A simple way to estimate equipment pressure drops

The equivalent line length method can be used to estimate equipment pressure drop at different operating conditions

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Sometimes we need to estimate the pressure drop of equipment at different operating conditions. This can happen in feasibility, revamp and hazardous studies or a relief contingency analysis. An accurate pressure drop is not required for these situations. The equivalent line length method is simple and quick for these purposes.

The basic idea of the equivalent line length method is to use an equivalent line length of selected line size to represent the equipment's pressure drop under a set of operating conditions. Then, use this equivalent line length to estimate the equipment pressure drop at other operating conditions.

This article describes how to use the equivalent line length method to estimate equipment pressure drop and discusses its application to equipment such as shell and tube heat exchangers, air coolers and fired heaters.

EQUIVALENT LINE LENGTH METHOD

To use the equivalent line length method, we need one set of operating conditions of the subject equipment: its pressure drop, and its inlet/outlet flowrates and physical properties. Based on the average flow rate and physical properties, line pressure drop (in psi/100 ft) for a selected line size can be calculated. Then, the equivalent line length of this equipment can be calculated based on the known equipment pressure drop and the calculated line pressure drop. Once equivalent line length of the equipment is calculated, pressure drop of this equipment at other flow conditions can be estimated based on new average flow conditions and the new line pressure drop (in psi/100 ft).

The following steps outline the procedures to use the equivalent line length method:

1. Collect pressure drop, *DP*, psi, information of the equipment at one set of operating conditions: This information can be obtained from the final vendor equipment data sheet or plant operating data.

2. Calculate average flowrate and physical properties based on the operating conditions of step 1. From equipment inlet and outlet flowrates and physical properties (mainly density, viscosity and liquid surface tension), average flowrate and physical properties can be calculated. Flow to the equipment can be either single or two phase. For single-phase flow, average physical properties of density and viscosity need to be calculated. For two-phase flow, average physical properties of vapor and liquid density and viscosity, plus liquid surface tension need to be calculated.

3 From these average flowrate and physical properties, line pressure drop, *DP*100, psi/100 ft, can be calculated for a selected line size.

4. Calculate the equivalent line length, *Le*, ft, of this equipment, by using the following equation:

$$Le = 100(DP / DP100) \quad (1)$$

5. Calculate average flowrate and physical properties based on targeted operating conditions, as in step 2.

6. From these targeted average flowrate and physical properties, line pressure drop, *dp*100, psi/100 ft, can be calculated for the same selected line size in step 3.

7. Equipment pressure drop, *dp*, psi, under target conditions can be estimated by the following equation:

$$dp = dp100(Le /100) \quad (2)$$

APPLICATION

The equivalent line length method is applied to three different types of equipment for single- and two-phase flow operation. These three types of equipment are: shell and tube heat exchangers, air coolers and fired heaters. Equipment pressure drop is estimated at the following flowrates: 50%, 75%, 90%, 110%, 125% and 150% of normal flow.

Estimated equipment pressure drops are compared with the calculated equipment pressure drops. For heat exchangers and air coolers, Heat Transfer Research Institute (HTRI) computer programs are used to calculate the correct equipment pressure drops at different operating conditions. For fired heaters, pressure drops through a fixed coil configuration are used as the correct heater pressure drops. Results are presented below. Percentage of error between estimated pressure drop and the correct pressure drop is calculated by the following equation:

$$\%\ error = 100\ (estimated\ dp - correct\ DP)/correct\ DP \quad (3)$$

Shell and tube heat exchangers: reactor feed/effluent exchanger, E-1A/B/C. This unit has three AEU design shells. Each shell is 45-in. ID with 240 321SS U-tubes. Tube OD is 1.25 in. Tube layout is 90° with 1 5/16-in. pitch. Heat transfer area is 3,142 ft^2/shell.

Tube-side flow is reactor effluent at 645,000 lb/hr. Inlet

TABLE 1. Physical properties for E-1 tube-side inlet and outlet streams

	Inlet vapor	Inlet liquid	Outlet vapor	Outlet liquid
Density, lb/ft³	1.685	35.83	0.853	42.16
Viscosity, cp	0.018	0.13	0.014	0.323
Surface tension, dyne/cm		5.0		9.0

TABLE 2. Physical properties for E-1 shell-side inlet and outlet streams

	Inlet Vapor	Inlet Liquid	Outlet Vapor	Outlet Liquid
Density, lb/ft³	0.861	46.8	1.628	39.66
Viscosity, cp	0.014	0.536	0.017	0.175
Surface tension, dyne/cm		17.0		7.0

TABLE 3. Equivalent line lengths for three different line sizes for E-1

	Tube side Duckler method		Tube side homogeneous method	
Line size	*DP*100, psi/100 ft	*Le*, ft	*DP*100, psi/100 ft	*Le*, ft
24 in. STD	0.1448	27,869.5	0.08802	45,848.1
16 in. STD	1.2884	3,132.2	0.7739	5,214.8
8 in. S40	42.1136	95.8	22.2375	181.5

	Shell side Duckler method		Shell side homogeneous method	
Line size	*DP*100, psi/100 ft	*Le*, ft	*DP*100, psi/100 ft	Le, ft
24 in. STD	0.06157	25,900.6	0.04411	36,152.8
16 in. STD	0.5461	2,920.2	0.3833	4,160.9
8 in. S40	17.2671	92.4	10.9270	145.9

TABLE 4. E-1 pressure drop estimation

Tube-side pressure drop estimation, psi—Duckler method:

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	10.41	–4.61	22.92	–2.04	32.77	–0.76	48.69	0.66	62.73	1.67	90.21	–2.86
16 in. STD	10.07	–7.66	22.59	–3.44	32.61	–1.27	48.98	1.26	63.60	3.08	92.58	–0.31
8 in. S40	9.21	–15.58	21.70	–7.26	32.12	–2.74	49.63	2.61	65.50	6.15	96.96	4.41
HTRI	10.909		23.397		32.026		48.371		61.704		92.87	

Tube-side pressure drop estimation, psi—homogeneous method:

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	10.32	–5.35	22.88	–2.20	32.78	–0.75	48.74	0.76	62.72	1.65	90.05	–3.04
16 in. STD	10.20	–6.50	22.79	–2.60	32.73	–0.90	48.78	0.84	62.91	1.95	90.44	–2.61
8 in. S40	10.12	–7.21	22.72	–2.87	32.70	–0.99	48.81	0.92	63.01	2.12	90.70	–2.34
HTRI	10.909		23.397		32.026		48.371		61.704		92.87	

Shell-side pressure drop estimation, psi—Duckler method:

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	4.14	–20.69	9.08	–6.87	12.97	–2.16	19.24	1.77	24.78	3.68	35.61	2.00
16 in. STD	3.99	–23.66	8.94	–8.36	12.89	–2.73	19.34	2.31	25.09	4.99	36.44	4.36
8 in. S40	3.73	–28.52	8.69	–10.93	12.75	–3.76	19.54	3.32	25.69	7.50	38.06	9.01
HTRI	5.225		9.751		13.252		18.909		23.897		34.914	

Shell-side pressure drop estimation, psi—homogeneous method:

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	4.14	–20.71	9.10	–6.72	12.98	–2.06	19.22	1.64	24.70	3.34	35.38	1.34
16 in. STD	4.07	–22.12	9.03	–7.36	12.95	–2.29	19.26	1.84	24.81	3.81	35.62	2.01
8 in. S40	4.01	–23.21	8.99	–7.81	12.93	–2.46	19.28	1.99	24.88	4.13	35.80	2.54
HTRI	5.225		9.751		13.252		18.909		23.897		34.914	

conditions are 728°F, 750 psig, with 64.3% (wt) of vapor. Outlet conditions are 470°F, 710 psig, with 44.5% (wt) vapor. HTRI calculated pressure drop is 40.355 psi.

Shell-side flow is reactor feed at 605,000 lb/hr. Inlet conditions are 287°F, 966 psig, with 11.3% (wt) of vapor. Outlet conditions are 611°F, 950 psig, with 23.1% (wt) vapor. HTRI calculated pressure drop is 15.947 psi.

Physical properties of the tube-side inlet and outlet streams are shown in Table 1. Physical properties of the shell-side inlet and outlet streams are shown in Table 2.

Total duty of this unit is 152.1 mm Btu/hr.

Equivalent line length. Average flowrates and physical properties are calculated for tube- and shell-side flows. Both are two phase. The Duckler and homogeneous methods are used to calculate *DP*100. The purpose is to see whether a different calculation method will affect the equipment pressure drop estimation.

*DP*100 and equivalent line length are calculated for the tube and shell sides of this unit based on three different line sizes. The purpose is to see the effect of different line sizes to equip-

TABLE 5. Physical properties of E-2 tube- and shell-side inlet and outlet streams

	Tube inlet	Tube outlet	Shell inlet	Shell outlet
Density, lb/ft^3	51.5	48.424	43.8	46.94
Viscosity, cp	1.36	0.5548	0.38	0.6445

ment pressure drop estimation. Calculated equivalent line lengths for three different line sizes are shown in Table 3.

Equipment pressure drop estimation. Eq. 2 is used to estimate tube- and shell-side pressure drops of this unit at the following flowrates: 50%, 75%, 90%, 110%, 125% and 150% of normal flow. Percent error in estimated pressure drop is calculated by Eq. 3. Estimated equipment pressure drops are shown in Table 4.

From these results, the following observations are made:

1. For tube-side pressure drop estimates of this unit based on a 24-in. line, both Duckler and homogeneous methods provide similar estimations at various flows. Based on a 16-in. line, tube-side pressure drop estimation for the homogeneous method is little bit better than those using the Duckler method. Based on an 8-in. line, tube-side pressure drop estimation for the homogeneous method is much better than those using the Duckler method. Pressure drop estimates using the homogeneous method are less sensitive to selected line size, but those using the Duckler method are not. The same can be claimed for shell-side pressure drop estimation.

TABLE 6. Equivalent line lengths for three different line sizes for E-2

	Tube side		Shell side	
Line size	DP100, psi/100 ft	Le, ft	DP100, psi/100 ft	Le, ft
24 in. STD	0.004662	254,826.3	0.004228	290066.2
16 in. STD	0.03645	32,592.6	0.03365	36442.5
8 in. S40	0.9073	1,309.4	0.8674	1,413.9

2. The homogeneous method tube-side pressure drop estimation is within 10% of error for flow within 50% of normal flow and for the three line sizes selected, but for the Duckler method this claim is only valid for estimation based on 24-in. and 16-in. lines. For shell-side pressure drop estimation within 10% error, flow range is narrowed from 75% to 150% normal flow for the homogeneous method at the three line sizes selected, but for the Duckler method this claim is only valid for estimation based on 24-in. and 16-in. lines.

3. The greater the flow is from normal, the larger the error in pressure drop estimation.

Reactor feed/stripper bottoms exchanger, E-2 A/B. This unit has two AEU design shells. Each shell is 30-in. ID

TABLE 7. E–2 pressure drop estimation

Tube–side pressure drop estimation, psi:

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	3.39	1.18	7.04	0.53	9.81	0.22	14.14	–0.19	17.86	–0.45	24.94	–0.83
16 in. STD	3.33	–0.61	6.99	–0.09	9.78	–0.09	14.17	0.08	17.97	0.19	25.25	0.39
8 in. S40	3.20	–4.42	6.87	–0.72	9.72	–0.72	14.26	0.66	18.22	1.56	25.88	2.89
HTRI	3.348		7.006		9.787		14.162		17.937		25.152	

Shell–side pressure drop estimation, psi:

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	3.45	3.93	7.23	1.47	10.10	0.51	14.62	–0.45	18.52	–1.02	25.99	–1.29
16 in. STD	3.38	1.75	7.16	0.52	10.07	0.16	14.67	–0.13	18.67	–0.25	26.36	–0.38
8 in. S40	3.24	–2.41	7.04	–1.21	10.00	–0.46	14.76	–0.45	18.92	–1.09	26.94	–2.01
HTRI	3.318		7.123		10.049		14.69		18.714		26.462	

TABLE 8. Physical properties of AC-1 inlet and outlet streams

	Inlet vapor	Inlet liquid	Outlet vapor	Outlet liquid
Density, lb/ft^3	0.461	37.634	0.305	39.769
Viscosity, cp	0.0142	0.232	0.012	0.3213
Surface tension, dyne/cm		15.4		19.75

TABLE 9. Equivalent line lengths for three different line sizes for AC-1

	Duckler method		Homogeneous method	
Line size	*DP*100, psi/100 ft	*Le*, ft	*DP*100, psi/100 ft	*Le*, ft
24 in. STD	0.1687	2,611.7	0.15453	2,851.2
16 in. STD	1.64704	267.5	1.3606	323.8
8 in. S40	68.4574	6.4	39.1329	11.3

TABLE 10. AC–1 pressure drop estimation

Duckler method:

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	1.09	–21.21	2.45	–6.30	3.55	–2.01	5.36	1.93	6.99	4.42	10.26	8.17
16 in. STD	1.01	–26.61	2.37	–9.27	3.50	–3.28	5.42	2.95	7.18	7.16	10.78	13.65
8 in. S40	0.86	–37.40	2.20	–15.96	3.36	–7.30	5.34	1.51	7.14	6.65	10.67	12.51
HTRI	1.379		2.613		3.622		5.26		6.698		9.482	

Homogeneous method:

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	1.12	–18.43	2.50	–4.46	3.58	–1.21	5.32	1.09	6.85	2.33	9.84	3.77
16 in. STD	1.11	–19.31	2.49	–4.82	3.57	–1.35	5.33	1.20	6.87	2.57	9.88	4.18
8 in. S40	1.10	–19.89	2.48	–5.06	3.57	–1.43	5.33	1.27	6.88	2.72	9.90	4.45
HTRI	1.379		2.613		3.622		5.26		6.698		9.482	

TABLE 11. Physical properties of AC-2 inlet and outlet streams

	Inlet	Outlet
Density, lb/ft^3	46.643	50.621
Viscosity, cp	0.432	1.2785

TABLE 12. Equivalent line lengths for three different line sizes for AC-2

Line size	*DP*100, psi/100 ft	*Le*, ft
24 in. STD	0.005994	161,227.9
16 in. STD	0.04720	20,474.6
8 in. S40	1.1926	810.3

with 263 CS U-tubes. Tube OD is 0.75 in. Tube layout is 45° with 1.0-in. pitch. Heat transfer area is 2,149 ft^2/shell.

Tube-side flow is liquid reactor feed at 525,000 lb/hr. Inlet conditions are 165°F, 1,010 psig. Outlet conditions are 309°F, 998 psig. HTRI calculated pressure drop is 11.88 psi.

Shell-side flow is liquid stripper bottoms at 500,000 lb/hr. Inlet conditions are 424°F, 135 psig. Outlet conditions are 296°F, 123 psig. HTRI calculated pressure drop is 12.264 psi.

Physical properties of tube- and shell-side inlet and outlet streams are shown in Table 5.

Total duty of this unit is 81.5 mm Btu/hr.

Equivalent line length. Calculated equivalent line lengths for three different line sizes are shown in Table 6.

Equipment pressure drop estimation. Eq. 2 is used to estimate tube-side and shell-side pressure drop of this unit at the following flowrates: 50%, 75%, 90%, 110%, 125% and

TABLE 13. AC–2 pressure drop estimations

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	2.74	–1.38	5.72	–0.53	7.97	–0.17	11.51	0.17	14.55	0.38	20.37	0.71
16 in. STD	2.69	–3.23	5.67	–1.36	7.95	–0.49	11.54	0.47	14.66	1.11	20.64	2.05
8 in. S40	2.58	–7.09	5.57	–3.06	7.89	–1.14	11.61	1.05	14.86	2.48	21.15	4.59
HTRI	2.778		5.746		7.985		11.49		14.499		20.223	

TABLE 14. Physical properties of H-1 inlet and out streams

	Inlet vapor	Inlet liquid	Outlet vapor	Outlet liquid
Density, lb/ft^3	1.63	39.7	1.86	38.0
Viscosity, cp	0.017	0.175	0.018	0.15
Surface tension, dyne/cm		7.0		6.0

TABLE 15. Equivalent line lengths for three different line sizes for H-1

Line size	*DP*100, psi/100 ft	*Le*, ft
24 in. STD	0.001721	4,475,305
16 in. STD	0.01401	549,750
8 in. S40	0.3761	20,479

TABLE 16. H–1 pressure drop estimation, psi

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	24.35	8.59	48.20	2.86	64.98	0.88	89.60	–0.63	109.38	–1.10	144.38	–0.71
16 in. STD	23.85	6.38	47.83	2.07	64.82	0.62	89.78	–0.43	109.90	–0.63	145.36	–0.03
8 in. S40	23.12	3.13	47.37	1.09	64.67	0.40	90.01	–0.18	110.32	–0.25	145.92	0.35
Calculated	22.42		46.86		64.42		90.17		110.60		145.41	

TABLE 17. Physical properties of H-2 inlet and outlet stream

	Inlet	Outlet
Density, lb/ft^3	1.63	1.86
Viscosity, cp	0.017	0.018

TABLE 18. Equivalent line lengths for three different line sizes for H-2

Line size	*DP*100, psi/100 ft	*Le*, ft
24 in. STD	0.0006254	4,396,386
16 in. STD	0.005136	535,339
8 in. S40	0.1388	19,809

150% of normal flow. Percent error in estimated pressure drop is calculated by Eq. 3. Estimated equipment pressure drops are shown in Table 7.

From these results, the following observations are made:

1. All tube- and shell-side pressure drop estimates of this unit are within 5% of error over the flow range studied and for the three line sizes selected. Pressure drop estimates using 16-in. line provide the smallest error in estimation.

2. In general, the greater the flow is from the normal, the larger the error in pressure drop estimation.

Air coolers: reactor effluent air cooler, AC-1A/B/C/D. This unit is a forced-draft air cooler with four bays. Each bay has 540 CS tubes with aluminum fins. Each tube is 1-in. OD, 30 ft long. There are nine tube rows in two passes. Tube

TABLE 19. H-2 pressure drop estimation, psi

	50% flow	% error	75% flow	% error	90% flow	% error	110% flow	% error	125% flow	% error	150% flow	% error
24 in. STD	7.55	9.13	16.04	3.52	22.56	1.24	32.90	-1.07	41.88	-2.74	59.18	-4.35
16 in. STD	7.36	6.34	15.86	2.38	22.47	0.84	33.02	-0.72	42.24	-1.64	60.07	-2.91
8 in. S40	7.08	2.38	15.63	0.85	22.34	0.28	33.16	-0.30	42.67	-0.64	61.17	-1.12
Calculated	6.917		15.493		22.282		33.260		42.944		61.866	

layout is triangular, with 2⅜-in. pitch. Fins are ⅝-in. height at 10 fins/in. Bare tube surface per bay is 88,513 ft^2. Each bay has two 25 hp motor-driven fans.

Flow to this unit is reactor effluent at 775,000 lb/hr. Inlet conditions are 220°F, 260 psig, with 20.8% (wt) of vapor. Outlet conditions are 132°F, 256 psig, with 11.6% (wt) vapor. HTRI calculated pressure drop is 4.406 psi. Physical properties of the inlet and outlet streams of this unit are shown in Table 8. Total duty of this unit is 52.7 mm Btu/hr.

Equivalent line length. Calculated equivalent line lengths for three different line sizes are shown in Table 9.

Equipment pressure drop estimation. Eq. 2 is used to estimate pressure drop of this air cooler at the following flowrates: 50%, 75%, 90%, 110%, 125% and 150% of normal flow. Percentage error in estimated pressure drop is calculated by Eq. 3. Estimated equipment pressure drops are shown in Table 10.

From these results, the following observations are made:

1. For all air cooler pressure drop estimates of this unit, estimates by the homogeneous method are better than those by the Duckler method. Pressure drop estimates using the homogeneous method are less sensitive to selected line size, but those using the Duckler method are not.

2. The homogeneous method pressure drop estimation of this unit is within 10% of error for a flow range from 75% to 150% of normal flow and for the three line sizes selected, but for the Duckler method this claim is only valid for estimation based on a 24-in. line. For either method, pressure drop estimations based on a 24-in. line are better than those using 16-in. or 8-in. line.

3. The greater the flow is from the normal, the larger the error in pressure drop estimation.

Stripper bottoms air cooler, AC-2 A-C. This unit is a forced-draft air cooler with three bays. Each bay has 388 CS tubes with aluminum fins. Each tube is 1.25-in. OD, 30 ft long. There are eight tube rows in eight passes. Tube layout is triangular with 2¾-in. pitch. The fins are ⅝-in. high at 10 fins/in. Bare tube surface is 3,537 ft^2 per bay. Each bay has two 20 hp motor-driven fans.

Flow to this unit is liquid stripper bottoms at 600,000 lb/hr. Inlet conditions are 318°F, 135 psig. Outlet conditions are 142°F, 125 psig. HTRI calculated pressure drop is 9.664 psi. Physical properties of the inlet and outlet streams of this unit are shown in Table 11. Total duty of this unit is 56.6 mm Btu/hr.

Equivalent line length. Calculated equivalent line lengths for three different line sizes are shown in Table 12.

Equipment pressure drop estimation. Eq. 2 is used to estimate pressure drop of this air cooler at the following flowrates: 50%, 75%, 90%, 110%, 125% and 150% of normal flow. Percentage of error in estimated pressure drop is calculated by Eq. 3. Estimated equipment pressure drops are shown in Table 13.

From these results, the following observations are made:

1. All air cooler pressure drop estimates are within 10% of error over the flow range studied and over the three pipe sizes selected. Pressure drop estimates based on a 24-in. line are better than those using 16-in. or 8-in. lines.

2. In general, the greater the flow is from the normal, the larger the error in pressure drop estimation.

Fired heaters: reactor charge heater, H-1. The radiant section of this unit has eight coils. Each coil is made of ten 4-in. sch 40 321SS tubes. Each tube is 46 ft long. Tubes are connected by 180° return bends.

Flow to this unit is reactor feed at 604,551 lb/hr. Inlet conditions are 611°F, 936 psig, with 34.8% (wt) of vapor. Outlet conditions are 683°F, 859 psig, with 50.8% (wt) vapor. Heater pressure drop is calculated based on the coil's configuration described above. Calculated pressure drop is 77.024 psi using the Duckler method. Physical properties of inlet and outlet stream of this unit are shown in Table 14. Total duty of this unit is 30.75 mm Btu/hr.

Equivalent line length. Calculated equivalent line lengths for three different line sizes are shown in Table 15.

Equipment pressure drop estimation. Eq. 2 is used to estimate pressure drop of this heater at the following flowrates: 50%, 75%, 90%, 110%, 125% and 150% of normal flow. Percentage of error in estimated pressure drop is calculated by Eq. 3. Estimated equipment pressure drops are shown in Table 16.

From these results, the following observations are made:

1. All pressure drop estimates of this unit are within 10% of error for a flow range from 50% to 150% of normal flow and for the three line sizes selected. Pressure drop estimates based on a 16-in. line are better than those estimations using 24-in. or 8-in. lines.

2. In general, the greater the flow is from the normal, the larger the error in pressure drop estimation.

Vapor feed heater, H-2. This heater configuration is the same as H-1, except it is used to heat a vapor feed. Flow to this unit is a vapor feed at 320,000 lb/hr. Inlet conditions are 611°F, 936 psig. Outlet conditions are 683°F, 125 psig. HTRI calculated pressure drop is 27.495 psi. Physical properties of inlet and outlet stream of this unit are shown in Table 17. Total duty of this unit is 10.63 mm Btu/hr.

Equivalent line length. Calculated equivalent line lengths for three different line sizes are shown in Table 18.

Equipment pressure drop estimation. Eq. 2 is used to

estimate pressure drop of this heater at the following flowrates: 50%, 75%, 90%, 110%, 125% and 150% of normal flow. Percentage of error in estimated pressure drop is calculated by Eq. 3. Estimated equipment pressure drops are shown in Table 19.

From these results, the following observations are made:

1. All pressure drop estimates of this unit are within 10% of error for a flow range from 50% to 150% of normal flow and for the three line sizes selected. Pressure drop estimations based on an 8-in. line are better than those estimations using 24-in. or 16-in. lines.

2. In general, the greater the flow is from the normal, the larger the error in pressure drop estimation.

Discussion.

1. The equivalent line length method is a simple and quick way to estimate equipment pressure drop at other operating conditions if the equipment pressure drop at one operating condition is known. For the pressure drop estimates calculated in the six cases, it is found that the error in pressure drop estimation is within 10% for a flow range from 75% to 150% of normal flow. For flow at 50% of normal, the error is usually still within 10%, but in some cases it goes up to 20–30%.

2. For two-phase flow, heat exchanger and air cooler pressure drops estimated by the homogeneous method are better than using the Duckler method and are less sensitive to line size selection. This may be due to the HTRI using the homogeneous method to calculate pressure drop.

3. Among the three selected line sizes used in pressure drop estimation, no conclusion can be made on which line size will provide better pressure drop estimation.

4. It is suggested to use at least four significant digits in $DP100$ or $dp100$ (line pressure drop per 100 ft) to increase accuracy of equipment pressure drop estimation.

5. Actually, we can eliminate the step of the equivalent line length calculation (step 4 outlined in the equivalent line length method section) and calculate estimated equipment pressure drop directly by the ratio of line pressure drops, see Eq. 4. This equation is obtained by substituting Eq. 1 into Eq. 2.

$$dp = (dp100/DP100)\ DP \qquad (4)$$

Eq. 4 shows that the ratio of equipment pressure drop at a new operating condition to the equipment pressure drop at a known condition, is proportional to the ratio of line pressure drop at the new operating condition to line pressure drop at the known condition. HP

NOMENCLATURE

DP	Equipment pressure drop at a known operating condition, psi
dp	Equipment pressure drop at a new operating condition, psi
$DP100$	Line pressure drop in psi/100 ft at a known operating condition
$dp100$	Line pressure drop in psi/100 ft at a new operating condition
Le	Equivalent line length, ft

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