pends on the Reynolds number and pipe roughness, as well as size and geometry. Thus the use of the equivalent length method requires the consideration of these parameters.

The resistance coefficient or excess head loss, K, in a fitting is due mostly to turbulence, caused by sudden changes in the direction and speed of flow. The conversion between equivalent pipe length and the resistance coefficient can be expressed as:

$$K = f_D\,(Leg/D) \qquad (8)$$

This method gives a more accurate prediction of the equivalent length of fittings and valves, the exit length and the entrance length than the nomographs published by Crane Co. Ltd.[5]. The total length of pipe is estimated by summing the actual length and the equivalent length.

Overall pressure drop. Process engineers involved in the design of pipe sizing often apply a trial and error procedure. A pipe size is selected. From the system parameters and flow characteristics, its Reynolds number, friction factor and resistance are calculated. The pressure drop per 100 ft of pipe, i.e. ΔP_{100} is then evaluated.

For a given mass flowrate and physical properties of a single phase fluid, ΔP_{100} can be expressed as:

$$\Delta P_{100} = 0.00036\, f_D\, W^2/d^5, \text{ psi/100 ft} \qquad (9)$$

Alternatively, for a given volumetric rate, P_{100} can be expressed as:

$$\Delta P_{100} = 0.0216\, f_D\, \rho\, Q^2/d^5, \text{ psi/100 ft} \qquad (10)$$

Multiplying either equation 9 or 10 by the total length of pipe between two points yields the overall pressure loss, and this can be expressed as:

$$\Delta P = P_{100}\, L_{TOTAL}/100, \text{ psi} \qquad (11)$$

Pipe size for a given flowrate is often selected on the basis that the overall pressure loss is close to and less than the available pressure difference between two points in the line.

Running the program. PIPECAL is a program for sizing pipelines for single phase incompressible fluids and also for compressible fluids of shorter lines where pressure drops are no more than 10% of inlet pressure in psia. The program is interactive with the user and generates report quality outputs. The program can be downloaded onto the hard disc of the PC or run from a floppy diskette. The program can only be used on an IBM XT/AT or compatible PC.

To run the program with PIPECAL on a hard disc type in: C: PIPECAL.EXE (or PIPECAL). Alternatively, on a floppy diskette make sure that your default drive is A and type in: A:PIPECAL.EXE (or PIPECAL).

Sample problem 1. What is the overall pressure loss between points 1 and 2 for a 6 in. Schedule 40 (ID = 6.065 inch) line for kerosine?

Liquid conditions are: Flowrate, Q_{60} = 900 gpm, density at 60°F, ρ = 51 lb/ft^3 and temperature, t = 321°F.

Fig. 1 shows an isometric layout of the pipeline with fittings. Specific gravity at 60°F, S_{60} = 51/62.37 = 0.82. Specific gravity at 321°F, S_{321} = 0.72 (Ref 5 on p93). Density at 321°F, ρ = 62.37 (0.72) = 44.9 lb/ft^3. Expansion factor, $E = S_{60}/S_{321}$ = 0.82/0.72 = 1.14. Flowrate at 321°F, $Q = Q_{60}\,E$ = 900 (1.14) = 1,026 gpm. Viscosity, μ = 0.3 cP (Ref 5 on p93). Actual length of pipe = 78 ft. Fittings are six long radius 90° elbows and two flow-through tees.

Table 3 shows the printout of the input and results.

Sample problem 2. What is the pressure drop per 100 ft in a 4 inch Schedule 40 (ID = 4.026 in.) gas line for methane?

TABLE 3—Input data

INPUT PIPE INTERNAL DIAMETER inch?	6.065
DO YOU WANT VOLUMETRIC RATE YES/NO?	Y
INPUT VOLUMETRIC RATE gal/min.?	1026
INPUT FLUID DENSITY lb/ft^3?	44.9
FLUID VISCOSITY cP?	0.3
WHAT IS LENGTH OF PIPE. ft?	78
INITIAL GUESS OF FRICTION FACTOR F=0.01?	0.01
PIPE ROUGHNESS PR=0.00015 ft.?	0.00015
RESULTS	
PIPE INTERNAL DIAMETER: inches	6.065
FLUID FLOWRATE: gal/min.	1026.000
FLUID VISCOSITY: cP	.3000
FLUID DENSITY: lb/ft^3	44.900
FLUID VELOCITY: ft/sec.	13.680
VELOCITY HEAD LOSS DUE TO FITTINGS:	2.57
EQUIVALENT LENGTH OF PIPE: ft	83.775
ACTUAL LENGTH OF PIPE: ft	78.000
TOTAL LENGTH OF PIPE: ft	161.775
REYNOLDS NUMBER:	1282332.
PIPE ROUGHNESS: ft	.00015
DARCY FRICTION FACTOR.=	.0155
EXCESS HEAD LOSS: ft	10.005
PIPE PRESSURE DROP/100 ft: psi/100 ft	1.9264
OVERALL PRESSURE DROP OF PIPE: psi	3.1165
DO YOU WANT TO TERMINATE THE PROGRAM? YES/NO	N

TABLE 4—Input data

INPUT PIPE INTERNAL DIAMETER inch?	4.026
DO YOU WANT VOLUMETRIC RATE YES/NO?	N
OTHERWISE INPUT MASS FLOWRATE lb/hr.?	10750
INPUT FLUID DENSITY lb/ft^3?	0.334
FLUID VISCOSITY cP?	0.0145
WHAT IS LENGTH OF PIPE ft?	100
INITIAL GUESS OF FRICTION FACTOR F=0.01?	0.01
PIPE ROUGHNESS PR=0.00015 ft.?	0.00015
RESULTS	
PIPE INTERNAL DIAMETER: inches	4.026
FLUID FLOWRATE: lb/h	10750.000
FLUID VISCOSITY: cP	.0145
FLUID DENSITY: lb/ft^3	.334
FLUID VELOCITY: ft/sec.	101.131
VELOCITY HEAD LOSS DUE TO FITTINGS:	.00
EQUIVALENT LENGTH OF PIPE: ft	.000
ACTUAL LENGTH OF PIPE: ft	100.000
TOTAL LENGTH OF PIPE: ft	100.000
REYNOLDS NUMBER:	1162636.
PIPE ROUGHNESS: ft	.00015
DARCY FRICTION FACTOR:=	.0168
EXCESS HEAD LOSS: ft	795.187
PIPE PRESSURE DROP/100 ft: psi/100 ft	1.8426
OVERALL PRESSURE DROP OF PIPE: psi	1.8426
DO YOU WANT TO TERMINATE THE PROGRAM? YES/NO	Y

Gas flowrate, W = 10,750 lb/h; molecular weight, M_w = 16; temperature, t = 172°F; pressure, P = 127 psig; and viscosity, μ = 0.0145 cP. Calculated density, $\rho = P\,Mw/10.72\,Tz$ where z = compressibility factor (assumed z = 1), $T = t + 460$°F and $P = P + 14.7$.

Calculated density, ρ = 0.334 lb/ft^3. Actual length, L = 100 ft.

The input data and printout of the pressure loss are shown in Table 4.

Sample problem 3. A centrifugal pump having a 4 in. nozzle and a 3 in. discharge nozzle will handle a gas oil at a normal flowrate of 250 gpm through a piping and components system as detailed below. What are the overall pressure losses at the suction and discharge lines of the pump?

Specific gravity and density are: S_{60} = 1.18 and