Saturated Water Substance-Temperature (SI units)

Temp., K	Pressure, bar	Volume m^3/kg		Enthalpy, kJ/kg		Entropy, kJ/kg.K		C_p, kJ/kg.K		Viscosity, Ns/m^2		K, W/m.K		Prandtl		Surface tension, N/m Condensed	Temp., K
		Condensed	Vapor	Condensed	Vapor	Condensed	Vapor	Condensed	Vapor	Condensed	Vapor	Condensed	Vapor	Condensed	Vapor		
150	6.30.-11	1.073.-3	9.55.+9	-539.6	2273	-2.187	16.54	1.155				3.73					150
160	7.72.-10	1.074.-3	9.62.+8	-525.7	2291	-2.106	15.49	1.233				3.52					160
170	7.29.-9	1.076.-3	1.08.+8	-511.7	2310	-2.026	14.57	1.311				3.34					170
180	5.38.-8	1.077.-3	1.55.+7	-497.8	2328	-1.947	13.76	1.389				3.18					180
190	3.23.-7	1.078.-3	2.72.+6	-483.8	2347	-1.868	13.03	1.467				3.04					190
200	1.62.-6	1.079.-3	5.69.+5	-467.5	2366	-1.789	12.38	1.545				2.91					200
210	7.01.-6	1.081.-3	1.39.+5	-451.2	2384	-1.711	11.79	1.623				2.79					210
220	2.65.-5	1.082.-3	3.83.+4	-435.0	2403	-1.633	11.20	1.701				2.69					220
230	8.91.-5	1.084.-3	1.18.+4	-416.3	2421	-1.555	10.79	1.779				2.59					230
240	3.72.-4	1.085.-3	4.07.+3	-400.1	2440	-1.478	10.35	1.857				2.50					240
250	7.59.-4	1.087.-3	1.52.+3	-381.5	2459	-1.400	9.954	1.935				2.42					250
255	1.23.-3	1.087.-3	956.4	-369.8	2468	-1.361	9.768	1.974				2.38					255
260	1.96.-3	1.088.-3	612.2	-360.5	2477	-1.323	9.590	2.013				2.35					260
265	3.06.-3	1.089.-3	400.4	-351.2	2486	-1.281	9.461	2.052				2.31					265
270	4.69.-3	1.090.-3	265.4	-339.6	2496	-1.296	9.255	2.091				2.27					270
273.15	6.11.-3	1.091.-3	206.3	-333.5	2502	-1.221	9.158	2.116				2.26					273.15
273.15	0.00611	1.000.-3	206.3	0.0	2502	0.000	9.158	4.217	1.854	1750.-6	8.02.-6	0.569	0.0182	12.99	0.815	0.0755	273.15
275	0.00697	1.000.-3	181.7	7.8	2505	0.028	9.109	4.211	1.855	1652.-6	8.09.-6	0.574	0.0183	12.22	0.817	0.0753	275
280	0.00990	1.000.-3	130.4	28.8	2514	0.104	8.980	4.198	1.858	1422.-6	8.29.-6	0.582	0.0186	10.26	0.825	0.0748	280
285	0.01387	1.000.-3	99.4	49.8	2523	0.178	8.857	4.189	1.861	1225.-6	8.49.-6	0.590	0.0189	8.81	0.833	0.0743	285
290	0.01917	1.001.-3	69.7	70.7	2532	0.251	8.740	4.184	1.864	1080.-6	8.69.-6	0.598	0.0193	7.56	0.841	0.0737	290
295	0.02617	1.002.-3	51.94	91.6	2541	0.323	8.627	4.181	1.868	959.-6	8.89.-6	0.606	0.0195	6.62	0.849	0.0727	295
300	0.03531	1.003.-3	39.13	112.5	2550	0.393	8.520	4.179	1.872	855.-6	9.09.-6	0.613	0.0196	5.83	0.857	0.0717	300
305	0.04712	1.005.-3	27.90	133.4	2559	0.462	8.417	4.178	1.877	769.-6	9.29.-6	0.620	0.0201	5.20	0.865	0.0709	305
310	0.06221	1.007.-3	22.93	154.3	2568	0.530	8.318	4.178	1.882	695.-6	9.49.-6	0.628	0.0204	4.62	0.873	0.0700	310
315	0.08132	1.009.-3	17.82	175.2	2577	0.597	8.224	4.179	1.888	631.-6	9.69.-6	0.634	0.0207	4.16	0.883	0.0692	315
320	0.1053	1.011.-3	13.98	196.1	2586	0.649	8.151	4.180	1.895	577.-6	9.89.-6	0.640	0.0210	3.77	0.894	0.0683	320
325	0.1351	1.013.-3	11.06	217.0	2595	0.727	8.046	4.182	1.903	528.-6	10.09.-6	0.645	0.0213	3.42	0.901	0.0675	325
330	0.1719	1.016.-3	8.82	237.9	2604	0.791	7.962	4.184	1.911	489.-6	10.29.-6	0.650	0.0217	3.15	0.908	0.0666	330
335	0.2167	1.018.-3	7.09	258.8	2613	0.854	7.881	4.186	1.920	453.-6	10.49.-6	0.655	0.0220	2.88	0.916	0.0658	335
340	0.2713	1.021.-3	5.74	279.8	2622	0.916	7.804	4.188	1.930	420.-6	10.69.-6	0.660	0.0223	2.66	0.925	0.0649	340
345	0.3372	1.024.-3	4.683	300.7	2630	0.977	7.729	4.191	1.941	389.-6	10.89.-6	0.665	0.0226	2.45	0.933	0.0641	345
350	0.4163	1.027.-3	3.846	321.7	2639	1.038	7.657	4.195	1.954	365.-6	11.09.-6	0.668	0.0230	2.29	0.942	0.0632	350
355	0.5100	1.030.-3	3.180	342.7	2647	1.097	7.588	4.199	1.968	343.-6	11.29.-6	0.671	0.0233	2.14	0.951	0.0623	355
360	0.6209	1.034.-3	2.645	363.7	2655	1.156	7.521	4.203	1.983	324.-6	11.49.-6	0.674	0.0237	2.02	0.960	0.0614	360
365	0.7514	1.038.-3	2.212	384.7	2663	1.214	7.456	4.209	1.999	306.-6	11.69.-6	0.677	0.0241	1.91	0.969	0.0605	365
370	0.9040	1.041.-3	1.861	405.8	2671	1.271	7.394	4.214	2.017	289.-6	11.89.-6	0.679	0.0245	1.80	0.978	0.0595	370
373.15	1.0133	1.044.-3	1.679	419.1	2676	1.307	7.356	4.217	2.029	279.-6	12.02.-6	0.680	0.0248	1.76	0.984	0.0589	373.15
375	1.0815	1.045.-3	1.574	426.8	2679	1.328	7.333	4.220	2.036	274.-6	12.09.-6	0.681	0.0249	1.70	0.987	0.0586	375
380	1.2869	1.049.-3	1.337	448.0	2687	1.384	7.275	4.226	2.057	260.-6	12.29.-6	0.683	0.0254	1.61	0.995	0.0576	380
385	1.5233	1.053.-3	1.142	469.2	2694	1.439	7.218	4.232	2.080	248.-6	12.49.-6	0.685	0.0258	1.53	1.004	0.0566	385
390	1.794	1.058.-3	0.980	490.4	2702	1.494	7.163	4.239	2.104	237.-6	12.69.-6	0.686	0.0263	1.47	1.013	0.0556	390
400	2.455	1.067.-3	0.731	532.9	2716	1.605	7.058	4.256	2.158	217.-6	13.05.-6	0.688	0.0272	1.34	1.033	0.0536	400
410	3.302	1.077.-3	0.553	575.6	2729	1.708	6.959	4.278	2.221	200.-6	13.42.-6	0.688	0.0282	1.24	1.054	0.0515	410
420	4.370	1.088.-3	0.425	618.6	2742	1.810	6.865	4.302	2.291	185.-6	13.79.-6	0.688	0.0293	1.16	1.075	0.0494	420
430	5.699	1.099.-3	0.331	661.8	2753	1.911	6.775	4.331	2.369	173.-6	14.14.-6	0.685	0.0304	1.09	1.10	0.0472	430

Saturated Water Substance-Temperature (SI units)

Temp., K	Pressure, bar	Volume m^3/kg		Enthalpy, kJ/kg		Entropy, kJ/kg.K		C_p, kJ/kg.K		Viscosity, Ns/m^2		K, W/m.K		Prandtl		Surface tension, N/m Condensed	Temp., K
		Condensed	Vapor	Condensed	Vapor	Condensed	Vapor	Condensed	Vapor	Condensed	Vapor	Condensed	Vapor	Condensed	Vapor		
440	7.333	1.110.-3	0.261	705.3	2764	2.011	6.689	4.36	2.46	162.-6	14.50.-6	0.682	0.0317	1.04	1.12	0.0451	440
450	9.319	1.123.-3	0.208	749.2	2773	2.109	6.607	4.40	2.56	152.-6	14.85.-6	0.678	0.0331	0.99	1.14	0.0429	450
460	11.71	1.137.-3	0.167	793.5	2782	2.205	6.528	4.44	2.68	143.-6	15.19.-6	0.673	0.0346	0.95	1.17	0.0407	460
470	14.55	1.152.-3	0.136	838.2	2789	2.301	6.451	4.48	2.79	136.-6	15.54.-6	0.667	0.0363	0.92	1.20	0.0385	470
480	17.90	1.167.-3	0.111	883.4	2795	2.395	6.377	4.53	2.94	129.-6	15.88.-6	0.660	0.0381	0.89	1.23	0.0362	480
490	21.83	1.184.-3	0.0922	929.1	2799	2.479	6.312	4.59	3.10	124.-6	16.23.-6	0.651	0.0401	0.87	1.25	0.0339	490
500	26.40	1.203.-3	0.0766	975.6	2801	2.581	6.233	4.66	3.27	118.-6	16.59.-6	0.642	0.0423	0.86	1.28	0.0316	500
510	31.66	1.222.-3	0.0631	1023	2802	2.673	6.163	4.74	3.47	113.-6	16.95.-6	0.631	0.0447	0.85	1.31	0.0293	510
520	37.70	1.244.-3	0.0525	1071	2801	2.765	6.093	4.84	3.70	108.-6	17.33.-6	0.621	0.0475	0.84	1.35	0.0269	520
530	44.58	1.268.-3	0.0445	1119	2798	2.856	6.023	4.95	3.96	104.-6	17.72.-6	0.608	0.0506	0.85	1.39	0.0245	530
540	52.38	1.294.-3	0.0375	1170	2792	2.948	5.953	5.08	4.27	101.-6	18.1.-6	0.594	0.0540	0.86	1.43	0.0221	540
550	61.19	1.323.-3	0.0317	1220	2784	3.039	5.882	5.24	4.64	97.-6	18.6.-6	0.580	0.0583	0.87	1.47	0.0197	550
560	71.08	1.355.-3	0.0269	1273	2772	3.132	5.808	5.43	5.09	94.-6	19.1.-6	0.563	0.0637	0.90	1.52	0.0173	560
570	82.16	1.392.-3	0.0228	1328	2757	3.225	5.733	5.68	5.67	91.-6	19.7.-6	0.548	0.0698	0.94	1.59	0.0150	570
580	94.51	1.433.-3	0.0193	1384	2737	3.321	5.654	6.00	6.40	88.-6	20.4.-6	0.528	0.0767	0.99	1.68	0.0128	580
590	108.3	1.482.-3	0.0163	1443	2717	3.419	5.569	6.41	7.35	84.-6	21.5.-6	0.513	0.0841	1.05	1.84	0.0105	590
600	123.5	1.541.-3	0.0137	1506	2682	3.520	5.480	7.00	8.75	81.-6	22.7.-6	0.497	0.0929	1.14	2.15	0.0084	600
610	137.3	1.612.-3	0.0115	1573	2641	3.627	5.318	7.85	11.1	77.-6	24.1.-6	0.467	0.103	1.30	2.60	0.0063	610
620	159.1	1.705.-3	0.0094	1647	2588	3.741	5.259	9.35	15.4	72.-6	25.9.-6	0.444	0.114	1.52	3.46	0.0045	620
625	169.1	1.778.-3	0.0085	1697	2555	3.805	5.191	10.6	18.3	70.-6	27.0.-6	0.430	0.121	1.65	4.20	0.0035	625
630	179.7	1.856.-3	0.0075	1734	2515	3.875	5.115	12.6	22.1	67.-6	28.0.-6	0.412	0.130	2.0	4.8	0.0026	630
635	190.9	1.935.-3	0.0066	1783	2466	3.950	5.025	16.4	27.6	64.-6	30.0.-6	0.392	0.141	2.7	6.0	0.0015	635
640	202.7	2.075.-3	0.0057	1841	2401	4.037	4.912	26	42	59.-6	32.0.-6	0.367	0.155	4.2	9.6	0.0008	640
645	215.2	2.351.-3	0.0045	1931	2292	4.223	4.732	90		54.-6	37.0.-6	0.331	0.178	12	26	0.0001	645
647.3	221.2	3.170.-3	0.0032	2107	2107	4.443	4.443	∝	∝	45.-6	45.0.-6	0.238	0.238	∝	∝	0.0000	647.3

PROPIEDADES TERMODINÁMICAS I

Compound	Formula	Mol. Wt.	SG (20°/4°)	T_m(°C)[b]	$\Delta\hat{H}_m(T_m)$[c,j] kJ/mol	T_b(°C)[d]	$\Delta\hat{H}_v(T_b)$[e,j] kJ/mol	T_c(K)[f]	P_c(atm)[g]	$(\Delta\hat{H}_f°)$[h,j] kJ/mol	$(\Delta\hat{H}_c°)$[i,j] kJ/mol
Acetaldehyde	CH_3CHO	44.05	$0.783^{18°}$	−123.7	—	20.2	25.1	461.0	—	−166.2(g)	−1192.4(g)
Acetic acid	CH_3COOH	60.05	1.049	16.6	12.09	118.2	24.39	594.8	57.1	−486.18(l)	−871.69(l)
										−438.15(g)	−919.73(g)
Acetone	C_3H_6O	58.08	0.791	−95.0	5.69	56.0	30.2	508.0	47.0	−248.2(l)	−1785.7(l)
										−216.7(g)	−1821.4(g)
Acetylene	C_2H_2	26.04	—	—	—	−81.5	17.6	309.5	61.6	+226.75(g)	−1299.6(g)
Ammonia	NH_3	17.03	—	−77.8	5.653	−33.43	23.351	405.5	111.3	−67.20(l)	
										−46.19(g)	−382.58(g)
Ammonium hydroxide	NH_4OH	35.03	—	—	—	—	—	—	—	−366.48(aq)	—
Ammonium nitrate	NH_4NO_3	80.05	$1.725^{25°}$	169.6	5.4		Decomposes at 210°C			−365.14(c)	—
										−399.36(aq)	
Ammonium sulfate	$(NH_4)_2SO_4$	132.14	1.769	513	—		Decomposes at 513°C after melting			−1179.3(c)	
										−1173.1(aq)	
Aniline	C_6H_7N	93.12	1.022	−6.3	—	184.2	—	699	52.4	—	—
Benzaldehyde	C_6H_5CHO	106.12	1.046	−26.0	—	179.0	38.40	—	—	−88.83(l)	−3520.0(l)
										−40.04(g)	—
Benzene	C_6H_6	78.11	0.879	5.53	9.837	80.10	30.765	562.6	48.6	+48.66(l)	−3267.6(l)
										+82.93(g)	−3301.5(g)
Benzoic acid	$C_7H_6O_2$	122.12	$1.266^{15°}$	122.2	—	249.8	—	—	—	—	−3226.7(g)
Benzyl alcohol	C_7H_8O	108.13	1.045	−15.4	—	205.2	—	—	—	—	−3741.8(l)
Bromine	Br_2	159.83	3.119	−7.4	10.8	58.6	31.0	584	102	0(l)	—
1,2-Butadiene	C_4H_6	54.09	—	−136.5	—	10.1	—	446	—	—	—
1,3-Butadiene	C_4H_6	54.09	—	−109.1	—	−4.6	—	425	42.7	—	—
n-Butane	C_4H_{10}	58.12	—	−138.3	4.661	−0.6	22.305	425.17	37.47	−147.0(l)	−2855.6(l)
										−124.7(g)	−2878.5(g)
Isobutane	C_4H_{10}	58.12	—	−159.6	4.540	−11.73	21.292	408.1	36.0	−158.4(l)	−2849.0(l)
										−134.5(g)	−2868.8(g)
1-Butene	C_4H_8	56.10	—	−185.3	3.8480	−6.25	21.916	419.6	39.7	+1.17(g)	−2718.6(g)
Calcium carbide	CaC_2	64.10	$2.22^{18°}$	2300	—	—	—	—	—	−62.76(c)	—
Calcium carbonate	$CaCO_3$	100.09	2.93			Decomposes at 825°C				−1206.9(c)	—
Calcium chloride	$CaCl_2$	110.99	$2.152^{15°}$	782	28.37	>1600	—	—	—	−794.96(c)	—
Calcium hydroxide	$Ca(OH)_2$	74.10	2.24			($-H_2O$ at 580°C)				−986.59(c)	—
Calcium oxide	CaO	56.08	3.32	2570	50	2850	—	—	—	−635.6(c)	—
Calcium phosphate	$Ca_3(PO_4)_2$	310.19	3.14	1670	—	—	—	—	—	−4138(c)	—
Calcium silicate	$CaSiO_3$	116.17	2.915	1530	48.62	—	—	—	—	−1584(c)	—
Calcium sulfate	$CaSO_4$	136.15	2.96	—	—	—	—	—	—	−1432.7(c)	—
										−1450.4(aq)	
Calcium sulfate (gypsum)	$CaSO_4 \cdot 2H_2O$	172.18	2.32		($-1.5\ H_2O$ at 128°C)		—	—	—	−2021(c)	—
Carbon (graphite)	C	12.010	2.26	3600	46.0	4200	—	—	—	0(c)	−393.51(c)
Carbon dioxide	CO_2	44.01	—	−56.6 at 5.2 atm	8.33	(Sublimes at −78°C)		304.2	72.9	−412.9(l)	—
										−393.5(g)	—
Carbon disulfide	CS_2	76.14	$1.261^{22°/20°}$	−112.1	4.39	46.25	26.8	552.0	78.0	+87.9(l)	−1075.2(l)
										+115.3(g)	1102.6(g)
Carbon monoxide	CO	28.01	—	−205.1	0.837	−191.5	6.042	133.0	34.5	−110.52(g)	−282.99(g)
Carbon tetrachloride	CCl_4	153.84	1.595	−22.9	2.51	76.7	30.0	556.4	45.0	−139.5(l)	−352.2(l)
										−106.7(g)	−385.0(g)
Chlorine	Cl_2	70.91	—	−101.00	6.406	−34.06	20.4	417.0	76.1	0(g)	—
Chlorobenzene	C_6H_5Cl	112.56	1.107	−45	—	132.10	36.5	632.4	44.6	—	—
Chloroethane	C_2H_5Cl	See ethyl chloride									

[a] Adapted in part from D. M. Himmelblau, *Basic Principles and Calculations in Chemical Engineering*, 3rd Edition, ©1974, Tables D.1 and F.1. Adapted by permission of Prentice-Hall, Inc., Englewood Cliffs, NJ.

[b] Melting point at 1 atm.

[c] Heat of fusion at T_m and 1 atm.

[d] Boiling point at 1 atm.

[e] Heat of vaporization at T_b and 1 atm.

[f] Critical temperature.

[g] Critical pressure.

[h] Heat of formation at 25°C and 1 atm.

[i] Heat of combustion at 25°C and 1 atm. Standard states of products are CO_2(g), H_2O(l), SO_2(g), HCl(aq), and N_2(g). To calculate $\Delta\hat{H}_c°$ with H_2O(g) as a product, add $44.01n_w$ to the tabulated value, where n_w = moles H_2O formed/mole fuel burned.

[j] To convert $\Delta\hat{H}$ to kcal/mol, divide given value by 4.184; to convert to Btu/lb-mole, multiply by 430.28.

PROPIEDADES TERMODINÁMICAS II

Compound	Formula	Mol. Wt.	SG (20°/4°)	T_m(°C)[b]	$\Delta\hat{H}_m(T_m)$[c,j] kJ/mol	T_b(°C)[d]	$\Delta\hat{H}_v(T_b)$[e,j] kJ/mol	T_c(K)[f]	P_c(atm)[g]	$(\Delta\hat{H}_f°)$[h,j] kJ/mol	$(\Delta\hat{H}_c°)$[i,j] kJ/mol
Chloroform	$CHCl_3$	119.39	1.489	−63.7	—	61.0		536.0	54.0	−131.8(l)	−373(l)
Copper	Cu	63.54	8.92	1083	13.01	2595	304.6	—		0(c)	—
Cupric sulfate	$CuSO_4$	159.61	$3.606^{15°}$			Decomposes > 600°C				−769.9(c) −843.1(aq)	—
Cyclohexane	C_6H_{12}	84.16	0.779	6.7	2.677	80.7	30.1	553.7	40.4	−156.2(l) −123.1(g)	−3919.9(l) −3953.0(g)
Cyclopentane	C_5H_{10}	70.13	0.745	−93.4	0.609	49.3	27.30	511.8	44.55	−105.9(l) −77.2(g)	−3290.9(l) −3319.5(g)
n-Decane	$C_{10}H_{22}$	142.28	0.730	−29.9	—	173.8	—	619.0	20.8	−249.7(l) —	−6778.3(l) −6829.7(g)
Diethyl ether	$(C_2H_5)_2O$	74.12	$0.708^{25°}$	−116.3	7.30	34.6	26.05	467	35.6	−272.8(l)	−2726.7(l)
Ethane	C_2H_6	30.07	—	−183.3	2.859	−88.6	14.72	305.4	48.2	−84.67(g)	−1559.9(g)
Ethyl acetate	$C_4H_8O_2$	88.10	0.901	−83.8	—	77.0	—	523.1	37.8	−463.2(l) −426.8(g)	−2246.4(l) —
Ethyl alcohol (Ethanol)	C_2H_5OH	46.07	0.789	−114.6	5.021	78.5	38.58	516.3	63.0	−277.63(l) −235.31(g)	−1366.91(l) −1409.25(g)
Ethyl benzene	C_8H_{10}	106.16	0.867	−94.67	9.163	136.2	35.98	619.7	37.0	−12.46(l) +29.79(g)	−4564.9(l) −4607.1(g)
Ethyl bromide	C_2H_5Br	108.98	1.460	−119.1	—	38.2	—	504	61.5	−54.4(g)	—
Ethyl chloride	C_2H_5Cl	64.52	$0.903^{15°}$	−138.3	4.452	13.1	24.7	460.4	52.0	−105.0(g)	—
3-Ethyl hexane	C_8H_{18}	114.22	0.717	—	—	118.5	34.27	567.0	26.4	−250.5(l) −210.9(g)	−5407.1(l) −5509.8(g)
Ethylene	C_2H_4	28.05	—	−169.2	3.350	−103.7	13.54	283.1	50.5	+52.28(g)	−1410.99(g)
Ethylene glycol	$C_2H_6O_2$	62.07	$1.113^{19°}$	−13	11.23	197.2	56.9	—	—	−451.5(l) −387.1(g)	−1179.5(l) —
Ferric oxide	Fe_2O_3	159.70	5.12			Decomposes at 1560°C				−822.2(c)	
Ferrous oxide	FeO	71.85	5.7	—	—	—	—	—	—	−266.5(c)	—
Ferrous sulfide	FeS	87.92	4.84	1193	—	—	—	—	—	−95.1(c)	—
Formaldehyde	H_2CO	30.03	$0.815^{-20°}$	−92	—	−19.3	24.48	—	—	−115.90(g)	−563.46(g)
Formic acid	CH_2O_2	46.03	1.220	8.30	12.68	100.5	22.25	—	—	−409.2(l) −362.6(g)	−262.8(l) —
Glycerol	$C_3H_8O_3$	92.09	$1.260^{50°}$	18.20	18.30	290.0	—	—	—	−665.9(l)	−1661.1(l)
Helium	He	4.00	—	−269.7	0.02	−268.9	0.084	5.26	2.26	0(g)	—
n-Heptane	C_7H_{16}	100.20	0.684	−90.59	14.03	98.43	31.69	540.2	27.0	−224.4(l) −187.8(g)	−4816.9(l) −4853.5(g)
n-Hexane	C_6H_{14}	86.17	0.659	−95.32	13.03	68.74	28.85	507.9	29.9	−198.8(l) −167.2(g)	−4163.1(l) −4194.8(g)
Hydrogen	H_2	2.016	—	−259.19	0.12	−252.76	0.904	33.3	12.8	0(g)	−285.84(g)
Hydrogen bromide	HBr	80.92	—	−86	—	−67	—	—	—	−36.23(g)	—
Hydrogen chloride	HCl	36.47	—	−114.2	1.99	−85.0	16.1	324.6	81.5	−92.31(g)	—
Hydrogen cyanide	HCN	27.03	—	−14	—	26	—	—	—	+130.54(g)	—
Hydrogen fluoride	HF	20.0	—	−83	—	20	—	503.2	—	−268.6(g) −316.9(aq, 200)	— —
Hydrogen sulfide	H_2S	34.08	—	−85.5	2.38	−60.3	18.67	373.6	88.9	−19.96(g)	−562.59(g)
Iodine	I_2	253.8	4.93	113.3	—	184.2	—	826.0	—	0(c)	—
Iron	Fe	55.85	7.7	1535	15.1	2800	354.0	—	—	0(c)	—
Lead	Pb	207.21	$11.337^{20°/20°}$	327.4	5.10	1750	179.9	—		0(c)	—
Lead oxide	PbO	223.21	9.5	886	11.7	1472	213	—	—	−219.2(c)	—
Magnesium	Mg	24.32	1.74	650	9.2	1120	131.8	—	—	0(c)	—
Magnesium chloride	$MgCl_2$	95.23	$2.325^{25°}$	714	43.1	1418	136.8	—	—	−641.8(c)	—
Magnesium hydroxide	$Mg(OH)_2$	58.34	2.4		Decomposes at 350°C			—			—
Magnesium oxide	MgO	40.32	3.65	2900	77.4	3600	—	—	—	−601.8(c)	—
Mercury	Hg	200.61	13.546	−38.87	—	−356.9	—	—	—	0(c)	—
Methane	CH_4	16.04	—	−182.5	0.94	−161.5	8.179	190.70	45.8	−74.85(g)	−890.36(g)
Methyl acetate	$C_3H_6O_2$	74.08	0.933	−98.9	—	57.1	—	506.7	46.30	−409.4(l)	−1595(l)
Methyl alcohol (Methanol)	CH_3OH	32.04	0.792	−97.9	3.167	64.7	35.27	513.20	78.50	−238.6(l) −201.2(g)	726.6(l) −764.0(g)
Methyl amine	CH_5N	31.06	$0.699^{-11°}$	−92.7	—	−6.9	—	429.9	73.60	−28.0(g)	−1071.5(l)
Methyl chloride	CH_3Cl	50.49	—	−97.9	—	−24	—	416.1	65.80	−81.92(g)	—

PROPIEDADES TERMODINÁMICAS III

Compound	Formula	Mol. Wt.	SG (20°/4°)	T_m(°C)[b]	$\Delta\hat{H}_m(T_m)$[c,j] kJ/mol	T_b(°C)[d]	$\Delta\hat{H}_v(T_b)$[e,j] kJ/mol	T_c(K)[f]	P_c(atm)[g]	$(\Delta\hat{H}_f°)$[h,j] kJ/mol	$(\Delta\hat{H}_c°)$[i,j] kJ/mol
Methyl ethyl ketone	C_4H_8O	72.10	0.805	−87.1	—	78.2	32.0	—	—	—	−2436(l)
Naphthalene	$C_{10}H_8$	128.16	1.145	80.0	—	217.8	—	—	—	—	−5157(g)
Nickel	Ni	58.69	8.90	1452	—	2900	—	—	—	0(c)	—
Nitric acid	HNO_3	63.02	1.502	−41.6	10.47	86	30.30	—	—	−173.23(l) −206.57(aq)	—
Nitrobenzene	$C_6H_5O_2N$	123.11	1.203	5.5	—	210.7	—	—	—	—	−3092.8(l)
Nitrogen	N_2	28.02	—	−210.0	0.720	−195.8	5.577	126.20	33.5	0(g)	—
Nitrogen dioxide	NO_2	46.01	—	−9.3	7.335	21.3	14.73	431.0	100.0	+33.8(g)	—
Nitric oxide	NO	30.01	—	−163.6	2.301	−151.8	13.78	179.20	65.0	+90.37(g)	—
Nitrogen pentoxide	N_2O_5	108.02	$1.63^{18°}$	30	—	47	—	—	—	—	—
Nitrogen tetraoxide	N_2O_4	92.0	1.448	−9.5	—	21.1	—	431.0	99.0	+9.3(g)	—
Nitrous oxide	N_2O	44.02	$1.226^{-89°}$	−91.1	—	−88.8	—	309.5	71.70	+81.5(g)	—
n-Nonane	C_9H_{20}	128.25	0.718	−53.8	—	150.6	—	595	23.0	−229.0(l) —	−6124.5(l) −6171.0(g)
n-Octane	C_8H_{18}	114.22	0.703	−57.0	—	125.5	—	568.8	24.5	−249.9(l) −208.4(g)	−5470.7(l) −5512.2(g)
Oxalic acid	$C_2H_2O_4$	90.04	1.90	Decomposes at 186°C				—	—	−826.8(c)	−251.9(s)
Oxygen	O_2	32.00	—	−218.75	0.444	−182.97	6.82	154.4	49.7	0(g)	—
n-Pentane	C_5H_{12}	72.15	$0.63^{18°}$	−129.6	8.393	36.07	25.77	469.80	33.3	−173.0(l) −146.4(g)	−3509.5(l) −3536.1(g)
Isopentane	C_5H_{12}	72.15	$0.62^{19°}$	−160.1	—	27.7	— —	461.00	32.9	−179.3(l) −152.0(g)	−3507.5(l) −3529.2(g)
1-Pentene	C_5H_{10}	70.13	0.641	−165.2	4.94	29.97		474	39.9	−20.9(g)	−3375.8(g)
Phenol	C_6H_5OH	94.11	$1.071^{25°}$	42.5	11.43	181.4	—	692.1	60.5	−158.1(l) −90.8(g)	−3063.5(s) —
Phosphoric acid	H_3PO_4	98.00	$1.834^{18°}$	42.3	10.54	$(-\frac{1}{2}H_2O$ at 213°C)		—	—	−1281.1(c) −1278.6(aq, $1H_2O$)	— —
Phosphorus (red)	P_4	123.90	2.20	$590^{43\ atm}$	81.17	Ignites in air, 725°C		—	—	−17.6(c) 0(c)	—
Phosphorus (white)	P_4	123.90	1.82	44.2	2.51	280	49.71	—	—		—
Phosphorus pentoxide	P_2O_5	141.95	2.387	Sublimes at 250°C				—	—	−1506.2(c)	—
Propane	C_3H_8	44.09	—	−187.69	3.52	−42.07	18.77	369.9	42.0	−119.8(l) −103.8(g)	−2204.0(l) −2220.0(g)
Propylene	C_3H_6	42.08	—	−185.2	3.00	−47.70	18.42	365.1	45.4	+20.41(g)	−2058.4(g)
n-Propyl alcohol	C_3H_7OH	60.09	0.804	−127	—	97.04	—	536.7	49.95	−300.70(l) −255.2(g)	−2010.4(l) −2068.6(g)
Isopropyl alcohol	C_3H_7OH	60.09	0.785	−89.7	—	82.24	—	508.8	53.0	−310.9(l)	−1986.6(l)
n-Propyl benzene	C_9H_{12}	120.19	0.862	−99.50	8.54	159.2	38.24	638.7	31.3	−38.40(l) +7.82(g)	−5218.2(l) −5264.48(g)
Silicon dioxide	SiO_2	60.09	2.25	1710	14.2	2230	—	—	—	−851.0(c)	—
Sodium bicarbonate	$NaHCO_3$	84.01	2.20	Decomposes at 270°C				—	—	−945.6(c)	—
Sodium bisulfate	$NaHSO_4$	120.07	2.742	—	—	—	—	—	—	−1126.3(c)	—
Sodium carbonate	Na_2CO_3	105.99	2.533	Decomposes at 854°C				—	—	−1130.9(c)	—
Sodium chloride	NaCl	58.45	2.163	808	28.5	1465	170.7	—	—	−411.0(c)	—
Sodium cyanide	NaCN	49.01	—	562	16.7	1497	155	—	—	−89.79(c)	—
Sodium hydroxide	NaOH	40.00	2.130	319	8.34	1390	—	—	—	−426.6(c) −469.4(aq)	— —
Sodium nitrate	$NaNO_3$	85.00	2.257	310	15.9	Decomposes at 380°C			—	−466.7(c)	—
Sodium nitrite	$NaNO_2$	69.00	$2.168^{0°}$	271	—	Decomposes at 320°C			—	−359.4(c)	—
Sodium sulfate	Na_2SO_4	142.05	2.698	890	24.3	—	—	—	—	−1384.5(c)	—
Sodium sulfide	Na_2S	78.05	1.856	950	6.7	—	—	—	—	−373.2(c)	—
Sodium sulfite	Na_2SO_3	126.05	$2.633^{15°}$	Decomposes				—	—	−1090.3(c)	—

PROPIEDADES TERMODINÁMICAS IV

Compound	Formula	Mol. Wt.	SG (20°/4°)	T_m(°C)[b]	$\Delta\hat{H}_m(T_m)$[c,j] kJ/mol	T_b(°C)[d]	$\Delta\hat{H}_v(T_b)$[e,j] kJ/mol	T_c(K)[f]	P_c(atm)[g]	$(\Delta\hat{H}_f°)$[h,j] kJ/mol	$(\Delta\hat{H}_c°)$[i,j] kJ/mol
Sodium thiosulfate	$Na_2S_2O_3$	158.11	1.667	—	—	—	—	—	—	−1117.1(c)	—
Sulfur (rhombic)	S_8	256.53	2.07	113	10.04	444.6	83.7	—	—	0(c)	—
Sulfur (monoclinic)	S_8	256.53	1.96	119	14.17	444.6	83.7	—	—	+0.30(c)	—
Sulfur dioxide	SO_2	64.07	—	−75.48	7.402	−10.02	24.91	430.7	77.8	−296.90(g)	—
Sulfur trioxide	SO_3	80.07	—	16.84	25.48	43.3	41.80	491.4	83.8	−395.18(g)	—
Sulfuric acid	H_2SO_4	98.08	$1.834^{18°}$	10.35	9.87	Decomposes at 340°C		—	—	−811.32(l) −907.51(aq)	— —
Toluene	C_7H_8	92.13	0.866	−94.99	6.619	110.62	33.47	593.9	40.3	+12.00(l) +50.00(g)	−3909.9(l) −3947.9(g)
Water	H_2O	18.016	$1.00^{4°}$	0.00	6.0095	100.00	40.656	647.4	218.3	−285.84(l) −241.83(g)	— —
m-Xylene	C_8H_{10}	106.16	0.864	−47.87	11.569	139.10	36.40	619	34.6	−25.42(l) +17.24(g)	−4551.9(l) −4594.5(g)
o-Xylene	C_8H_{10}	106.16	0.880	−25.18	13.598	144.42	36.82	631.5	35.7	−24.44(l) +18.99(g)	−4552.9(l) −4596.3(g)
p-Xylene	C_8H_{10}	106.16	0.861	13.26	17.11	138.35	36.07	618	33.9	−24.43(l) 17.95(g)	−4552.91(l) −4595.2(g)
Zinc	Zn	65.38	7.140	419.5	6.674	907	114.77	—	—	0(c)	—

CALORES ESPECÍFICOS I

Form 1: C_p[kJ/(mol·°C)] or [kJ/(mol·K)] $= a + bT + cT^2 + dT^3$

Form 2: C_p[kJ/(mol·°C)] or [kJ/(mol·K)] $= a + bT + cT^{-2}$

Example: $(C_p)_{acetone(g)} = 0.07196 + (20.10 \times 10^{-5})T - (12.78 \times 10^{-8})T^2 + (34.76 \times 10^{-12})T^3$, where T is in °C.

Note: The formulas for gases are strictly applicable at pressures low enough for the ideal gas equation of state to apply.

Compound	Formula	Mol. Wt.	State	Form	Temp. Unit	$a \times 10^3$	$b \times 10^5$	$c \times 10^8$	$d \times 10^{12}$	Range (Units of T)
Acetone	CH_3COCH_3	58.08	l	1	°C	123.0	18.6			−30–60
			g	1	°C	71.96	20.10	−12.78	34.76	0–1200
Acetylene	C_2H_2	26.04	g	1	°C	42.43	6.053	−5.033	18.20	0–1200
Air		29.0	g	1	°C	28.94	0.4147	0.3191	−1.965	0–1500
			g	1	K	28.09	0.1965	0.4799	−1.965	273–1800
Ammonia	NH_3	17.03	g	1	°C	35.15	2.954	0.4421	−6.686	0–1200
Ammonium sulfate	$(NH_4)_2SO_4$	132.15	c	1	K	215.9				275–328
Benzene	C_6H_6	78.11	l	1	°C	126.5	23.4			6–67
			g	1	°C	74.06	32.95	−25.20	77.57	0–1200
Isobutane	C_4H_{10}	58.12	g	1	°C	89.46	30.13	−18.91	49.87	0–1200
n-Butane	C_4H_{10}	58.12	g	1	°C	92.30	27.88	−15.47	34.98	0–1200
Isobutene	C_4H_8	56.10	g	1	°C	82.88	25.64	−17.27	50.50	0–1200
Calcium carbide	CaC_2	64.10	c	2	K	68.62	1.19	-8.66×10^{10}	—	298–720
Calcium carbonate	$CaCO_3$	100.09	c	2	K	82.34	4.975	-12.87×10^{10}	—	273–1033
Calcium hydroxide	$Ca(OH)_2$	74.10	c	1	K	89.5				276–373
Calcium oxide	CaO	56.08	c	2	K	41.84	2.03	-4.52×10^{10}		273–1173
Carbon	C	12.01	c	2	K	11.18	1.095	-4.891×10^{10}		273–1373
Carbon dioxide	CO_2	44.01	g	1	°C	36.11	4.233	−2.887	7.464	0–1500
Carbon monoxide	CO	28.01	g	1	°C	28.95	0.4110	0.3548	−2.220	0–1500
Carbon tetrachloride	CCl_4	153.84	l	1	K	93.39	12.98			273–343
Chlorine	Cl_2	70.91	g	1	°C	33.60	1.367	−1.607	6.473	0–1200
Copper	Cu	63.54	c	1	K	22.76	0.6117			273–1357

CALORES ESPECÍFICOS II

Compound	Formula	Mol. Wt.	State	Form	Temp. Unit	$a \times 10^3$	$b \times 10^5$	$c \times 10^8$	$d \times 10^{12}$	Range (Units of T)
Cumene (Isopropyl benzene)	C_9H_{12}	120.19	g	1	°C	139.2	53.76	−39.79	120.5	0–1200
Cyclohexane	C_6H_{12}	84.16	g	1	°C	94.140	49.62	−31.90	80.63	0–1200
Cyclopentane	C_5H_{10}	70.13	g	1	°C	73.39	39.28	−25.54	68.66	0–1200
Ethane	C_2H_6	30.07	g	1	°C	49.37	13.92	−5.816	7.280	0–1200
Ethyl alcohol	C_2H_5OH	46.07	l	1	°C	103.1				0
(Ethanol)			l	1	°C	158.8				100
			g	1	°C	61.34	15.72	−8.749	19.83	0–1200
Ethylene	C_2H_4	28.05	g	1	°C	+40.75	11.47	−6.891	17.66	0–1200
Ferric oxide	Fe_2O_3	159.70	c	2	K	103.4	6.711	-17.72×10^{10}	—	273–1097
Formaldehyde	CH_2O	30.03	g	1	°C	34.28	4.268	0.0000	−8.694	0–1200
Helium	He	4.00	g	1	°C	20.8				0–1200
n-Hexane	C_6H_{14}	86.17	l	1	°C	216.3				20–100
			g	1	°C	137.44	40.85	−23.92	57.66	0–1200
Hydrogen	H_2	2.016	g	1	°C	28.84	0.00765	0.3288	−0.8698	0–1500
Hydrogen bromide	HBr	80.92	g	1	°C	29.10	−0.0227	0.9887	−4.858	0–1200
Hydrogen chloride	HCl	36.47	g	1	°C	29.13	−0.1341	0.9715	−4.335	0–1200
Hydrogen cyanide	HCN	27.03	g	1	°C	35.3	2.908	1.092		0–1200
Hydrogen sulfide	H_2S	34.08	g	1	°C	33.51	1.547	0.3012	−3.292	0–1500
Magnesium chloride	$MgCl_2$	95.23	c	1	K	72.4	1.58			273–991
Magnesium oxide	MgO	40.32	c	2	K	45.44	0.5008	-8.732×10^{10}		273–2073
Methane	CH_4	16.04	g	1	°C	34.31	5.469	0.3661	−11.00	0–1200
			g	1	K	19.87	5.021	1.268	−11.00	273–1500
Methyl alcohol	CH_3OH	32.04	l	1	°C	75.86	16.83			0–65
(Methanol)			g	1	°C	42.93	8.301	−1.87	−8.03	0–700
Methyl cyclohexane	C_7H_{14}	98.18	g	1	°C	121.3	56.53	−37.72	100.8	0–1200
Methyl cyclopentane	C_6H_{12}	84.16	g	1	°C	98.83	45.857	−30.44	83.81	0–1200
Nitric acid	NHO_3	63.02	l	1	°C	110.0				25
Nitric oxide	NO	30.01	g	1	°C	29.50	0.8188	−0.2925	0.3652	0–3500
Nitrogen	N_2	28.02	g	1	°C	29.00	0.2199	0.5723	−2.871	0–1500
Nitrogen dioxide	NO_2	46.01	g	1	°C	36.07	3.97	−2.88	7.87	0–1200
Nitrogen tetraoxide	N_2O_4	92.02	g	1	°C	75.7	12.5	−11.3		0–300
Nitrous oxide	N_2O	44.02	g	1	°C	37.66	4.151	−2.694	10.57	0–1200
Oxygen	O_2	32.00	g	1	°C	29.10	1.158	−0.6076	1.311	0–1500
n-Pentane	C_5H_{12}	72.15	l	1	°C	155.4	43.68			0–36
			g	1	°C	114.8	34.09	−18.99	42.26	0–1200
Propane	C_3H_8	44.09	g	1	°C	68.032	22.59	−13.11	31.71	0–1200
Propylene	C_3H_6	42.08	g	1	°C	59.580	17.71	−10.17	24.60	0–1200
Sodium carbonate	Na_2CO_3	105.99	c	1	K	121				288–371
Sodium carbonate decahydrate	$Na_2CO_3 \cdot 10H_2O$	286.15	c	1	K	535.6				298
Sulfur	S	32.07	c (Rhombic)	1	K	15.2	2.68			273–368
			c (Monoclinic)	1	K	18.3	1.84			368–392
Sulfuric acid	H_2SO_4	98.08	l	1	°C	139.1	15.59			10–45
Sulfur dioxide	SO_2	64.07	g	1	°C	38.91	3.904	−3.104	8.606	0–1500
Sulfur trioxide	SO_3	80.07	g	1	°C	48.50	9.188	−8.540	32.40	0–1000
Toluene	C_7H_8	92.13	l	1	°C	148.8	32.4			0–110
			g	1	°C	94.18	38.00	−27.86	80.33	0–1200
Water	H_2O	18.016	l	1	°C	75.4				0–100
			g	1	°C	33.46	0.6880	0.7604	−3.593	0–1500

ENTALPÍAS ESPECÍFICAS DE GASES

Specific Enthalpies of Selected Gases: SI Units

$\hat{H}$(kJ/mol)
Reference state: Gas, P_{ref} = 1 atm, T_{ref} = 25°C

T	Air	O_2	N_2	H_2	CO	CO_2	H_2O
0	−0.72	−0.73	−0.73	−0.72	−0.73	−0.92	−0.84
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	2.19	2.24	2.19	2.16	2.19	2.90	2.54
200	5.15	5.31	5.13	5.06	5.16	7.08	6.01
300	8.17	8.47	8.12	7.96	8.17	11.58	9.57
400	11.24	11.72	11.15	10.89	11.25	16.35	13.23
500	14.37	15.03	14.24	13.83	14.38	21.34	17.01
600	17.55	18.41	17.39	16.81	17.57	26.53	20.91
700	20.80	21.86	20.59	19.81	20.82	31.88	24.92
800	24.10	25.35	23.86	22.85	24.13	37.36	29.05
900	27.46	28.89	27.19	25.93	27.49	42.94	33.32
1000	30.86	32.47	30.56	29.04	30.91	48.60	37.69
1100	34.31	36.07	33.99	32.19	34.37	54.33	42.18
1200	37.81	39.70	37.46	35.39	37.87	60.14	46.78
1300	41.34	43.38	40.97	38.62	41.40	65.98	51.47
1400	44.89	47.07	44.51	41.90	44.95	71.89	56.25
1500	48.45	50.77	48.06	45.22	48.51	77.84	61.09

CONSTANTES DE ANTOINE I

$$\log_{10} p^* = A - \frac{B}{T + C} \qquad p^* \text{ in mm Hg}, \quad T \text{ in °C}$$

Example: The vapor pressure of acetaldehyde at 25°C is determined as follows:

$$\log_{10} p^*_{C_2H_4O}(25°C) = 8.00552 - \frac{1600.017}{25 + 291.809} = 2.9551$$

$$\Longrightarrow p^*_{C_2H_4O}(25°C) = 10^{2.9551} = 902 \text{ mm Hg}$$

Compound	Formula	Range (°C)	A	B	C
Acetaldehyde	C_2H_4O	−0.2 to 34.4	8.00552	1600.017	291.809
Acetic acid	$C_2H_4O_2$	29.8 to 126.5	7.38782	1533.313	222.309
Acetic acid*	$C_2H_4O_2$	0 to 36	7.18807	1416.7	225
Acetic anhydride	$C_4H_6O_3$	62.8 to 139.4	7.14948	1444.718	199.817
Acetone	C_3H_6O	−12.9 to 55.3	7.11714	1210.595	229.664
Acrylic acid	$C_3H_4O_2$	20.0 to 70.0	5.65204	648.629	154.683
Ammonia*	NH_3	−83 to 60	7.55466	1002.711	247.885
Aniline	C_6H_7N	102.6 to 185.2	7.32010	1731.515	206.049
Benzene	C_6H_6	14.5 to 80.9	6.89272	1203.531	219.888
n-Butane	n-C_4H_{10}	−78.0 to −0.3	6.82485	943.453	239.711
i-Butane	i-C_4H_{10}	−85.1 to −11.6	6.78866	899.617	241.942
1-Butanol	$C_4H_{10}O$	89.2 to 125.7	7.36366	1305.198	173.427
2-Butanol	$C_4H_{10}O$	72.4 to 107.1	7.20131	1157.000	168.279
1-Butene	C_4H_8	−77.5 to −3.7	6.53101	810.261	228.066
Butyric acid	$C_4H_8O_2$	20.0 to 150.0	8.71019	2433.014	255.189
Carbon disulfide	CS_2	3.6 to 79.9	6.94279	1169.110	241.593
Carbon tetrachloride	CCl_4	14.1 to 76.0	6.87926	1212.021	226.409
Chlorobenzene	C_6H_5Cl	62.0 to 131.7	6.97808	1431.053	217.550
Chlorobenzene*	C_6H_5Cl	0 to 42	7.10690	1500.0	224.0
Chlorobenzene*	C_6H_5Cl	42 to 230	6.94504	1413.12	216.0
Chloroform	$CHCl_3$	−10.4 to 60.3	6.95465	1170.966	226.232
Chloroform*	$CHCl_3$	−30 to 150	6.90328	1163.03	227.4
Cyclohexane	C_6H_{12}	19.9 to 81.6	6.84941	1206.001	223.148
Cyclohexanol	$C_6H_{12}O$	93.7 to 160.7	6.25530	912.866	109.126
n-Decane	n-$C_{10}H_{22}$	94.5 to 175.1	6.95707	1503.568	194.738
1-Decene	$C_{10}H_{20}$	86.8 to 171.6	6.95433	1497.527	197.056
1,1-Dichloroethane	$C_2H_4Cl_2$	−38.8 to 17.6	6.97702	1174.022	229.060
1,2-Dichloroethane	C_2H_4Cl	−30.8 to 99.4	7.02530	1271.254	222.927
Dichloromethane	CH_2Cl_2	−40.0 to 40	7.40916	1325.938	252.616
Diethyl ether	$C_4H_{10}O$	−60.8 to 19.9	6.92032	1064.066	228.799
Diethyl ketone	$C_5H_{10}O$	56.5 to 111.3	7.02529	1310.281	214.192
Diethylene glycol	$C_4H_{10}O_2$	130.0 to 243.0	7.63666	1939.359	162.714
Dimethyl ether	C_2H_6O	−78.2 to −24.9	6.97603	889.264	241.957
Dimethylamine	C_2H_7N	−71.8 to 6.9	7.08212	960.242	221.667
N,N-Dimethylformamide	C_3H_7NO	30.0 to 90.0	6.92796	1400.869	196.434
1,4-Dioxane	$C_4H_8O_2$	20.0 to 105.0	7.43155	1554.679	240.337
Ethanol	C_2H_6O	19.6 to 93.4	8.11220	1592.864	226.184
Ethanolamine	C_2H_7NO	65.4 to 170.9	7.45680	1577.670	173.368
Ethyl acetate	$C_4H_8O_2$	15.6 to 75.8	7.10179	1244.951	217.881
Ethyl acetate*	$C_4H_8O_2$	−20 to 150	7.09808	1238.710	217.0
Ethyl chloride	C_2H_5Cl	−55.9 to 12.5	6.98647	1030.007	238.612
Ethylbenzene	C_8H_{10}	56.5 to 137.1	6.95650	1423.543	213.091

CONSTANTES DE ANTOINE II

Compound	Formula	Range (°C)	*A*	*B*	*C*
Ethylene glycol	$C_2H_6O_2$	50.0 to 200.0	8.09083	2088.936	203.454
Ethylene oxide	C_2H_4O	0.3 to 31.8	8.69016	2005.779	334.765
1,2-Ethylenediamine	$C_2H_8N_2$	26.5 to 117.4	7.16871	1336.235	194.366
Formaldehyde	HCHO	−109.4 to −22.3	7.19578	970.595	244.124
Formic acid	CH_2O_2	37.4 to 100.7	7.58178	1699.173	260.714
Glycerol	$C_3H_8O_3$	183.3 to 260.4	6.16501	1036.056	28.097
n-Heptane	*n*-C_7H_{16}	25.9 to 99.3	6.90253	1267.828	216.823
i-Heptane	*i*-C_7H_{16}	18.5 to 90.9	6.87689	1238.122	219.783
1-Heptene	C_7H_{14}	21.6 to 94.5	6.91381	1265.120	220.051
n-Hexane	*n*-C_6H_{14}	13.0 to 69.5	6.88555	1175.817	224.867
i-Hexane	*i*-C_6H_{14}	12.8 to 61.1	6.86839	1151.401	228.477
1-Hexene	C_6H_{12}	15.9 to 64.3	6.86880	1154.646	226.046
Hydrogen Cyanide	HCN	−16.4 to 46.2	7.52823	1329.49	260.418
Methanol	CH_3OH	14.9 to 83.7	8.08097	1582.271	239.726
Methanol*	CH_3OH	−20 to 140	7.87863	1473.11	230.0
Methyl acetate	$C_3H_6O_2$	1.8 to 55.8	7.06524	1157.630	219.726
Methyl bromide	CH_3Br	−70.0 to 3.6	7.09084	1046.066	244.914
Methyl chloride	CH_3Cl	−75.0 to 5.0	7.09349	948.582	249.336
Methyl ethyl ketone	C_4H_8O	42.8 to 88.4	7.06356	1261.339	221.969
Methyl isobutyl ketone	$C_6H_{12}O$	21.7 to 116.2	6.67272	1168.408	191.944
Methyl methacrylate	$C_5H_8O_2$	39.2 to 89.2	8.40919	2050.467	274.369
Methylamine	CH_5N	−83.1 to −6.2	7.33690	1011.532	233.286
Methylcyclohexane	C_7H_{14}	25.6 to 101.8	6.82827	1273.673	221.723
Naphthalene	$C_{10}H_8$	80.3 to 179.5	7.03358	1756.328	204.842
Nitrobenzene	$C_6H_5NO_2$	134.1 to 210.6	7.11562	1746.586	201.783
Nitromethane	CH_3NO_2	55.7 to 136.4	7.28166	1446.937	227.600
n-Nonane	*n*-C_9H_{20}	70.3 to 151.8	6.93764	1430.459	201.808
1-Nonane	C_9H_{18}	66.6 to 147.9	6.95777	1437.862	205.814
n-Octane	*n*-C_8H_{18}	52.9 to 126.6	6.91874	1351.756	209.100
i-Octane	*i*-C_8H_{18}	41.7 to 118.5	6.88814	1319.529	211.625
1-Octene	C_8H_{16}	44.9 to 122.2	6.93637	1355.779	213.022
n-Pentane	*n*-C_5H_{12}	13.3 to 36.8	6.84471	1060.793	231.541
i-Pentane	*i*-C_5H_{12}	16.3 to 28.6	6.73457	992.019	229.564
1-Pentanol	$C_5H_{12}O$	74.7 to 156.0	7.18246	1287.625	161.330
1-Pentene	C_5H_{10}	12.8 to 30.7	6.84268	1043.206	233.344
Phenol	C_6H_6O	107.2 to 181.8	7.13301	1516.790	174.954
1-Propanol	C_3H_8O	60.2 to 104.6	7.74416	1437.686	198.463
2-Propanol	C_3H_8O	52.3 to 89.3	7.74021	1359.517	197.527
Propionic acid	$C_3H_6O_2$	72.4 to 128.3	7.71423	1733.418	217.724
Propylene oxide	C_3H_6O	−24.2 to 34.8	7.01443	1086.369	228.594
Pyridine	C_5H_5N	67.3 to 152.9	7.04115	1373.799	214.979
Styrene	C_8H_8	29.9 to 144.8	7.06623	1507.434	214.985
Toluene	C_7H_8	35.3 to 111.5	6.95805	1346.773	219.693
1,1,1-Trichloroethane	$C_2H_3Cl_3$	−5.4 to 16.9	8.64344	2136.621	302.769
1,1,2-Trichloroethane	$C_2H_3Cl_3$	50.0 to 113.7	6.95185	1314.410	209.197
Trichloroethylene	C_2HCl_3	17.8 to 86.5	6.51827	1018.603	192.731
Vinyl acetate	$C_4H_6O_2$	21.8 to 72.0	7.21010	1296.130	226.655
Water*	H_2O	0 to 60	8.10765	1750.286	235.000
Water*	H_2O	60 to 150	7.96681	1668.210	228.000
m-Xylene	*m*-C_8H_{10}	59.2 to 140.0	7.00646	1460.183	214.827
o-Xylene	*o*-C_8H_{10}	63.5 to 145.4	7.00154	1476.393	213.872
p-Xylene	*p*-C_8H_{10}	58.3 to 139.3	6.98820	1451.792	215.111

Density (kg/m3) of Water from 0 to 100°C to P atm

	ρ, kg/m³									
***t*, °C**	**0.0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0	999.839	999.846	999.852	999.859	999.865	999.871	999.877	999.882	999.888	999.893
1	999.898	999.903	999.908	999.913	999.917	999.921	999.925	999.929	999.933	999.936
2	999.940	999.943	999.946	999.949	999.952	999.954	999.956	999.959	999.961	999.962
3	999.964	999.966	999.967	999.968	999.969	999.970	999.971	999.971	999.972	999.972
4	999.972	999.972	999.972	999.971	999.971	999.970	999.969	999.968	999.967	999.965
5	999.964	999.962	999.960	999.958	999.956	999.954	999.951	999.949	999.946	999.943
6	999.940	999.937	999.934	999.930	999.926	999.923	999.919	999.915	999.910	999.906
7	999.901	999.897	999.892	999.887	999.882	999.877	999.871	999.866	999.860	999.854
8	999.848	999.842	999.836	999.829	999.823	999.816	999.809	999.802	999.795	999.788
9	999.781	999.773	999.765	999.758	999.750	999.742	999.734	999.725	999.717	999.708
10	999.699	999.691	999.682	999.672	999.663	999.654	999.644	999.635	999.625	999.615
11	999.605	999.595	999.584	999.574	999.563	999.553	999.542	999.531	999.520	999.509
12	999.497	999.486	999.474	999.462	999.451	999.439	999.426	999.414	999.402	999.389
13	999.377	999.364	999.351	999.338	999.325	999.312	999.299	999.285	999.272	999.258
14	999.244	999.230	999.216	999.202	999.188	999.173	999.159	999.144	999.129	999.114
15	999.099	999.084	999.069	999.054	999.038	999.022	999.007	998.991	998.975	998.958
16	998.943	998.926	998.910	999.894	998.877	998.860	998.843	998.826	998.809	998.792
17	998.775	998.757	998.740	998.722	998.704	998.686	998.668	998.650	998.632	998.614
18	998.595	998.577	998.558	998.539	998.520	998.502	998.482	998.463	998.444	998.425
19	998.405	998.385	998.366	998.346	998.326	998.306	998.286	998.265	998.245	998.224
20	998.204	998.183	998.162	998.141	998.120	998.099	998.078	998.057	998.035	998.014
21	997.992	997.971	997.949	997.927	997.905	997.883	997.860	997.838	997.816	997.793
22	997.770	997.747	997.725	997.702	997.679	997.656	997.632	997.609	997.585	997.562
23	997.538	997.515	997.491	997.467	997.443	997.419	997.394	997.370	997.345	997.321
24	997.296	997.272	997.247	997.222	997.197	997.172	997.146	997.121	997.096	997.070
25	997.045	997.019	996.993	996.967	996.941	996.915	996.889	996.863	996.836	996.810
26	996.783	996.757	996.730	996.703	996.676	996.649	996.622	996.595	996.568	996.540
27	996.513	996.485	996.458	996.430	996.402	996.374	996.346	996.318	996.290	996.262
28	996.233	996.205	996.176	996.148	996.119	996.090	996.061	996.032	996.003	995.974
29	995.945	995.915	995.886	995.856	995.827	995.797	995.767	995.737	995.707	995.677
30	995.647	995.617	995.586	995.556	995.526	995.495	995.464	995.433	995.403	995.372
31	995.341	995.310	995.278	995.247	995.216	995.184	995.153	995.121	995.090	995.058
32	995.026	994.997	994.962	994.930	994.898	994.865	994.833	994.801	994.768	994.735
33	994.703	994.670	994.637	994.604	994.571	994.538	994.505	994.472	994.438	994.405
34	994.371	994.338	994.304	994.270	994.236	994.202	994.168	994.134	994.100	994.066
35	994.032	993.997	993.963	993.928	993.893	993.859	993.824	993.789	993.754	993.719
36	993.684	993.648	993.613	993.578	993.543	993.507	993.471	993.436	993.400	993.364
37	993.328	993.292	993.256	993.220	993.184	993.148	993.111	993.075	993.038	993.002
38	992.965	992.928	992.891	992.855	992.818	992.780	992.743	992.706	992.669	992.631
39	992.594	992.557	992.519	992.481	992.444	992.406	992.368	992.330	992.292	992.254
40	992.215	992.177	992.139	992.100	992.062	992.023	991.985	991.946	991.907	992.868
41	991.830	991.791	991.751	991.712	992.673	991.634	991.594	991.555	991.515	991.476
42	991.436	991.396	991.357	991.317	991.277	991.237	991.197	991.157	991.116	991.076
43	991.036	990.995	990.955	990.914	990.873	990.833	990.792	990.751	990.710	990.669
44	990.628	990.587	990.546	990.504	990.463	990.421	990.380	990.338	990.297	990.255
45	990.213	990.171	990.129	990.087	990.045	990.003	989.961	989.919	989.876	989.834
46	989.792	989.749	989.706	989.664	989.621	989.578	989.535	989.492	989.449	989.406
47	989.363	989.320	989.276	989.233	989.190	989.146	989.103	989.059	989.015	988.971
48	988.928	988.884	988.840	988.796	988.752	988.707	988.663	988.619	988.574	988.530
49	988.485	988.441	988.396	988.352	988.307	988.262	988.217	988.172	988.127	988.082

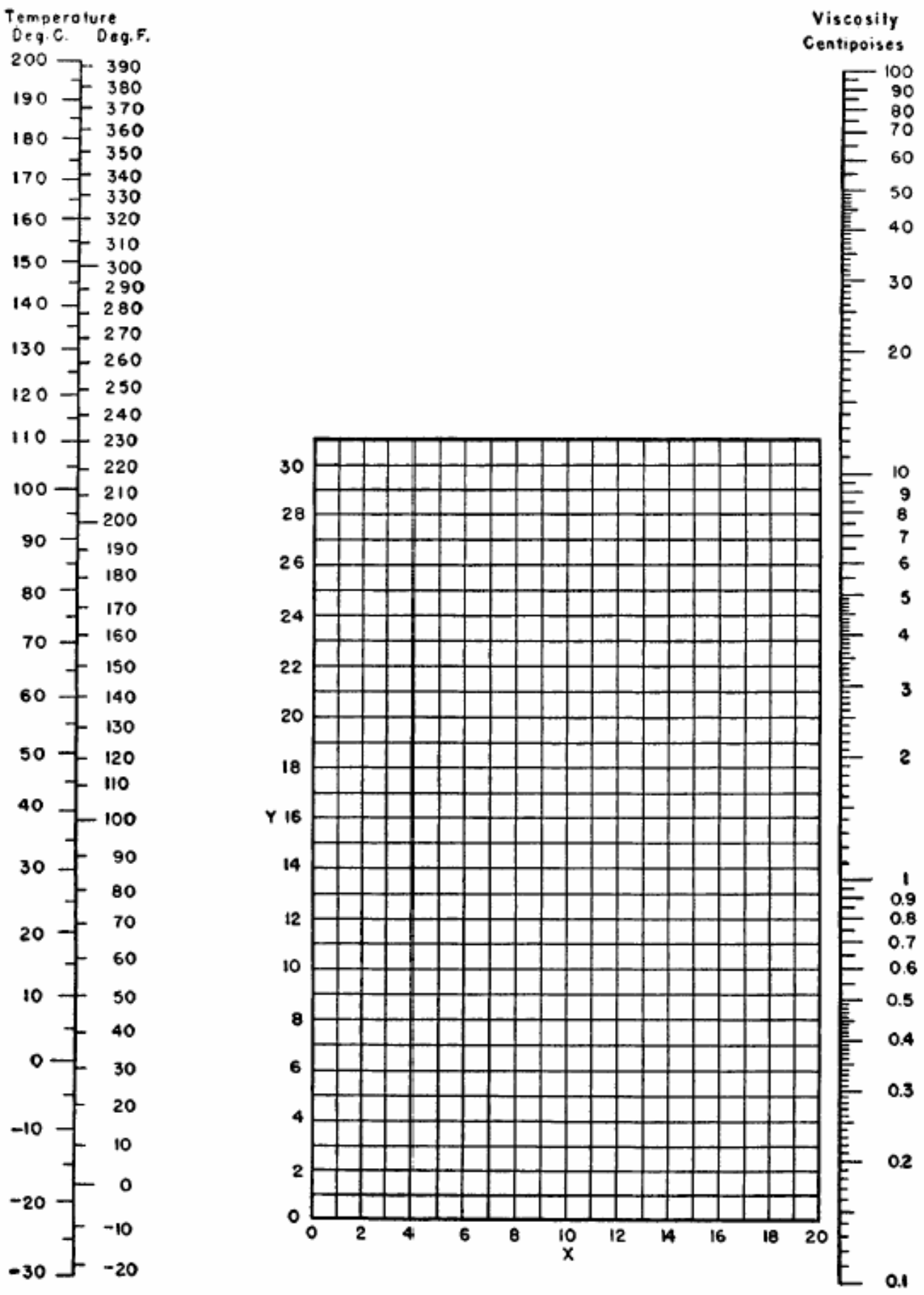
50	988.037	987.992	987.946	987.901	987.844	987.810	987.764	987.719	987.673	987.627
51	987.581	987.536	987.490	987.444	987.398	987.351	987.305	987.259	987.213	987.166
52	987.120	987.073	987.027	986.980	986.933	986.886	986.840	986.793	986.746	986.699
53	986.652	986.604	986.557	986.510	986.463	986.415	986.368	986.320	986.272	986.225
54	986.177	986.129	986.081	986.033	985.985	985.937	985.889	985.841	985.793	985.745
55	985.696	985.648	985.599	985.551	985.502	985.454	985.405	985.356	985.307	985.258
56	985.219	985.160	985.111	985.062	985.013	984.963	984.914	984.865	984.815	984.766
57	984.716	984.666	984.617	984.567	984.517	984.467	984.417	984.367	984.317	984.267
58	984.217	984.167	984.116	984.066	984.016	983.965	983.914	983.864	983.813	983.762
59	983.712	983.661	983.610	983.559	983.508	983.457	983.406	983.354	983.303	983.252
60	983.200	983.149	983.097	983.046	982.994	982.943	982.891	982.839	982.787	982.735
61	982.683	982.631	982.579	982.527	982.475	982.422	982.370	982.318	982.265	982.213
62	982.160	982.108	982.055	982.002	981.949	981.897	981.844	981.791	981.738	981.685
63	981.631	981.578	981.525	981.472	981.418	981.365	981.311	981.258	981.204	981.151
64	981.097	981.043	980.989	980.935	980.881	980.827	980.773	980.719	980.665	980.611
65	980.557	980.502	980.443	980.393	980.339	980.284	980.230	980.175	980.120	980.065
66	980.011	979.956	979.901	979.846	979.791	979.736	979.680	979.625	979.570	979.515
67	979.459	979.403	979.348	979.293	979.237	979.181	979.126	979.070	979.014	978.958
68	978.902	978.846	978.790	978.734	978.678	978.621	978.565	978.509	978.452	978.396
69	978.339	978.283	978.226	978.170	978.113	978.056	977.999	977.942	977.885	977.828
70	977.771	977.714	977.657	977.600	977.543	977.485	977.428	977.370	977.313	977.255
71	977.198	977.140	977.082	977.025	976.967	976.909	976.851	976.793	976.735	976.677
72	976.619	976.561	976.503	976.444	976.386	976.327	976.269	976.211	976.152	976.093
73	976.035	975.976	975.917	975.858	975.800	975.741	975.682	975.623	975.564	975.504
74	975.445	975.386	975.327	975.267	975.208	975.148	975.089	975.029	974.970	974.910
75	974.850	974.791	974.731	974.671	974.611	974.551	974.491	974.431	974.371	974.311
76	974.250	974.190	974.130	974.069	974.009	973.948	973.888	973.827	973.767	973.706
77	973.645	973.584	973.524	973.463	973.402	973.341	973.280	973.218	973.157	973.096
78	973.025	972.974	972.912	972.851	972.789	972.728	972.666	972.605	972.543	972.481
79	972.419	972.358	972.296	972.234	972.172	972.110	972.048	971.986	971.923	971.861
80	971.799	971.737	971.674	971.612	971.549	971.487	971.424	971.361	971.299	971.236
81	971.173	971.110	971.048	970.985	970.922	970.859	970.796	970.732	970.669	970.606
82	970.543	970.479	970.416	970.353	970.289	970.226	970.162	970.098	970.035	969.971
83	969.907	969.843	969.772	969.715	969.652	969.587	969.523	969.459	969.395	969.331
84	969.267	969.202	969.138	969.073	969.009	968.944	968.880	968.815	968.751	968.686
85	968.621	968.556	968.491	968.427	968.362	968.297	969.232	968.166	968.101	968.036
86	967.971	967.906	967.840	967.775	967.709	967.641	967.578	967.513	967.447	967.381
87	967.316	967.250	967.184	967.118	967.052	966.986	966.920	966.854	966.788	966.722
88	966.656	966.589	966.523	966.457	966.390	966.324	966.257	966.191	966.124	966.057
89	965.991	965.924	965.857	965.790	965.723	965.656	965.589	965.522	965.455	965.388
90	965.321	965.254	965.187	965.119	965.052	964.984	964.917	964.849	964.782	964.714
91	964.647	954.579	964.511	964.443	964.376	964.308	964.240	964.172	964.104	964.036
92	963.967	963.899	963.831	963.763	963.694	963.626	963.558	963.489	963.421	963.352
93	963.284	963.215	963.146	963.077	963.009	962.940	962.871	962.802	962.733	962.664
94	962.595	962.526	962.457	962.387	962.318	962.249	962.180	962.110	962.041	961.971
95	961.902	961.832	961.762	961.693	961.693	961.553	961.483	961.414	961.344	961.274
96	961.204	961.134	961.064	960.993	960.923	960.853	960.783	960.712	960.642	960.572
97	960.501	960.431	960.360	960.289	960.219	960.148	960.077	960.006	959.936	959.865
98	959.794	959.723	959.652	959.581	959.510	959.438	959.367	959.296	959.225	959.153
99	959.082	959.010	958.939	958.867	958.796	958.724	958.653	958.581	958.509	958.431
100	958.365									

VISCOSIDAD DEL AGUA LÍQUIDA

Temperatura °C	*Viscosidad en Cp*	*Temperatura °C*	*Viscosidad en Cp*	*Temperatura °C*	*Viscosidad en Cp*
0	1.792	33	0.7523	67	0.4233
1	1.731	34	0.7371	68	0.4174
2	1.673	35	0.7225	69	0.4117
3	1.619	36	0.7085	70	0.4061
4	1.567	37	0.6947	71	0.4006
5	1.519	38	0.6814	72	0.3952
6	1.473	39	0.6685	73	0.3900
7	1.428	40	0.6560	74	0.3849
8	1.386	41	0.6439	75	0.3799
9	1.346	42	0.6321	76	0.3750
10	1.308	43	0.6207	77	0.3702
11	1.271	44	0.6097	78	0.3655
12	1.236	45	0.5988	79	0.3610
13	1.203	46	0.5883	80	0.3565
14	1.171	47	0.5782	81	0.3521
15	1.140	48	0.5683	82	0.3478
16	1.111	49	0.5588	83	0.3436
17	1.083	50	0.5494	84	0.3395
18	1.056	51	0.5404	85	0.3355
19	1.030	52	0.5315	86	0.3315
20	1.005	53	0.5229	87	0.3276
20.2	1.000	54	0.5146	88	0.3239
21	0.9810	55	0.5064	89	0.3203
22	0.9579	56	0.4985	90	0.3165
23	0.9358	57	0.4907	91	0.3130
24	0.9142	58	0.4832	92	0.3095
25	0.8937	59	0.4759	93	0.3060
26	0.8737	60	0.4688	94	0.3027
27	0.8545	61	0.4618	95	0.2994
28	0.8360	62	0.4550	96	0.2962
29	0.8180	63	0.4483	97	0.2930
30	0.8007	64	0.4418	98	0.2899
31	0.7840	65	0.4355	99	0.2868
32	0.7679	66	0.4293	100	0.2838

Viscosities of Liquids

Liquid	X	Y	Liquid	X	Y
Acetaldehyde	15.2	4.8	Freon-113	12.5	11.4
Acetic acid, 100%	12.1	14.2	Glycerol, 100%	2.0	30.0
Acetic acid, 70%	9.5	17.0	Glycerol, 50%	6.9	19.6
Acetic anhydride	12.7	12.8	Heptane	14.1	8.4
Acetone, 100%	14.5	7.2	Hexane	14.7	7.0
Acetone, 35%	7.9	15.0	Hydrochloric acid, 31.5%	13.0	16.6
Acetonitrile	14.4	7.4	Iodobenzene	12.8	15.9
Acrylic acid	12.3	13.9	Isobutyl alcohol	7.1	18.0
Allyl alcohol	10.2	14.3	Isobutyric acid	12.2	14.4
Allyl bromide	14.4	9.6	Isopropyl alcohol	8.2	16.0
Allyl iodide	14.0	11.7	Isopropyl bromide	14.1	9.2
Ammonia, 100%	12.6	2.0	Isopropyl chloride	13.9	7.1
Ammonia, 26%	10.1	13.9	Isopropyl iodide	13.7	11.2
Amyl acetate	11.8	12.5	Kerosene	10.2	16.9
Amyl alcohol	7.5	18.4	Linseed oil, raw	7.5	27.2
Aniline	8.1	18.7	Mercury	18.4	16.4
Anisole	12.3	13.5	Methanol, 100%	12.4	10.5
Arsenic trichloride	13.9	14.5	Methanol, 90%	12.3	11.8
Benzene	12.5	10.9	Methanol, 40%	7.8	15.5
Brine, CaCl2, 25%	6.6	15.9	Methyl acetate	14.2	8.2
Brine, NaCl, 25%	10.2	16.6	Methyl acrylate	13.0	9.5
Bromine	14.2	13.2	Methyl i-butyrate	12.3	9.7
Bromotoluene	20.0	15.9	Methyl n-butyrate	13.2	10.3
Butyl acetate	12.3	11.0	Methyl chloride	15.0	3.8
Butyl acrylate	11.5	12.6	Methyl ethyl ketone	13.9	8.6
Butyl alcohol	8.6	17.2	Methyl formate	14.2	7.5
Butyric acid	12.1	15.3	Methyl iodide	14.3	9.3
Carbon dioxide	11.6	0.3	Methyl propionate	13.5	9.0
Carbon disulfide	16.1	7.5	Methyl propyl ketone	14.3	9.5
Carbon tetrachloride	12.7	13.1	Methyl sulfide	15.3	6.4
Chlorobenzene	12.3	12.4	Napthalene	7.9	18.1
Chloroform	14.4	10.2	Nitric acid, 95%	12.8	13.8
Chlorosulfonic acid	11.2	18.1	Nitric acid, 60%	10.8	17.0
Chlorotoluene, ortho	13.0	13.3	Nitrobenzene	10.6	16.2
Chlorotoluene, meta	13.3	12.5	Nitrogen dioxide	12.9	8.6
Chlorotoluene, para	13.3	12.5	Nitrotoluene	11.0	17.0
Cresol, meta	2.5	20.8	Octane	13.7	10.0
Cyclohexanol	2.9	24.3	Octyl alcohol	6.6	21.1
Cyclohexane	9.8	12.9	Pentachloroethane	10.9	17.3
Dibromomethane	12.7	15.8	Pentane	14.9	5.2
Dichloroethane	13.2	12.2	Phenol	6.9	20.8
Dichloromethane	14.6	8.9	Phosphorus tribromide	13.8	16.7
Diethyl ketone	13.5	9.2	Phosphorus trichloride	16.2	10.9
Diethyl oxalate	11.0	16.4	Propionic acid	12.8	13.8
Diethylene glycol	5.0	24.7	Propyl acetate	13.1	10.3
Diphenyl	12.0	18.3	Propyl alcohol	9.1	16.5
Dipropyl ether	13.2	8.6	Propyl bromide	14.5	9.6
Dipropyl oxalate	10.3	17.7	Propyl chloride	14.4	7.5
Ethyl acetate	13.7	9.1	Propyl formate	13.1	9.7
Ethyl acrylate	12.7	10.4	Propyl iodide	14.1	11.6
Ethyl alcohol, 100%	10.5	13.8	Sodium	16.4	13.9
Ethyl alcohol, 95%	9.8	14.3	Sodium hydroxide, 50%	3.2	25.8
Ethyl alcohol, 40%	6.5	16.6	Stannic chloride	13.5	12.8
Ethyl benzene	13.2	11.5	Succinonitrile	10.1	20.8
Ethyl bromide	14.5	8.1	Sulfur dioxide	15.2	7.1
2-Ethyl butyl acrylate	11.2	14.0	Sulfuric acid, 110%	7.2	27.4
Ethyl chloride	14.8	6.0	Sulfuric acid, 100%	8.0	25.1
Ethyl ether	14.5	5.3	Sulfuric acid, 98%	7.0	24.8
Ethyl formate	14.2	8.4	Sulfuric acid, 60%	10.2	21.3
2-Ethyl hexyl acrylate	9.0	15.0	Sulfuryl chloride	15.2	12.4
Ethyl iodide	14.7	10.3	Tetrachloroethane	11.9	15.7
Ethyl propionate	13.2	9.9	Thiophene	13.2	11.0
Ethyl propyl ether	14.0	7.0	Titanium tetrachloride	14.4	12.3
Ethyl sulfide	13.8	8.9	Toluene	13.7	10.4
Ethylene bromide	11.9	15.7	Trichloroethylene	14.8	10.5
Ethylene chloride	12.7	12.2	Triethylene glycol	4.7	24.8
Ethylene glycol	6.0	23.6	Turpentine	11.5	14.9
Ethylidene chloride	14.1	8.7	Vinyl acetate	14.0	8.8
Fluorobenzene	13.7	10.4	Vinyl toluene	13.4	12.0
Formic acid	10.7	15.8	Water	10.2	13.0
Freon-11	14.4	9.0	Xylene, ortho	13.5	12.1
Freon-12	16.8	5.6	Xylene, meta	13.9	10.6
Freon-21	15.7	7.5	Xylene, para	13.9	10.9
Freon-22	17.2	4.7			


Temperature
Deg. C.
Deg. F.
200
390
190
380
370
180
360
350
170
340
330
160
320
310
150
300
290
140
280
270
130
260
250
120
240
110
230
220
100
210
200
90
190
180
80
170
160
70
150
140
60
130
120
50
110
40
100
90
30
80
70
20
60
50
10
40
0
30
20
-10
10
0
-20
-10
-30
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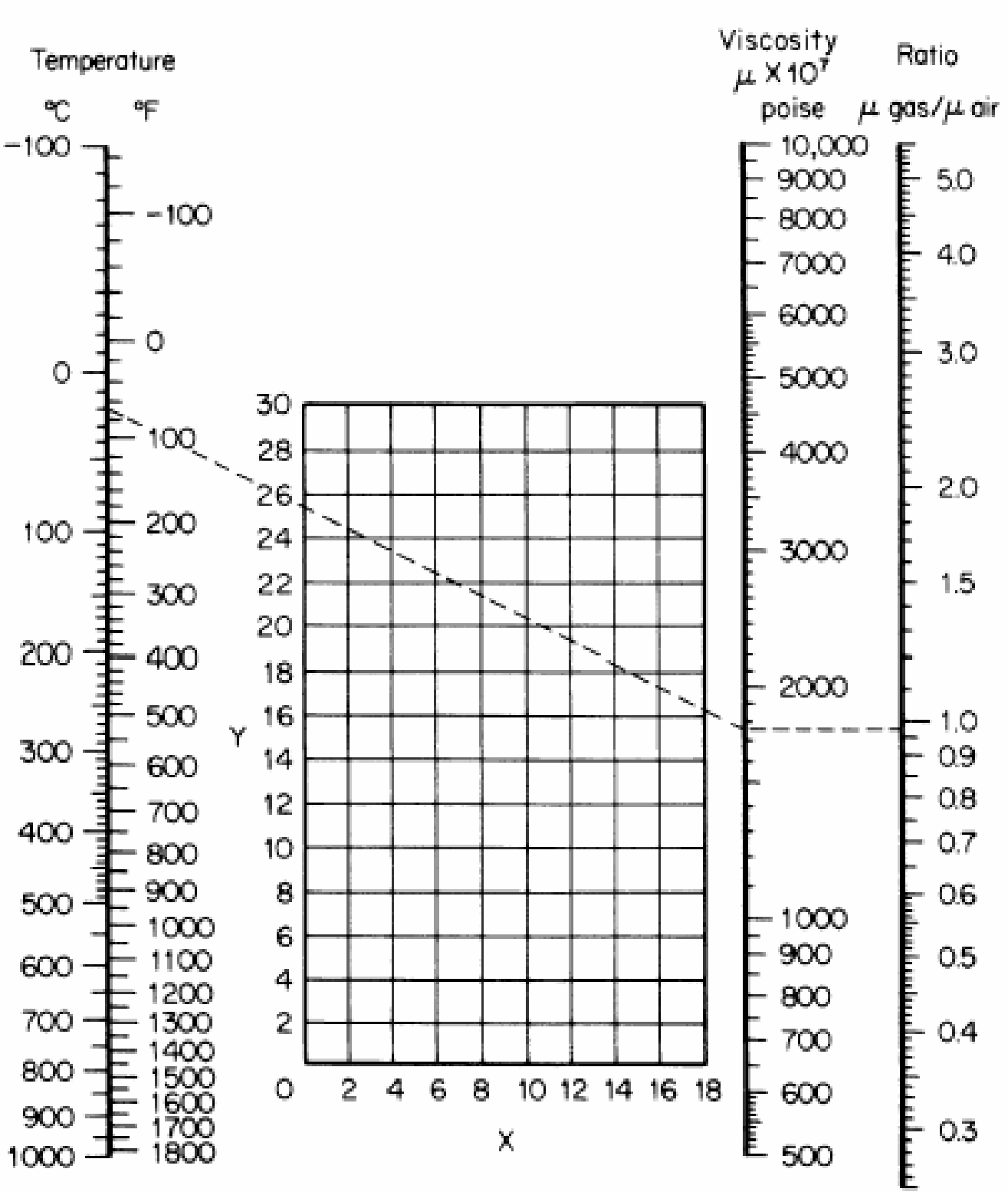
Y
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0 2 4 6 8 10 12 14 16 18 20
X
Viscosity
Centipoises
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

Viscosities of Gases a 20 ºC

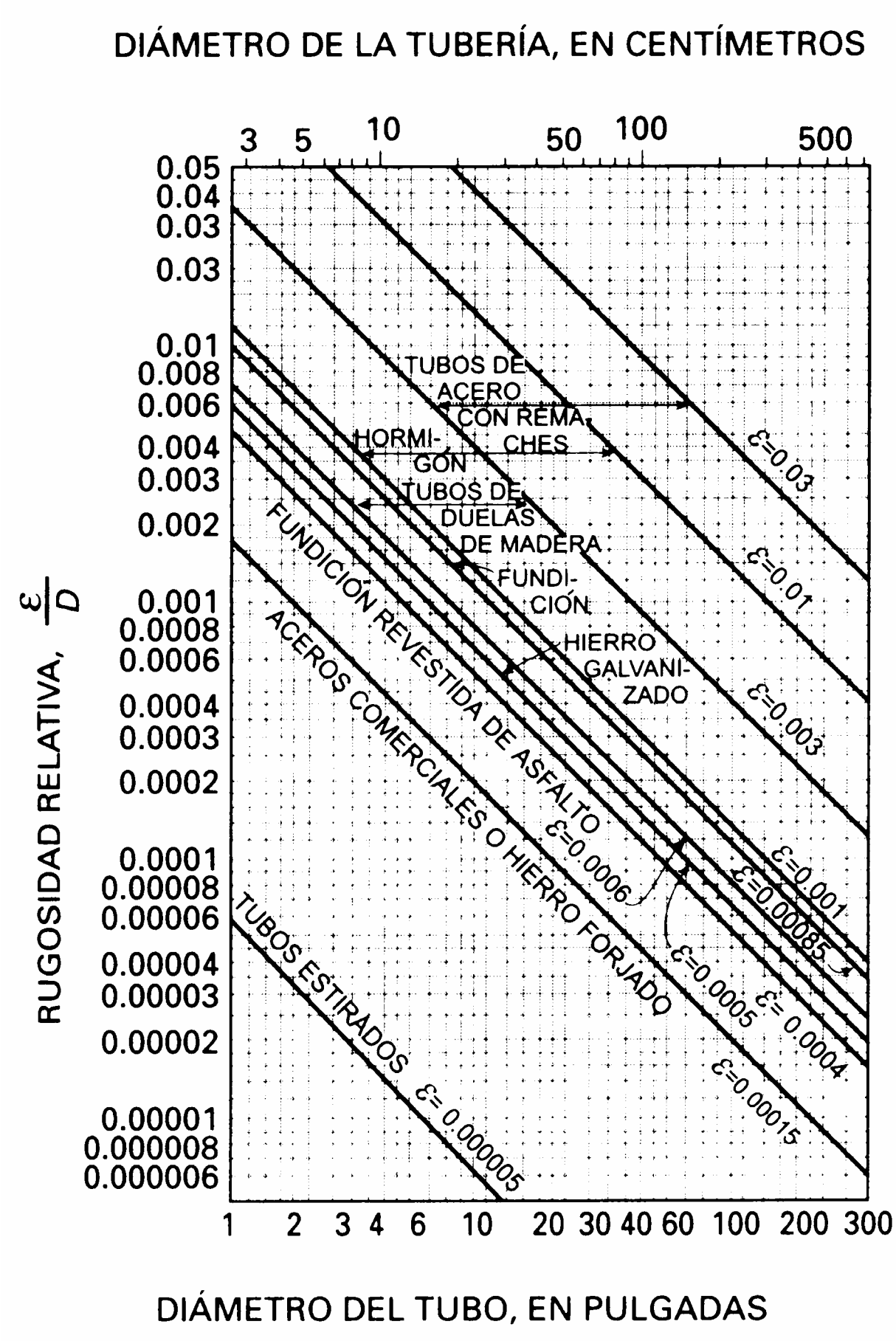
Gas	X	Y	$\mu * 10^7$ p	Gas	X	Y	$\mu * 10^7$ p
Acetic acid	7.0	14.6	825 (50°C)	Hydrogen–sulfur dioxide			
Acetone	8.4	13.2	735	10 % H2, 90% SO2	8.7	18.1	1259 (17)
Acetylene	9.3	15.5	1017	20 % H2, 80% SO2	8.6	18.2	1277 (17)
Air	10.4	20.4	1812	50 % H2, 50% SO2	8.9	18.3	1332 (17)
Ammonia	8.4	16.0	1000	80 % H2, 20% SO2	9.7	17.7	1306 (17)
Amylene (b)	8.6	12.2	676	Hydrogen bromide	8.4	21.6	1843
Argon	9.7	22.6	2215	Hydrogen chloride	8.5	19.2	1425
Arsine	8.6	20.0	1576	Hydrogen cyanide	7.1	14.5	737
Benzene	8.7	13.2	746	Hydrogen iodide	8.5	21.5	1830
Bromine	8.8	19.4	1495	Hydrogen sulfide	8.4	18.0	1265
Butane (n)	8.6	13.2	735	Iodine	8.7	18.7	1730 (100)
Butane (iso)	8.6	13.2	744	Krypton	9.4	24.0	2480
Butyl acetate (iso)	5.7	16.3	778	Mercury	7.4	24.9	4500 (200)
Butylene (a)	8.4	13.5	761	Mercuric bromide	8.5	19.0	2253
Butylene (b)	8.7	13.1	746	Mercuric chloride	7.7	18.7	2200 (200)
Butylene (iso)	8.3	13.9	786	Mercuric iodide	8.4	18.0	2045 (200)
Butyl formate (iso)	6.6	16.0	840	Mesitylene	9.5	10.2	660 (50)
Cadmium	7.8	22.5	5690 (500)	Methane	9.5	15.8	1092
Carbon dioxide	8.9	19.1	1463	Methane (deuterated)	9.5	17.6	1290
Carbon disulfide	8.5	15.8	990	Methanol	8.3	15.6	935
Carbon monoxide	10.5	20.0	1749	Methyl acetate	8.4	14.0	870 (50)
Carbon oxysulfide	8.2	17.9	1220	Methyl acetylene	8.9	14.3	867
Carbon tetrachloride	8.0	15.3	966	3-Methyl-1-butene	8.0	13.3	716
Chlorine	8.8	18.3	1335	Methyl butyrate (iso)	6.6	15.8	824
Chloroform	8.8	15.7	1000	Methyl bromide	8.1	18.7	1327
Cyanogen	8.2	16.2	1002	Methyl chloride	8.5	16.5	1062
Cyclohexane	9.0	12.2	701	3-Methylene-1-butene	8.0	13.3	716
Cyclopropane	8.3	14.7	870	Methylene chloride	8.5	15.8	989
Deuterium	11.0	16.2	1240	Methyl formate	5.1	18.0	923
Diethyl ether	8.8	12.7	730	Neon	11.1	25.8	3113
Dimethyl ether	9.0	15.0	925	Nitric oxide	10.4	20.8	1899
Diphenyl ether	8.6	10.4	610 (50)	Nitrogen	10.6	20.0	1766
Diphenyl methane	8.0	10.3	605 (50)	Nitrous oxide	9.0	19.0	1460
Ethane	9.0	14.5	915	Nonane (n)	9.2	8.9	554 (50)
Ethanol	8.2	14.5	835	Octane (n)	8.8	9.8	586 (50)
Ethyl acetate	8.4	13.4	743	Oxygen	10.2	21.6	2026
Ethyl chloride	8.5	15.6	978	Pentane (n)	8.5	12.3	668
Ethylene	9.5	15.2	1010	Pentane (iso)	8.9	12.1	685
Ethyl propionate	12.0	12.4	890	Phosphene	8.8	17.0	1150
Fluorine	7.3	23.8	2250	Propane	8.9	13.5	800
Freon-11	8.6	16.2	1298 (93)	Propanol (n)	8.4	13.5	770
Freon-12	9.0	17.4	1496 (93)	Propanol (iso)	8.4	13.6	774
Freon-14	9.5	20.4	1716	Propyl acetate	8.0	14.3	797
Freon-21	9.0	16.7	1389 (93)	Propylene	8.5	14.4	840
Freon-22	9.0	17.7	1554 (93)	Pyridine	8.6	13.3	830 (50)
Freon-113	11.0	14.0	1166 (93)	Silane	9.0	16.8	1148
Freon-114	9.4	16.4	1364 (93)	Stannic chloride	9.1	16.0	1330 (100)
Helium	11.3	20.8	1946	Stannic bromide	9.0	16.7	142 (100)
Heptane (n)	8.6	10.6	618 (50)	Sulfur dioxide	8.4	18.2	1250
Hexane (n)	8.4	12.0	644	Thiazole	10.0	14.4	958
Hydrogen	11.3	12.4	880	Thiophene	8.3	14.2	901 (50)
Hydrogen-helium				Toluene	8.6	12.5	686
10% H2, 90% He	11.0	20.5	1780 (0)	2,2,3-Trimethylbutane	10.0	10.4	691 (50)
25% H2, 75% He	11.0	19.4	1603 (0)	Trimethylethane	8.0	13.0	686
40% H2, 60% He	10.7	18.4	1431 (0)	Water	8.0	16.0	1250 (100)
60% H2, 40% He	10.8	16.7	1227 (0)	Xenon	9.3	23.0	2255
81% H2, 19% He	10.5	15.0	1016 (0)	Zinc	8.0	22.0	5250 (500)


Temperature
°C
°F
Viscosity
μ X 10⁷
poise
Ratio
μ gas/μ air
Y
X

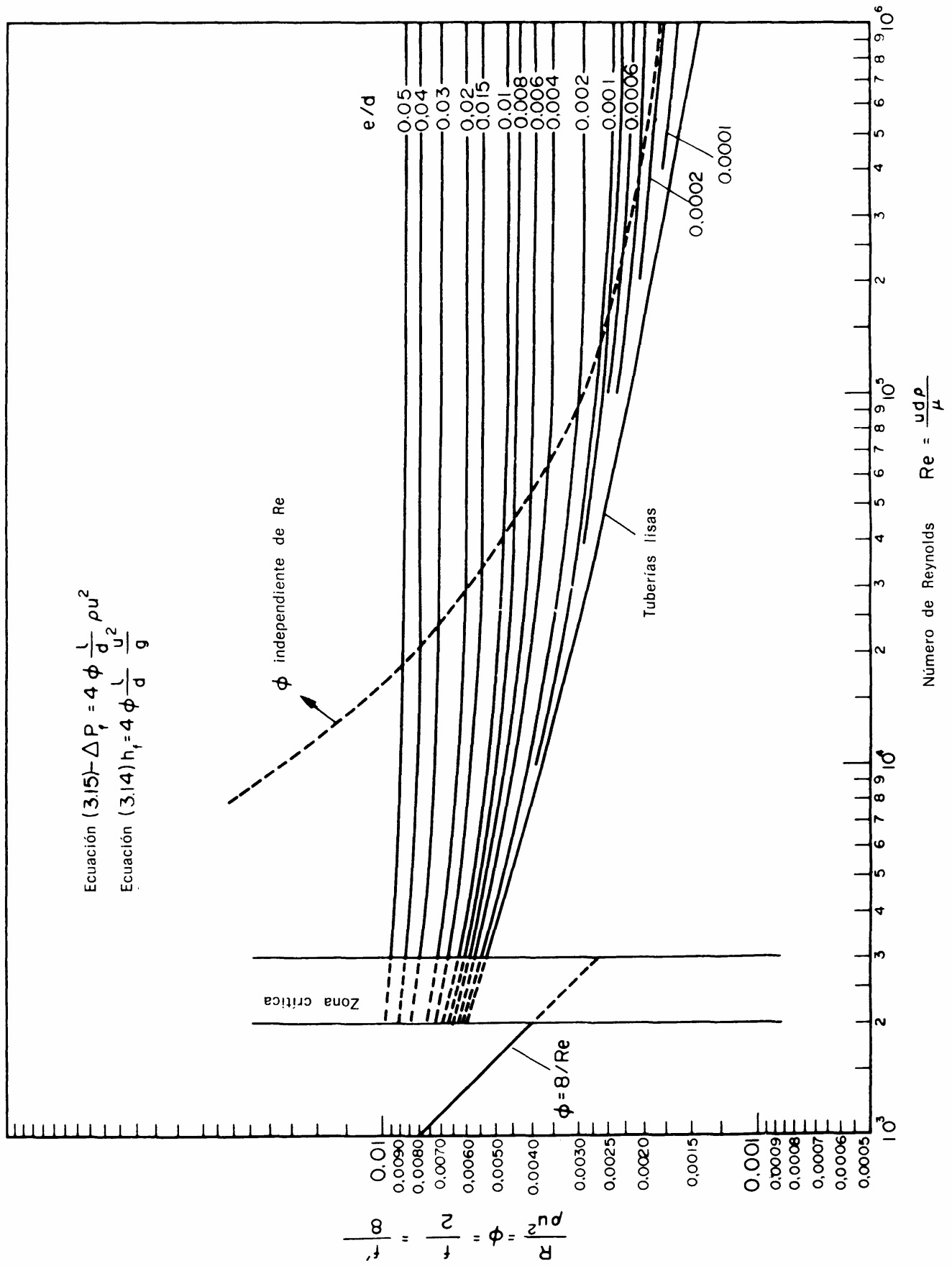
TUBERÍAS NORMALIZADAS DE ACERO

Diámetro nominal (pulgadas)	*Diámetro exterior* (cm)	*Diámetro interior* (cm)	*Espesor de pared* (cm)	*Número de catálogo*
1/8	1,029	0,683	0,173	40
1/8	1,029	0,546	0,241	80
1/4	1,372	0,925	0,224	40
1/4	1,372	0,767	0,302	80
3/8	1,715	1,252	0,231	40
3/8	1,715	1,074	0,320	80
1/2	2,134	1,580	0,277	40
1/2	2,134	1,387	0,373	80
3/4	2,667	2,093	0,287	40
3/4	2,667	1,885	0,391	80
1	3,340	2,664	0,338	40
1	3,340	2,431	0,455	80
1 1/4	4,216	3,505	0,356	40
1 1/4	4,216	3,246	0,485	80
1 1/2	4,826	4,089	0,368	40
1 1/2	4,826	3,810	0,508	80
2	6,033	5,250	0,391	40
2	6,033	4,925	0,554	80
2 1/2	7,303	6,271	0,516	40
2 1/2	7,303	5,900	0,701	80
3	8,890	7,793	0,549	40
3	8,890	7,366	0,762	80
3 1/2	10,16	9,012	0,574	40
3 1/2	10,16	8,545	0,808	80
4	11,43	10,226	0,602	40
4	11,43	9,718	0,856	80
5	14,13	12,819	0,655	40
5	14,13	12,225	0,953	80
6	16,83	15,405	0,711	40
6	16,83	14,633	1,097	80
8	21,91	20,272	0,818	40
8	21,91	19,368	1,270	80
10	27,31	25,451	0,927	40
10	27,31	24,287	1,509	80
12	32,39	30,323	1,031	40
12	32,39	28,890	1,748	80

RUGOSIDAD

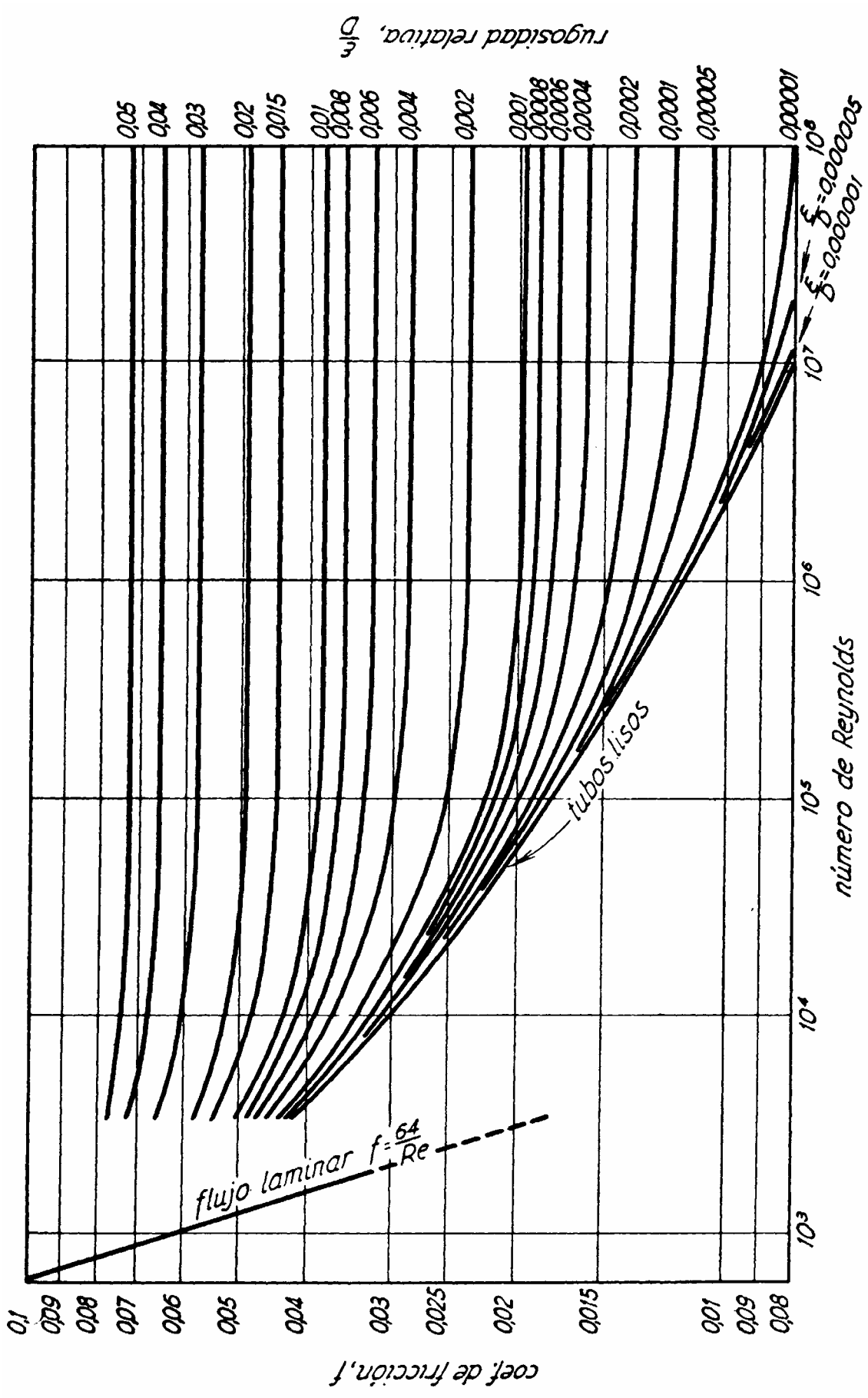

DIÁMETRO DE LA TUBERÍA, EN CENTÍMETROS
3
5
10
50
100
500
0.05
0.04
0.03
0.03
0.01
0.008
0.006
0.004
0.003
0.002
0.001
0.0008
0.0006
0.0004
0.0003
0.0002
0.0001
0.00008
0.00006
0.00004
0.00003
0.00002
0.00001
0.000008
0.000006
RUGOSIDAD RELATIVA, ε/D
TUBOS DE ACERO CON REMACHES
HORMIGÓN
TUBOS DE DUELAS DE MADERA
FUNDICIÓN
HIERRO GALVANIZADO
FUNDICIÓN REVESTIDA DE ASFALTO
ACEROS COMERCIALES O HIERRO FORJADO
TUBOS ESTIRADOS
ε=0.03
ε=0.01
ε=0.003
ε=0.001
ε=0.0006
ε=0.00085
ε=0.0005
ε=0.0004
ε=0.00015
ε=0.000005
1
2
3
4
6
10
20
30
40
60
100
200
300
DIÁMETRO DEL TUBO, EN PULGADAS

FACTOR DE FRICCIÓN



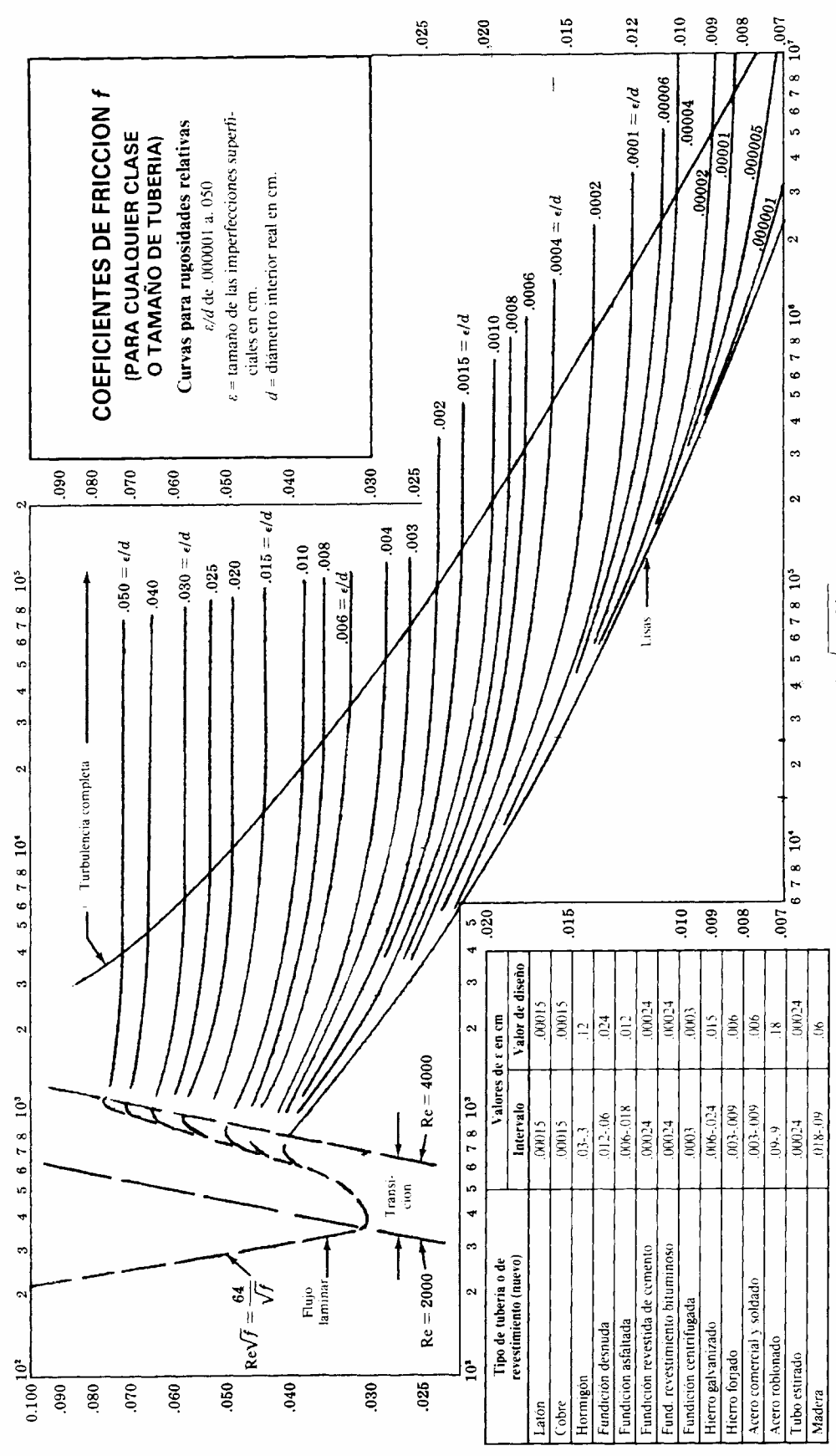
Gráfica de ϕ frente a *Re* para la fricción en tuberías.

FACTOR DE FRICCIÓN DE MOODY



Representación de la función $f = \Phi\left(Re, \frac{\varepsilon}{D}\right)$ (Buthod y Whiteley).

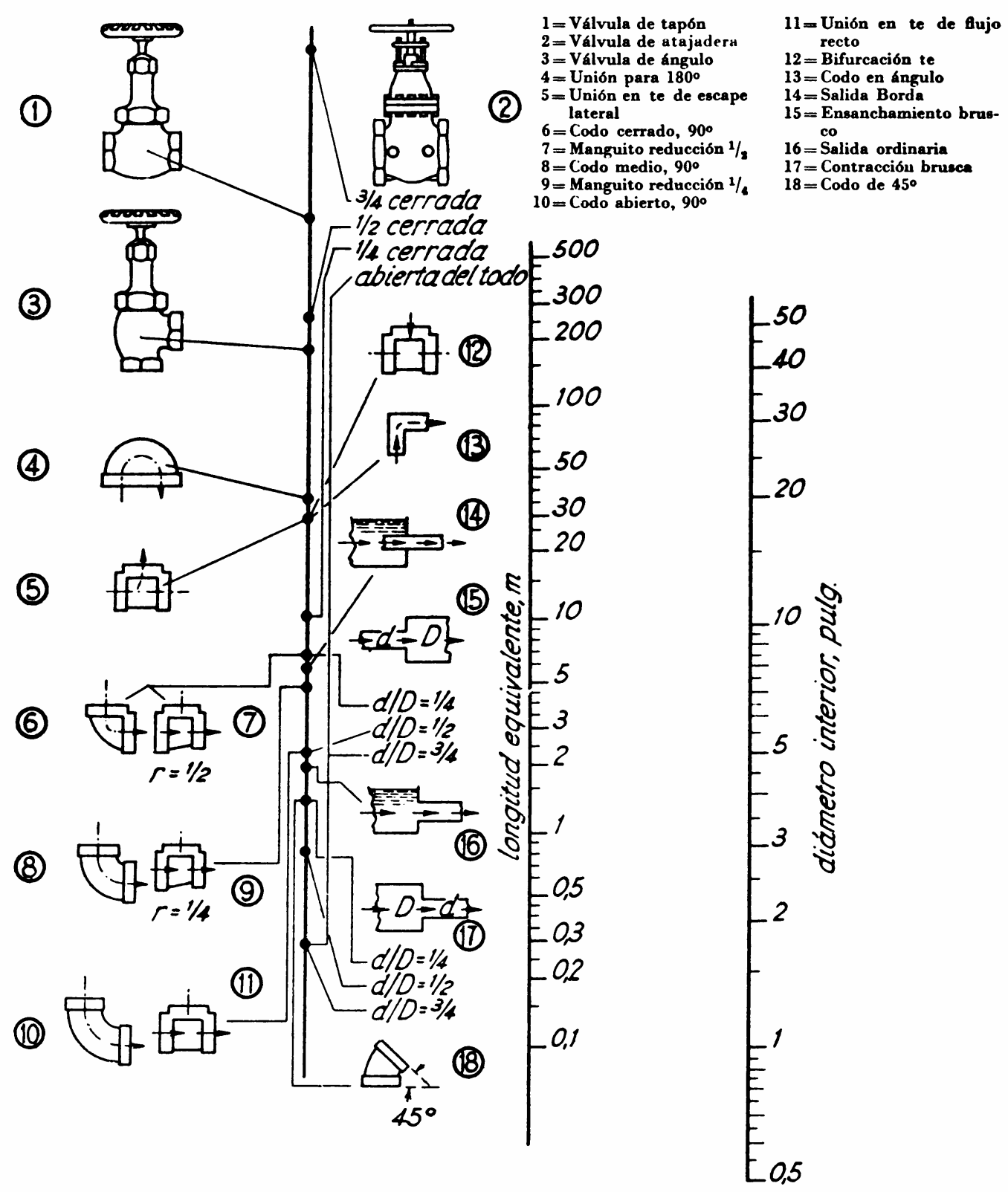
GRÁFICA DE FRICCIÓN DE VON KARMAN



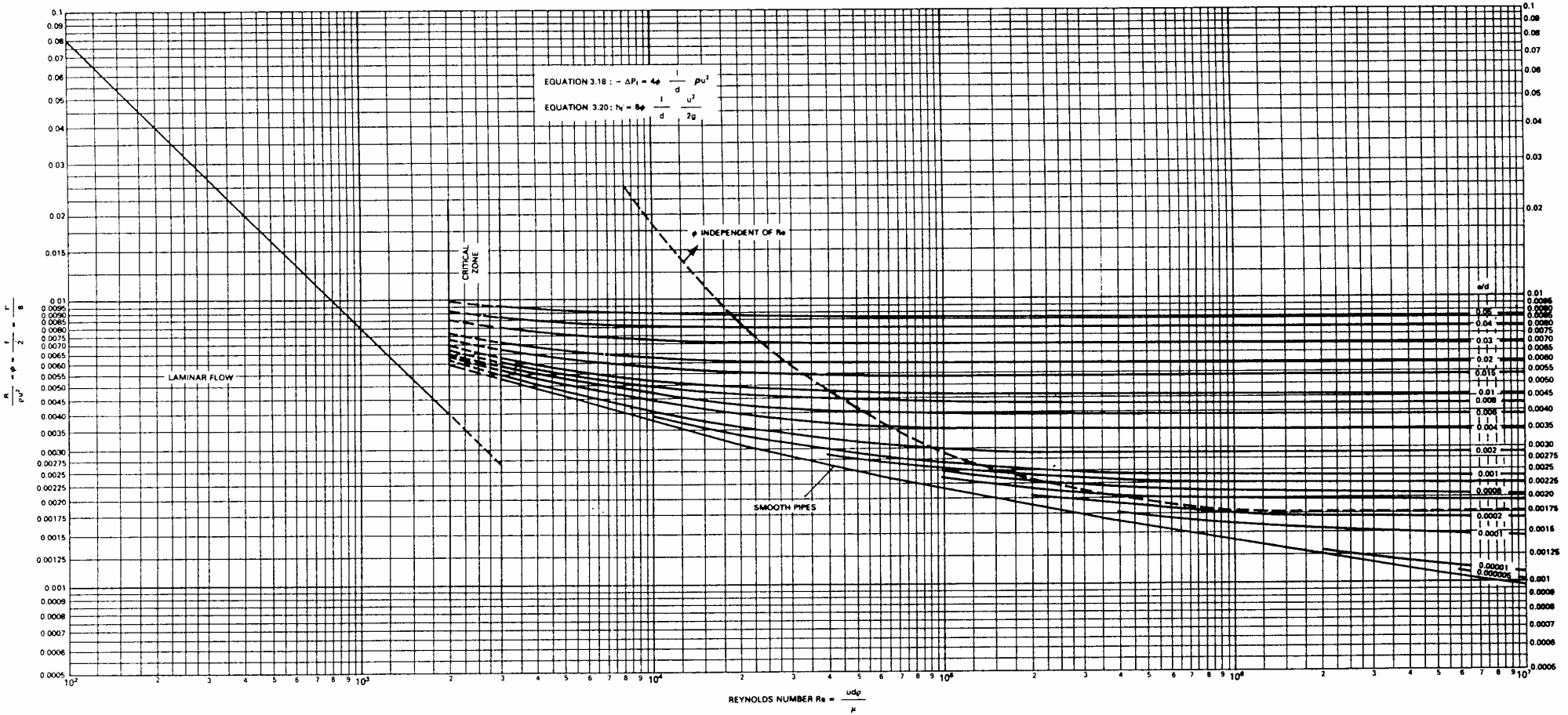
Tipo de tubería o de revestimiento (nuevo)	Valores de ε en cm	
	Intervalo	Valor de diseño
Latón	.00015	.00015
Cobre	.00015	.00015
Hormigón	.03–.3	.12
Fundición desnuda	.012–.06	.024
Fundición asfaltada	.006–.018	.012
Fundición revestida de cemento	.00024	.00024
Fund. revestimiento bituminoso	.00024	.00024
Fundición centrifugada	.0003	.0003
Hierro galvanizado	.006–.024	.015
Hierro forjado	.003–.009	.006
Acero comercial y soldado	.003–.009	.006
Acero roblonado	.09–.9	.18
Tubo estirado	.00024	.00024
Madera	.018–.09	.06

Note: 1 ft = 0.3048 m.

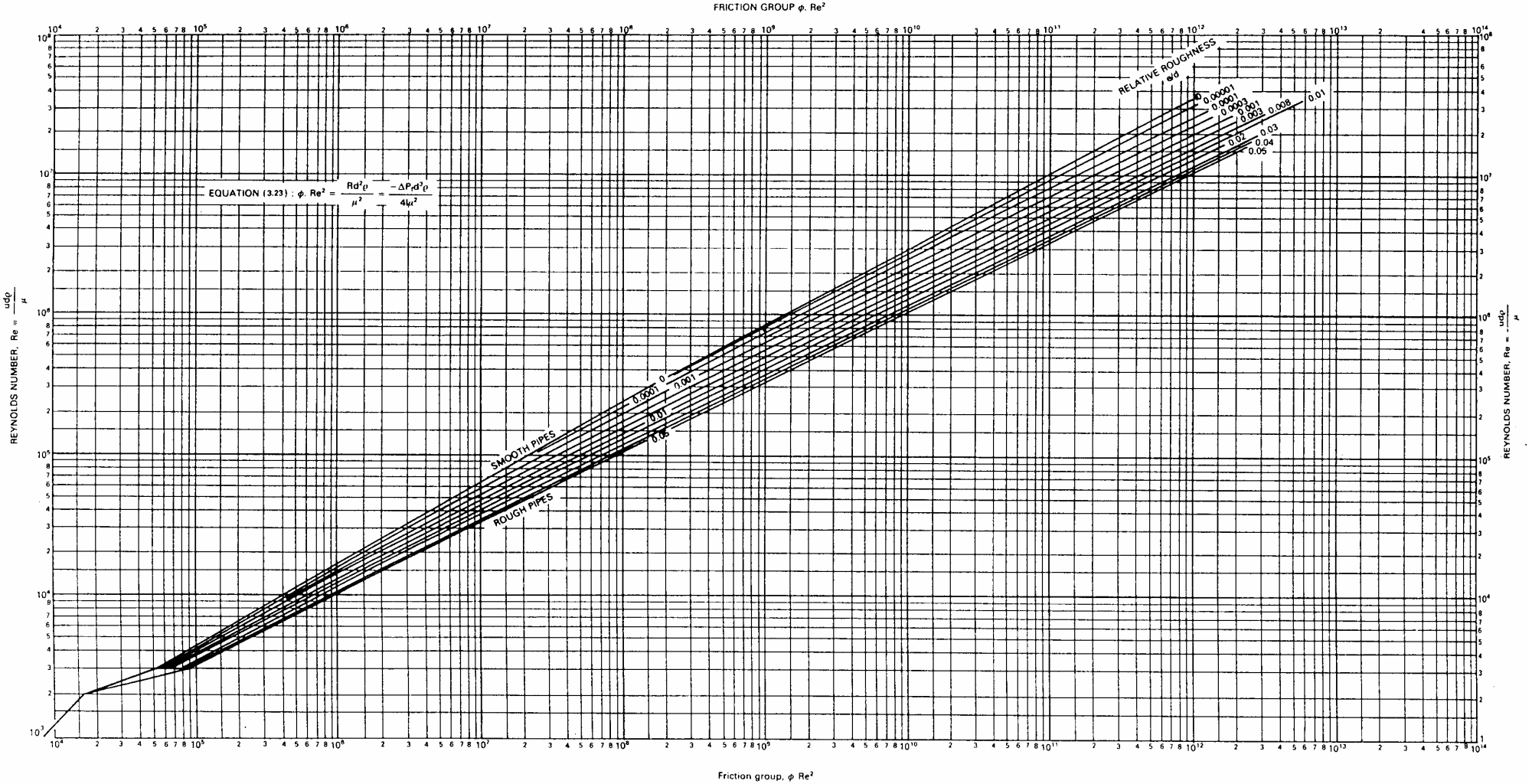
LONGITUD EQUIVALENTE



Los símbolos en el dibujo significan: r = reducción; D = diámetro de la sección mayor; d = diámetro de la sección menor.



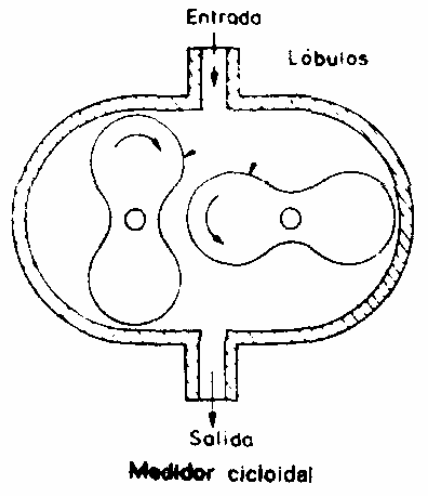
Pipe friction chart ϕ versus Re.


FRICTION GROUP ϕ. Re^2
EQUATION (3.23) : ϕ. Re^2 = $\frac{Rd^2\varrho}{\mu^2} = \frac{-\Delta P_f d^3 \varrho}{4\mu^2}$
RELATIVE ROUGHNESS $\frac{\epsilon}{d}$
0
0.00001
0.0001
0.0003
0.001
0.003
0.008
0.01
0.02
0.03
0.04
0.05
SMOOTH PIPES
ROUGH PIPES
0.0001
0.001
0.01
0.05
REYNOLDS NUMBER, Re = $\frac{ud\rho}{\mu}$
Friction group, ϕ Re^2

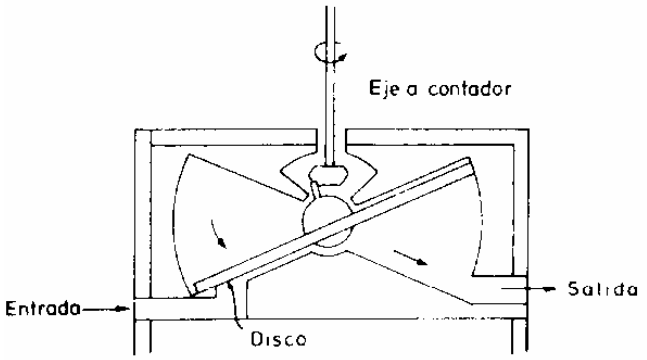
MEDIDA DEL FLUJO

- *Directos* (*Medidores de desplazamiento positivo*)
- *Indirectos*
  - *Dinámicos*
    - *Dispositivos de estrangulamiento*
    - *Rotámetro*
    - *Tubo de Pitot*
  - *Térmicos*
  - *Magnéticos*
  - *Método de mezcla*
  - *Ultrasonidos*

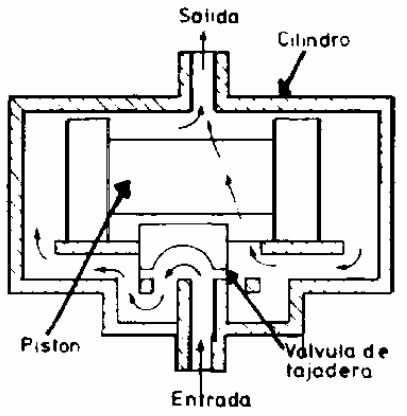
MEDIDORES DE DESPLAZAMIENTO POSITIVO



Medidor cicloidal



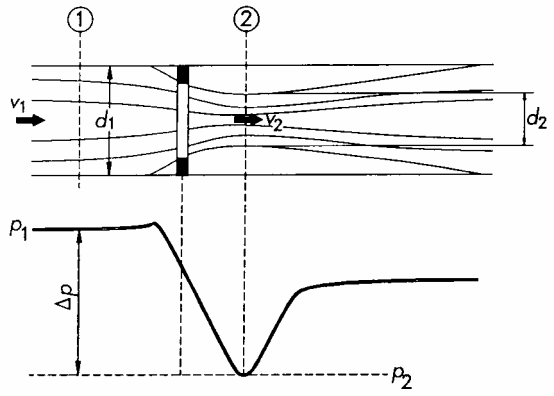
Medidor de disco oscilante.



Medidor de pistón convencional.

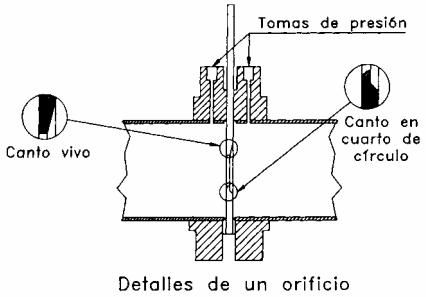
MEDIDORES DEPRIMÓGENOS

Caída de presión en elementos deprimógenos

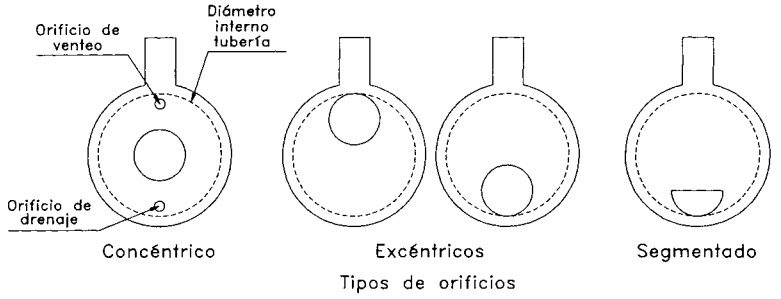


Restricción en un conducto.

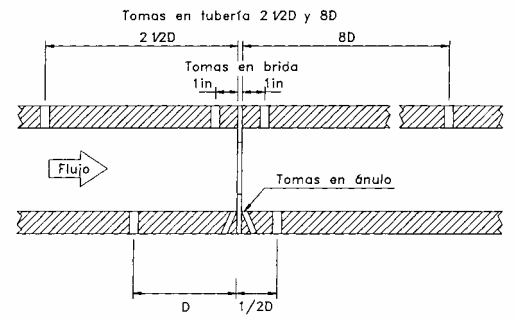
❍ *Diafragma o placa de orificio*



Detalles de un orificio

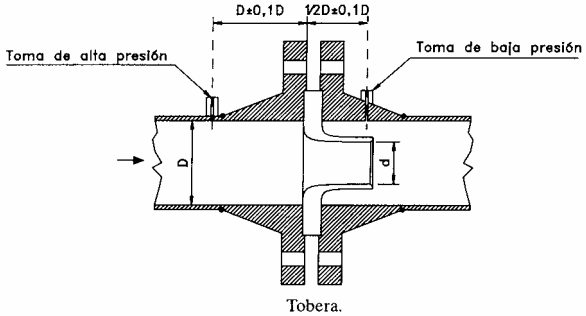


Tipos de orificios



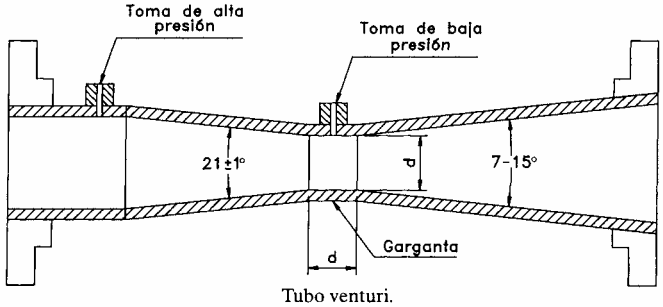
Tomas en D y 1/2D (similar a tomas "vena contracta")

❍ *Boquillas y toberas*



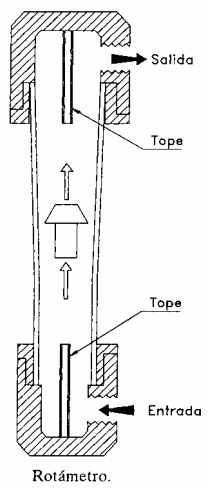
Tobera.

❍ *Venturis*

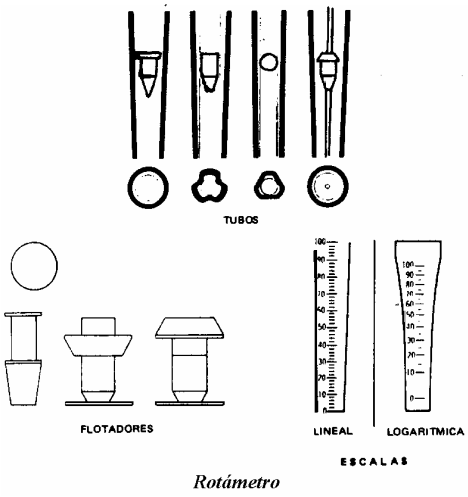


Tubo venturi.

ROTÁMETRO

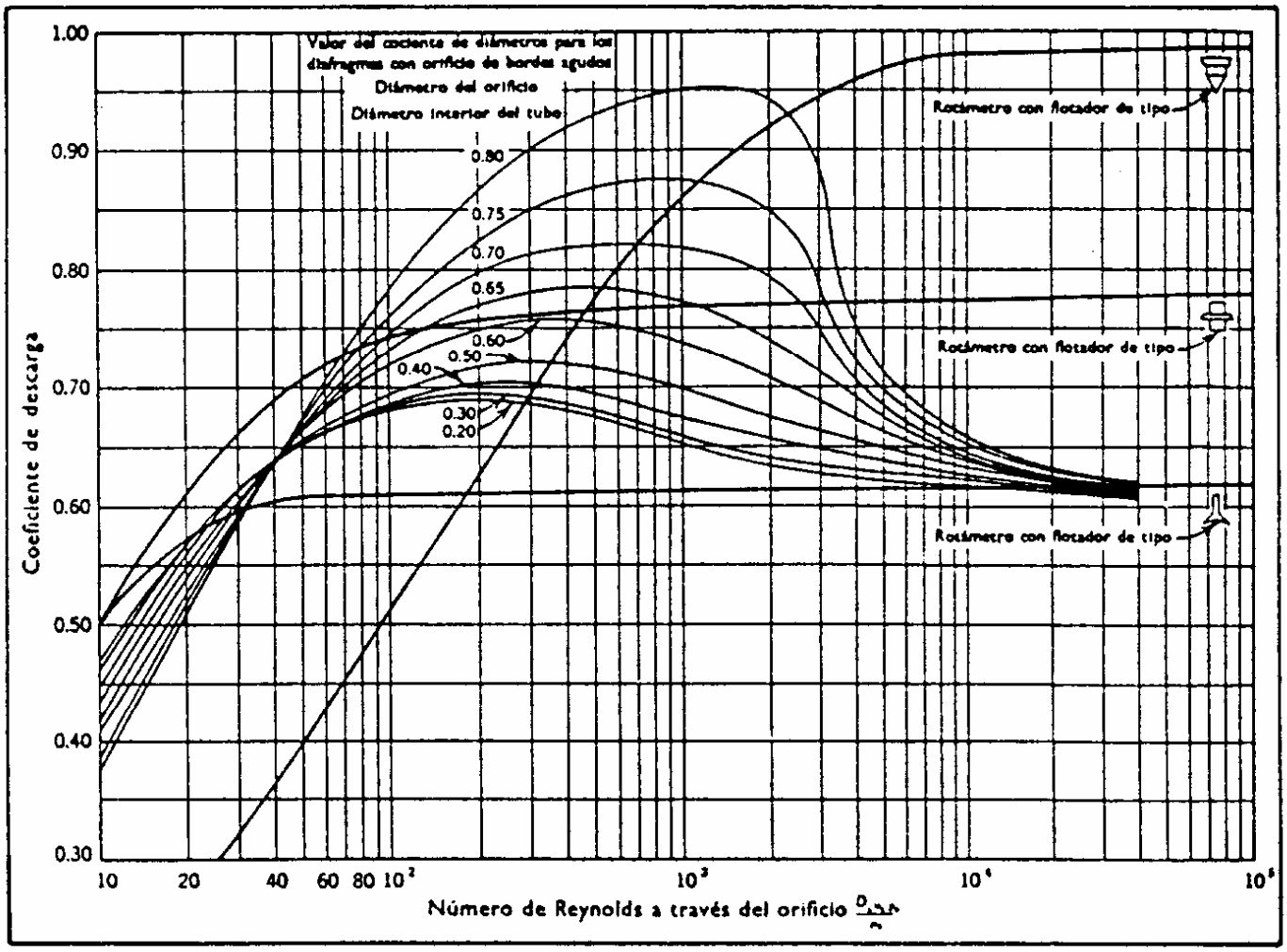


Rotámetro.



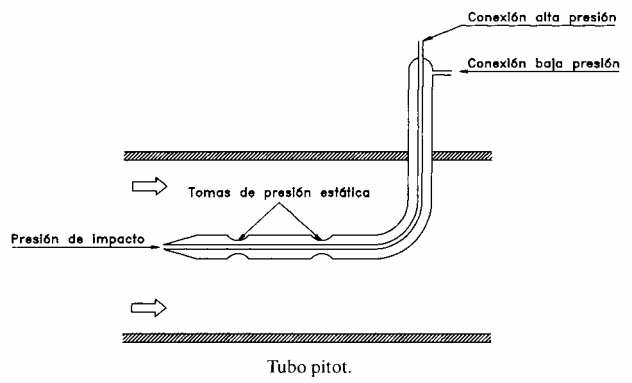
Rotámetro

❍ *Coeficiente de descarga en orificios y rotámetros*



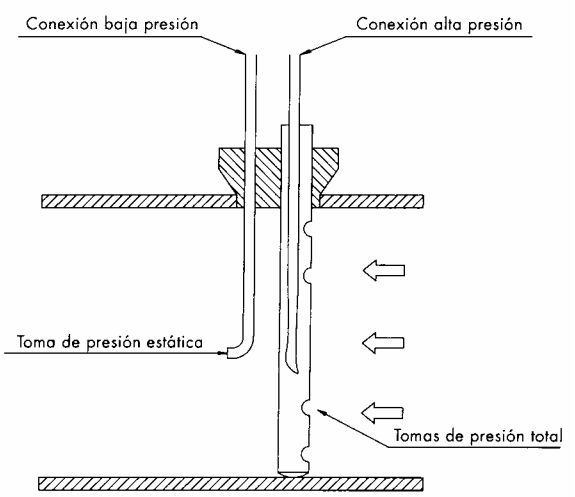
Variación del coeficiente de descarga de placas de orificio y rotámetros en función del número de Reynolds.

TUBO DE PITOT



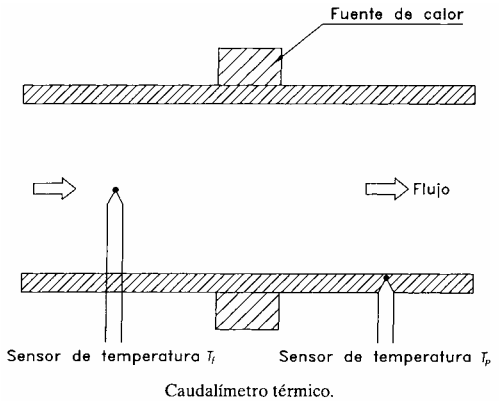
Tubo pitot.

❍ *Tubo Annubar*



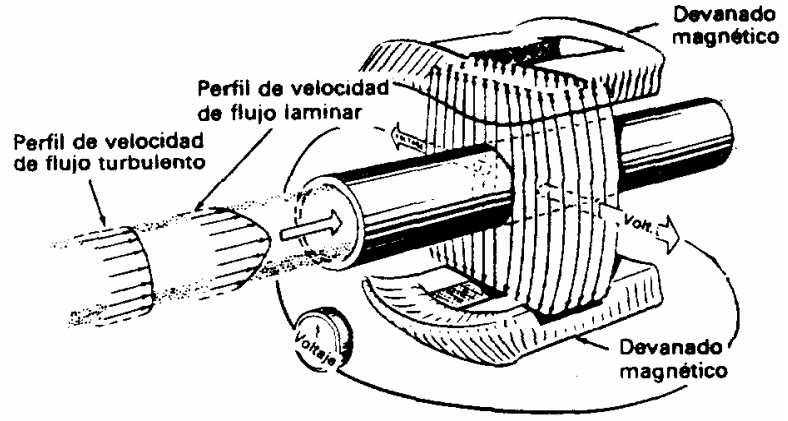
Tubo annubar.

MÉTODO TÉRMICO

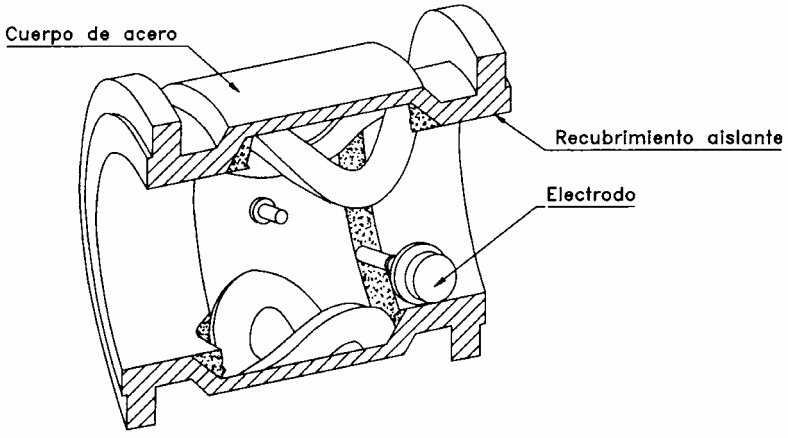


Caudalímetro térmico.

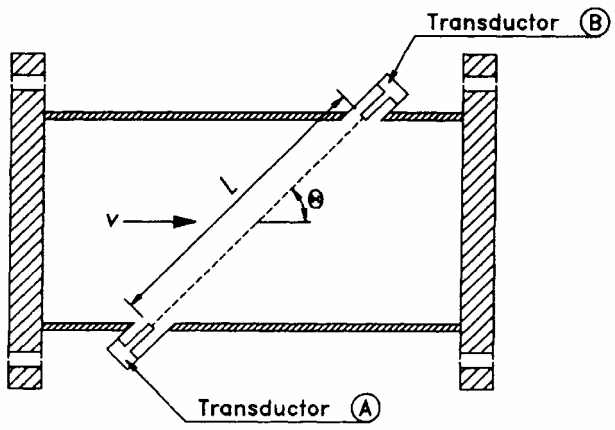
MÉTODO MAGNÉTICO



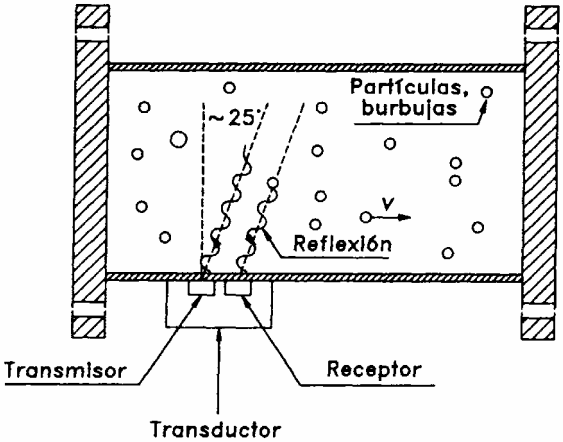
Sensor magnético de flujo



MÉTODO DE ULTRASONIDOS



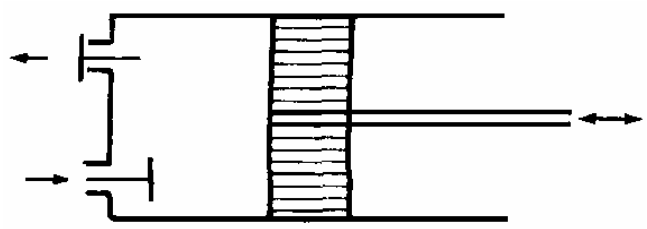
medidor de ultrasonidos

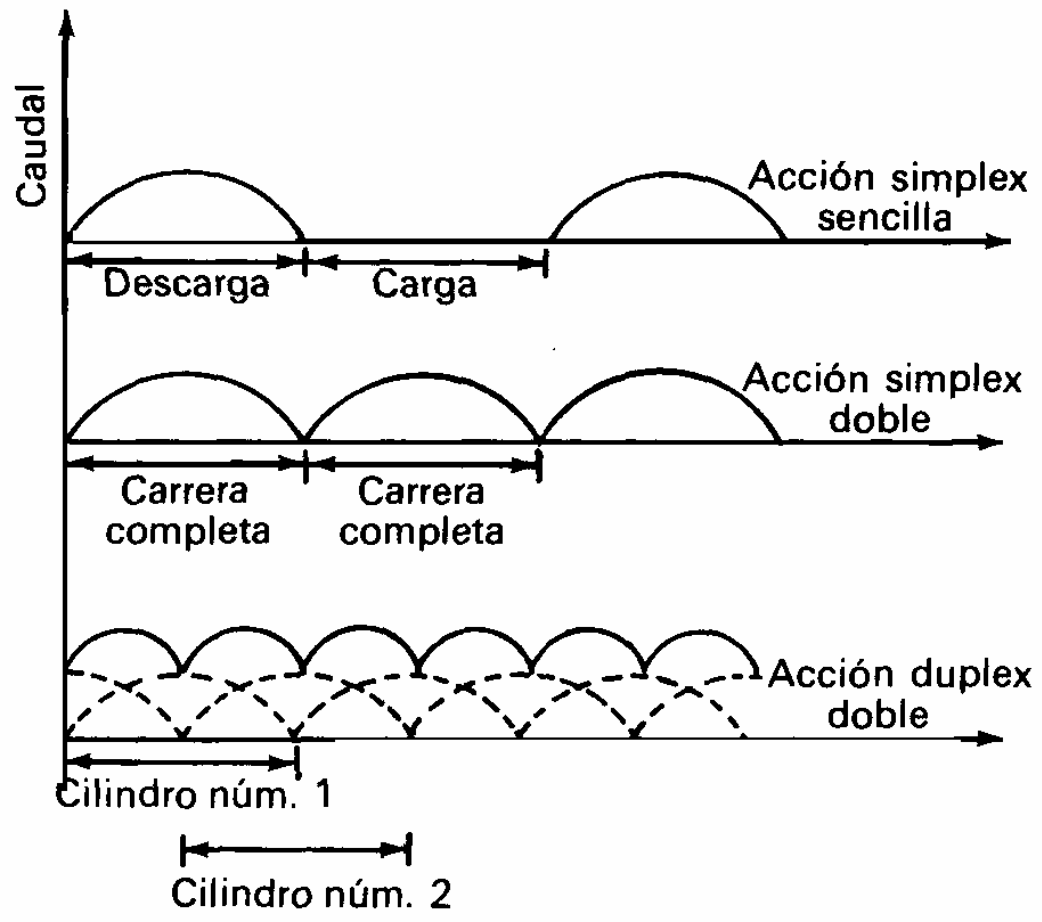


medidor Doppler

BOMBAS DE DESPLAZAMIENTO POSITIVO I

Bomba de émbolo alternativo

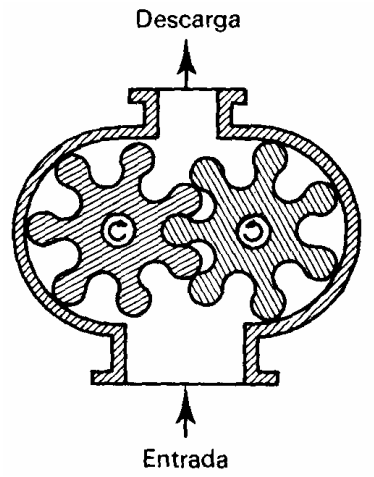




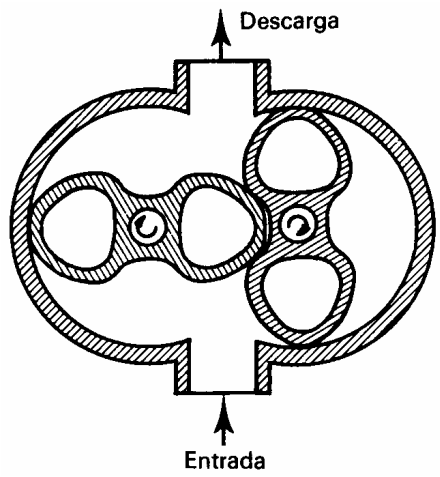
BOMBAS DE DESPLAZAMIENTO POSITIVO II

❍ *Bombas de engranajes rotatorios*

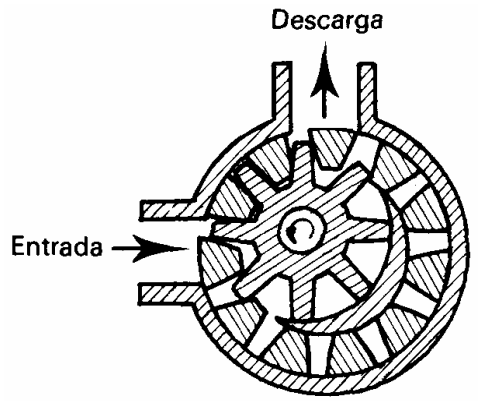
Ruedas dentadas



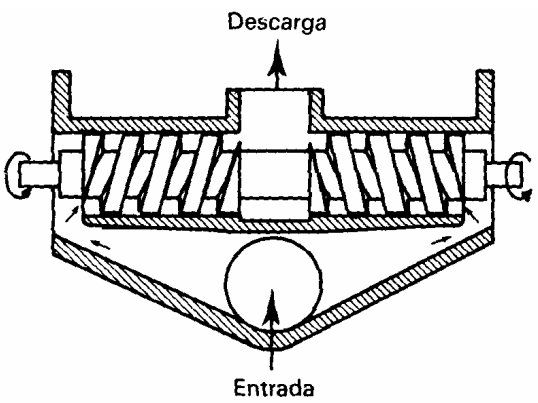
Lóbulos giratorios



Ruedas excéntricas

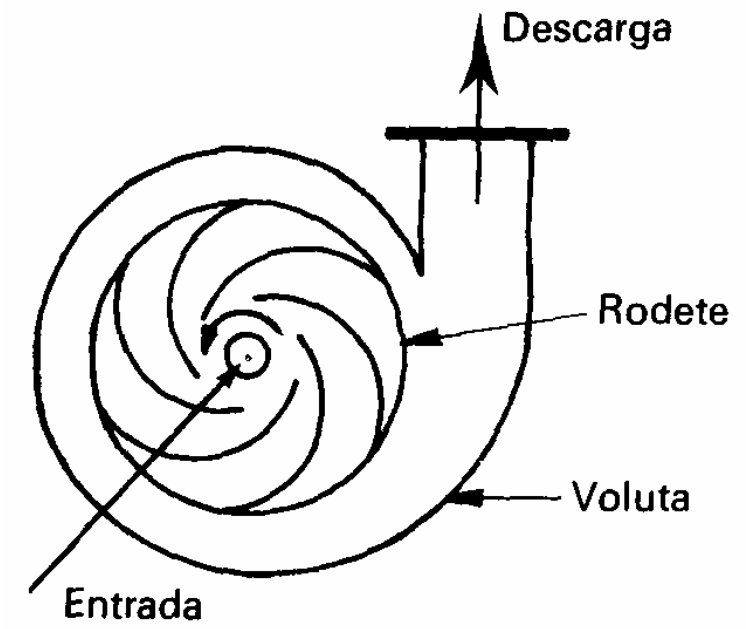


Tornillo

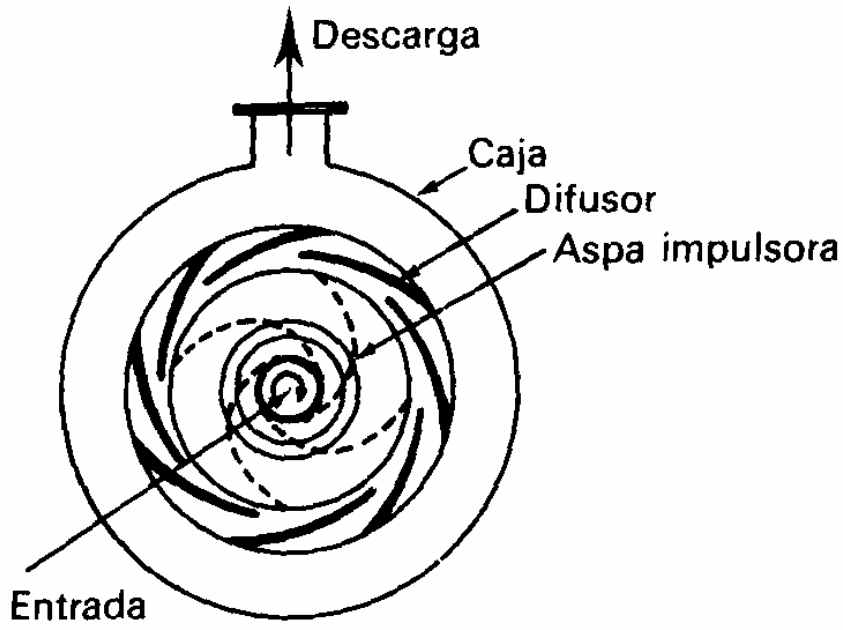


BOMBAS CENTRÍFUGAS

❍ *Bomba centrífuga de voluta*

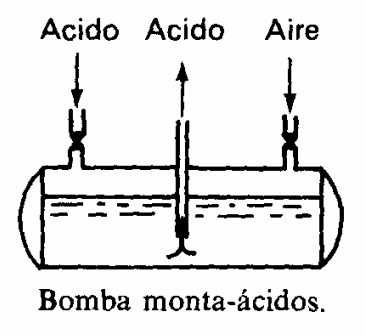


❍ *Bomba centrífuga de difusor*



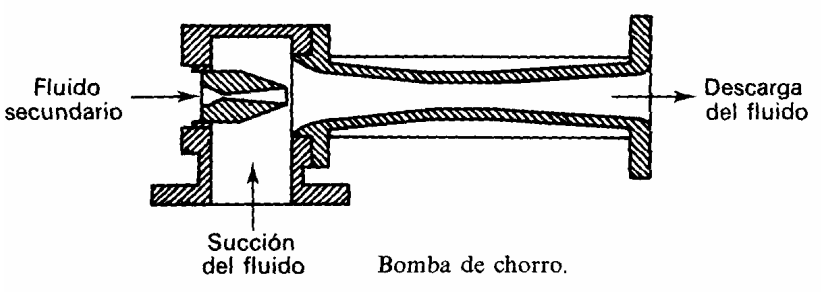
BOMBAS ESPECIALES

❍ Bomba Monta-ácidos



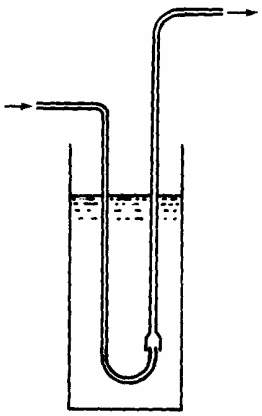
Bomba monta-ácidos.

❍ Eyector

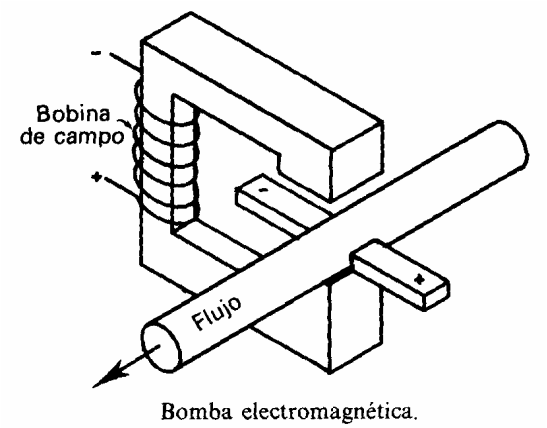


Bomba de chorro.

❍ Bomba mamut


Bomba Mamut.

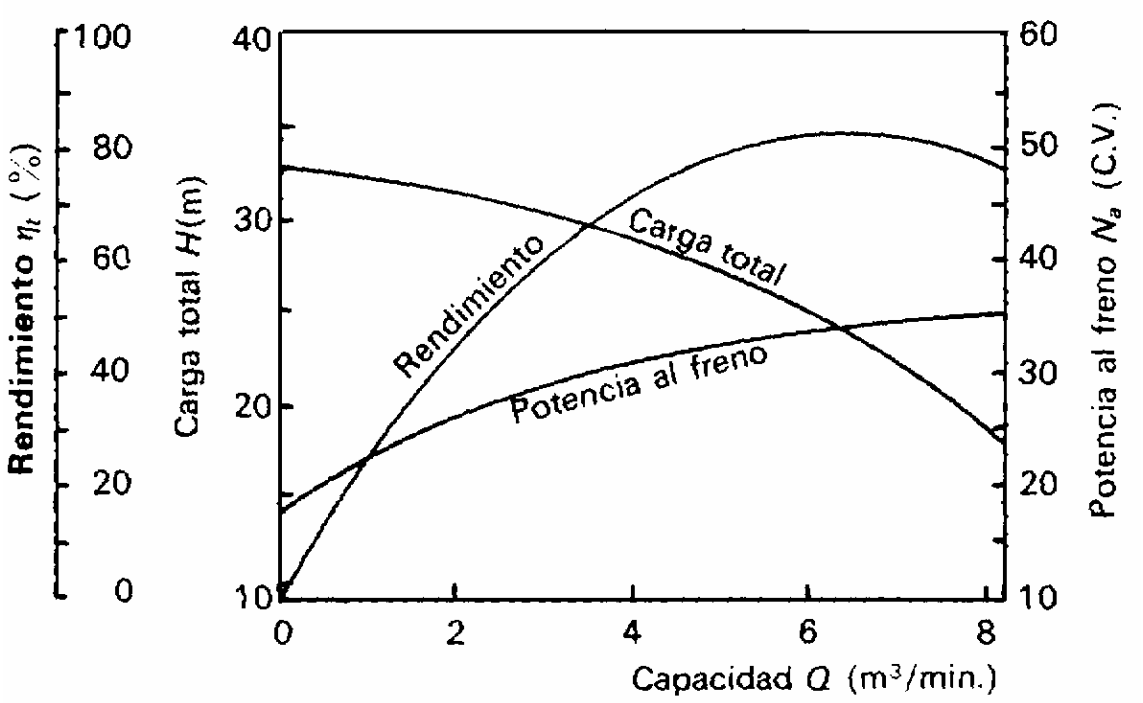
❍ Bomba electromagnética

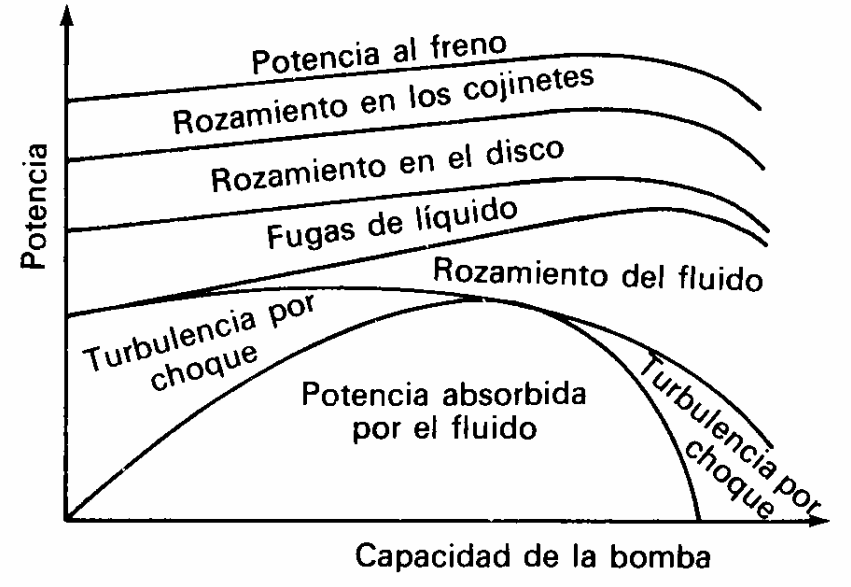


Bomba electromagnética.

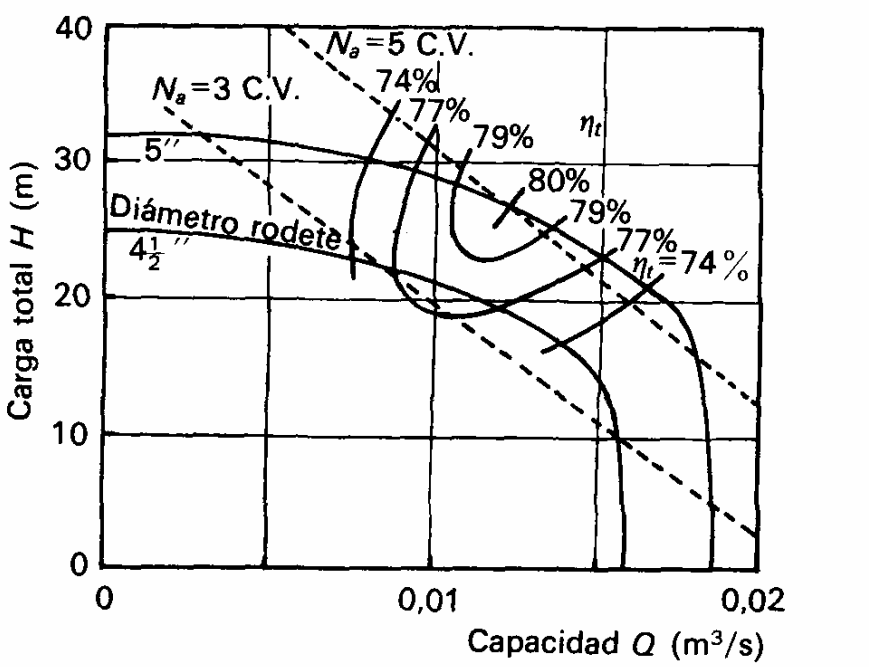
CURVAS CARACTERÍSTICAS I

- Curva *carga total – caudal* (H-Q)
- Curva *potencia al freno – caudal* (N_a-Q)
- Curva *rendimiento – caudal* (η_t-Q)

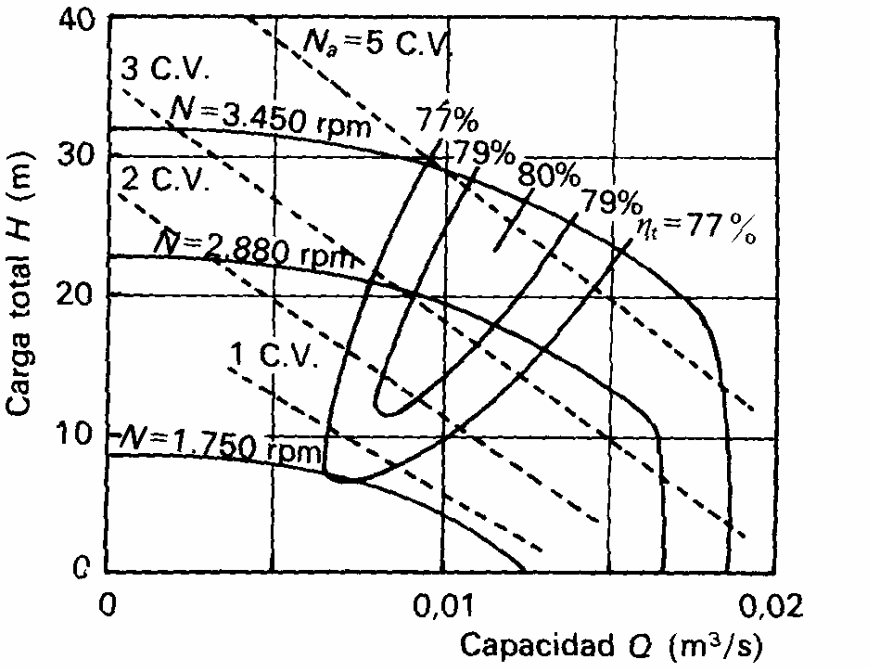




CURVAS CARACTERÍSTICAS II

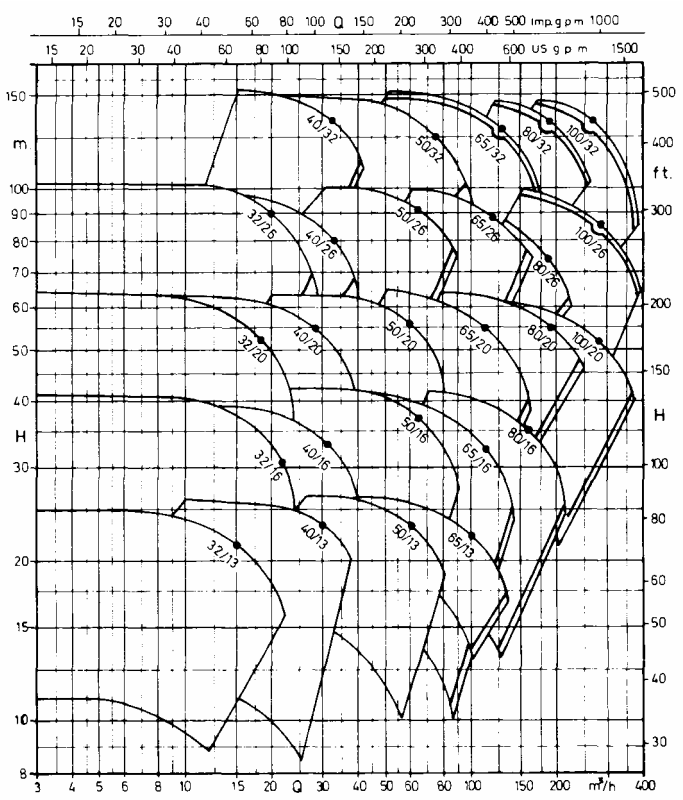


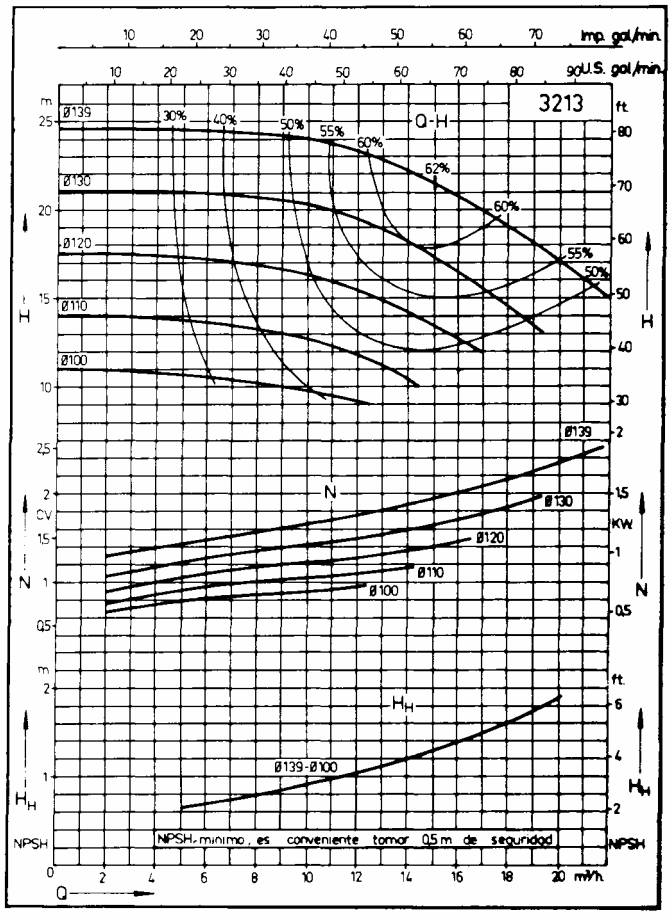
Curvas características de una bomba centrífuga a 3.450 rpm en función del tamaño del rodete.



Curvas características de una bomba centrífuga de 5″ de tamaño del rodete en función de la velocidad de giro.

CURVAS CARACTERÍSTICAS III





CONVECCIÓN NATURAL Y FORZADA I

ECUACIONES DE CORRELACIÓN PARA CONVECCIÓN NATURAL

Superficie	**L**	**Gr.Pr**	**a**	**m**	**Condiciones ambientales**					
					Aire			**Agua**		
					b	**c**	**d**	**b**	**c**	**d**
Placas y cilindros verticales (D/L ≥35.Gr$^{1/4}$)	*L*	< 10^4 (Laminar) 10^4 - 10^9 (Laminar) >10^9 (turbulento)	1.36 0.59 0.13	1/5 1/4 1/3	 1.4 1.3	 1/4 1/3	 -1/4 0	 120	 1/3	 0
Esferas y cilindros horizontales (De<0,2 m)	D_e	< 10^{-5} 10^{-5} – 10^{-3} 10^{-3} – 1 1 - 10^4 10^4 - 10^9 (Laminar) >10^9 (Turbulento)	0.49 0.71 1.09 1.09 0.53 0.13	0 1/25 1/10 1/5 1/4 1/3	 1.31 .2	 1/4 1/3	 -1/4 0			
Placa caliente hacia arriba o placa fría hacia abajo. *Placa caliente hacia abajo o placa fría hacia arriba*	*L*	10^5 – 2.10^7 (Laminar) 2.10^7 – 3.10^{10} (Turbulento) 3.10^5 – 3.10^{10} (Laminar)	0.54 0.14 0.27	1/4 1/3 1/4	1.31 .5 0.64	1/4 1/3 1/4	-1/4 0 -1/4			
Cilindros y placas verticales	*L*	1 < Pr < 40	Gr > 10^9; $(Nu) = 0.138 \cdot (Gr)^{0.36} \cdot \left(Pr^{0.175} - 0.55\right)$ Gr < 10^9; $(Nu) = 0.683 \cdot (Gr)^{0.25} \cdot \left(\frac{Pr}{0.861 + Pr}\right)^{0.25}$							
Esfera solitaria	*D*	$Gr^{0.25}.Pr^{0.33}$ < 200	$Nu = 2.0 + 0.6 \cdot Gr^{0.25} \cdot Pr^{0.33}$							

Para el caso del aire y el agua en condiciones ambientales (20ºC y presión atmosférica), se ha utilizado una ecuación dimensional aproximada de la expresión de Nusselt, que viene dada por:

$$h = b.\Delta T^{c}.L^{d} \quad con \begin{cases} h\left[=\right]\frac{W}{m^2.K} \\ \Delta T\left[=\right]K \\ L\left[=\right]m \end{cases}$$

Todas las propiedades en las expresiones se toman a la temperatura de película

$$T_P = \frac{T_G + T_{pared}}{2}, \quad T_G = \frac{T_{ent.} + T_{sal.}}{2} \qquad T_P = Temp.\,de\,película \qquad T_G = Temp.\,global$$

CONVECCIÓN NATURAL Y FORZADA II

ECUACIONES DE CORRELACIÓN PARA CONVECCIÓN FORZADA I

FLUJO POR EL INTERIOR DE TUBOS

Flujo turbulento Re>10000 0.7<Pr<700 ΔT moderado

Propiedades en el interior del fluido (temperatura global del fluido). $\left(T_G = \frac{T_{ent.} + T_{sal.}}{2}\right)$

Ecuación general

$$\frac{h.D}{K} = 0.023\left[1+\left(\frac{D}{L}\right)^{0.7}\right]\left[1+3.5\frac{D}{D_{serp}}\right]\left(\frac{\rho.u.D}{\mu}\right)^{0.8}\left(\frac{C_p.\mu}{K}\right)^{1/3}\left(\frac{\mu}{\mu_S}\right)^{0.14}$$

Nusselt *Efecto de entrada* *Serpentines* *Reynolds* *Prandtl*

Aproximaciones

gases comunes (error ± 25%) $h = 0.0018\frac{C_p\dot{m}^{0.8}}{D^{0.2}} \quad \frac{W}{m^2K}$

agua $h = 91(T+68)\frac{u^{0.8}}{D^{0.2}} \quad \frac{W}{m^2K} \quad con\ T\ en\ ^oC$

Dittus-Böelter

Calentamiento $Nu = 0.023Re^{0.8}Pr^{0.4}$

Enfriamiento $Nu = 0.023Re^{0.8}Pr^{0.3}$

Ecuación de Colburn $Nu = 0.023Re_{T_P}^{0.8}Pr_{T_P}^{1/3} \qquad j_H = 0.023Re_{T_P}^{-0.2}$

$$Stanton = St = \frac{Nu}{Re.Pr} = \frac{h}{u.\rho.C_P} \qquad j_H = St.Pr^{2/3} = \frac{Nu}{Re.Pr^{1/3}} \quad factor\ de\ Chilton-Colburn$$

Ecuación de Sieder-Tate. (Fluidos muy viscosos)

$$Nu = 0.023Re^{0.8}.Pr^{1/3}\left(\frac{\mu}{\mu_s}\right)^{0.14}$$

Para ΔT elevados $Nu = \frac{0.023Re^{0.8}Pr^{0.4}}{(T_S/T_G)^{0.29+0.0019L/D}} \qquad T_S/T_G < 8$

Tubos no circulares $D_H = 4(A/P_m)$

Se utiliza el diámetro hidráulico en las ecuaciones estudiadas.

Sección anular

$$\frac{h_iD_H}{K} = 0.02\left(\frac{D_H\dot{m}}{\mu}\right)^{0.8}\left(\frac{C_P\mu}{K}\right)^{1/3}\left(\frac{D_o}{D_i}\right)^{0.53} \qquad D_i = diámetro\ tubo\ interno,\ D_o = diámeto\ tubo\ externo$$

Flujo de transición 2100<Re<10000

$$\frac{hD}{K} = 0.116\left(Re^{2/3}-125\right)Nu^{1/3}\left[1+\left(\frac{D}{L}\right)^{2/3}\right]\left(\frac{\mu}{\mu_s}\right)^{0.14}$$

CONVECCIÓN NATURAL Y FORZADA III

ECUACIONES DE CORRELACIÓN PARA CONVECCIÓN FORZADA II

FLUJO POR EL INTERIOR DE TUBOS

Flujo laminar Re<2100

Perfiles de velocidad y térmicos completamente desarrollados

El perfil de velocidad está completamente desarrollado para: $L/D = 0.05.Re$

El perfil térmico está completamente desarrollado para: $L/D = 0.05.Re.Pr$

Flujo de calor de entrada en la pared constante $\frac{hD}{K} = 4.36$

Temperatura constante de pared $\frac{hD}{K} = 3.66$

FLUJO POR EL EXTERIOR DE SÓLIDOS

Flujo normal a un cilindro solitario

Gases $\frac{h.D}{K_{T_P}} = a(Re)^n_{T_P}(Pr)^{0.3}_{T_P}$ $T_P = \frac{T_G + T_{pared}}{2}$ $T_G = \frac{T_{ent.} + T_{sal.}}{2}$ $T_P = Temp.\,de\,película$ $T_G = Temp.\,global$

Líquidos $\frac{hD}{K_{T_P}} = \left[0.35 + 0.56(Re)^{0.52}_{T_P}\right]\left(\frac{C_{T_P}.\mu}{K_{T_P}}\right)^{0.3}$

Coeficientes para flujo de gas normal a un cilindro solitario:

Re_P	a	n
1-4	0.960	0.330
4-40	0.885	0.385
40-4000	0.663	0.466
4000-40000	0.174	0.618
40000-250000	0.257	0.805

FLUJO POR EL EXTERIOR DE SÓLIDOS

Flujo para bancadas de tubos $(Nu)_{T_P} = 0.33.C_h Re^{0.6}_{T_P} Pr^{0.3}_{T_P}$

C_h, es un coeficiente corrector que depende de la geometría de la bancada (Coulson, p.288)

Flujo sobre esferas solitarias

Gases $(Nu)_{T_P} = 2 + 0.6.Re^{0.5}_{T_P} Pr^{1/3}_{T_P}$ $Re_{T_P} < 325$

$(Nu)_{T_P} = 0.4.Re^{0.6}_{T_P} Pr^{1/3}_{T_P}$ $Re_{T_P} < 325 - 70000$

Líquidos $(Nu)_{T_P} = \left(0.97 + 0.68.Re^{0.52}_{T_P}\right) Pr^{0.3}_{T_P}$

Lechos porosos $j_H = 0.91\phi Re^{-0.51}_{T_P}$ $Re_{T_P} < 50$

$j_H = 0.61\phi Re^{-0.41}_{T_P}$ $Re_{T_P} > 50$

Φ, factor de forma (Bird)

CONVECCIÓN NATURAL Y FORZADA IV

ECUACIONES DE CORRELACIÓN PARA CONVECCIÓN FORZADA III

TANQUES ENCAMISADOS Y AGITADOS

$$\frac{hD_{camisa}}{K} = a\left(\frac{L^2.N_r.\rho}{\mu}\right)^b\left(\frac{C_P.\mu}{K}\right)^{1/3}\left(\frac{\mu}{\mu_S}\right)^m$$

Coeficientes para tanques agitados:

Agitador	*a*	*b*	*m*	*Re*
Paleta	0.36	2/3	0.21	$300\text{-}3.10^5$
Turbina de palas flotante	0.53	2/3	0.24	80-200
Disco, turbina de				
palas planas	0.54	2/3	0.14	$40\text{-}3.10^5$
hélice	0.54	2/3	0.14	2.10^3
áncora	1.0	1/2	0.18	10-300
áncora	0.36	2/3	0.18	300-40000
helicoidal	0.633	1/2	0.18	$8\text{-}10^5$

CONVECCIÓN CON CAMBIO DE ESTADO

ECUACIONES DE CORRELACIÓN PARA CONVECCIÓN CON CAMBIO DE FASE

EBULLICIÓN DE LÍQUIDOS

Ebullición de líquidos saturados

Ebullición nucleada

$$\frac{C_{Pl}.\Delta T}{\Delta H_{vap} Pr_l^{1.7}} = C_{sf}\left[\frac{q/A}{\mu_l.\Delta H_{vap}}\sqrt{\frac{\sigma^*}{(\rho_l-\rho_v)}}\right]^{0.33}$$

Ecuación de *Rohsenow*

C_{Pl}, calor específico del líquido saturado
Pr_l, número de Prandtl del líquido saturado
μ_l, viscosidad del líquido saturado
σ^*, tensión superficial en la superficie sólido-líquido
ΔH_{vap}, calor latente de vaporización
ΔT, diferencia de temperaturas entre la pared y la de saturación
ρ_l y ρ_v, densidades de líquido y vapor saturados
C_{sf}, constante función superficie sólido-líquido (≈ 0.013)

Ebullición de película estable sobre tubos horizontales

$$h = 0.62\left[\frac{k_v^3.\rho_v(\rho_l-\rho_v)g.\Delta H_{vap}}{\mu_v.D_{ex}.\Delta T}\left(1+\frac{0.4C_{pv}.\Delta T}{\Delta H_{vap}}\right)\right]^{1/4}$$

Ecuación de *Bromley*

k_v, conductividad térmica del vapor saturado.
D_{ex}, diámetro exterior del tubo

CONDENSACIÓN DE VAPORES

Condensación en película

Tubos verticales (exterior)

$$\frac{hL}{k_l} = 0.943\left(\frac{L^2.\rho_l^2.g.\Delta H_{vap}}{k_l.\mu_l.\Delta T}\right)^{1/4}$$

Ecuación de Nusselt

Tubos horizontales (exterior)

$$\frac{h.D_o}{k_l} = 0.725\left(\frac{D_o^2.\rho_l^2.g.\Delta H_{vap}}{k_l.\mu_l.\Delta T}\right)^{1/4}$$

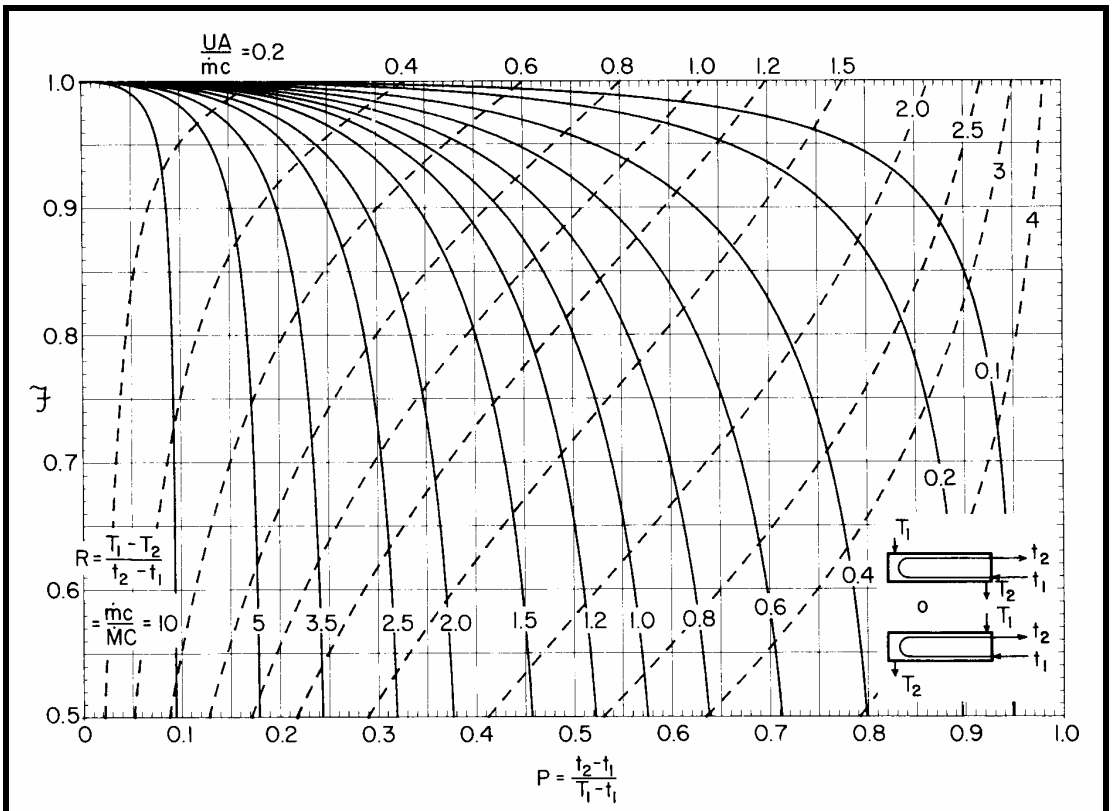
$T_l = T_v - \frac{3}{4}(T_v - T_s)$, temperatura de referencia

L, longitud del tubo
D_o, diámetro exterior del tubo
ΔT, temperatura del vapor – temperatura de la superficie externa del tubo
ρ_l y μ_l, densidad y viscosidad del condensado a T_L.
h, coeficiente individual medio del tubo

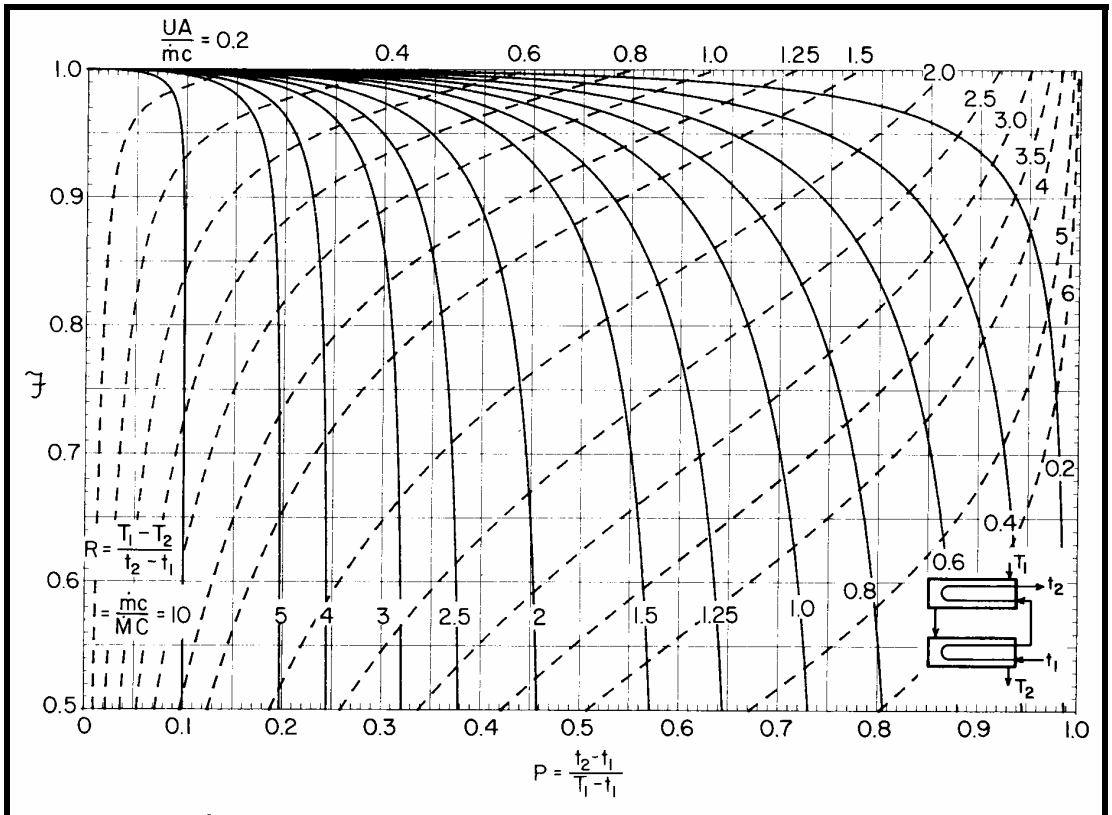
Condensación en gotas

No hay correlaciones (h muy elevado)

FACTORES DE CORRECCIÓN PARA INTERCAMBIADORES DE CARCASA Y TUBOS I

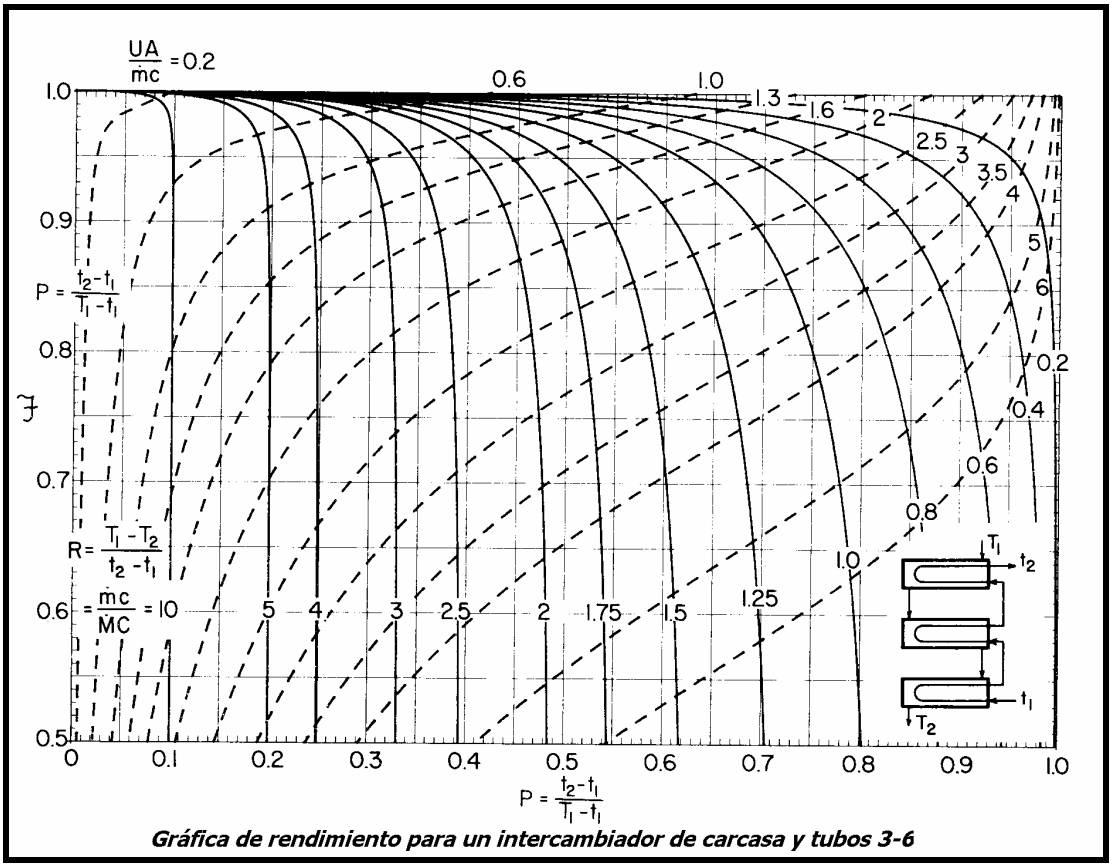


Gráfica de rendimiento para un intercambiador de carcasa y tubos 1-2

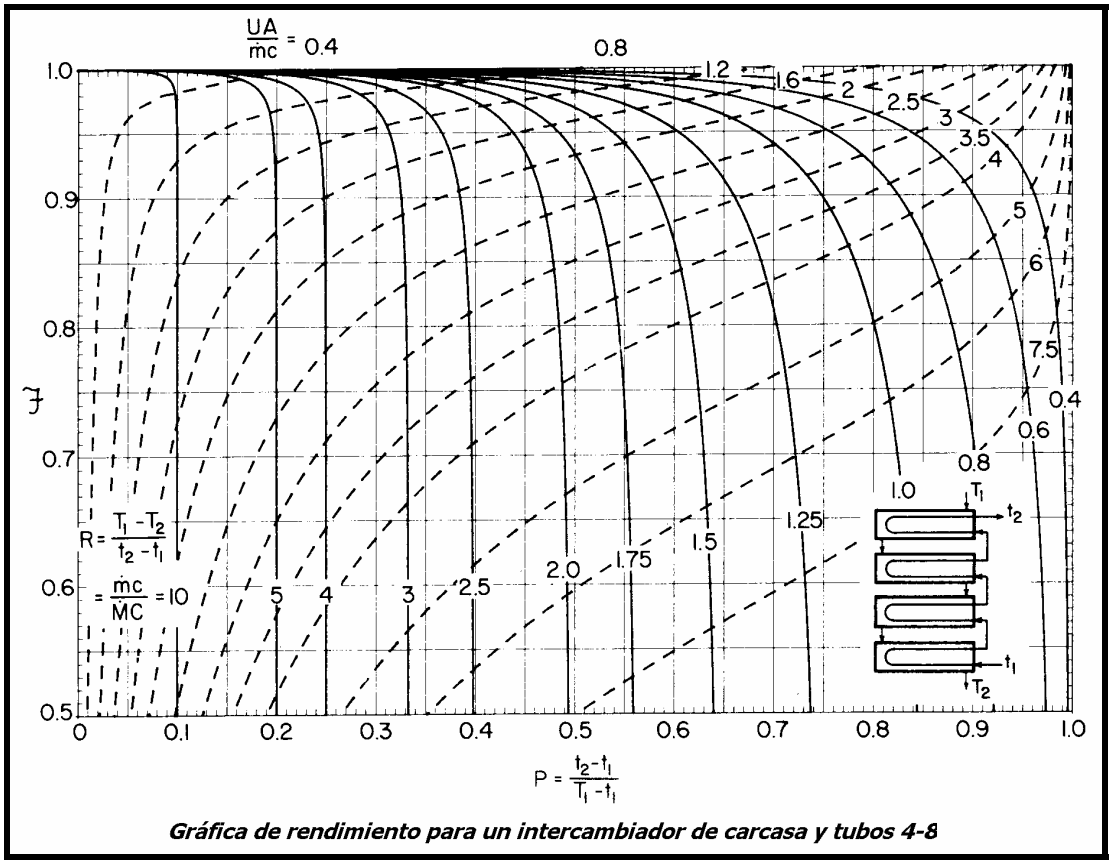


Gráfica de rendimiento para un intercambiador de carcasa y tubos 2-4

FACTORES DE CORRECCIÓN PARA INTERCAMBIADORES DE CARCASA Y TUBOS II

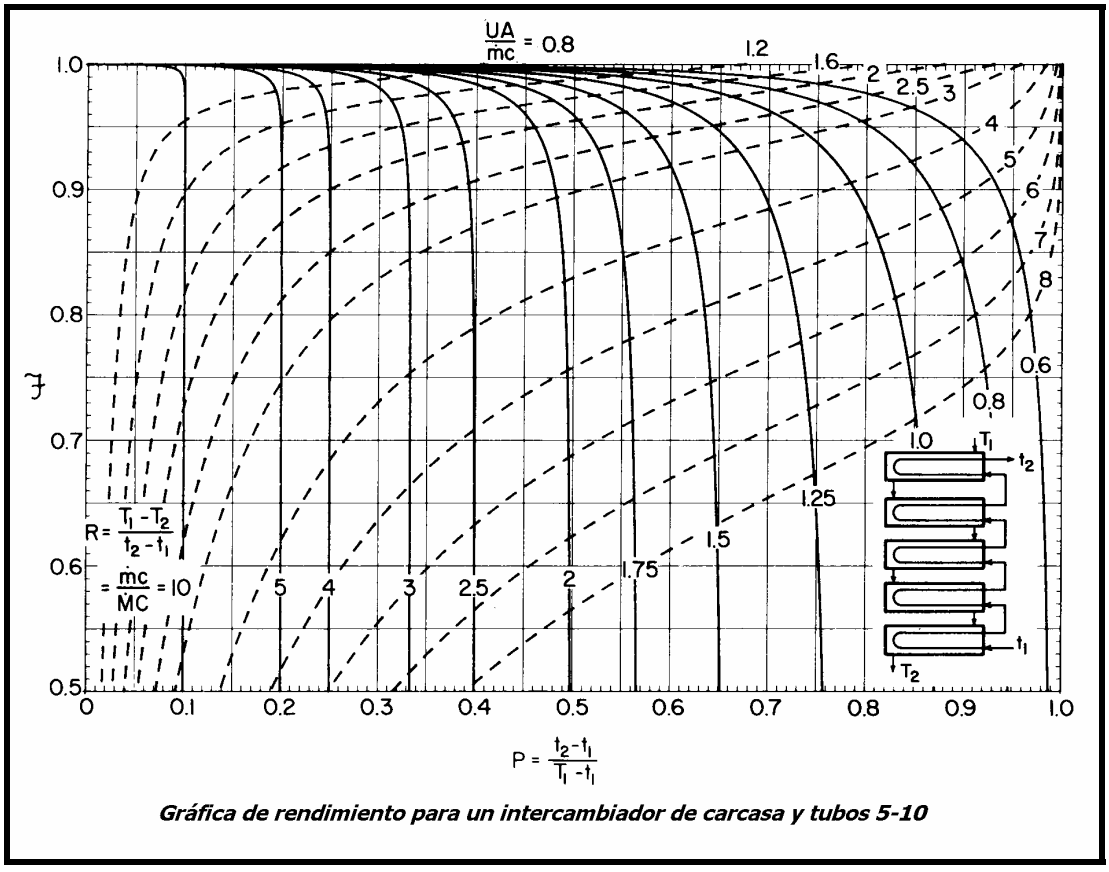


Gráfica de rendimiento para un intercambiador de carcasa y tubos 3-6

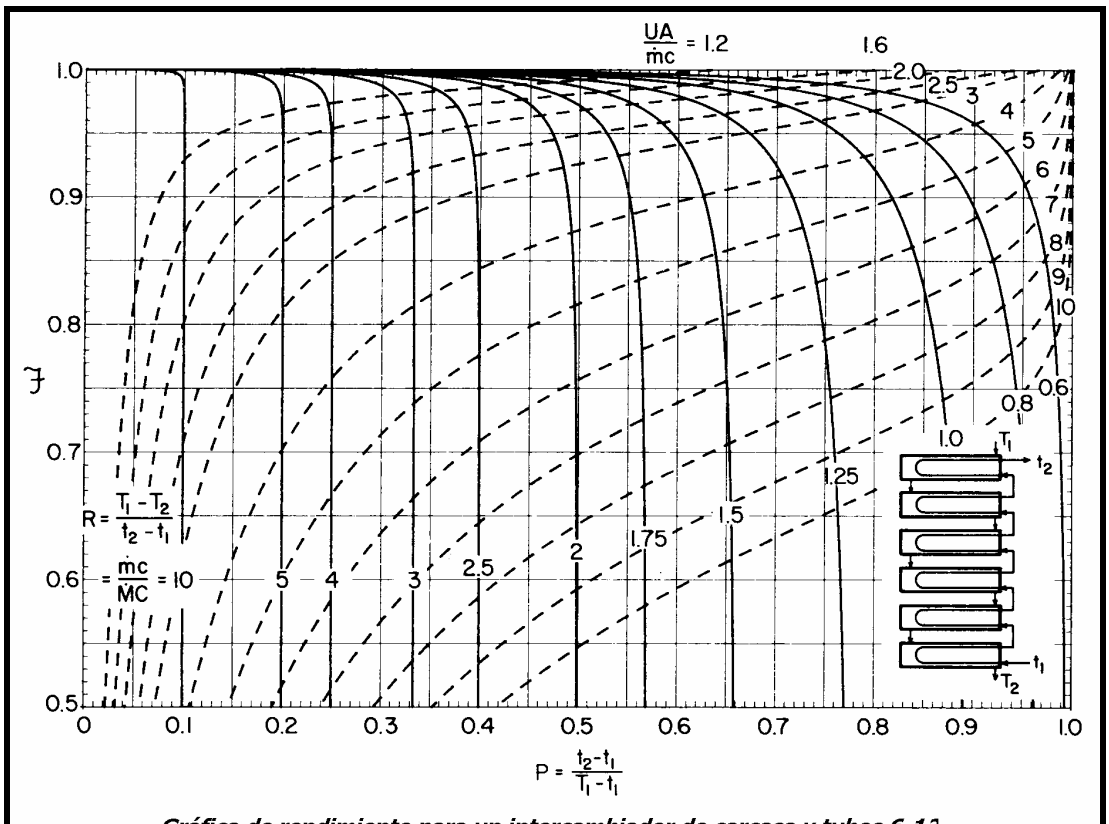


Gráfica de rendimiento para un intercambiador de carcasa y tubos 4-8

FACTORES DE CORRECCIÓN PARA INTERCAMBIADORES DE CARCASA Y TUBOS III

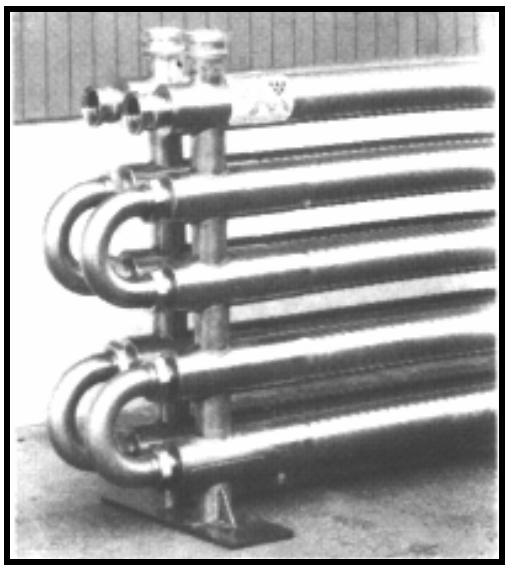


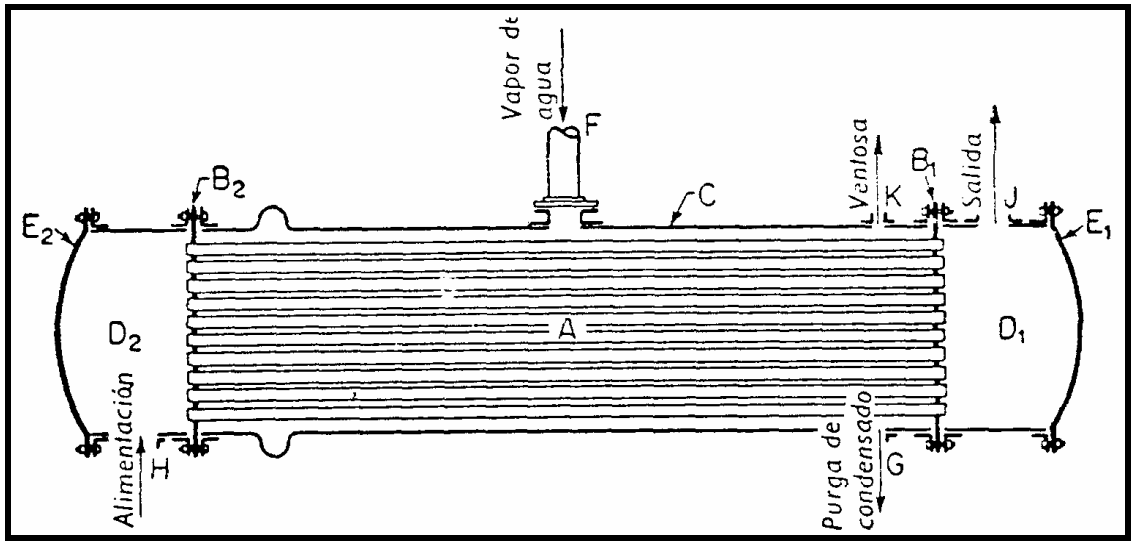
Gráfica de rendimiento para un intercambiador de carcasa y tubos 5-10

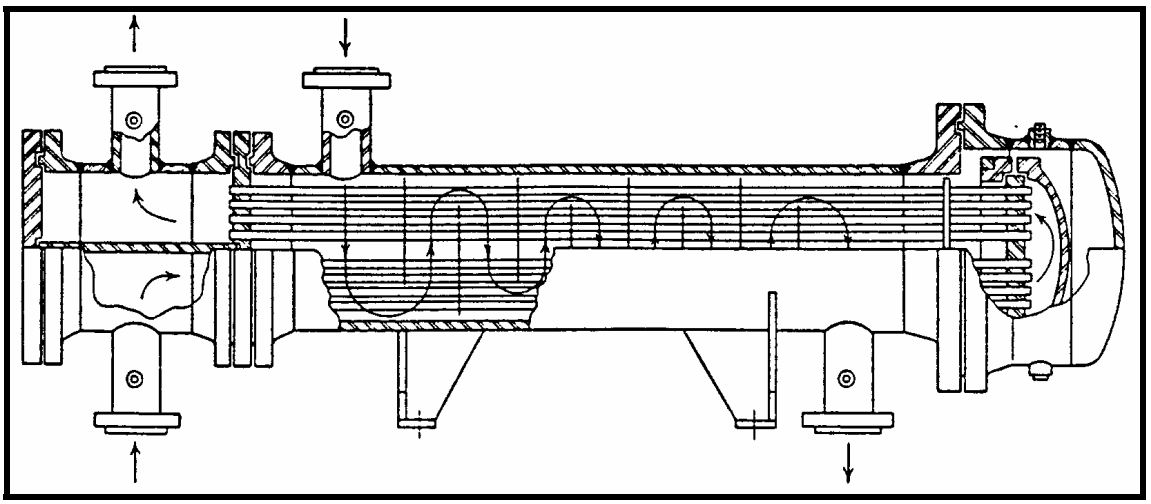


Gráfica de rendimiento para un intercambiador de carcasa y tubos 6-12

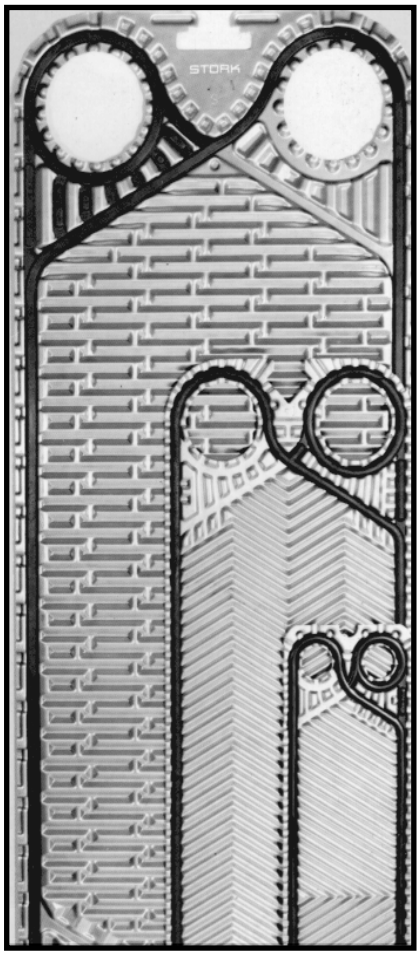
EQUIPO DE INTERCAMBIO I

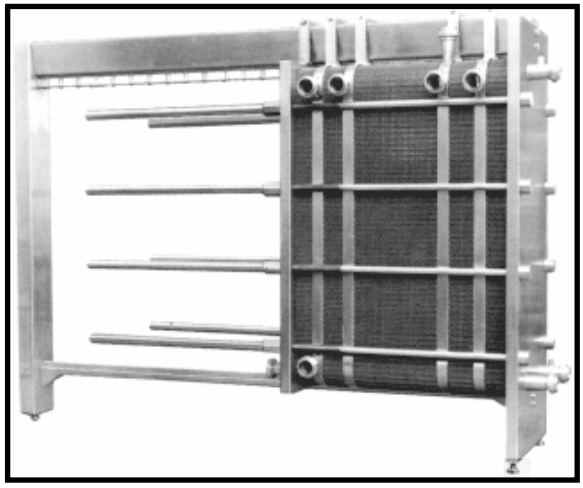


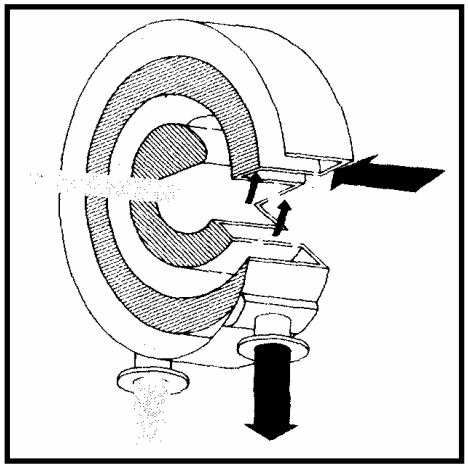


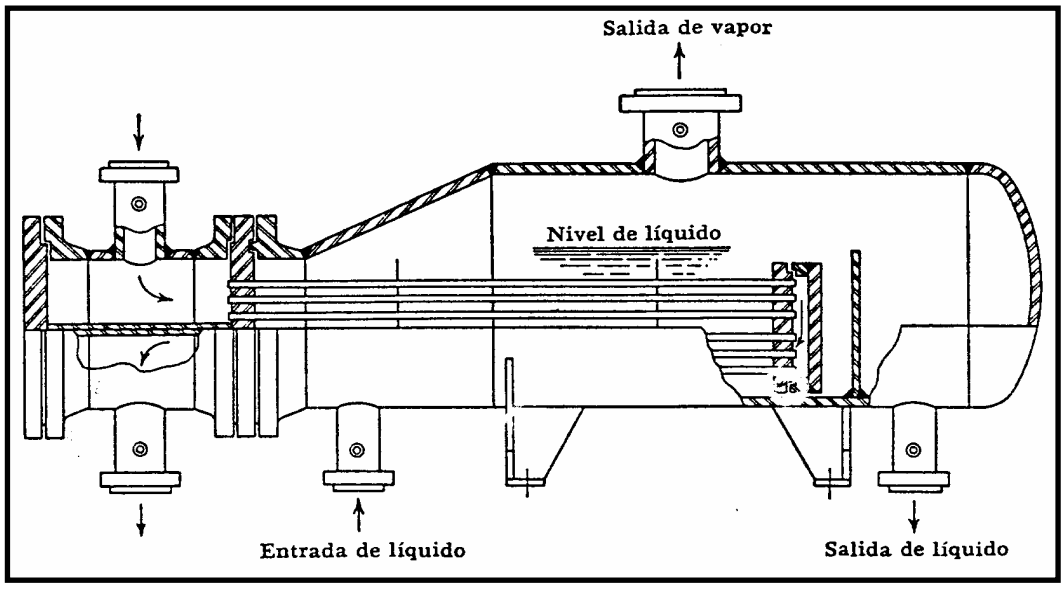


EQUIPO DE INTERCAMBIO II

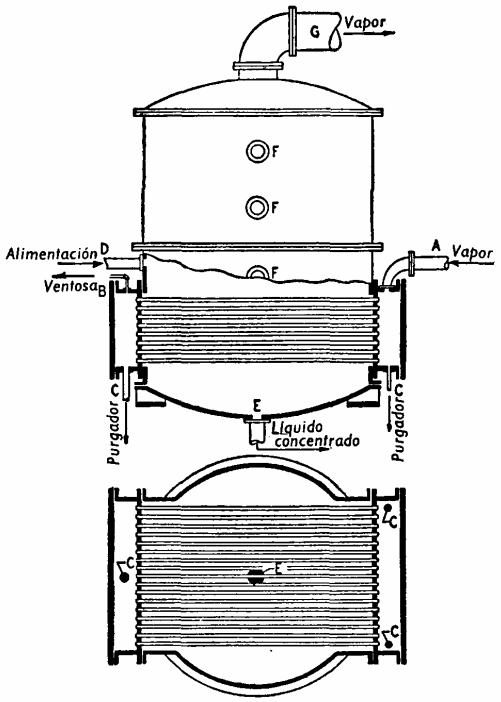




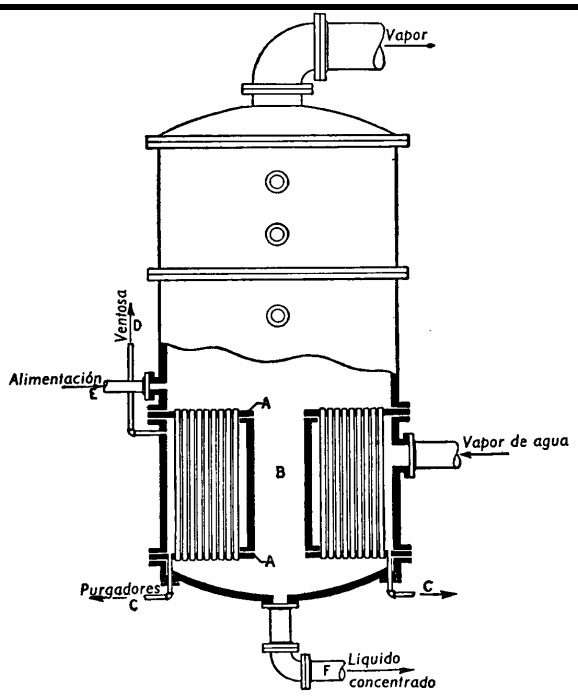




EQUIPO EVAPORADORES I

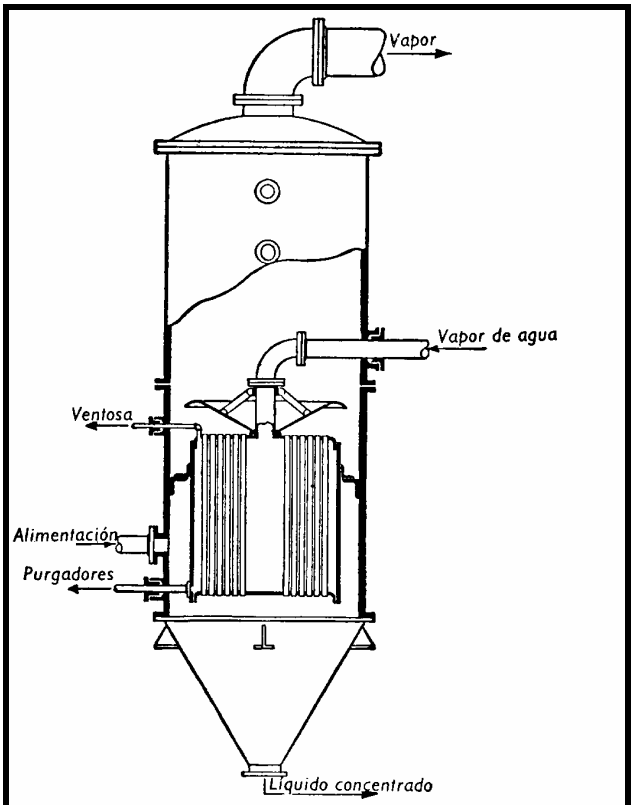


Evaporador de tubos horizontales: *A*, entrada de vapor; *B*, salida de gases incondensables; *C*, salidas de condensado; *D*, entrada de líquido diluido; *E*, salida del líquido concentrado; *F*, mirillas; *G*, salida de vapor. *(Swenson.)*

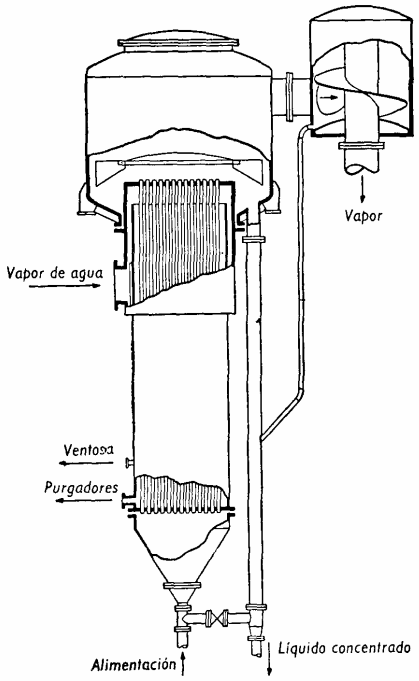


Evaporador normal de tubos verticales: *A*, placas tubulares *B*, tubo central; *C*, salida del condensado; *D*, salida de gases incondensables; *E*, entrada de líquido; *F*, salida del líquido concentrado. *(Swenson.)*

EQUIPO EVAPORADORES II

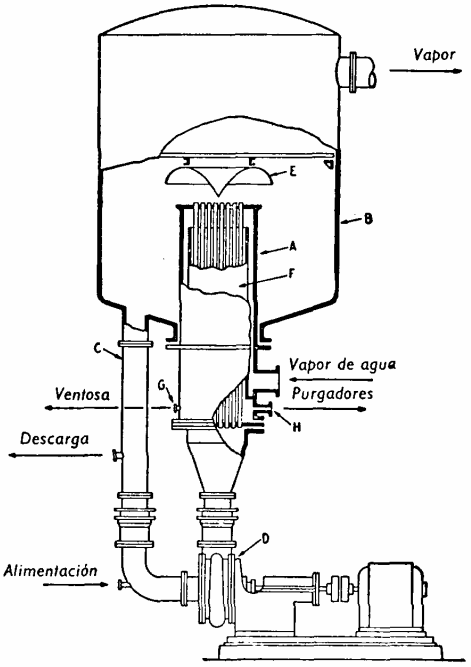


Evaporador de tipo cesta con tubos verticales. *(Swenson.)*

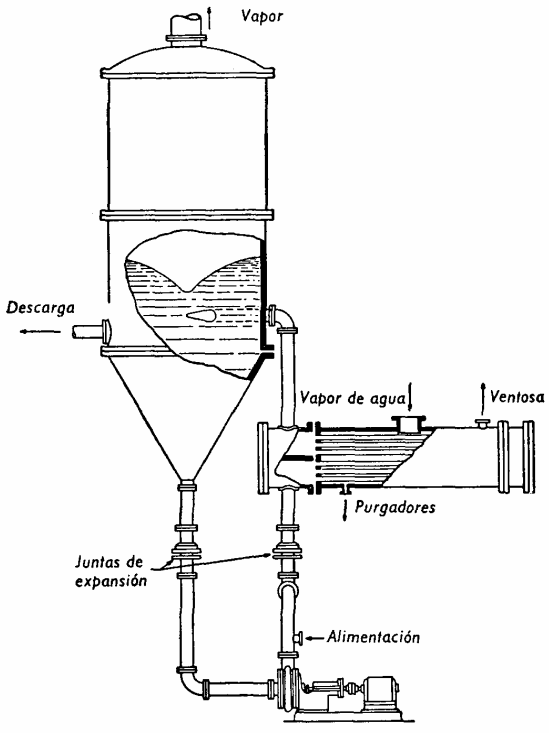


Evaporador de tubos largos verticales. *(Swenson, cortesía del American Institute of Chemical Engineers.)*

EQUIPO EVAPORADORES III



Evaporador de circulación forzada con elemento de calentamiento interno: *A*, elemento calentador; *B*, cabeza o espacio de vapor; *C*, tubería de retorno del líquido; *D*, bomba de circulación: *E*, deflector; *F*, pantalla cilíndrica; *G*, ventosa para salida de gases incondensables; *H*, salida del condensado. *(Swenson, cortesía del American Institute of Chemical Engineers.)*



Evaporador de circulación forzada con un calentador exterior de superficie de calefacción horizontal. *(Swenson, cortesía del American Institute of Chemical Engineers.)*