MEMORIAL UNIVERSITY OF NEWFOUNDLAND

FACULTY OF ENGINEERING AND APPLIED SCIENCE

ENGINEERING 4020 MARINE FLUID DYNAMICS

DATE : FRIDAY 6 AUGUST 2010
TIME : 2:00 PM TO 5:00 PM

INSTRUCTOR
M. HINCHEY

A) Write brief notes on any 4 of the following topics: (1) turbulent hydrodynamic flows (2) boundary layer flows (3) potential flows (4) fluid transients (5) scaling laws. Make extensive use of the formula sheets provided. [THIS QUESTION IS WORTH 20%: EACH QUESTION PART IS WORTH 5%]

B) Describe how you would calculate any 4 of the following: (1) critical speed for panel flutter (2) critical speeds for pipes due to internal flow (3) critical speeds for slender structures due to external flow (4) pressures generated beneath hydrodynamic lubrication thrust bearings (5) pressures and flows in a large pipe network by pressure iteration. Make extensive use of the formula sheets provided. [THIS QUESTION IS WORTH 20%: EACH QUESTION PART IS WORTH 5%]

C) State the conservation laws for fluid flow. Outline briefly the derivation of the stream tube form of the laws from the integral form of the laws. State all assumptions and approximations. [THIS QUESTION IS WORTH 10%]

D) Describe briefly the purpose, the setup, the procedure, the results and the conclusions of any 5 of the 7 labs conducted during the semester. [THIS QUESTION IS WORTH 10%]

E) A pipe network on a ship consists of two closed storage tanks at different vertical heights connected by a pipe. A pump moves water at [60.0]/[3.79] GPM from the lower tank to the upper tank. Both tanks are large relative to the size of the pipe. For the lower tank, Z is 0m and P is 3BAR gage, while for the upper tank, Z is 10m and P is 2BAR gage. The pipe is 50m long. It is drawn tubing. The pump speed is 1750 RPM. Its power is 500w. It is located 20m along the pipe from the lower tank. The NPSH suggested by the manufacturer is 5m. Assume that the vapor pressure of water is 5000Pa and that its density is 1000kg/m^3. Also assume that the acceleration due to gravity g is 10m/s^2. Note that 1 BAR is 100000Pa. Ignore K losses. Determine: (1) the head of the pump (2) the type of pump (3) the diameter of the pipe (4) the vertical height of the pump. [THIS QUESTION IS WORTH 24%: EACH PART IS WORTH 6%]

F) A boat uses a U shaped pipe as a brake device by sticking it into the water. The pipe is 0.1m in diameter. The boat is moving at 10m/s. What is the brake force F on the boat? Imagine that the exit jet from the device was used to operate an ideal Pelton Wheel turbine. What is the maximum power that the Pelton Wheel could extract from the jet? [THIS QUESTION IS WORTH 16%: EACH PART IS WORTH 8%]

BONUS QUESTION [5]

A water sprinkler can be used as a turbine. Derive an equation for the power output of such a turbine. Assume you know the volumetric flow rate and all geometry.

$$\sum[\rho CA]_{OUT} - \sum[\rho CA]_{IN} = 0$$

$$\sum \dot{M}_{OUT} - \sum \dot{M}_{IN} = 0 \qquad \sum \dot{M}_{OUT} = \sum \dot{M}_{IN}$$

$$\sum[\rho \mathbf{v} CA]_{OUT} - \sum[\rho \mathbf{v} CA]_{IN}$$

$$= - \sum[PA\mathbf{n}]_{OUT} - \sum[PA\mathbf{n}]_{IN} + \mathbf{R}$$

$$\sum [\dot{M} U]_{OUT} - \sum [\dot{M} U]_{IN} = - \sum PAn_x + R_x$$

$$\sum [\dot{M} V]_{OUT} - \sum [\dot{M} V]_{IN} = - \sum PAn_y + R_y$$

$$\sum [\dot{M} W]_{OUT} - \sum [\dot{M} W]_{IN} = - \sum PAn_z + R_z$$

$$\sum [\dot{M} (C^2/2 + gz)]_{OUT} - \sum [\dot{M} (C^2/2 + gz)]_{IN} =$$

$$- \sum[PA\mathbf{C}]_{OUT} + \sum[PA\mathbf{C}]_{IN} + \sum\dot{T} - \sum\dot{L}$$

$$\sum [\dot{M} gh]_{OUT} - \sum [\dot{M} gh]_{IN} = + \sum\dot{T} - \sum\dot{L}$$

$$h = C^2/2g + P/\rho g + z$$

$$\dot{T} = \dot{M} gh_T \qquad \dot{L} = \dot{M} gh_L$$

$$h_{OUT} - h_{IN} = h_T - h_L$$

$$h_L = (fL/D + \Sigma K)\ C^2/2g$$

$$\frac{D}{Dt}\int_V \rho \, dV = \int_V \partial\rho/\partial t \, dV + \int_S \rho \, \mathbf{v.n} \, dS = 0$$

$$\frac{D}{Dt}\int_V \rho\mathbf{v} \, dV = \int_V \partial\rho\mathbf{v}/\partial t \, dV + \int_S \rho\mathbf{v} \; \mathbf{v.n} \, dS$$

$$= \int_S \boldsymbol{\sigma} \, dS + \int_V \rho\mathbf{b} \, dV$$

$$\frac{D}{Dt}\int_V \rho e \, dV = \int_V \partial\rho e/\partial t \, dV + \int_S \rho e \; \mathbf{v.n} \, dS$$

$$= -\int_S \mathbf{q.n} \, dS + \int_S \mathbf{v.\boldsymbol{\sigma}} \, dS$$

$$C^2/2g + P/\rho g + z = K$$

$$C^2/2 + P/\rho + gz = \kappa$$

$$H = X + Y\,Q^2$$

$$Q = C\,A \qquad A = \pi\,D^2/4$$

$$X = \Delta\,[P/\rho g + z]$$

$$Y = [fL/D + \Sigma K]/[2gA^2]$$

$$\mathbf{N} = [N\,\sqrt{Q}]/[H^{3/4}]$$

$$NPSH = P_s/\rho g + C_s C_s/2g - P_v/\rho g$$

$$d = (P_o - P_v)/\rho g - h_L - NPSH$$

$$\mathbf{P} = \Delta\,[T\,\omega] = \Delta\,[\rho Q\,V_t\,R\,\omega]$$

$$\mathbf{P} = \rho g\,H\,Q$$

$$\partial/\partial r\ (rh^3\ \partial P/\partial r) + r\ \partial/\partial c(h^3\ \partial P/\partial c) = 6\mu S\ \partial h/\partial\Theta$$

$$P_P = \frac{(A\ P_E + B\ P_W + C\ P_N + D\ P_S + H)}{(A + B + C + D)}$$

$$A = [(h_E+h_P)/2]^3\ r_P / [\Delta c^2]$$

$$B = [(h_W+h_P)/2]^3\ r_P / [\Delta c^2]$$

$$C = [(h_N+h_P)/2]^3\ [(r_N+r_P)/2] / [\Delta r^2]$$

$$D = [(h_S+h_P)/2]^3\ [(r_S+r_P)/2] / [\Delta r^2]$$

$$H = -\ 6\mu\ r_P\omega\ (h_E-h_W)/[2\Delta\Theta]$$

$$\rho\Gamma S \qquad \Gamma = 4\pi SR\ \mathrm{Sin}\kappa$$

$$\kappa = \Theta+\varepsilon \qquad \varepsilon = \tan^{-1}[m/(n+a)]$$

$$a = \sqrt{[R^2-m^2]} - n$$

$$\alpha = x + [xa^2/(x^2+y^2)]$$

$$\beta = y - [ya^2/(x^2+y^2)]$$

$$\delta^*\ \mathbf{U} \qquad \delta^* = \int (1-U/\mathbf{U})dy \qquad \delta^* = I\delta$$

$$\rho\ \mathbf{U}^2\ \Theta \qquad \Theta = \int U/\mathbf{U}(1-U/\mathbf{U})dy \qquad \Theta = J\delta$$

$$U/\mathbf{U} = (y/\delta)^{1/n} \qquad \tau = C\ \rho\mathbf{U}^2/(\mathbf{U}\delta/\nu)^{1/k}$$

$$\mathbf{D}/b = \rho\ \mathbf{U}^2\Theta \qquad \tau = d[\mathbf{D}/b]/dx = \rho\mathbf{U}^2\ d\Theta/dx$$

$$\mathbf{D} = M\ bL\ R_{EL}^{-1/m}\ \rho\mathbf{U}^2 \qquad \mathbf{W} = C\ B\ \rho\mathbf{U}^2/2$$

$$\mathbf{P} = [\ \mathbf{D} + \mathbf{W}\ ]\ \mathbf{U}$$

$$C_P = P / [\rho N^2 D^2] \qquad C_Q = Q / [N D^3] \qquad C_{\mathbf{P}} = \mathbf{P} / [\rho N^3 D^5]$$

$$C_{\mathbf{P}} = \mathbf{P} \; / \; [\rho \; S^3/2 \; A] \qquad C_{\mathbf{S}} = r\omega / S$$

$$C_D = \mathbf{D} / [[\rho S^2/2] \; A] \qquad Re = SD/\nu \qquad Fr = S/\sqrt{[gL]}$$

$$T = D/S \qquad C_T = \mathbf{T}/T \qquad St = T/\mathbf{T}$$

$$S^2 = [\; EI/[\rho A] \; \pi^2/L^2 + T/[\rho A] - P/\rho \;]$$

$$S = [4 + 14 \; M_o/M] \; S_o$$

$$S_o = \sqrt{[[EI]/[M_o L^2]]} \qquad M_o = \rho A$$

$$|\Delta P| = \rho \; a \; |\Delta S| \qquad a = \sqrt{[\mathbf{K}/\rho]}$$

$$\mathbf{K} = K \; / \; [1 + [DK]/[Ee]]$$

$$S^2 = [Tk^2 + Dk^4 + K/w + \rho_B g - \rho_T g] \; *$$

$$[\rho_T/k + \rho_B/k + \sigma] \; / \; [\rho_B \rho_T + \sigma \rho_T k]$$

$$S = S_o \; M/M_o \; \zeta \; a \qquad S_o = D/\mathbf{T} \qquad M_o = \rho D^2$$

$$S = \beta/\mathbf{T} \; \sqrt{[M\delta/\rho]} = \beta S_o \; \sqrt{[\delta M/M_o]}$$

$$S = D/[\mathbf{ST}] \qquad \mathbf{T} = \mathbf{T}$$

$$\mathbf{T}_n = [2L/n] \; \sqrt{[m/T]}$$

$$\mathbf{T}_n = [L/n]^2 \; [2/\pi] \; \sqrt{[m/EI]}$$

$$\mathbf{T}_n = 2\pi L^2/K_n \; \sqrt{[m/EI]}$$

$$\rho\ (\ \partial U/\partial t + U\partial U/\partial x + V\partial U/\partial y + W\partial U/\partial z\ ) + A = -\ \partial P/\partial x$$
$$+\ [\ \partial/\partial x\ (\mu\ \partial U/\partial x) + \partial/\partial y\ (\mu\ \partial U/\partial y) + \partial/\partial z\ (\mu\ \partial U/\partial z)\ ]$$

$$\rho\ (\ \partial V/\partial t + U\partial V/\partial x + V\partial V/\partial y + W\partial V/\partial z\ ) + B = -\ \partial P/\partial y$$
$$+\ [\ \partial/\partial x\ (\mu\ \partial V/\partial x) + \partial/\partial y\ (\mu\ \partial V/\partial y) + \partial/\partial z\ (\mu\ \partial V/\partial z)\ ]$$

$$\rho\ (\ \partial W/\partial t + U\partial W/\partial x + V\partial W/\partial y + W\partial W/\partial z\ ) + C = -\ \partial P/\partial z - \rho g$$
$$+\ [\ \partial/\partial x\ (\mu\ \partial W/\partial x) + \partial/\partial y\ (\mu\ \partial W/\partial y) + \partial/\partial z\ (\mu\ \partial W/\partial z)\ ]$$

$$\partial P/\partial t + \rho\ c^2\ (\ \partial U/\partial x + \partial V/\partial y + \partial W/\partial z\ ) = 0$$

$$\partial F/\partial t + U\partial F/\partial x + V\partial F/\partial y + W\partial F/\partial z = 0$$

$$\partial k/\partial t + U\partial k/\partial x + V\partial k/\partial y + W\partial k/\partial z = T_P - T_D$$
$$+\ [\ \partial/\partial x\ (\mu/a\ \partial k/\partial x) + \partial/\partial y\ (\mu/a\ \partial k/\partial y) + \partial/\partial z\ (\mu/a\ \partial k/\partial z)\ ]$$

$$\partial \varepsilon/\partial t + U\partial \varepsilon/\partial x + V\partial \varepsilon/\partial y + W\partial \varepsilon/\partial z = D_P - D_D$$
$$+\ [\ \partial/\partial x\ (\mu/b\ \partial \varepsilon/\partial x) + \partial/\partial y\ (\mu/b\ \partial \varepsilon/\partial y) + \partial/\partial z\ (\mu/b\ \partial \varepsilon/\partial z)\ ]$$

$$\partial M/\partial t = N \qquad M_{NEW} = M_{OLD} + \Delta t\ N_{OLD}$$

$$T_P = G\ \mu_t\ /\ \rho \qquad D_P = T_P\ C_1\ \varepsilon\ /\ k$$
$$T_D = C_D\ \varepsilon \qquad D_D = C_2\ \varepsilon^2\ /\ k$$
$$\mu_t = C_3\ k^2\ /\ \varepsilon \qquad \mu = \mu_t + \mu_1$$

$$\mathbf{P} = T\,\omega \qquad T = \Delta\,(\dot{M}\,V_T\,R) \qquad \dot{M} = \rho Q$$

$$V_{IN} = V_J \qquad V_{OUT} = (V_J - V_B)\ K\ \cos\beta + V_B$$

$$V_B = R\,\omega \qquad V_J = k\ \sqrt{2\Delta P/\rho}$$

$$\mathbf{P} = \dot{M}\ (V_J - V_B)\ (1 - K\ \cos\beta)\ V_B$$

$$C_{\mathbf{P}} = \mathbf{P}\ /\ [P\ Q] = \mathbf{P}\ /\ [\Delta P\ Q]$$

$$C_{\mathbf{S}} = R\boldsymbol{\omega}\ /\ V_J$$

$$S_D = [\sqrt{2(P_U-P_D)/\rho}]/[\sqrt{1-(A_D/A_U)^2}]$$

$$S_D = [\sqrt{2(P_U-P_D)/\rho}]/[\sqrt{1-(D_D/D_U)^4}]$$

$$Q = K\ S_D\ A_D \qquad A = \pi D^2/4$$

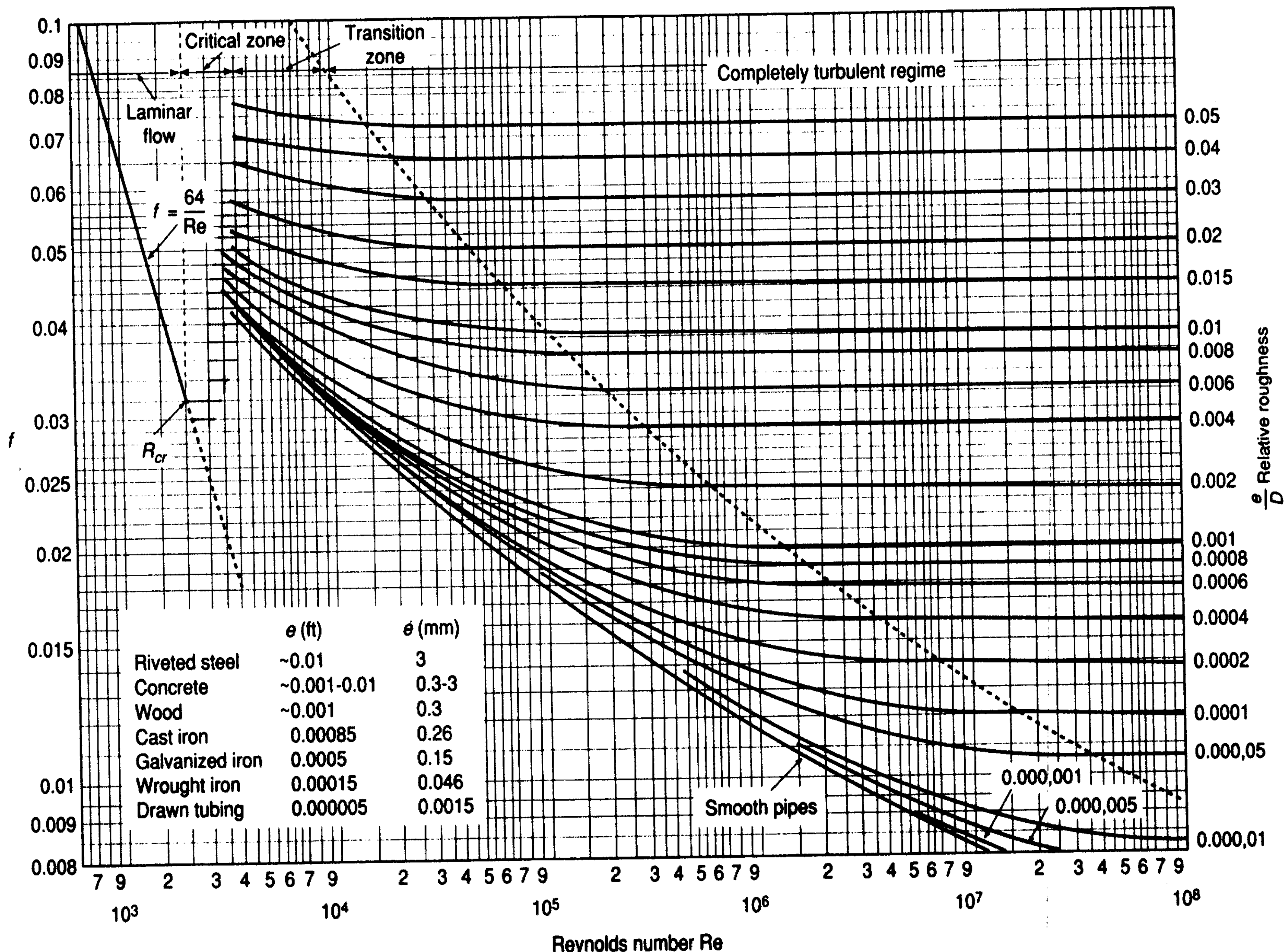
$$Q = \Sigma\ S_k\ A_k \qquad A_k = \pi\ D_k\ \Delta D$$

$$\Sigma\ P\Delta c\ \sin(\boldsymbol{\theta} - \theta)$$

$$\Sigma\ P\Delta c\ \cos(\boldsymbol{\theta} - \theta)$$

$$h_L = [P_U - P_D]\ /\ [\rho g]$$

$$h_L = f\ L/D\ C^2/[2g]$$



Moody diagram. (From L. F. Moody, *Trans. ASME*, Vol. 66, 1944.)

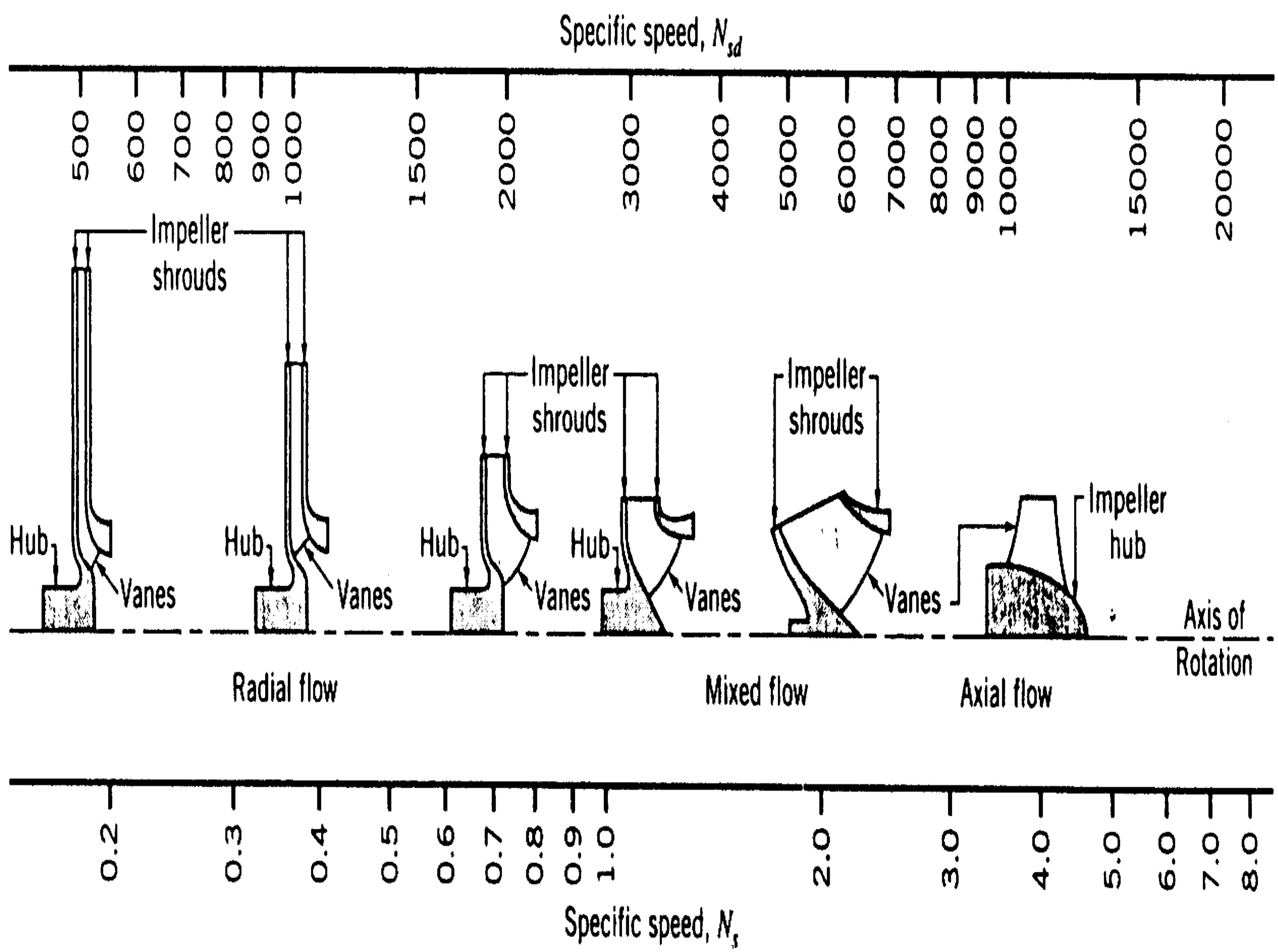
Nominal Loss Coefficients K (Turbulent Flow)[a]

Type of fitting	Screwed			Flanged		
Diameter	1 in.	2 in.	4 in.	2 in.	4 in.	8 in.
Globe valve (fully open)	8.2	6.9	5.7	8.5	6.0	5.8
(half open)	20	17	14	21	15	14
(one-quarter open)	57	48	40	60	42	41
Angle valve (fully open)	4.7	2.0	1.0	2.4	2.0	2.0
Swing check valve (fully open)	2.9	2.1	2.0	2.0	2.0	2.0
Gate valve (fully open)	0.24	0.16	0.11	0.35	0.16	0.07
Return bend	1.5	.95	.64	0.35	0.30	0.25
Tee (branch)	1.8	1.4	1.1	0.80	0.64	0.58
Tee (line)	0.9	0.9	0.9	0.19	0.14	0.10
Standard elbow	1.5	0.95	0.64	0.39	0.30	0.26
Long sweep elbow	0.72	0.41	0.23	0.30	0.19	0.15
45° elbow	0.32	0.30	0.29			
Square-edged entrance			0.5			
Reentrant entrance			0.8			
Well-rounded entrance			0.03			
Pipe exit			1.0			
Sudden contraction[b] — Area ratio 2:1			0.25			
Sudden contraction — Area ratio 5:1			0.41			
Sudden contraction — Area ratio 10:1			0.46			
Orifice plate — Area ratio A/A_0 1.5:1			0.85			
Orifice plate — Area ratio A/A_0 2:1			3.4			
Orifice plate — Area ratio A/A_0 4:1			29			
Orifice plate — Area ratio A/A_0 $\geq$ 6:1			$2.78\left(\frac{A}{A_0}-0.6\right)^2$			
Sudden enlargement[c]			$\left(1-\frac{A_1}{A_2}\right)^2$			
90° miter bend (without vanes)			1.1			
(with vanes)			0.2			
General contraction (30° included angle)			0.02			
General contraction (70° included angle)			0.07			

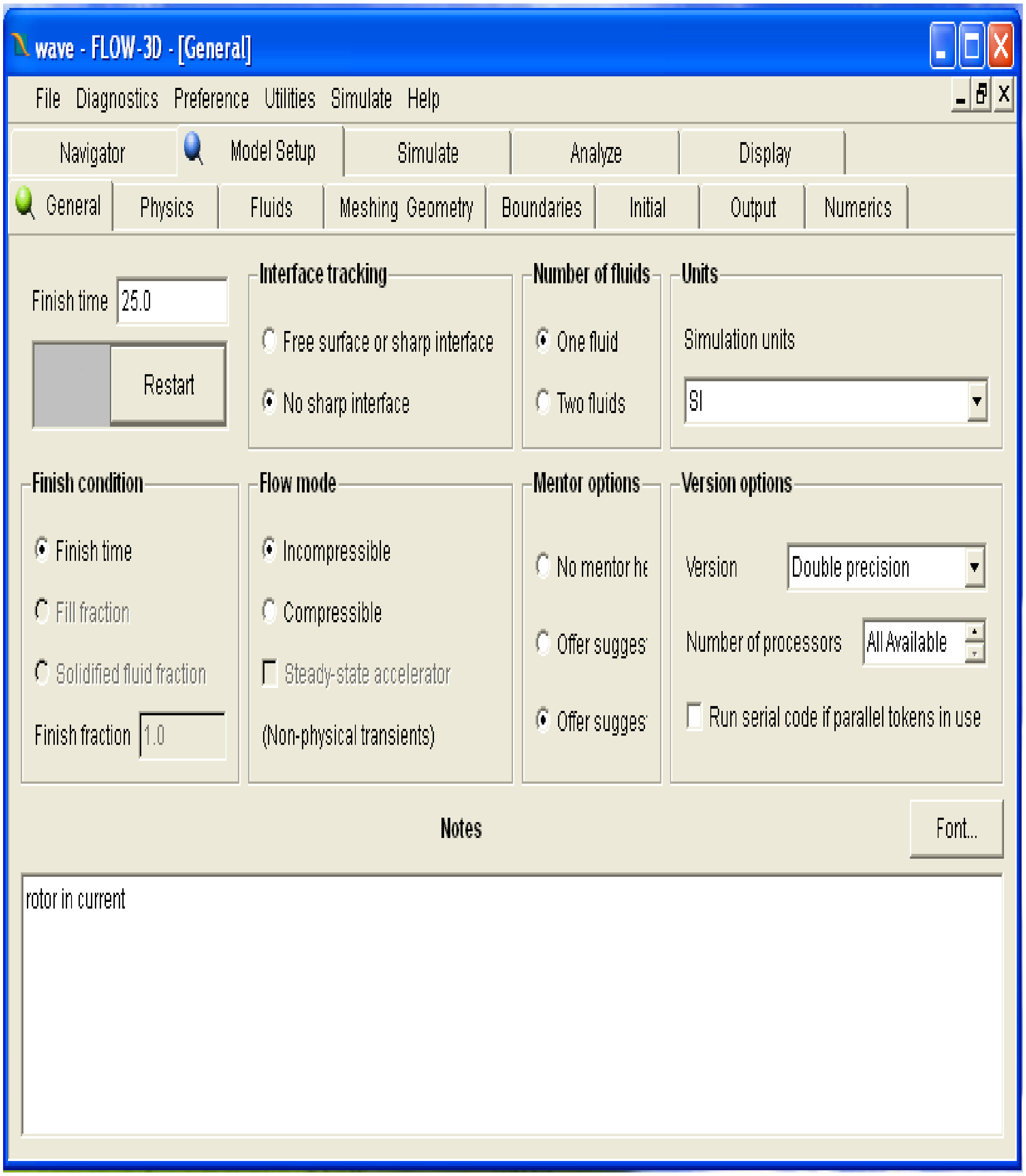
[a] Values for other geometries can be found in *Technical Paper 410*, The Crane Company, 1957.

[b] Based on exit velocity V_2.

[c] Based on entrance velocity V_1.



Specific speed, N_{sd}
500
600
700
800
900
1000
1500
2000
3000
4000
5000
6000
7000
8000
9000
10000
15000
20000
Impeller shrouds
Hub
Vanes
Impeller hub
Axis of Rotation
Radial flow
Mixed flow
Axial flow
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Specific speed, N_s


wave - FLOW-3D - [General]
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Navigator
Model Setup
Simulate
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Display
General
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Fluids
Meshing Geometry
Boundaries
Initial
Output
Numerics
Finish time 25.0
Restart
Interface tracking
Free surface or sharp interface
No sharp interface
Number of fluids
One fluid
Two fluids
Units
Simulation units
SI
Finish condition
Finish time
Fill fraction
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Finish fraction 1.0
Flow mode
Incompressible
Compressible
Steady-state accelerator
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