polytropic head, kJ/kg
k = adiabatic (isentropic) exponent, C_p/C_v
MC_p = molar specific heat at constant pressure, kJ/kg mol K
MC_v = molar specific heat at constant volume, kJ/kg mol K
M_w = molecular weight, kg/kg mol
n = polytropic exponent
P = absolute pressure, bara
P_1 = suction pressure, bara
P_2 = discharge pressure, bara
P_s = suction pressure, bara
Q = volume flow, $\frac{m^3}{h}$
Q_d = discharge volumetric flowrate, $\frac{m^3}{h}$
Q_s = Actual intake volume flow, m^3(st)/sec
$Q_{s(st)}$ = suction flow measured at 1.01325 bar and 288.15 K.
R = universal gas constant
$= 8.314 \frac{kJ}{kg\ mol\ K}$
R_c = compression ratio, P_2/P_1
T_1 = suction temperature, K
T_2 = discharge temperature, K
T_s = suction temperature, K
t_1 = inlet temperature, °C
t_2 = discharge temperature, °C
W = work done, kJ/kg
w = gas flow, kg/h
Z_{avg} = average compressibility factor for gas from suction to discharge conditions. A value of 1.0 will give conservative results.

LITERATURE CITED

1. Lapina, R. P., "Compressor Performance, How changes in inlet conditions affect Efficiency," *Chem. Eng.*, July 1990, pp. 110–113.
2. *Engineering Data Book*, vol. 2, Gas Processors Suppliers Association, 10th ed., 1987.
3. Perry, R. H., et al., *Perry's Chemical Engineers' Handbook*, 6th ed., McGraw-Hill Book Company, New York, 1986.
4. Branan, C., *The Process Engineer's Pocket Handbook*, Gulf Publishing Company, 1976.
5. Escoe, A. K., *Mechanical Design of Process Systems*, vol. 2, Gulf Publishing Company, 1986.
6. Sandler, J. H., and E. T. Luckiewicz, *Practical Process Engineering—A Working Approach to Plant Design*, McGraw-Hill, New York, 1987.
7. Coker, A. K., "Program calculated Z-factor for natural gas," *The Oil and Gas Journal*, Feb. 15, 1993., pp. 74–75.
8. Wunder, J. W. J., " How to design a natural gas drier," *The Oil & Gas Journal*, Aug. 6, 1962.
9. Coker, A. K., "Program sizes solid desiccant dryer for natural gas," *The Oil and Gas Journal*, Feb. 14, 1994, pp. 74–77.

For further reading. Installation Guide—*Guide to the Selection and Installation of Compressed Air Services*, 4th ed., 1989, by Ingersoll-Rand.



The author

***A. K. Coker** is a lecturer in process design and a consultant for A.K.C. Technology. Prior experience includes process engineering for Davy Energy and Environmental Ltd., Shell Petroleum Development Company of Nigeria, H&G Engineering in Glasgow, and research and development for Blue Circle Industry in the UK. Dr. Coker holds a BSc (Hons.) degree in chemical engineering, an MSc in process analysis and development, and a PhD in chemical engineering, all from Aston University, Birmingham, UK. He has published 19 articles in several international journals and is completing a book on Fortran programs for chemical process design analysis and simulation to be published by Gulf Publishing Co. in November 1994. Dr. Coker is also a chartered chemical engineer and corporate member of the Institution of Chemical Engineers in the UK.*