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APPENDICES

Appendix A

Table of experimental results and sample of calculation

Table A-1 Experimental results for $\sigma = \frac{1}{4}$, L/Dh = 100

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	178	9556	-2606	233700	.8699	.3483	.143	.857
2	394	42569	-10589	469137	.7987	.412	.0595	1.1168
3	524	65158	-17375	616829	.824	.442	.0428	1.2282
4	772	130316	-34750	920900	.7586	.4522	.0282	1.3975
5	1207	304070	-82533	1424789	.6818	.4931	.0173	1.622
6	1402	408323	-108596	1624607	.6912	.504	.0149	1.705
7	1724	564703	-152035	1946053	.54	.5356	.0113	1.8267
8	1931	738457	-17375	2180622	.5993	.5708	.0101	1.8971
9	2146	912212	-219365	2410847	.5996	.552	.0091	1.965
10	2402	1085967	-278007	2693199	.5234	.5702	.008	2.0402
11	2575	1172844	-308414	3045052	.5876	.5765	.0076	2.0881
12	2698	1238002	-304070	3279621	.5446	.5851	.0071	2.1208
13	2909	1520354	-334477	3466408	.497	.5898	.0065	2.1747
14	3066	1715828	-390948	3518534	.4973	.5917	.0062	2.2131
15	3241	1933022	-438730	3705320	.507	.6113	.006	2.2545
16	3604	2193654	-477825	3996360	.42	.595	.0052	2.3357
17	3773	2410847	-542983	4352557	.40	.577	.0051	2.3716
18	3942	2649760	-586422	4369933	.365	.5853	.0049	2.4065
19	4075	2823515	-608141	4778256	.383	.5873	.0048	2.4333
20	4217	2953831	-621173	4865134	.3903	.5911	.0047	2.4612
21	4292	3097179	-642892	5125766	.381	.585	.0046	2.4757

Table A-2 Experimental results for σ = ¼ , L/Dh = 75

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	256	17375	-4387	222406	.8103	.42	.0887	1.0647
2	428	51257	-12640	393120	.81	.473	.055	1.2636
3	582	83402	-21502	503888	.7536	.485	.0363	1.3999
4	720	123800	-30884	642892	.81	.51	.028	1.5028
5	936	194605	-51692	773208	.79	.4712	.0217	1.6402
6	1148	286695	-71673	916556	.724	.498	.017	1.7557
7	1280	339256	-86008	1055560	.708	.52	.0157	1.8205
8	1423	413970	-106424	1224971	.644	.549	.0138	1.886
9	1540	447418	-132488	1320536	.626	.5346	.0123	1.9363
10	1715	556015	-146822	1446508	.5526	.5315	.0107	2.007
11	1886	655924	-177229	1542073	.67	.55	.0101	2.0716
12	2065	755833	-218496	1763611	.5646	.5767	.0092	2.1352
13	2175	894837	-231962	1902614	.4881	.5761	.0095	2.1725
14	2389	1051216	-290170	2002524	.4805	.578	.0088	2.2415
15	2538	1129406	-319709	2141528	.528	.5505	.0083	2.2872
16	2805	1185876	-350116	2415192	.4341	.573	.0074	2.3647
17	3125	1598544	-367926	2684512	.3407	.602	.0063	2.4514
18	3445	1976461	-399202	3071116	.37	.624	.0037	2.5324
19	3809	2284876	-414840	3527222	.3414	.651	.0058	2.6186
20	4132	2671480	-443074	3996360	.326	.698	.0056	2.6906
21	4513	3118899	-456106	4561063	.318	.721	.0055	2.7709
22	4750	3292653	-482170	4865134	.284	.743	.0055	2.8186
23	4982	3700977	-486513	5125766	.269	.789	.0052	2.8637
24	5218	3944233	-490857	5386398	.250	.794	.005	2.9083
25	5562	4165771	-495201	5603592	.246	.81	.005	2.9708

Table A-3 Experimental results for $\sigma = \frac{1}{4}$, L/Dh = 50

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	235	15290	-4322	151166	.892	-	.09	1.1845
2	500	59945	-15985	304505	.814	.528	.0403	1.5234
3	666	97302	-29929	395726	.7338	.477	.0303	1.6762
4	842	154641	-41353	503889	.726	.457	.026	1.8124
5	1008	212415	-62986	599454	.7207	.4684	.0215	1.9245
6	1140	283220	-72108	690675	.7478	.4918	.0194	2.0051
7	1231	321012	-86008	786240	.7302	.488	.0177	2.0571
8	1408	391817	-102080	834023	.6774	.5076	.0152	2.1513
9	1570	482169	-125103	951307	.7031	.5224	.0143	2.2308
10	1710	595110	-149863	1051216	.5612	.5521	.0126	2.2952
11	1885	690675	-167673	1120718	.67	.5719	.0118	2.371
12	2057	829679	-185048	1264066	.576	.6136	.0103	2.441
13	2151	890493	-193736	1355287	.5199	.5682	.0102	2.4777
14	2234	938275	-215455	1424789	.4814	.5946	.0098	2.5091
15	2457	964339	-231093	1542073	.4634	.625	.0089	2.59
16	2497	973026	-226315	1659358	.4687	.6924	.009	2.604
17	2652	1020809	-240650	1728860	.31	.6445	.0084	2.6568
18	2721	1120718	-242387	1746235	.30	.6362	.0086	2.6796
19	2853	1285785	-261935	1863520	.306	.61	.008	2.7223
20	3096	1420445	-281482	1993836	.26	.6332	.0079	2.7974
21	3201	1511666	-284523	2145871	.248	.6361	.0079	2.8287
22	3421	1733204	-308414	2376096	.2162	.6441	.0072	2.8921
23	3703	1924334	-335781	2628041	.1706	.6616	.0067	2.9695
24	3967	2150215	-345772	2879985	.1355	.6856	.0061	3.0384
25	4141	2258812	-355328	3162337	.1456	.6862	.006	3.0822

Table A-4 Experimental results for σ = ¼ , L/Dh = 25

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	196	10859	-3258	65158	1.1	.282	.13	1.4047
2	363	34751	-8688	108597	1.0	.428	.063	1.7251
3	500	56470	-16507	152035	.80	.427	.047	1.9194
4	750	124234	-33013	238913	.768	.48	.0328	2.1971
5	965	206334	-47782	308415	.77	.54	.025	2.3897
6	1123	244994	-60814	369229	.56	.56	.022	2.5136
7	1234	286695	-65158	412667	.52	.60	.021	2.5938
8	1333	321446	-72542	456106	.46	.62	.0198	2.6614
9	1524	412668	-82534	534296	.43	.66	.0178	2.7829
10	1712	486513	-91221	616829	.35	.69	.0163	2.8929
11	1852	542983	-99040	651580	.29	.71	.0147	2.9697
12	2083	686331	-112506	807959	.28	.73	.0144	3.0884
13	2222	747145	-122931	873117	.23	.74	.0137	3.1556
14	2348	825335	-122931	912212	.22	.76	.0128	3.2142
15	2431	890493	-130750	977370	.22	.76	.0128	3.2516
16	2598	968682	-136831	1042528	.17	.78	.0119	3.3244
17	2740	1059904	-142478	1129406	.15	.79	.0116	3.3839
18	2899	1207595	-147691	1207595	.17	.80	.0111	3.4482
19	3031	1275785	-159420	1303160	.14	.80	.011	3.4997
20	3312	1381350	-165935	1424789	.04	.82	.01	3.6047
21	3497	1646326	-174189	1520354	.10	.83	.0096	3.6706
22	3704	1702796	-176361	1598544	.02	.84	.009	3.7416
23	3907	1802705	-187220	1746235	-.02	.85	.0088	3.8088
24	4082	1928678	-202858	1815737	-.04	.84	.0084	3.8648
25	4387	2119808	-216759	1976460	-.08	.85	.0079	3.9588
26	4652	2358731	-231528	2206685	-.09	.86	.0079	4.0369
27	4855	2658448	-245428	2397816	-0.7	.87	.0075	4.0948

Table A-5 Experimental results for σ = ¼ , L/Dh = 10

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	190	9556	-2606	21719	1.107	.379	.116	1.88
2	595	65158	-13031	73845	.77	.65	.040	2.76
3	822	124234	-15203	102515	.49	.76	.029	3.07
4	1054	196777	-12162	138135	.43	.85	.024	3.34
5	1193	223709	-4343	154207	.30	.91	.021	3.48
6	1331	268451	-868	178098	.24	.9	.0194	3.61
7	1488	328396	0	199818	.21	.93	.0174	3.75
8	1611	351853	86	210677	.19	.93	.0157	3.85
9	1874	477825	2171	238912	.13	.94	.013	4.05
10	2126	573390	8687	281483	.09	.95	.012	4.22
11	2219	625517	-13031	292776	.05	.92	.0115	4.28
12	2353	673299	-86877	304070	.002	.816	.0114	4.36
13	2492	708050	-130316	326659	-.056	.77	.0102	4.45
14	2595	734114	-108596	338822	-.095	.81	.0097	4.51
15	2780	803615	-147691	369228	-.134	.789	.0092	4.61
16	2959	903524	-160723	395292	-.140	.79	.0087	4.71
17	3104	1085967	-165067	412667	-.066	.80	.0083	4.78
18	3264	1129406	-169410	438730	-.1185	.81	.008	4.87
19	3329	1164157	-173754	447418	-.126	.81	.0078	4.90
20	3419	1238002	-217193	456106	-.12	.79	.0075	4.94
21	3502	1311848	-260633	469137	-.11	.77	.0074	4.98
22	3653	1411757	-325790	486513	-.12	.75	.007	5.05
23	3776	1502979	-356197	499545	-.12	.745	.0068	5.11
24	3863	1555105	-408323	521264	-.133	.7261	.0067	5.15
25	4016	1624607	-477825	556015	-.16	.71	.0067	5.21
26	4270	1733204	-521264	608141	-.20	.72	.0064	5.32
27	4498	1924334	-521264	651580	-.21	.72	.0062	5.42

Table A-6 Experimental results for $\sigma = 1/4$, $L/Dh = 5$

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	289	21719	-3040	21719	1.0	.656	.100	2.73
2	412	36922	-4343	30407	.74	.74	.069	3.07
3	606	60814	-4778	43438	.35	.83	.0457	3.5
4	772	102081	-4343	56470	.39	.88	.0366	3.8
5	1078	176361	-2171	78189	.24	.92	.026	4.24
6	1293	262804	-434	99909	.277	.93	.0231	4.505
7	1437	282351	-8687	108596	.12	.90	.0203	4.66
8	1736	425699	-43438	132488	.154	.83	.017	4.96
9	1911	503888	-130316	147691	.11	.66	.015	5.13
10	2073	529952	-143347	160723	.015	.67	.0144	5.27
11	2257	569046	-195474	177229	-.075	.64	.0134	5.42
12	2386	668955	-208505	175926	-.03	.65	.012	5.52
13	2544	751489	-225881	198080	-.04	.66	.0118	5.64
14	2686	812303	-260632	220668	-.067	.66	.0118	5.75
15	2829	851398	-264976	234568	-.115	.68	.0113	5.85
16	2979	1016465	-282351	217193	-.05	.69	.01	5.95
17	3099	1064248	-308414	251944	-.08	.69	.0101	6.03
18	3275	1181532	-356197	261935	-.09	.68	.0094	6.14
19	3371	1242346	-369228	261066	-.093	.68	.0089	6.20
20	3538	1394382	-408323	299292	-.08	.68	.0092	6.30
21	3650	1424789	-456106	321446	-.111	.67	.0093	6.36
22	3785	1516010	-547327	356197	-.12	.64	.0096	6.44
23	3972	1780986	-573390	390948	-.10	.65	.0096	6.55
24	4146	1967773	-634204	408323	-.09	.65	.0088	6.64
25	4319	2150215	-686331	456106	-.095	.65	.0095	6.73
26	4575	2454286	-734114	477826	-.11	.66	.0089	6.68

Table A-7 Experimental results for σ = ¼ , L/Dh = 2

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	228	9134	-2203	6675	.42	.61	.124	3.43
2	373	23726	-5177	11237	.38	.65	.078	4.04
3	654	69619	-14256	16830	.32	.68	.038	4.87
4	894	118712	-20432	26484	.21	.74	.032	5.41
5	1129	169526	-19386	36957	.09	.82	.028	5.84
6	1337	226177	-20246	40723	.04	.85	.022	6.18
7	1614	312070	-19388	53950	-.012	.88	.020	6.58
8	1744	359642	-18700	59841	-.024	.89	.019	6.75
9	1915	407043	-17800	68354	-.08	.9	.018	6.97
10	2123	459430	-21877	84010	-.15	.90	.018	7.21
11	2300	546078	-18145	93124	-.14	.91	.017	7.41
12	2503	638618	-22569	110288	-.15	.92	.017	7.62
13	2589	735314	-32536	117997	-.09	.9	.017	7.71
14	2835	923301	-59819	133163	-.05	.88	.016	7.94
15	2999	1068139	-55298	149015	-.02	.89	.016	8.09
16	3222	1138832	-77266	182750	-.09	.88	.017	8.29
17	3365	1315447	-142903	187607	-.04	.84	.016	8.41
18	3464	1440584	-120372	211234	-.01	.86	.017	8.49
19	3630	1633131	-166298	231964	.02	.84	.017	8.62
20	3754	1600680	-159612	262675	-.06	.85	.018	8.72
21	3961	1680531	-116774	308689	-.11	.88	.019	8.88
22	4103	2021091	-125296	348652	-.01	.90	.02	8.98
23	4216	1972896	-86278	441745	-.08	.91	.024	9.06
24	4309	1964761	-138194	480675	-.12	.88	.025	9.13
25	4406	1652166	-194742	482457	-.28	.86	.024	9.20

Table B-1 Experimental results for σ = ½ , L/Dh = 100

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	219	10599	-4344	278007	.89	-.047	.108	1.092
2	315	21024	-9383	399636	.836	-.070	.075	1.23
3	406	34750	-15290	512576	.84	-.063	.075	1.34
4	510	52126	-23978	635942	.746	-.052	.0456	1.45
5	672	86877	-42917	868773	.68	.032	.036	1.58
6	854	140741	-67764	1042528	.69	.056	.0267	1.72
7	991	191130	-90352	1268409	.70	.063	.0241	1.80
8	1202	271057	-125103	1546417	.65	.10	.02	1.92
9	1450	365885	-170279	1859176	.64	.145	.0165	2.03
10	1516	417011	-191130	1949528	.60	.129	.0158	2.08
11	1722	528214	-243256	2206685	.57	.137	.0139	2.17
12	1861	625517	-278007	2380440	.59	.15	.0128	2.23
13	2110	781896	-347509	2710574	.56	.167	.0114	2.32
14	2282	886149	-399636	2936456	.52	.177	.0105	2.38
15	2509	1059904	-451762	3162337	.51	.214	.0094	2.46
16	2790	1251034	-538640	3648850	.45	.233	.0087	2.55
17	3008	1424789	-608141	3909482	.425	.248	.0081	2.61
18	3245	1650670	-712394	4222241	.42	.245	.0075	2.68
19	3472	1928678	-781896	4517624	.44	.267	.007	2.74
20	3711	2102432	-938275	4830383	.39	.24	.0065	2.80
21	3976	2380440	-1042528	5195268	.37	.26	.0061	2.87
22	4218	2641072	-1562793	5560153	.36	.17	.0058	2.92
23	4563	3005958	-1737548	6168295	.33	.127	.0055	3.00
24	4955	3648850	-1946053	7123946	.35	.158	.0054	3.08
25	5341	3996360	-2085057	7992720	.30	.20	.0052	3.16

Table B-2 Experimental results for σ = ½ , L/Dh = 75

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	190	6602	-3127	10251	.85	-.02	.125	1.14
2	355	22761	-11120	19113	.83	-.02	.066	1.41
3	482	42048	-20676	26584	.83	-.03	.05	1.56
4	595	62030	-30407	32492	.78	.001	.04	1.67
5	712	86008	41179	37183	.73	.04	.032	1.78
6	848	122670	59250	44481	.74	.03	.027	1.88
7	962	153772	76278	50910	.70	.03	.024	1.97
8	1178	230399	111203	69849	.70	.05	.022	2.10
9	1308	276270	133270	72456	.66	.07	.0185	2.18
10	1491	356544	168021	86530	.65	.09	.017	2.278
11	1681	446028	208331	97650	.62	.11	.015	2.37
12	1899	545242	243604	115820	.57	.16	.014	2.47
13	2212	722993	313801	132227	.54	.19	.0118	2.60
14	2365	807786	352374	134486	.50	.20	.0105	2.65
15	2549	915340	394423	148907	.48	.22	.01	2.72
16	2782	1054865	452109	166631	.44	.24	.0094	2.80
17	2955	1160160	500066	180009	.41	.25	.009	2.86
18	3098	1275186	538639	197906	.41	.26	.009	2.91
19	3302	1436083	574433	202250	.40	.29	.0081	2.96
20	3647	1706098	716043	228487	.37	.28	.0075	3.07
21	3843	1851878	774425	262717	.35	.29	.0078	3.12
22	3998	1977156	823771	274532	.33	.30	.0075	3.16
23	4143	2064207	884585	275227	.30	.30	.007	3.2
24	4387	2358547	1035926	299727	.32	.28	.0068	3.26
25	4622	2593464	1052085	318145	.31	.32	.0065	3.32

Table B-3 Experimental results for σ = ½ , L/D_h = 50

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	395	33013	-13726	253681	.83	-.02	.0607	1.67
2	465	43438	-28939	347509	.75	-.012	.06	1.76
3	643	79927	-39268	434387	.7	.041	.039	1.97
4	708	95565	-45176	443074	.67	.077	.033	2.03
5	825	130316	-60814	510839	.67	.083	.028	2.14
6	1010	194605	-90352	764521	.60	.088	.028	2.29
7	1130	231093	-112940	799272	.64	.09	.023	2.37
8	1249	291908	-139003	868773	.59	.085	.021	2.45
9	1356	330134	-156379	973027	.57	.115	.0198	2.52
10	1465	382260	-173755	990402	.62	.145	.0172	2.59
11	1582	460450	-191130	1059904	.52	.179	.0158	2.66
12	1861	590766	-208505	1285785	.50	.30	.0139	2.80
13	1978	660268	-225881	1285785	.49	.32	.0123	2.80
14	2110	745408	-260632	1390038	.44	.31	.0117	2.92
15	2260	816647	-295383	1494291	.42	.32	.0109	2.99
16	2373	886149	-312758	1511666	.41	.335	.01	3.04
17	2566	1025153	-347509	1737547	.37	.35	.0098	3.12
18	2697	1094655	-364885	1841800	.336	.37	.0095	3.17
19	2912	1233659	-382260	2050306	.34	.41	.009	3.26
20	3004	1320536	-399636	2171934	.31	.42	.009	3.29
21	3165	1424789	-434386	2258812	.28	.426	.0084	3.35
22	3331	1529042	-417011	2276187	.31	.46	.0077	3.40
23	3490	1737548	-486513	2606322	.32	.45	.008	3.46
24	3652	1928678	-521264	2780076	.28	.458	.0078	3.51
25	3738	1946053	-538639	2953831	.29	.46	.0079	3.54
26	4023	2258812	-573390	3214463	.27	.48	.0074	3.63
27	4201	2415191	-625517	3388218	.27	.48	.0072	3.68

Table B-4 Experimental results for σ = ½ , L/Dh = 25

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	Ke	f	B_F
1	312	20850	-10425	104253	.85	.05	.08	1.95
2	391	32144	-15638	123366	.82	-.014	.06	2.10
3	521	54211	-26063	145954	.74	.033	.040	2.31
4	694	95565	-43438	225881	.73	.076	.035	2.54
5	892	149429	-69501	304071	.65	.097	.0285	2.76
6	1129	231093	-104253	382260	.60	.139	.0224	3.0
7	1239	267582	-121628	417011	.55	.158	.020	3.08
8	1420	323184	-145954	486513	.45	.21	.018	3.23
9	1499	356197	-156379	512576	.43	.23	.017	3.29
10	1616	399636	-166804	529952	.39	.27	.0152	3.37
11	1905	538639	-194605	660268	.36	.35	.0136	3.56
12	2042	587291	-206768	715869	.34	.38	.0128	3.64
13	2304	729770	-225881	868774	.276	.43	.012	3.80
14	2466	816647	-234569	955651	.25	.46	.0117	3.88
15	2622	886149	-243256	1042528	.22	.486	.0113	3.96
16	2752	955651	-253682	1112030	.192	.50	.011	4.03
17	2930	1042528	-278007	1146781	.156	.51	.01	4.11
18	3113	1146781	-286695	1164157	.14	.53	.009	4.20
19	3296	1251034	-293645	1285785	.11	.55	.0088	4.28
20	3391	1337911	-304070	1303160	.12	.55	.0085	4.32
21	3516	1407413	-312758	1320536	.10	.56	.008	4.37
22	3723	1485603	-316234	1372662	.05	.58	.0074	4.46
23	3875	1615919	-312758	1390038	.05	.60	.0069	4.51
24	4057	1737547	-312758	1424789	.04	.61	.0065	4.58
25	4164	1824425	-321446	1442164	.035	.61	.0062	4.62
26	4375	1998180	-319708	1450852	.03	.62	.0057	4.70

Table B-5 Experimental results for σ = ½ , L/Dh = 10

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	Ke	f	B_F
1	144	4517	-2085	18418	.85	-.015	.166	2.04
2	268	14943	-6950	34577	.80	.02	.09	2.51
3	510	51952	-25020	66895	.74	.03	.048	3.12
4	663	87224	-41875	87224	.73	.04	.037	3.40
5	1075	209027	-103731	148560	.60	.08	.024	4.00
6	1170	245689	-109986	154120	.59	.15	.021	4.11
7	1326	303897	-131879	178967	.54	.19	.019	4.29
8	1463	358456	-146301	206420	.50	.24	.018	4.43
9	1507	383303	-158116	206941	.51	.23	.017	4.47
10	1658	449329	-180357	250380	.47	.26	.017	4.62
11	1950	565398	-249511	285305	.36	.26	.014	4.87
12	2163	670519	-294514	325963	.32	.28	.013	5.05
13	2369	759308	-360888	360888	.26	.27	.012	5.20
14	2551	871727	-392338	348725	.25	.30	.01	5.33
15	2764	982409	-409366	409366	.21	.35	.01	5.48
16	2926	1101084	-470180	458712	.21	.34	.01	5.58
17	3048	1207248	-522654	447939	.22	.33	.009	5.66
18	3361	1437647	-620478	484254	.20	.34	.008	5.84
19	3685	1684900	-716912	573564	.19	.35	.008	6.03
20	3826	1843190	-823598	627428	.19	.33	.008	6.10
21	3980	1888540	-785198	679033	.14	.38	.008	6.18
22	4180	2106429	-819253	702143	.15	.40	.0075	6.29
23	4564	2511278	-920900	803615	.15	.42	.0072	6.47
24	4728	2635165	-898312	958257	.13	.45	.008	6.55

Table B-6 Experimental results for σ = ½ , L/Dh = 5

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	213	7840	-4740	13613	.54	-.03	.112	2.93
2	388	25006	-14116	25006	.49	.05	.062	3.58
3	571	51974	-29262	39308	.44	.08	.045	4.08
4	883	111756	-64756	48045	.32	.14	.028	4.72
5	1110	158447	-102330	75922	.21	.13	.023	5.09
6	1295	204432	-128050	89860	.16	.18	.020	5.36
7	1388	242591	-144522	87745	.19	.19	.018	5.48
8	1518	280900	-157427	104951	.16	.24	.017	5.65
9	1966	393503	-232995	165685	.01	.30	.016	6.16
10	2137	449639	-244701	183526	-.015	.35	.015	6.33
11	2286	516626	-210010	196010	-.012	.45	.014	6.47
12	2340	539121	-220049	205379	-.015	.45	.014	6.53
13	2587	654461	-242060	268956	-.02	.48	.015	6.75
14	2731	709364	-249776	279749	-.04	.50	.014	6.87
15	2858	787816	-262605	306372	-.03	.51	.014	6.98
16	3109	867529	-258964	414342	-.08	.55	.016	7.17
17	3316	1016356	-309325	530273	-.06	.54	.018	7.33
18	3553	1183740	-338211	574959	-.05	.55	.017	7.50
19	3826	1398129	-451009	745146	-.037	.52	.019	7.69
20	3979	1484615	-509010	636263	-.05	.51	.015	7.79
21	4061	1561900	-486022	706942	-.043	.53	.016	7.84
22	4251	1609799	-484150	726225	-.085	.55	.015	7.96
23	4325	1578631	-425979	701614	-.12	.58	.014	8.01
24	4422	1571653	-419107	785826	-.15	.59	.015	8.07
25	4564	1590501	-390649	837106	-.18	.61	.015	8.157

Table B-7 Experimental results for σ = ½ , L/Dh = 2

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	217	6371	-4478	6055	.26	.04	.12	4.01
2	392	19555	-14203	10539	.20	.06	.064	4.88
3	523	32610	-23816	13484	.14	.10	.046	5.37
4	615	45599	-33946	16618	.15	.08	.041	5.67
5	767	65408	-47284	21435	.08	.15	.034	6.109
6	923	98146	-62768	24651	.11	.20	.027	6.50
7	1053	124768	-78723	28519	.09	.22	.024	6.79
8	1135	146682	-89735	31752	.10	.23	.023	6.96
9	1234	165227	-91793	34269	.06	.30	.021	7.16
10	1472	235108	-124810	41797	.06	.32	.018	7.6
11	1742	292682	-162601	58536	-.03	.35	.018	8.03
12	1891	335311	-177236	57482	-.05	.38	.015	8.25
13	2042	357486	-189914	62565	-.11	.41	.015	8.46
14	2158	393017	-187151	69869	-.12	.45	.014	8.62
15	2277	444502	-201415	72231	-.11	.46	.013	8.78
16	2434	531721	-214276	82535	-.08	.48	.013	8.98
17	2538	526357	-215720	82836	-.14	.50	.012	9.10
18	2623	525338	-221195	88478	-.18	.51	.012	9.20
19	2768	564498	-256590	106741	-.20	.50	.013	9.37
20	2912	567964	-238544	127224	-.25	.54	.014	9.53
21	3033	628246	-258780	138016	-.24	.54	.015	9.66
22	3186	639083	-299145	152292	-.28	.53	.014	9.82
23	3343	688650	-254501	155695	-.29	.58	.013	9.98
24	3503	772584	-295883	184105	-.28	.57	.014	10.13
25	3723	798404	-315648	222810	-.32	.58	.015	10.34
26	3907	920168	-265826	229019	-.30	.62	.014	10.51
27	4057	992180	-308678	229303	-.30	.61	.013	10.64

Table C-1 Experimental results for σ = 2/3 , L/Dh = 100

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	195	7413	-4353	235380	.85	-.28	.113	1.129
2	298	16989	-9923	370985	.84	-.26	.0762	1.30
3	443	37376	-21660	556015	.84	-.25	.0517	1.484
4	507	46952	-28723	617794	.78	-.26	.044	1.552
5	586	61779	-37430	710464	.75	-.24	.0378	1.6291
6	705	86491	-54857	871090	.70	-.25	.032	1.732
7	857	123558	-74018	1050251	.68	-.18	.0261	1.849
8	995	163715	-92669	1235589	.64	-.147	.0228	1.943
9	1110	197694	-114292	1349881	.60	-.12	.020	2.01
10	1200	225495	-126648	1482707	.576	-.091	.0188	2.068
11	1378	284185	-160626	1668046	.534	-.058	.016	2.166
12	1491	339787	-191516	1853384	.56	-.073	.0151	2.224
13	1728	438634	-237851	2094324	.522	-.031	.0128	2.336
14	1980	577638	-308897	2409399	.52	-.016	.0112	2.444
15	2220	704286	-370676	2727564	.494	.0093	.0101	2.54
16	2530	895802	-463346	3088974	.486	.0246	.0088	2.652
17	2784	1081140	-546748	3397871	.487	.041	.008	2.738
18	3020	1257212	-630150	3644989	.453	.053	.0073	2.814
19	3208	1390038	-710464	3830327	.4287	.0534	.0068	2.87
20	3480	1729825	-772243	4247339	.39	.0886	.0064	2.950
21	3763	1946053	-926692	4633461	.340	.08	.006	3.028
22	3988	2162281	-1050251	4787909	.344	.082	.0055	3.087
23	4232	2248773	-1130564	5096807	.340	.095	.0052	3.15
24	4552	2502069	-1183077	5004138	.313	.100	.0048	3.22
25	4863	2656517	-1328258	5220366	.285	.106	.0044	3.3
26	5036	2656517	-1368415	5220366	.28	.126	.0043	3.33

Table C-2 Experimental results for σ = 2/3 , L/Dh = 75

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	220	9387	-5408	218836	.86	-.26	.11	1.29
2	342	22364	-12909	331728	.84	-.25	.069	1.49
3	450	38720	-22627	407852	.84	-.26	.049	1.64
4	582	61982	-37385	522106	.78	-.25	.0375	1.79
5	734	94156	-57248	686492	.72	-.22	.031	1.93
6	890	134091	-79828	813957	.68	-.18	.025	2.061
7	1008	173398	-98222	918809	.69	-.15	.022	2.148
8	1193	233137	-127835	1105667	.64	-.10	.0189	2.27
9	1416	317451	-158115	1318646	.60	-.02	.016	2.40
10	1672	419631	-209347	1551272	.54	-.009	.0135	2.54
11	1980	566985	-293042	1901490	.50	.01	.0118	2.69
12	2210	692976	-362399	2208305	.48	.014	.011	2.79
13	3546	919709	-466762	2397955	.48	.03	.009	2.93
14	2838	1120699	-524791	2814009	.46	.08	.0085	3.03
15	3040	1260588	-602156	3038917	.44	.08	.008	3.10
16	3220	1357463	-661368	3196353	.40	.09	.0075	3.16
17	3414	1494022	-695554	3353566	.38	.12	.007	3.22
18	3567	1665799	-776727	3660884	.40	.11	.007	3.27
19	3755	1768744	-841441	3941037	.36	.12	.0068	3.33
20	4065	1982281	-918188	4279011	.32	.15	.0063	3.42
21	4342	2158318	-1021757	4649568	.28	.16	.006	3.50
22	4508	2326503	-1045688	4844819	.28	.18	.0058	3.54
23	4866	2613366	-1088602	5352894	.25	.22	.0054	3.63

Table C-3 Experimental results for σ = 2/3 , L/Dh = 50

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	235	10484	-6095	151330	.83	-.25	.10	1.51
2	368	25523	-14947	230079	.82	-.25	.062	1.75
3	476	42081	-24386	298020	.80	-.23	.048	1.92
4	592	63650	-38200	374540	.77	-.24	.039	2.06
5	753	101425	-59474	481662	.75	-.21	.031	2.23
6	846	122141	-70168	549147	.69	-.16	.028	2.32
7	968	157342	-84163	636785	.67	-.10	.0248	2.42
8	1140	211101	-106045	783470	.63	-.04	.022	2.56
9	1285	261431	-127498	904955	.60	-.008	.02	2.66
10	1364	294564	-136519	968663	.60	.02	.019	2.72
11	1547	362511	-169050	1114859	.55	.04	.017	2.83
12	1722	428852	-205397	1218843	.50	.05	.015	2.94
13	1884	503611	-245861	1361696	.48	.05	.014	3.03
14	2089	619171	-278361	1554572	.48	.09	.013	3.13
15	2267	701017	-348944	1689953	.44	.06	.012	3.22
16	2442	780742	-388555	1879228	.40	.08	.0115	3.30
17	2598	846688	-412041	2034517	.36	.11	.011	3.37
18	2863	983302	-511616	2246121	.32	.10	.01	3.48
19	2998	1065905	-548688	2413680	.31	.11	.0098	3.53
20	3186	1203779	-605753	2642443	.31	.12	.0095	3.61
21	3450	1362617	-726608	2935426	.28	.11	.009	3.70
22	3761	1561214	-824752	3410985	.25	.13	.0088	3.80
23	3942	1736390	-863463	3491705	.26	.15	.0082	3.87
24	4115	1776139	-871313	3990512	.21	.18	.0086	3.93
25	4280	1946529	-892391	4768718	.22	.20	.0095	3.98

Table C-4 Experimental results for σ = 2/3 , L/Dh = 25

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	224	9465	-5606	68747	.82	-.26	.10	1.87
2	410	31220	-17632	133584	.80	-.21	.058	2.29
3	556	55297	-31154	190599	.75	-.18	.045	2.54
4	668	77985	-43747	238439	.72	-.16	.039	2.70
5	805	108814	-58205	292299	.67	-.10	.033	2.87
6	986	161915	-77997	359648	.66	-.03	.027	3.07
7	1123	201397	-97722	406058	.61	-.01	.0235	3.21
8	1286	261838	-123844	453181	.60	-.009	.020	3.36
9	1406	299441	-142347	520035	.55	-.03	.0192	3.46
10	1559	368157	-167354	596081	.55	-.053	.0179	3.58
11	1674	415019	-186977	668399	.50	-.08	.017	3.68
12	1827	464452	-208343	686007	.46	.10	.015	3.77
13	2042	545918	-277402	782695	.40	.07	.0137	3.92
14	2261	669295	-333091	910552	.40	.08	.013	4.05
15	2504	786527	-382763	1030885	.36	.11	.012	4.196
16	2749	885846	-450976	1138945	.30	.12	.011	4.32
17	2968	960193	-489484	1206947	.24	.15	.01	4.44
18	3102	1048853	-521496	1318390	.24	.16	.01	4.5
19	3385	1217561	-620991	1444327	.22	.16	.0092	4.64
20	3544	1351838	-663490	1548782	.23	.17	.009	4.71
21	3712	1464162	-709007	1623584	.22	.18	.0086	4.78
22	3905	1662161	-784651	1713233	.24	.18	.0082	4.86
23	4086	1842692	-813326	2012982	.25	.20	.0088	4.94
24	4292	2058417	-846923	2145353	.26	.22	.0085	5.02
25	4556	2319431	-982756	2559590	.26	.21	.009	5.12

Table C-5 Experimental results for σ = 2/3 , L/Dh = 10

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	267	11384	-9626	37897	.61	-.43	.097	2.70
2	404	24276	-21368	61720	.53	-.40	.069	3.10
3	615	54700	-48481	99497	.50	-.38	.048	3.56
4	797	85774	-84033	132288	.43	-.41	.038	3.89
5	1041	134455	-155242	178172	.35	-.49	.03	4.25
6	1230	177345	-206365	207286	.30	-.44	.025	4.49
7	1381	213108	-239239	235174	.26	-.36	.0225	4.67
8	1519	245182	-273634	265555	.22	-.31	.021	4.82
9	1662	285949	-316226	302769	.20	-.28	.020	4.97
10	1877	345408	-306790	359138	.16	-.08	.0186	5.17
11	2017	370985	-304096	387955	.11	.01	.0174	5.29
12	2113	401022	-327615	415976	.10	.02	.0170	5.38
13	2220	415655	-341377	451068	.06	.05	.0167	5.47
14	2395	468051	-405179	484119	.04	.04	.0154	5.61
15	2525	511506	-441623	510147	.02	.05	.0146	5.71
16	2716	570593	-470534	553860	.009	.09	.0137	5.85
17	2818	593583	-484779	609299	-.01	.11	.014	5.92
18	3019	668792	-518938	674342	-.02	.14	.0135	6.06
19	3116	712459	-526214	691765	-.02	.16	.013	6.12
20	3241	756375	-583672	725352	-.03	.15	.0126	6.20
21	3448	872367	-644321	781873	-.02	.16	.012	6.33
22	3574	867285	-657270	840061	-.06	.18	.012	6.41
23	3739	968367	-700204	957726	-.05	.19	.0125	6.51
24	3920	1043337	-727529	1010587	-.06	.21	.012	6.61
25	4102	1096359	-750545	1014388	-.08	.23	.011	6.71
26	4283	1220381	-793108	1105883	-.07	.24	.011	6.81
27	4399	1234354	-810137	1166597	-.09	.25	.011	6.87

Table C-6 Experimental results for σ = 2/3 , L/Dh = 5

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	258	10082	-9991	17510	.55	-.54	.096	3.364
2	393	22125	-24030	27933	.49	-.58	.066	3.87
3	491	33544	-36848	37655	.46	-.56	.057	4.17
4	702	63169	-76673	56717	.38	-.58	.042	4.69
5	833	85141	-110811	72254	.34	-.61	.038	4.97
6	1035	118232	-175473	90998	.25	-.64	.031	5.34
7	1229	158431	-235002	120030	.21	-.58	.029	5.66
8	1357	188104	-273887	141288	.19	-.53	.028	5.85
9	1549	215512	-333862	157799	.10	-.46	.024	6.11
10	1711	238881	-351191	168465	.04	-.32	.021	6.32
11	1929	288336	-410696	193735	.01	-.25	.019	6.57
12	2024	314630	-373564	218900	.005	-.11	.0195	6.68
13	2138	314676	-379253	239243	-.01	-.05	.0191	6.80
14	2288	389149	-427164	262514	-.013	-.04	.0183	6.96
15	2399	422304	-430189	275987	-.02	.01	.0175	7.07
16	2602	494942	-478245	298697	-.222	.04	.0161	7.27
17	2779	577266	-450291	317438	-.01	.13	.015	7.43
18	2963	620153	-499865	336807	-.04	.14	.014	7.59
19	3093	584012	-518475	356524	-.11	.16	.0136	7.70
20	3123	541944	-528581	358128	-.15	.19	.0134	7.72
21	3257	574914	-502243	374986	-.16	.21	.0129	7.83
22	3440	608907	-527840	405338	-.18	.23	.0125	7.97
23	3858	702658	-602731	448649	-.21	.26	.011	8.29
24	4186	805607	-637550	528179	-.22	.29	.011	8.51

Table C-7 Experimenta result for σ = 2/3 , L/Dh = 2

No.	Re	ΔP_c	ΔP_e	ΔP_f	K_c	K_e	f	B_F
1	518	28144	-52041	17058	.21	-.86	.058	5.76
2	637	32554	-78142	22238	.03	-.85	.050	6.17
3	812	48381	-128782	30353	-.02	-.87	.042	6.69
4	974	48814	-189194	38474	-.18	-.90	.037	7.11
5	1133	62535	-257764	46432	-.20	-.91	.033	7.47
6	1260	75165	-312263	52205	-.21	-.88	.030	7.74
7	1423	93096	-376086	62146	-.22	-.80	.028	8.06
8	1690	123483	-499152	78264	-.24	-.72	.025	8.54
9	1854	129774	-558344	90423	-.28	-.63	.024	8.81
10	1975	136577	-569469	98336	-.30	-.51	.023	8.99
11	2086	128513	-593546	109700	-.34	-.44	.023	9.16
12	2220	138801	-618231	124246	-.35	-.36	.023	9.35
13	2380	182813	-663991	124175	-.32	-.30	.02	9.57
14	2502	202035	-656616	130370	-.32	-.21	.019	9.73
15	2637	233954	-662693	144818	-.31	-.14	.019	9.91
16	2813	244542	-710737	164794	-.33	-.10	.019	10.12
17	2956	258064	-736947	180059	-.34	-.06	.0188	10.29
18	3146	346547	-766925	201781	-.33	-.01	.0186	10.51
19	3329	312117	-813191	224724	-.35	.02	.0185	10.71
20	3516	331229	-873240	247970	-.36	.04	.0183	10.90
21	3556	408110	-823920	252258	-.32	.08	.0182	10.95
22	3646	392602	-866154	262274	-.34	.08	.018	11.04
23	3711	633150	-840706	271709	-.22	.11	.018	11.10
24	3840	839560	-839560	294160	-.14	.14	.0182	11.23
25	3936	1497621	-839611	310750	.15	.16	.0183	11.32
26	4100	1648054	-888004	337185	.16	.17	.0183	11.47
27	4636	2401601	-1194256	445245	.26	.15	.0189	11.96

Sample of Calculation

For = 1/2, L/D_h = 50 at Re = 1010.

Available data,

constricted perimeter, p	= 58.8	cm.
constricted cross-sectional area, A	= 28.4	cm^2
water temperature, T	= 33.3	C
h_c	= 0.112	$mm.H_2O$
h_e	= -.052	$mm.H_2O$
h_f	= 0.44	$mm.H_2O$

Due to water at 33.3 °C has = 7.51238×10^{-7} m^2/S and

= 994.57 Kg/m^3

Since, D_h = $4A/p$ = 1.932 cm. or 1.932×10^{-2} m.

Thus V = $Re. /D_h$

$$= \frac{1010 \times 7.51238 \times 10^{-7}}{1.932 \times 10^{-2}}$$

= 0.0392728 m/S.

From eqs.(4.1), (4.2) and (4.3) obtained,

$$K_c = \frac{0.112 \times 10^{-3} \times 2 \times 9.806}{(0.0392728)^2} - 1 + (0.5)^2 = 0.674$$

$$K_e = \frac{-0.052 \times 10^{-3} \times 2 \times 9.806}{(0.0392728)^2} + 1 - (0.5)^2 = 0.088$$

$$f = \frac{0.44 \times 10^{-3} \times 2 \times 9.806}{4 \times 50 \times (0.0392728)^2} = 0.028$$

And $B_F = (1010/50)^{1/3} . (0.5)^{1/4} = 2.29$

From Fig. 4.10, K_c = 0.68 and K_e = 0.079 while f = 24/Re = 0.024

By eq.(4.5) obtained

C_c = 0.674/0.68 = 0.99

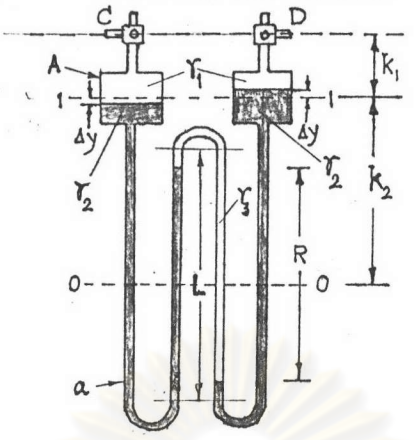
C_e = 0.088/0.079 = 1.11

C_f = 0.028/0.024 = 1.15

Appendix B

Micromanometer

MICROMANOMETER



Specification:
$a/A = d^2/D^2 = (.35/4.5)^2 = .006$
γ_1 = γ_3 = water
γ_2 = aniline(S.g.=1.022)
L = max. length = 80 cm.

With two gage liquids, immiscible in each other and in the fluid to be measured, a large gage difference R may be produced for a small pressure difference. The lighter gage liquid fills the ∩-tube to O-O; then the heavier gage liquid is added to both sides, filling the larger reservoirs up to 1-1. The liquid in the system fills the space above 1-1. When the pressure at C is slightly greater than at D, the menisci move as indicated in the figure. The volume of liquid displaced in each reservoir equals the displacement in the U-tube, thus

$$\Delta y A = aR/2$$

in which A and a are the cross-sectional areas of reservoir and U-tube, respectively. The manometer equation may be written, starting at C, in Kg/ m^2.,

$$P_C + (k_1+\Delta y)\gamma_1 + (k_2-\Delta y-\frac{R}{2})\gamma_2 + R\gamma_3 - (k_2+\Delta y+\frac{R}{2})\gamma_2 - (k_1- y)\gamma_1 = P_D$$

in which γ_1, γ_2, and γ_3 are the specific weights as indicated in above figure. After simplifying and substituting for Δy,

$$P_C - P_D = R[\gamma_3+\frac{a}{A}\gamma_1-\gamma_2(1+\frac{a}{A})] \qquad \text{.....(B-1)}$$

The quantity in brackets is a constant for specified gage and fluids; hence, the pressure difference is directly proportional to R.

In the micromanometer of the experiment the pressure difference $P_C - P_D$ is wanted in Kg./cm^2. when water is in the system. S_2=1.022, S_3(water)=1.0, a/A=0.006, R=5.0 cm.

Therefore $\gamma_1 = \gamma_3$, eq.(B-1) becomes,

$$P_C - P_D = R(\gamma_1 - \gamma_2)(1 + a/A)$$

Substituting,

$$P_C - P_D = 5.0(-0.022)(1.006) \times 10^{-3}$$

$$= -1.1066 \times 10^{-4} \text{ Kg/cm}^2$$

or $$h_C - h_D = -0.11066 \text{ cm. of water}$$

Thus, the magnification is about 45 (5.0/0.11066 = 45.2) and the smallest scale reading which is 1.0 mm. indicates the pressure difference of 0.022 mm. of water.

VITAE

Mr. Pongjet Promvonge was born on Dec. 3, 1956 in Roi-et province, Thailand. He finished the degree of B.Eng. in Mechanical Engineering from Khon Kaen University in 1978. After that he had worked at National Energy Administration for one year before deciding to further study at Chulalongkorn University.