16.	HANSEN, A.G. NA, T.Y.	A jet pump cavitation parameter based on NPSH. Paper 68-WA/FE-42, Am. Soc. mech. Engrs, 1968.
17.	REDDY, Y.R. KAR, S.	Theory and performance of water jet pumps. *Proc. am. Soc. civil Engrs., J. Hydraulic Div.*, Vol. 94, No. HY5, pp-1261-1281, 1968.
18.	SANGER, N.L.	Non-cavitating performance of two low-area-ratio water jet pumps having throat lengths of 7.25 diameters. NASA tech. Note D-4445,1968.
19.	SANGER, N.L.	Cavitating performance of two low-area-ratio jet pumps having throat lengths of 7.25 diameters. NASA tech.Note D-4592, 1968.
20.	SANGER, N.L.	Noncavitating and cavitating performance of two low-area-ratio water jet pumps with throat lengths of 5.66 diameters. NASA tech. Note D-4759, 1968.
21.	SILVESTER, R. MUELLER, N.H.G.	Design data for the liquid-liquid jet pump. *J. Hydraulic Research*, Vol. 6. No. 2, pp. 129-162, 1968.
22.	CAIRNS, J.R. NA, T.Y.	Optimum design of water jet pumps. Paper 68-WA/FE-13, Am. Soc. mech. Engrs, 1969.
23.	CUNNINGHAM, R.G. HANSEN, A.G. NA, T.Y.	Jet pump cavitation. Paper 69-WA/FE-29, Am. Soc. mech. Engrs, 1969.
24.	SANGER, N.L.	Noncavitating and cavitating performance of several low-area-ratio water jet pumps having throat lengths of 3.54 diameters. NASA tech. Note D-5095, 1969.
25.	SANGER, N.L.	An experimental investigation of several low-area-ratio water jet pumps. *J. basic Engng*, Vol. 92, No. 1, pp. 11-20, 1970.
26.	SANGER, N.L.	Fortran programs for the design of liquid-to-liquid jet pumps. NASA tech. Note D-6453, 1971.
27.	KENTFIELD, J.A.C. BARNES, R.W.	The prediction of the optimum performance of ejectors. *Proc. Inst. mech. Engrs, Thermodynamics Fluid Mech. Group*, Vol. 186, Pt 54/72, pp. 671-681, 1972.
28.	SILVESTER, R. VONGVISESSOMJAI, S.	The jet pump using liquids of different density. Paper 11, Symp. "Jet Pumps and Ejectors", Brit. Hydromechanics Res. Assoc., Cranfield, UK, 1972.
29.	VYAS, B.D. KAR, S.	Standardisation of water jet pumps. Paper 10, Symp. “Jet Pumps and Ejectors”, Brit. Hydromechanics Res. Assoc., Cranfield, UK, 1972.
30.	WAKEFIELD, A.W.	Practical solids-handling jet pumps. Paper 12, Symp. “Jet Pumps and Ejectors”, Brit. Hydromechanics Res. Assoc., Cranfield, UK, 1972.
31.	CUNNINGHAM, R.G.	Liquid jet pump modelling; effects of axial dimensions on theory-experiment agreement, Paper Fl, 2nd Symp. “Jet Pumps and Ejectors”, Brit. Hydromechanics Res. Assoc., Cranfield, UK, 1975.

32. WAKEFIELD, A.W. — Performance of solids-handling jet pumps at low Reynolds numbers. Paper A3, 2nd Symp. "Jet Pumps and Ejectors", Brit. Hydromechanics Res. Assoc., Cranfield, UK, 1975.

33. WAKEFIELD, A.W. — Jet pump set to take off. Coal, Gold and Base Minerals of Southern Africa, 1980.

34. GOVATOS, G.C. — The slurry jet pump. *J. Pipelines*, Vol. 1, pp. 145-157, 1981.

35. WAKEFIELD, A.W. — Hydraulic jet pumps for solids handling, Coal, Gold and Base Minerals of Southern Africa, 1981.

36. WAKEFIELD, A.W. — Private communication from Mr. A.W. Wakefield, Wakefield and Imberg, Stamford, UK, 1985.

10.2 References

The references are recommended sources of information supplementary to the information in this Item.

37. MOODY, L.F. — Friction factors for pipe flow. *Trans. am. Soc. mech. Engrs*, Vol. 66, pp. 671-684, 1944.

38. GREY, R.E., WILSTED, H.D. — Performance of conical jet nozzles in terms of flow and velocity coefficients. NACA Rep. 933, Nat. adv. Comm. Aeronautics, USA, 1949.

39. ESDU — Introduction to design and performance data for diffusers. ESDU 76027, ESDU International Ltd, London, November 1976.

40. ESDU — Friction losses for fully-developed flow in straight pipes. ESDU 66027, with Amendments A and B, ESDU International Ltd, London, April 1977.

41. MILLER, D.S. — Internal flow systems. Vol.5, Fluid Engineering Series, British Hydromechanics Res. Assoc., Cranfield, UK, 1978.

42. ESDU — Performance of conical diffusers in incompressible flow. ESDU 73024, ESDU International Ltd, London, March 1980.

43. BSI — Specification for square-edged orifice plates, nozzles and venturi tubes inserted in circular cross section conduits running full. BS 1042: Section 1.1, British Standards Inst., London, 1981.

44. ESDU — Ejectors and jet pumps. Design and performance for compressible air flow. ESDU84029, ESDU International Ltd, London, December 1984.

11. TABLES

TABLE 11.1 Jet Pump Design Parameters - Calculation Sheet

Parameter	**Relationship**	**Value**	
Primary pressure	$P_1 = [P_5(1+N)-P_2]/N$		
Secondary pressure	$P_2 = P_5 - N(P_1 - P_5)$		
Discharge pressure	$P_5 = (NP_1 + P_2)/(N+1)$		
Pressure ratio	$N = (P_5 - P_2)/(P_1 - P_5)$		
Primary flowrate	$Q_p = Q_s/M$		
Secondary flowrate	$Q_s = M \times Q_p$		
Flow ratio	$M = Q_s/Q_p$		
Mixing chamber diameter	$D = L/7$ or $L/5$		
Mixing chamber length	$L = 7D$ or $5D$		
Primary nozzle diameter	$d = D\sqrt{R}$		
Primary nozzle spacing	$s \approx d$		
Diffuser included angle	2ϕ		
Primary fluid density	ρ_p		
Secondary fluid density	ρ_s		
Density ratio	$C = \rho_s/\rho_p$		
Cavitation index	$\sigma = (P_2 - p_v)/(½\rho_s V_{3c}^{\;2})$		
Primary nozzle loss coefficient	K_p		
Secondary inlet loss coefficient	K_s		
Mixing chamber loss coefficient	K_m		
Diffuser loss coefficient	K_d		

TABLE 11.2 Test Primary Nozzle Description (see Figure 2a)

Source	R value	d (mm)	Nozzle profile
Derivation 1	0.25	7.9	Conical inlet to parallel section (effect of 180° bend included in K_p)
Derivation 4	0.10	2.54	Elliptical
	0.133	3.58	Elliptical
	0.174	2.54	Conical
	0.20	3.58	Elliptical
	0.30	4.39	Elliptical
	0.40	3.58	Elliptical
	0.54	4.50	Conical
	0.60	4.39	Elliptical
Derivation 10	–	10.7	Conical
	–	10.7	Elliptical
	–	10.7	Circular inlet to parallel section
Derivation 16	–	Varying	Conical
Derivation 20	0.066	8.8	Circular arc, radius 175 mm
	0.197	15.2	Circular arc, radius 203 mm
	0.108	11.3	Circular arc, radius 190 mm
	0.141	12.8	Circular arc, radius 190 mm
Derivation 27	–	Varying	Circular arc inlet, radius $0.8d$, to parallel section, length $5d$

TABLE 11.3 Secondary Flow Inlet Loss Coefficients

Source	**Inlet profile**	K_s **value**
Derivation 1	Conical	0.05
Derivation 15	Conical	0.05
Derivation 17	Bellmouth	0.108
Derivation 30	Bellmouth	0.04

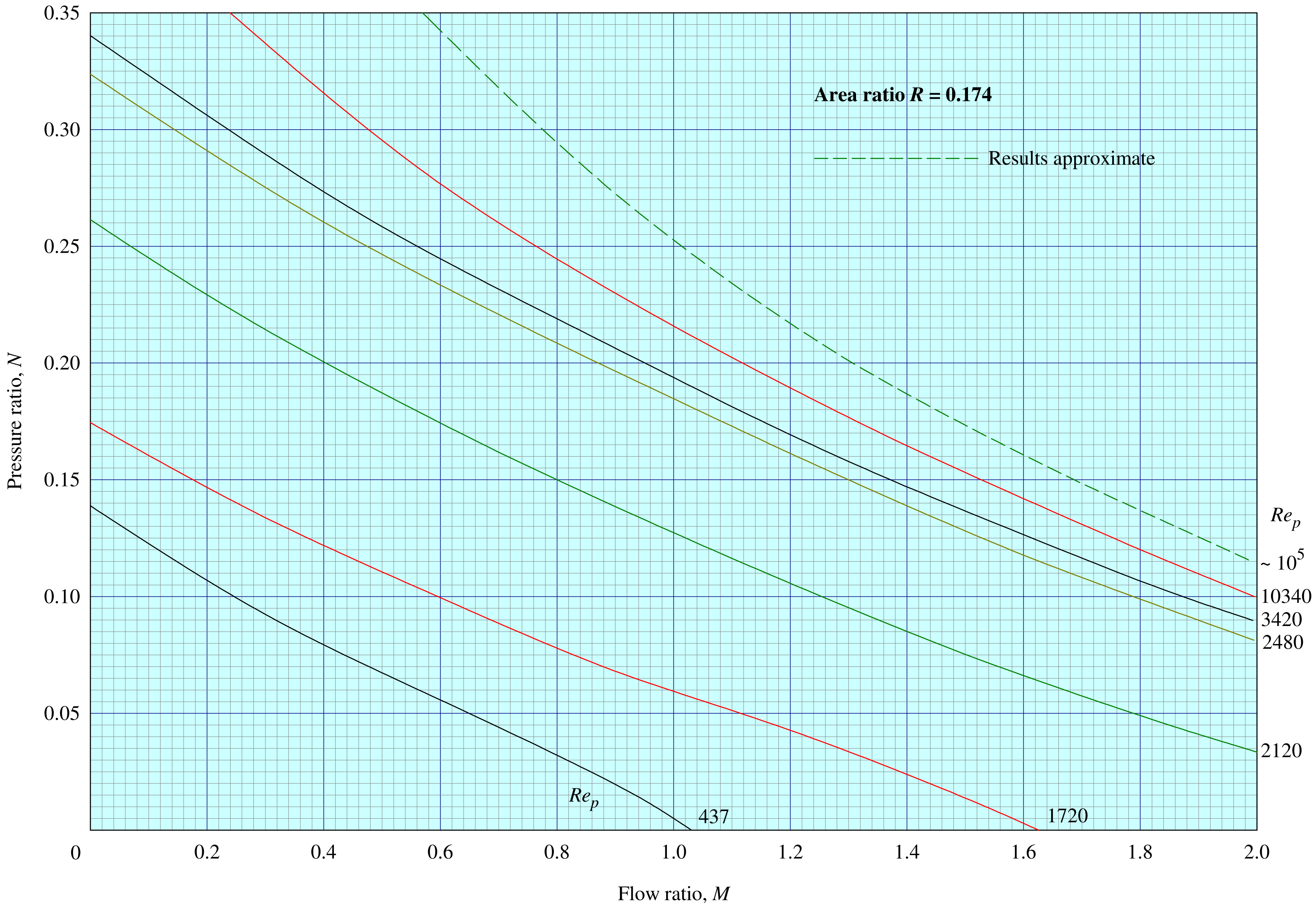

FIGURE 1 EFFECT OF VISCOSITY ON JET PUMP CHARACTERISTIC CURVE

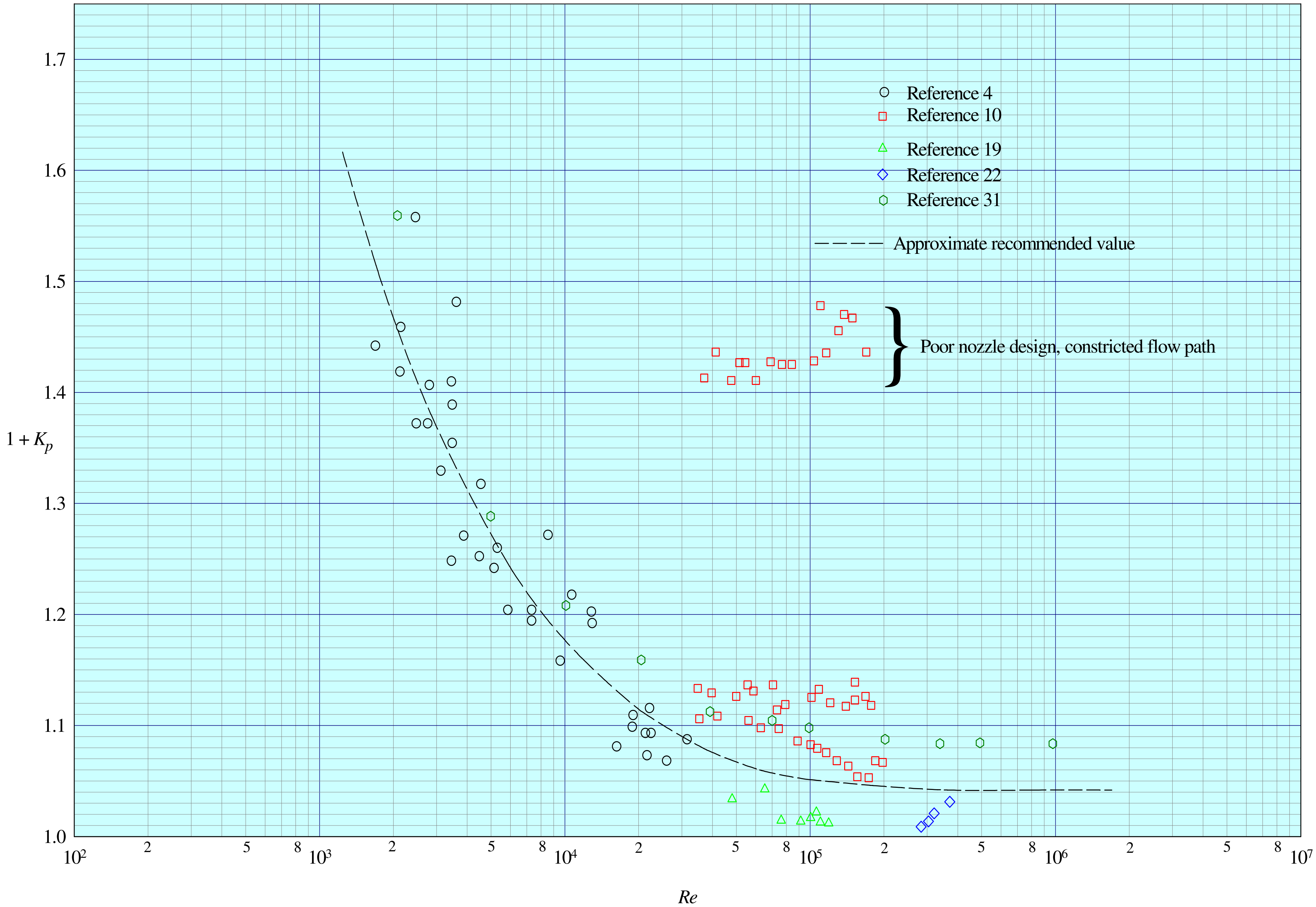

FIGURE 2a VARIATION OF K_p WITH REYNOLDS NUMBER

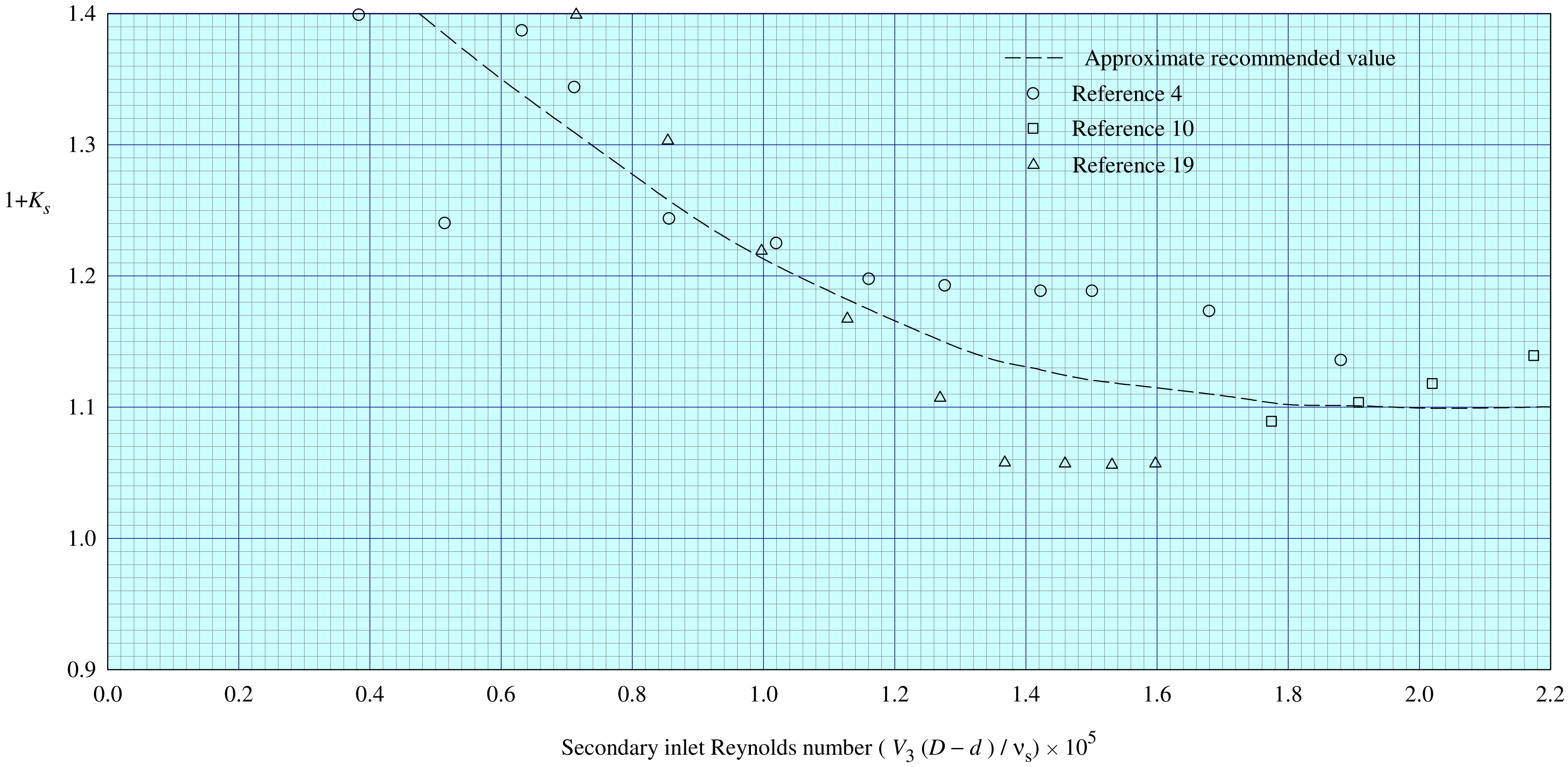

FIGURE 2b VARIATION OF K_s WITH REYNOLDS NUMBER

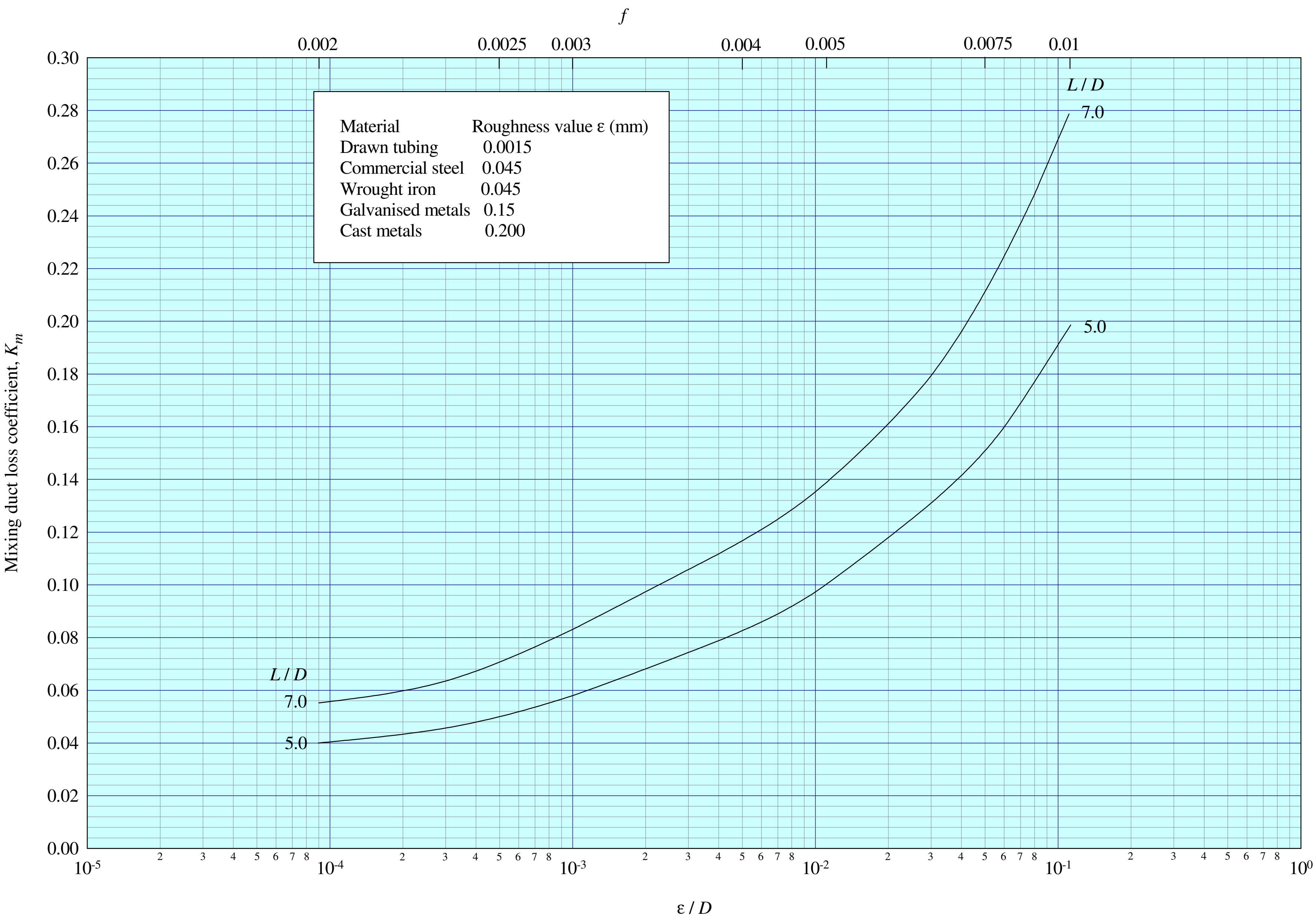

FIGURE 2c MIXING DUCT LOSS COEFFICIENT VERSUS DUCT RELATIVE ROUGHNESS

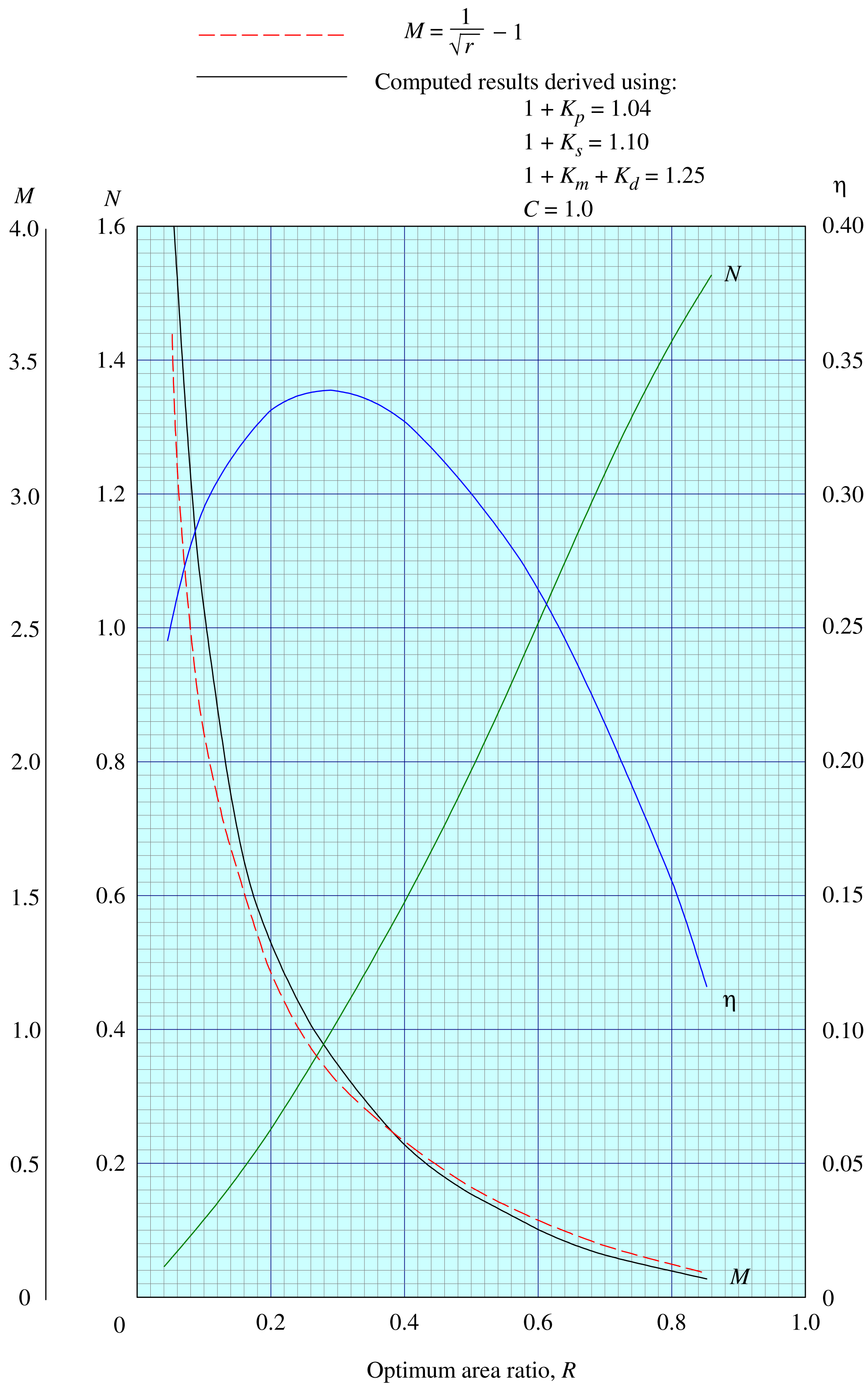

FIGURE 3a VARIATION OF OPTIMUM AREA RATIO WITH FLOW AND PRESSURE RATIOS, FOR A DENSITY RATIO OF 1.0

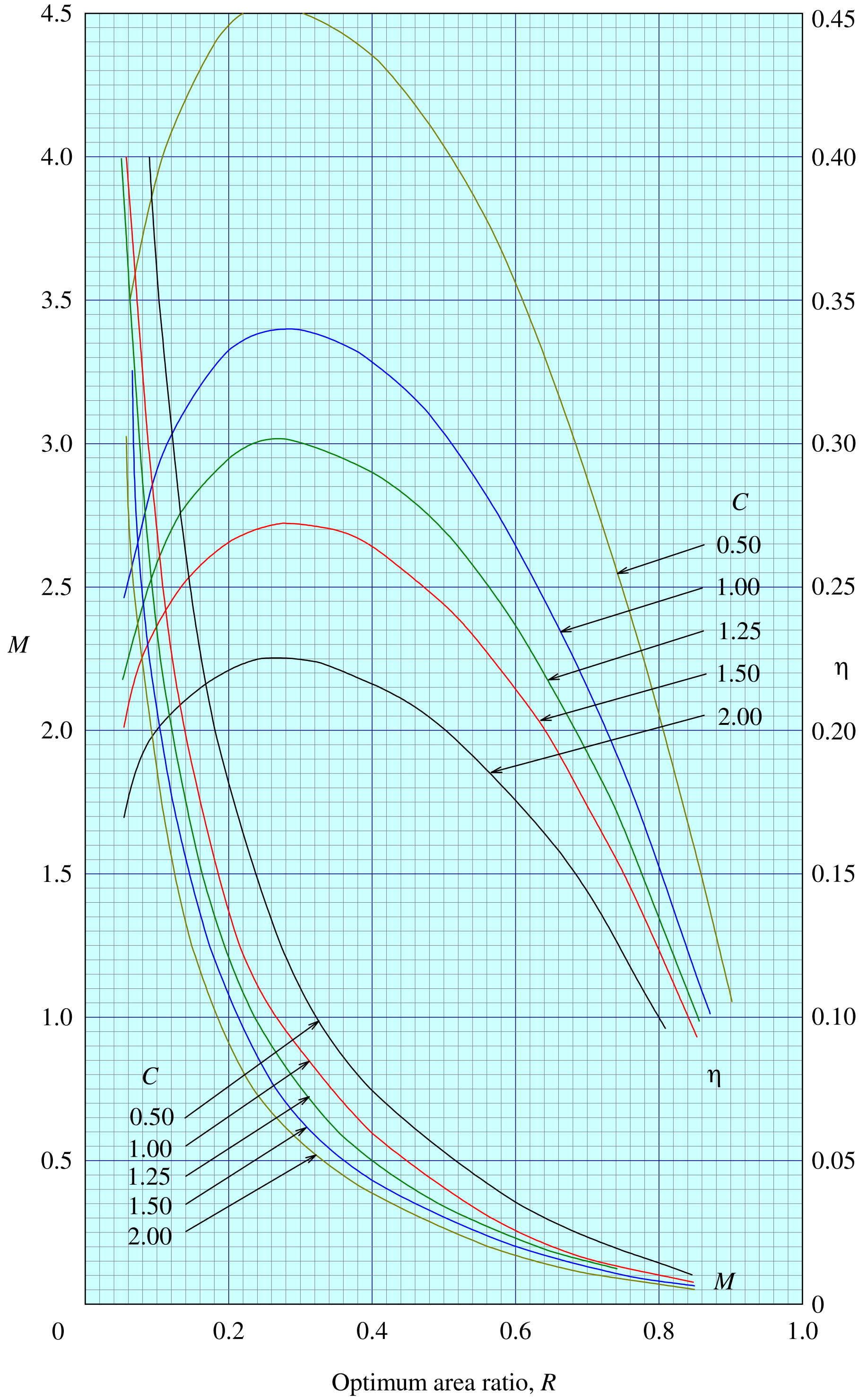

FIGURE 3b EFFECT OF DENSITY RATIO ON VARIATION OF OPTIMUM AREA RATIO WITH FLOW RATIO