Equazioni di bilancio

$$\frac{D\rho}{Dt} + \rho \underline{\nabla} \cdot \underline{V} = 0$$

$$\rho \frac{D\underline{V}}{Dt} + \underline{\nabla} p = \underline{\nabla} \cdot \underline{\underline{\tau_d}} \qquad \underline{\underline{\tau_d}} = k(\underline{\nabla} \cdot \underline{V})\underline{\underline{U}} + 2\mu(\underline{\nabla}\underline{V})_0^s$$

$$\rho \frac{DE_t}{Dt} = \underline{\nabla} \cdot (\lambda \underline{\nabla} T + \underline{V} \cdot \underline{\underline{\tau_d}} - p\underline{V})$$

$$\rho \frac{Ds}{Dt} = \underline{\nabla} \cdot \left(\lambda \frac{\underline{\nabla} T}{T}\right) + \frac{1}{T}\left(\lambda \frac{(\underline{\nabla} T)^2}{T} + \phi^2\right) \qquad \phi^2 = 2\mu(\underline{\nabla}\underline{V})_0^s : (\underline{\nabla}\underline{V})_0^s$$

Equazione di bilancio integrali in un condotto

$$\int_{A_c} \rho \underline{V}\underline{V} \cdot \underline{n} dA + \int_{A} p\underline{n} dA = \int_{A_w} \underline{\underline{\tau_d}} \cdot \underline{n} dA \qquad A_w = \wp L \qquad A_c = \frac{\pi}{4} D^2$$

$$\frac{\wp L \tau_d}{\frac{\pi}{4} D^2 \rho V^2} = \frac{\pi D L}{\frac{\pi}{4} D^2} \frac{\mu V/D}{\rho V^2} = \frac{4L}{D} \frac{\mu}{\rho V D} = \frac{4L}{D} \frac{1}{Re} \qquad Re = \frac{VD}{\nu} \qquad \nu = \frac{\mu}{\rho}$$

$$\int_{A_c} \rho E_t \underline{V} \cdot \underline{n} dA + \int_{A_w} J_q \cdot \underline{n} dA + \int_{A_w} J_q \cdot \underline{n} dA = 0$$

$$\frac{\wp L J_q}{\frac{\pi}{4} D^2 \rho V^2 V} = \frac{\pi D L}{\frac{\pi}{4} D^2} \frac{\lambda \Delta T/D}{\rho V^3} = \frac{4L}{D} \frac{\lambda}{c_p \mu} \frac{c_p \Delta T}{V^2} \frac{\mu}{\rho V D} = \frac{4L}{D} \frac{1}{Pr} \frac{1}{Ec} \frac{1}{Re}$$

$$Pr = \frac{\nu}{\alpha} \qquad Pe = PrRe = \frac{VD}{\alpha} \qquad \alpha = \frac{\lambda}{\rho c_p}$$

Termodinamica

$$u = u(s, v) \qquad du = Tds - pdv$$

$$h = h(s, p) \qquad dh = Tds + vdp$$

$$c_p = T\left(\frac{\partial s}{\partial T}\right)_p \qquad c_v = T\left(\frac{\partial s}{\partial T}\right)_v$$

$$a_L^2 = \left(\frac{\partial p}{\partial \rho}\right)_s = -v^2\left(\frac{\partial p}{\partial v}\right)_s \qquad a_N^2 = \left(\frac{\partial p}{\partial \rho}\right)_T = -v^2\left(\frac{\partial p}{\partial v}\right)_T$$

$$\left(\frac{\partial - p}{\partial v}\right)_s \geq \left(\frac{\partial - p}{\partial v}\right)_T \qquad \left(\frac{\partial T}{\partial s}\right)_v \geq \left(\frac{\partial T}{\partial s}\right)_p$$

Gas più che perfetto

$$\begin{cases} p = \rho RT \\ u = c_v T + u_0 \end{cases} \qquad \begin{cases} p = \rho RT \\ h = c_p T + h_0 \end{cases} \qquad \gamma = \frac{c_p}{c_v} \qquad R = c_p - c_v$$

$$c_p = \frac{\gamma}{\gamma - 1}R \qquad c_v = \frac{1}{\gamma - 1}R$$

In un processo isentropico si ha:

$$\frac{p_2}{p_1} = \left(\frac{T_2}{T_1}\right)^{\frac{c_p}{R}} = \left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{k}} \qquad \frac{p_2}{p_1} = \left(\frac{\rho_2}{\rho_1}\right)^{\frac{c_p}{c_v}} = \left(\frac{\rho_2}{\rho_1}\right)^{\gamma}$$

$$\frac{\rho_2}{\rho_1} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}}$$

Varie

$$H = h + \frac{V^2}{2} = c_p T + \frac{V^2}{2} = c_p T\left(1 + \frac{\gamma - 1}{2}M^2\right)$$

$$I = p + \rho V^2 = p(1 + \gamma M^2)$$

MOTI COMPRESSIBILI CON ATTRITO

Le ipotesi alla base del ***moto alla Fanno*** sono le seguenti:

- il moto è ***quasi-unidimensionale*** e ***quasi-stazionario***;
- l'***area*** della sezione di passaggio del condotto è ***costante***;
- ***il fluido non scambia né lavoro né calore*** con l'ambiente, cioè il moto è considerato ***omoenergetico***;
- gli ***effetti delle forze gravitazionali sono trascurabili***;
- le condizioni termofluidodinamiche del fluido cambiano per effetto degli ***sforzi viscosi*** alla parete (che costituiscono la ***forza spingente***).

MOTI COMPRESSIBILI E SCAMBIO TERMICO

Modello di ***moto alla Rayleigh*** basato sulle seguenti ipotesi:

- il moto è ***quasi-unidimensionale e quasi-stazionario***;
- ***l'area della sezione di passaggio del fluido nel condotto è ritenuta costante***;
- ***il fluido non scambia lavoro con l'ambiente*** e ***sia gli effetti viscosi, che quelli delle forze gravitazionali, sono trascurabili***;
- ***la produzione di entropia è trascurabile***, in altre parole la trasformazione termofluidodinamica è considerata ***reversibile***;
- l'unica ***forza spingente*** è lo ***scambio di calore*** lungo il condotto che dà luogo ad una variazione dell'entalpia totale H.

FANNO

Gino Girolamo Fanno (28 November 1888 - 1960)

Fig. 1.10: The photo of Gino Fanno approximately in 1950

RAYLEIGH

John William Strutt, 3rd Baron Rayleigh (12 November 1842 – 30 June 1919)

FANNO

$$\frac{dG}{G} = \frac{d\rho}{\rho} + \frac{dV}{V} = 0$$

$$dI = dp + \rho V dV = -4f\frac{1}{2}\rho V^2 \frac{dx}{D_e}$$

$$dH = dh + VdV = 0$$

$$G = \rho V = cost$$

$$H = h + V^2/2 = cost$$

RAYLEIGH

$$\frac{dG}{G} = \frac{d\rho}{\rho} + \frac{dV}{V} = 0$$

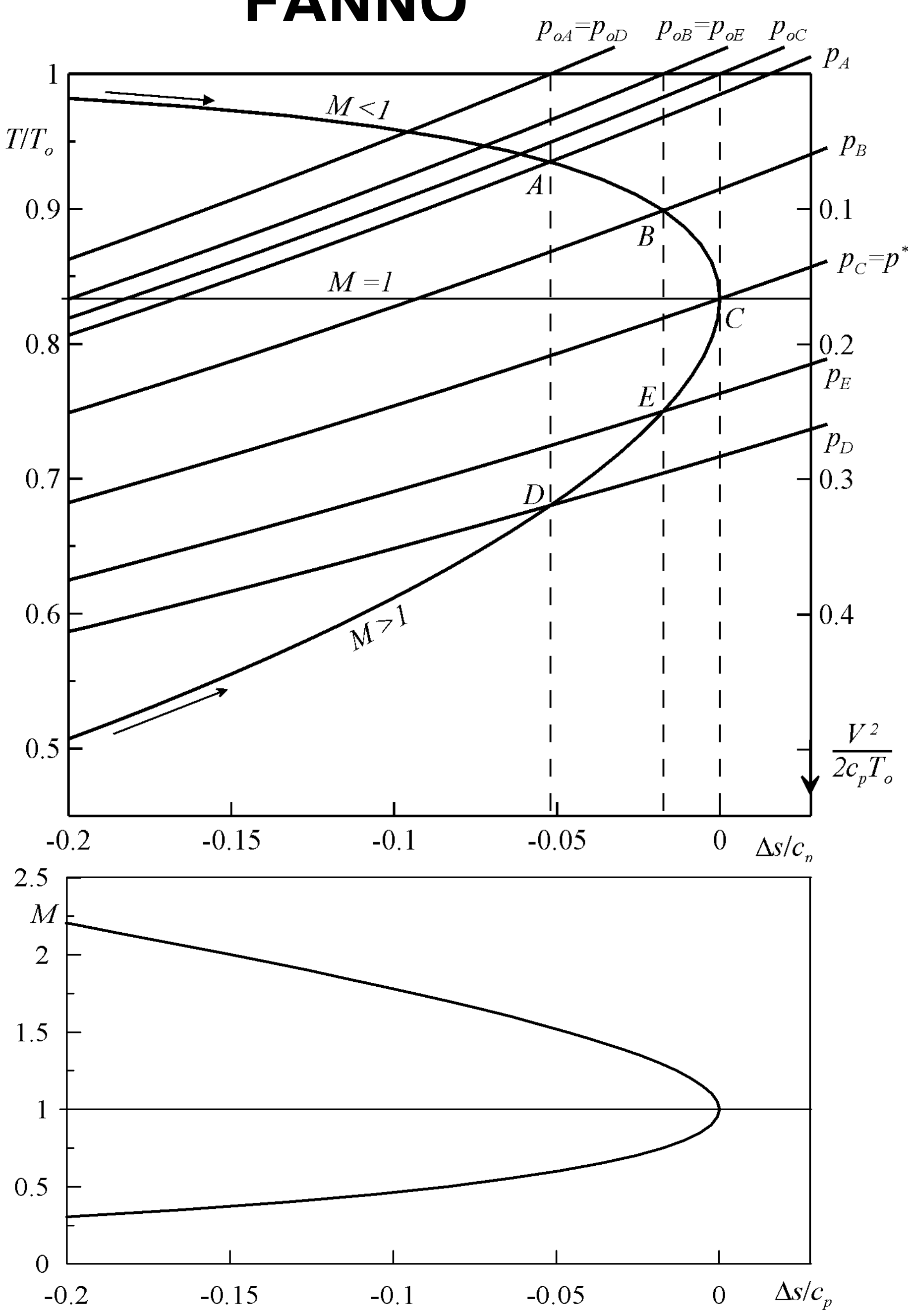
$$dI = dp + \rho V dV = dp + GdV = 0$$

$$G\left(dh + VdV\right) = GdH = Gc_p dT_o = 4\dot{q}\frac{dx}{D_e}$$

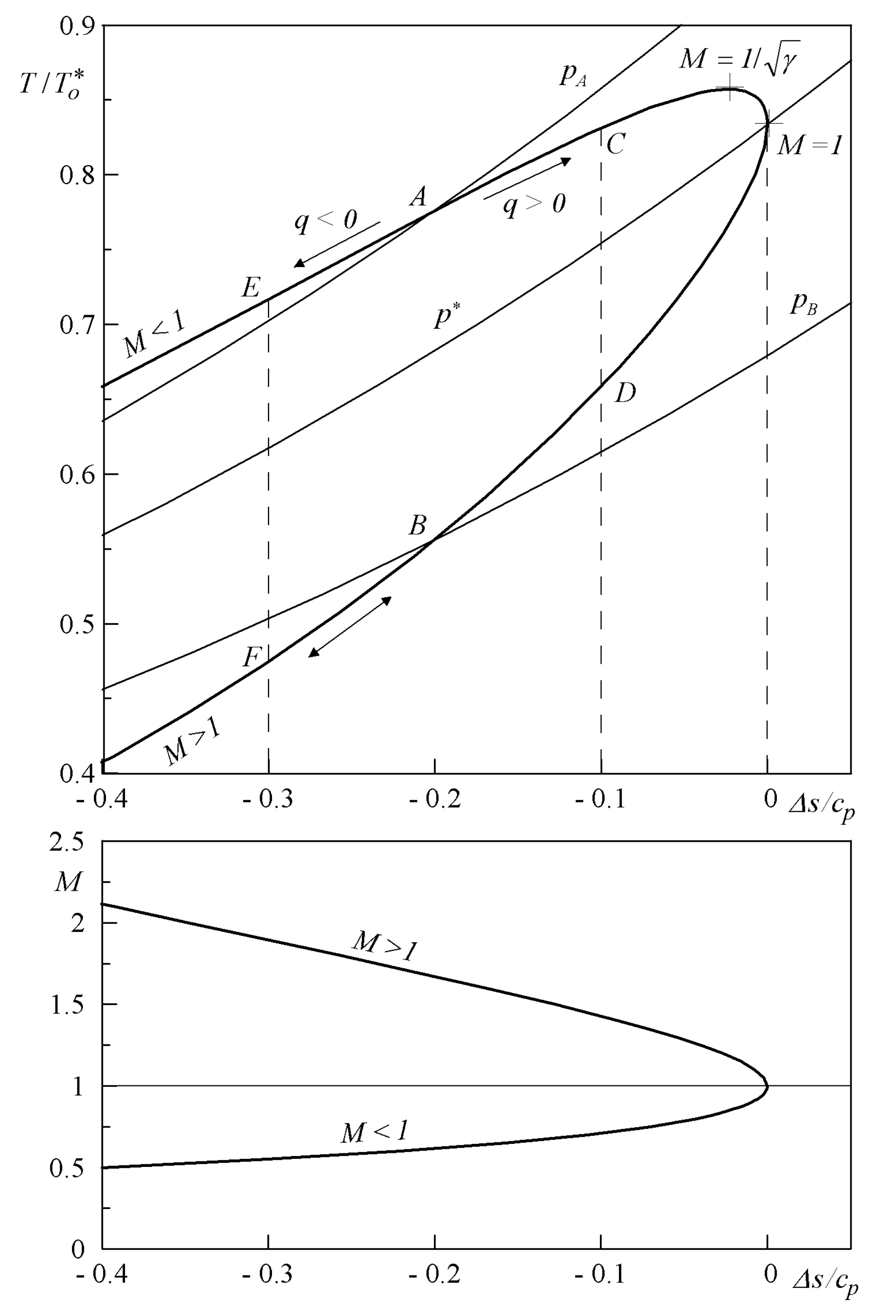
$$G = \rho V = cost$$

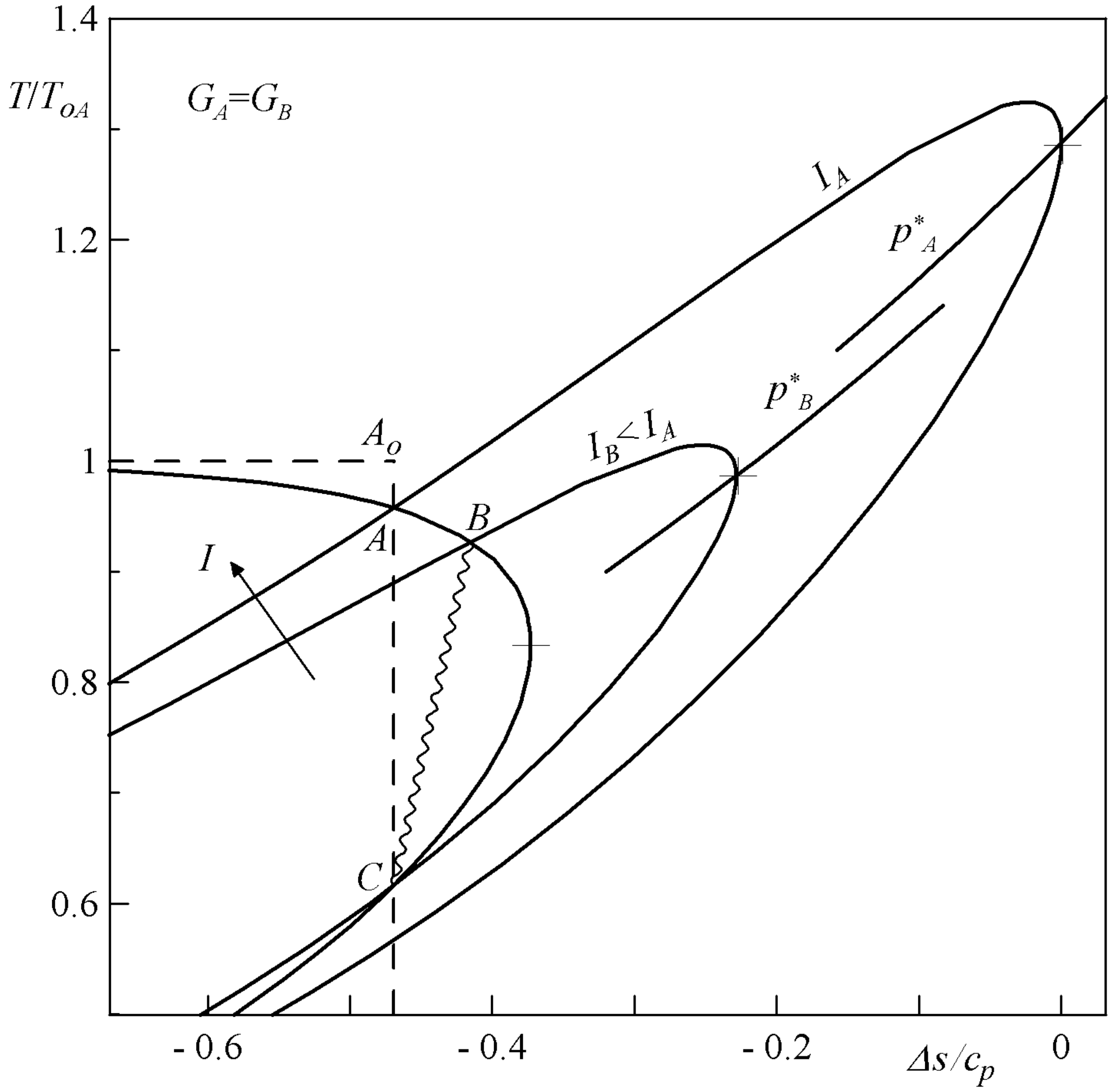
$$I = p + \rho V^2 = cost$$

FANNO



RAYLEIGH





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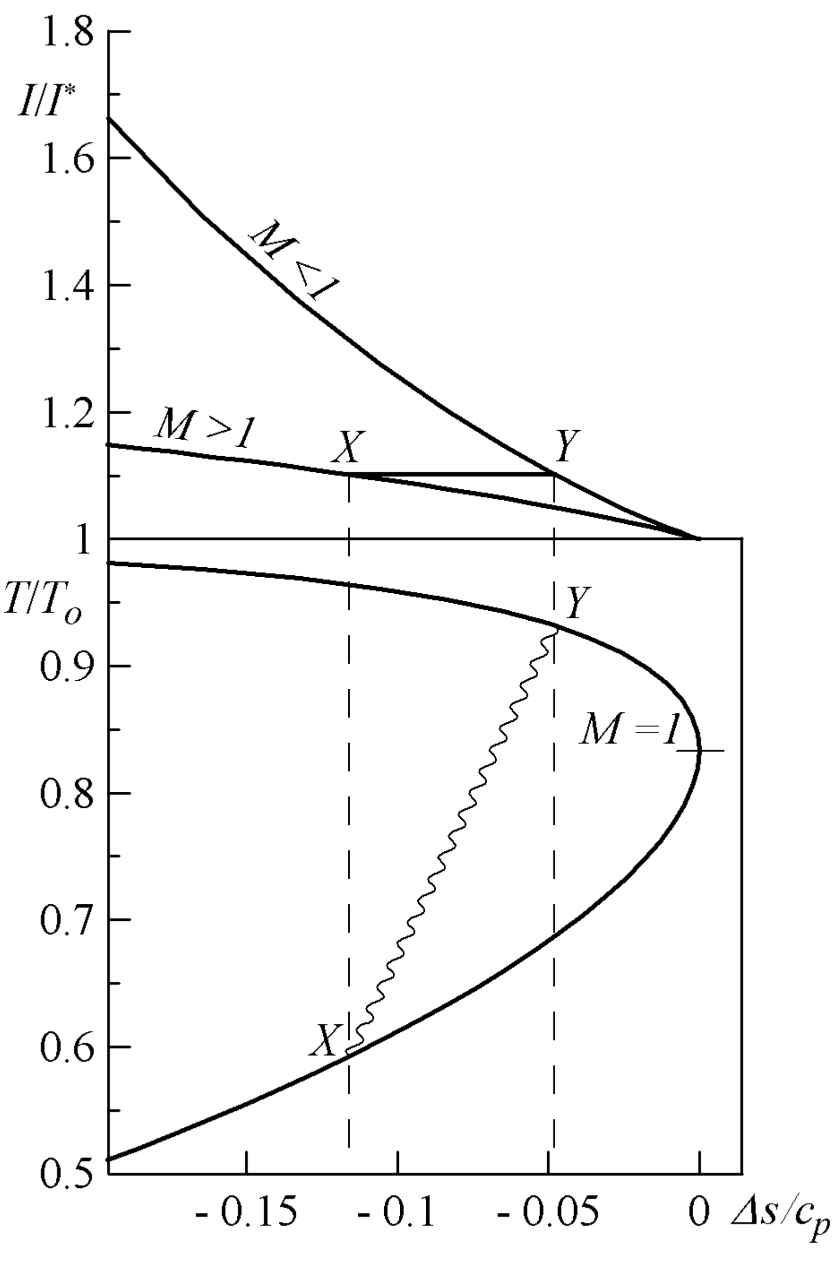

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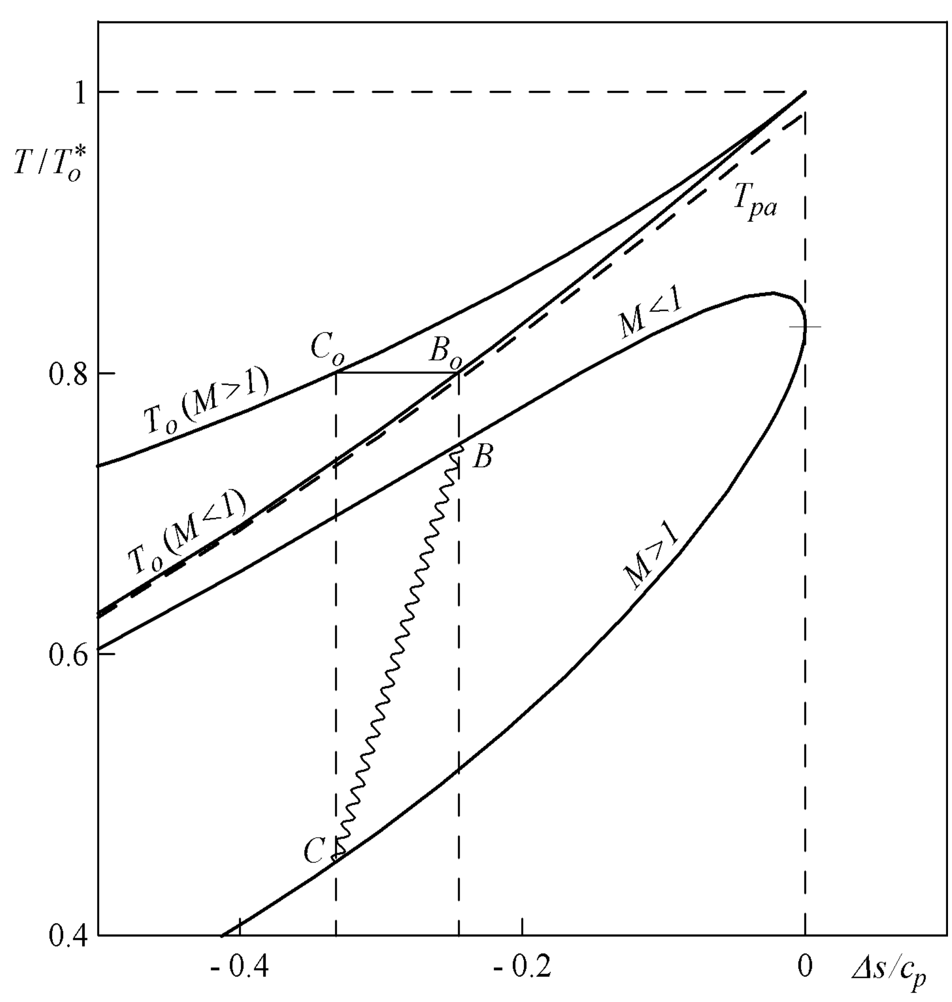

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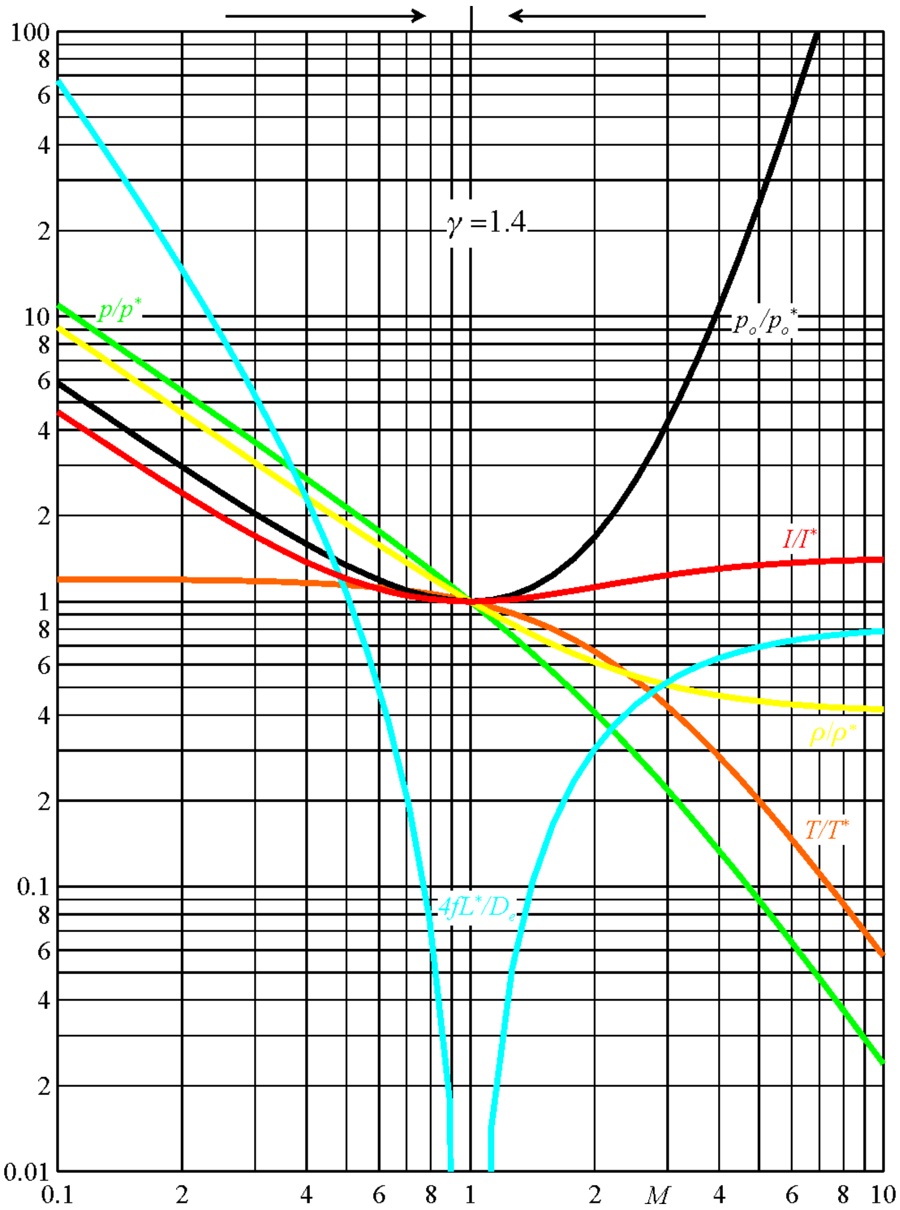

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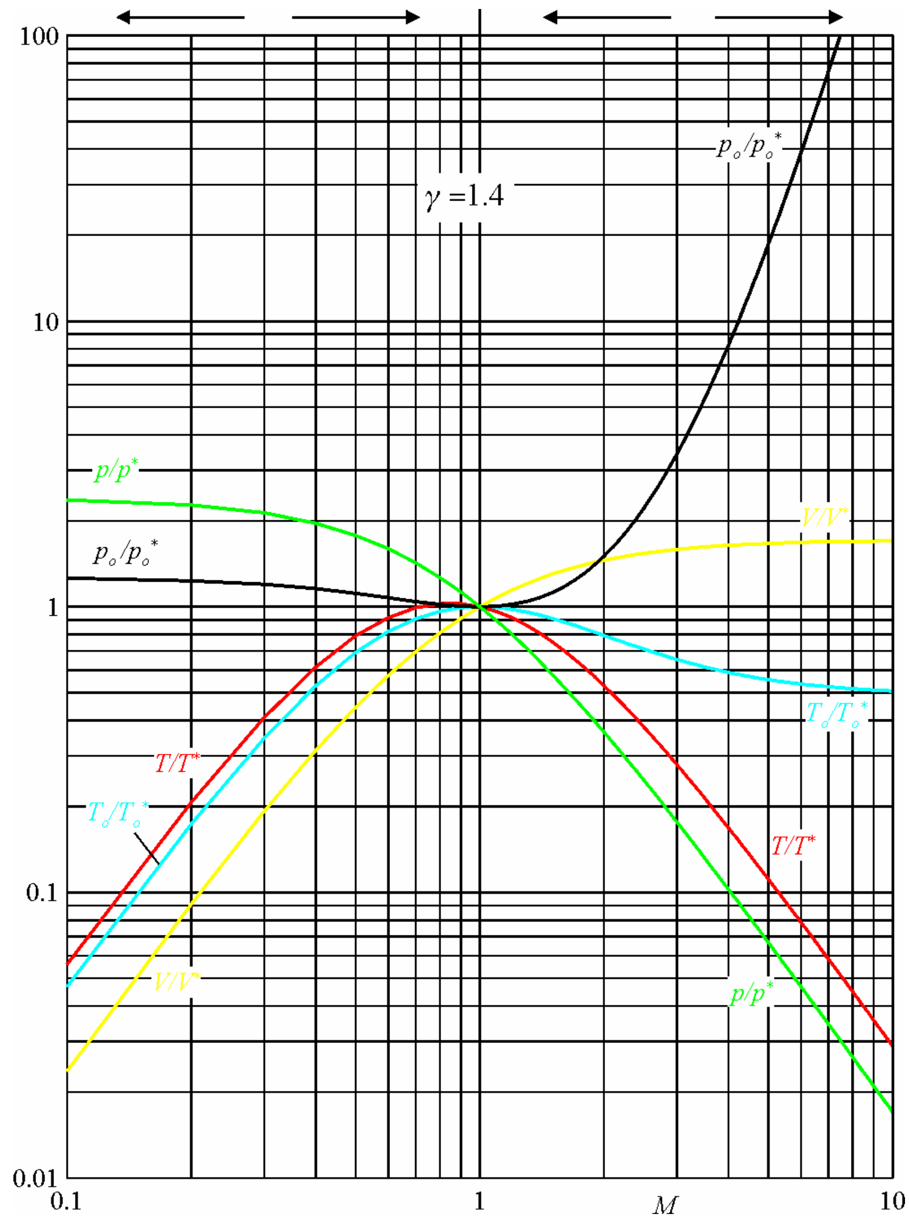

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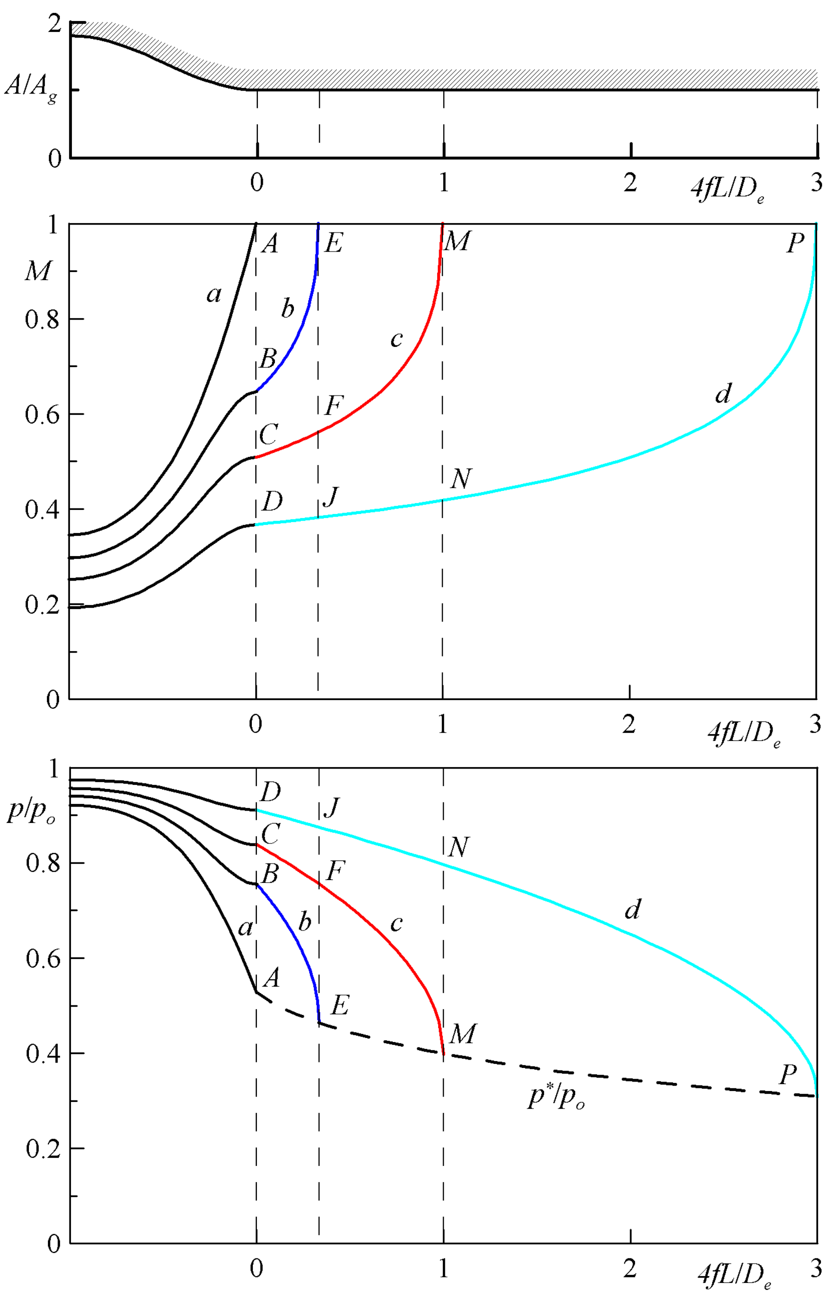

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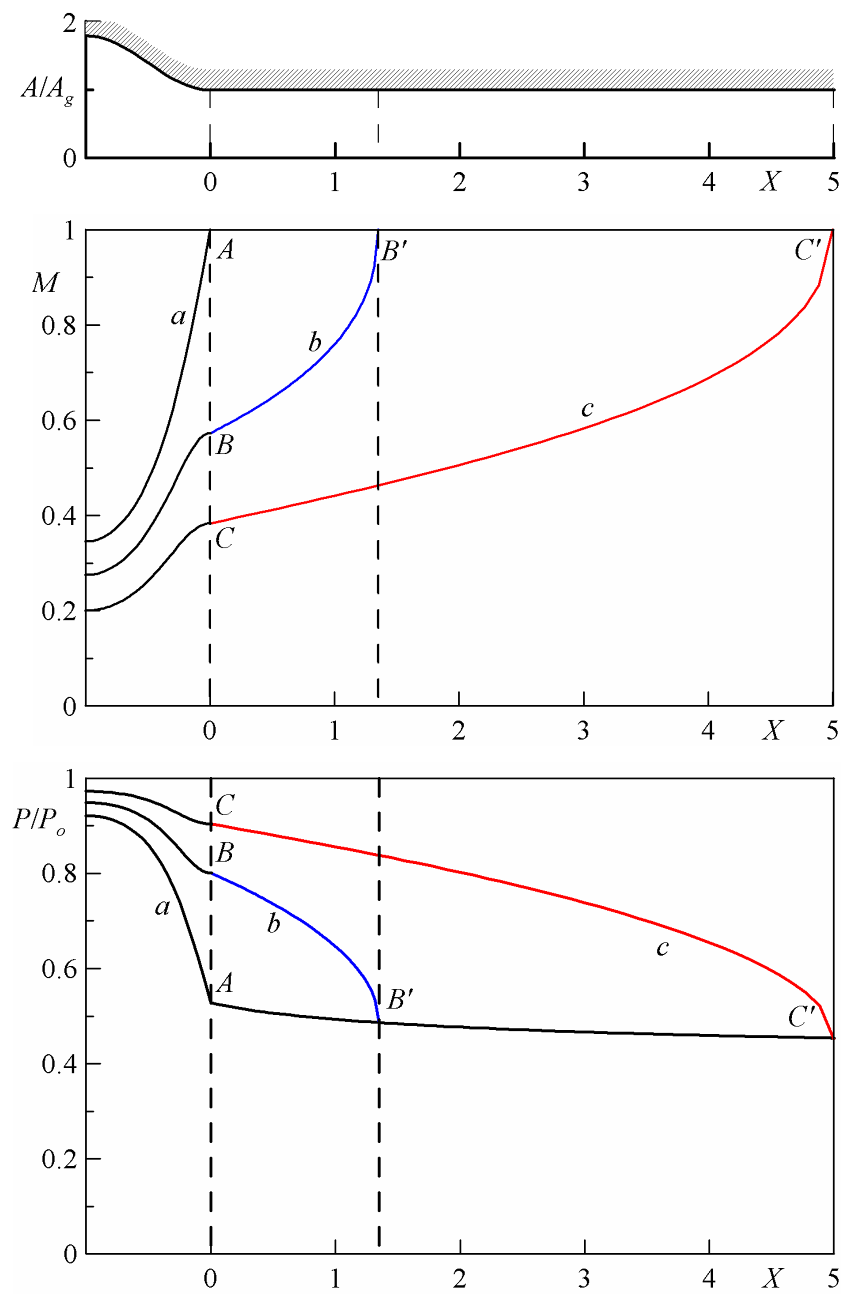

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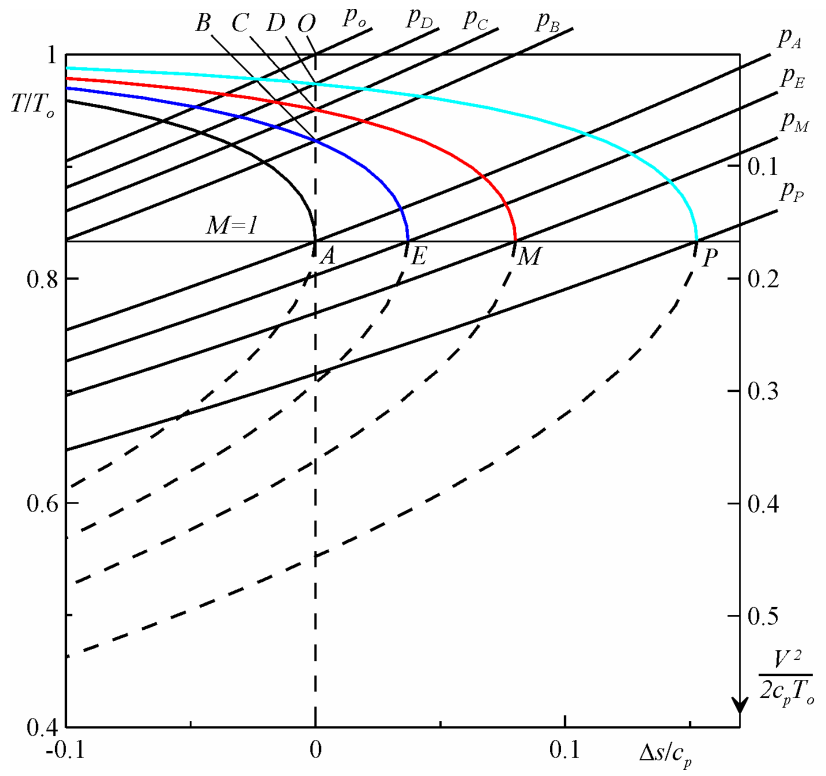

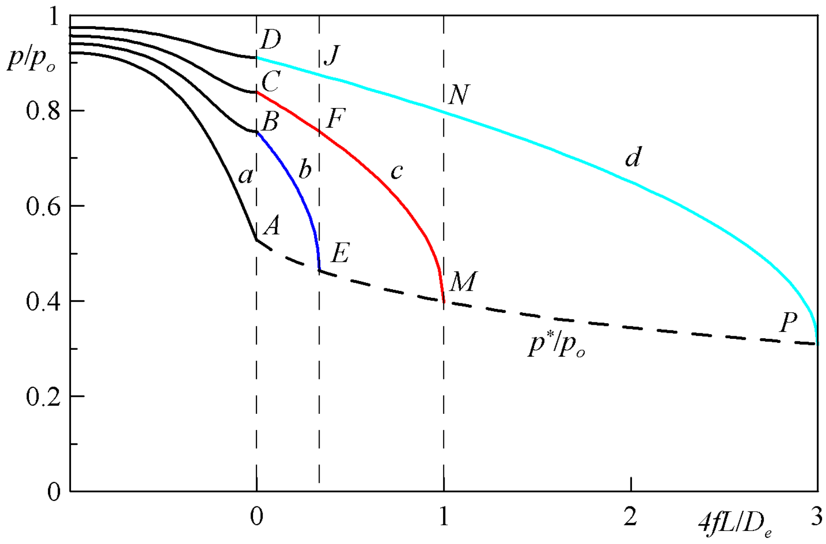

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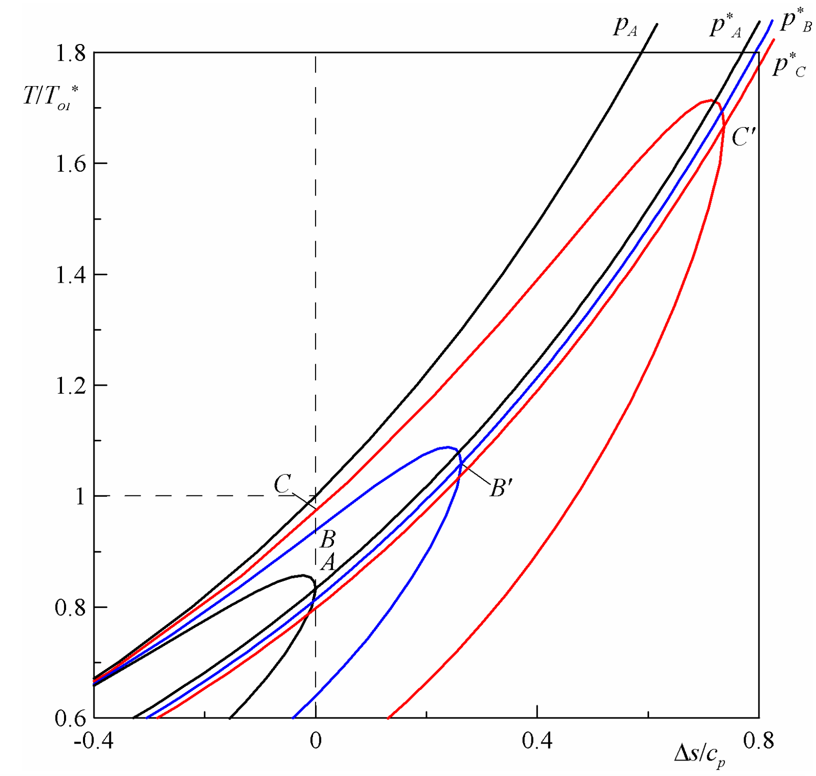

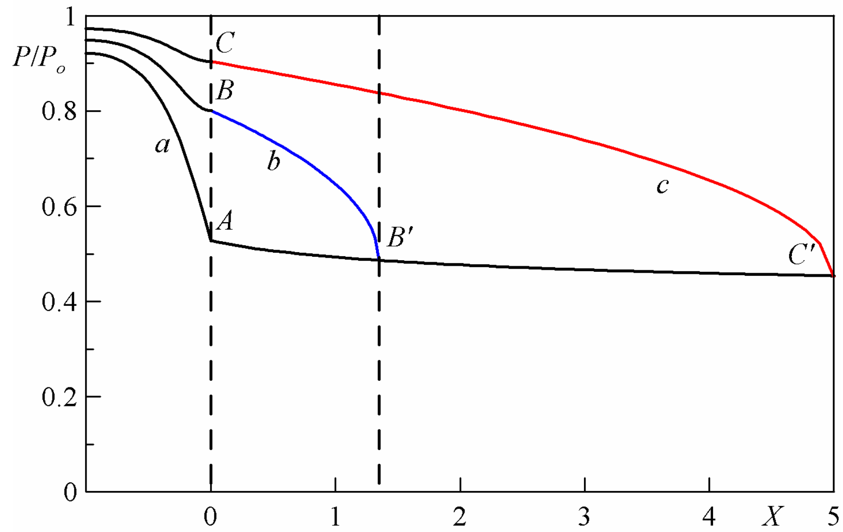

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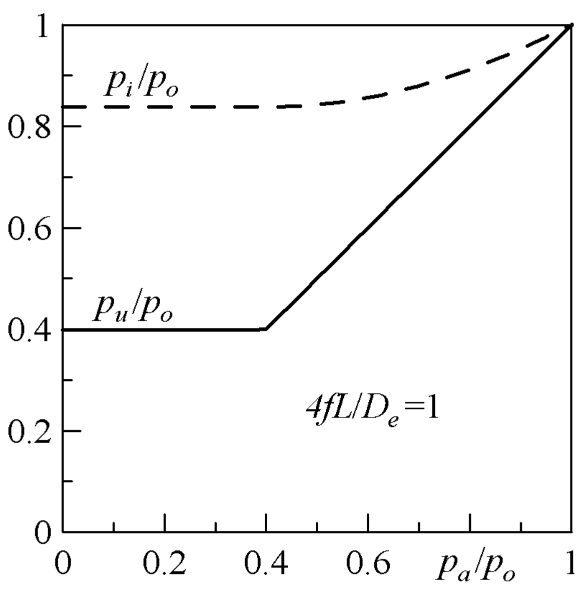

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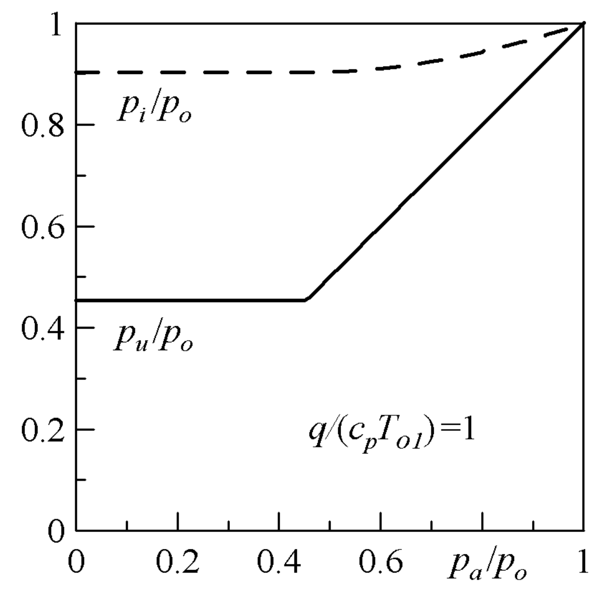

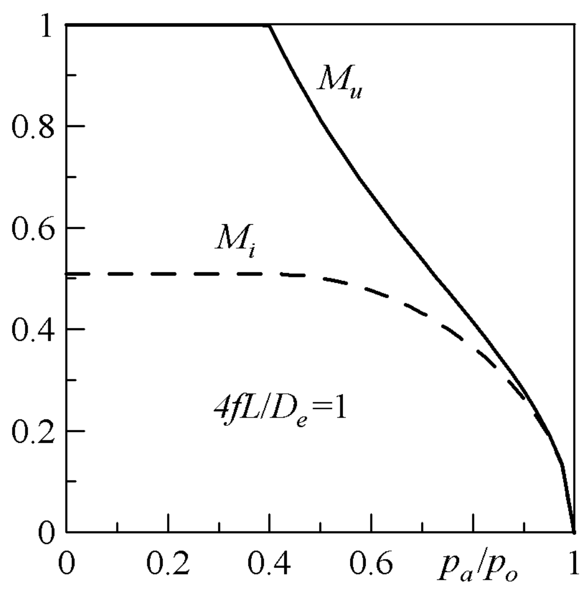

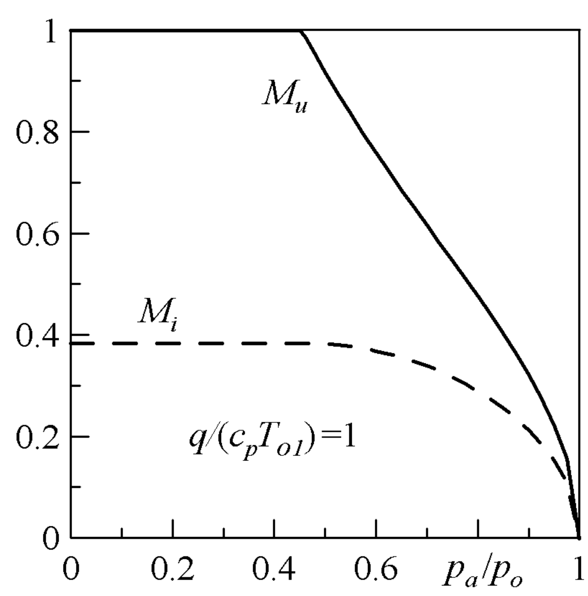

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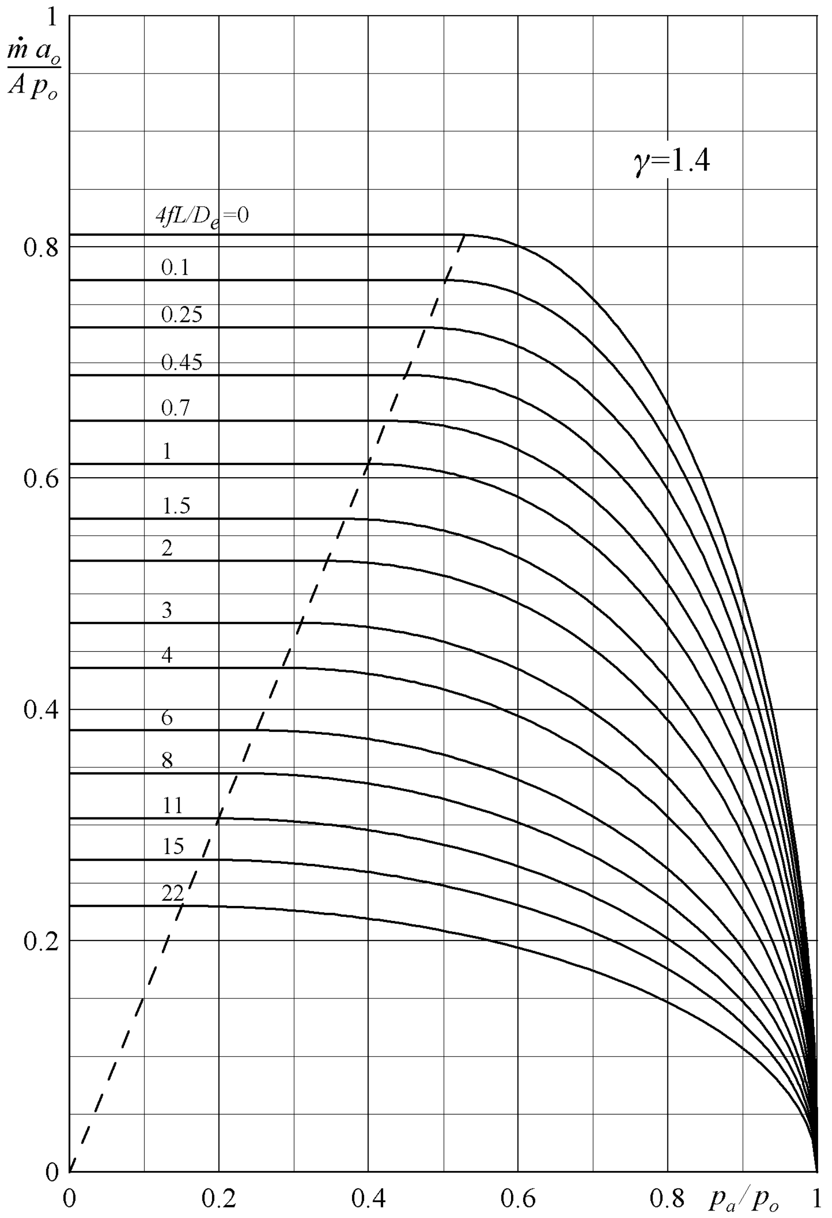

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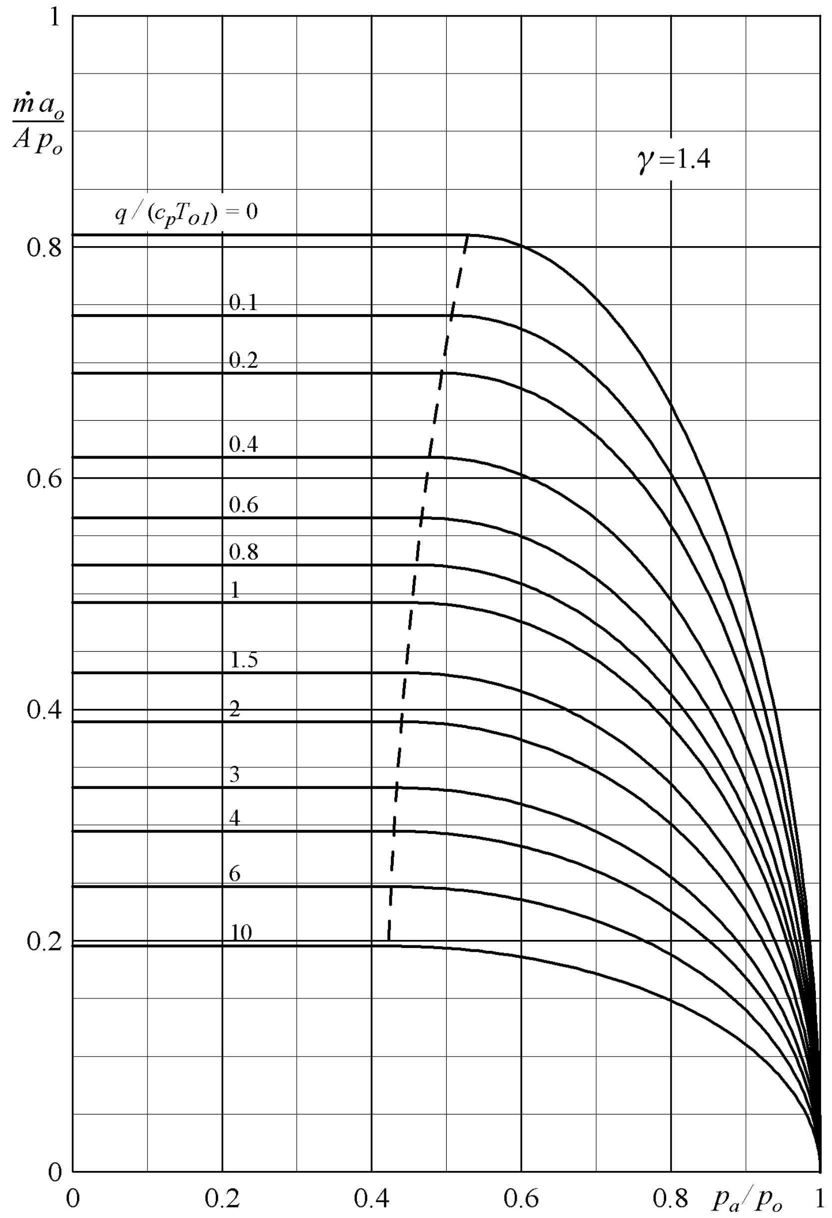

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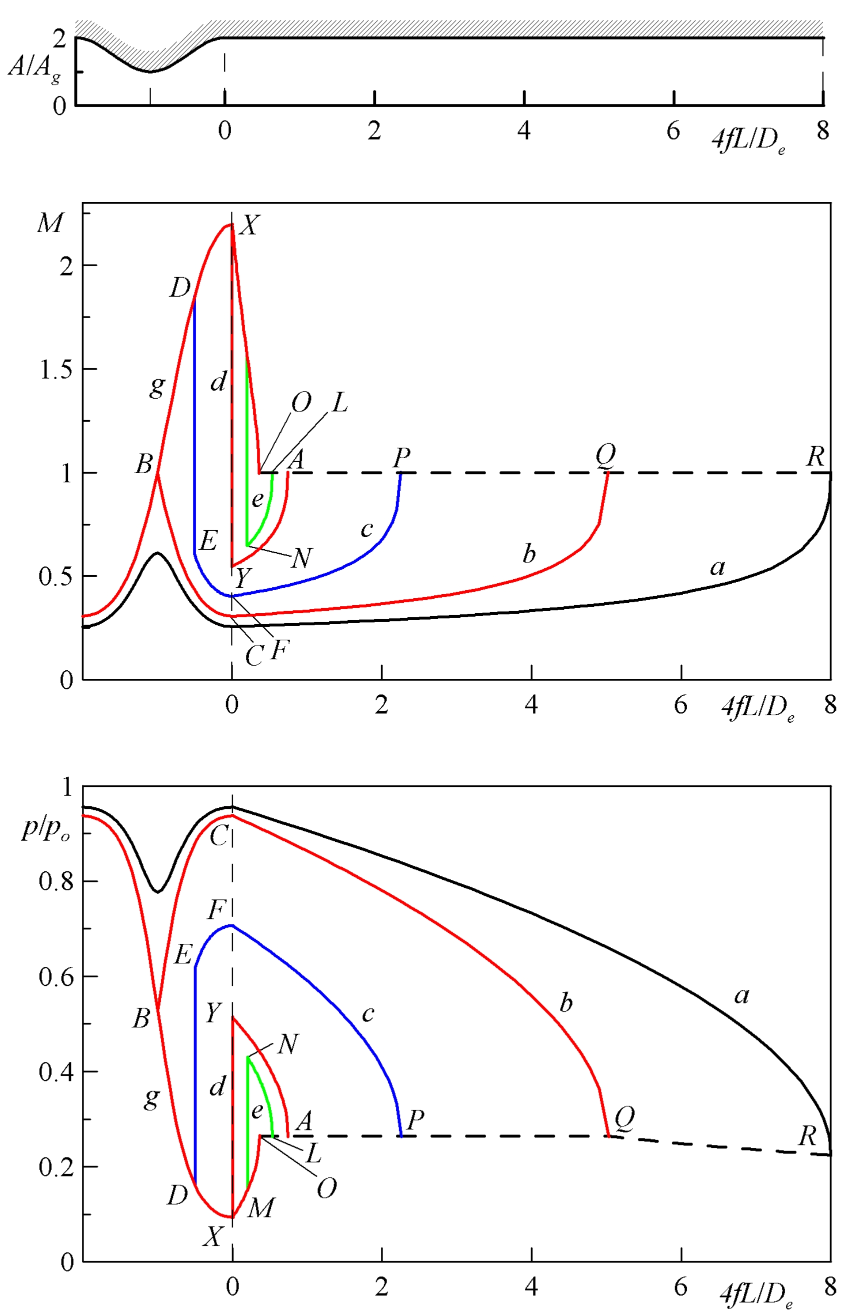

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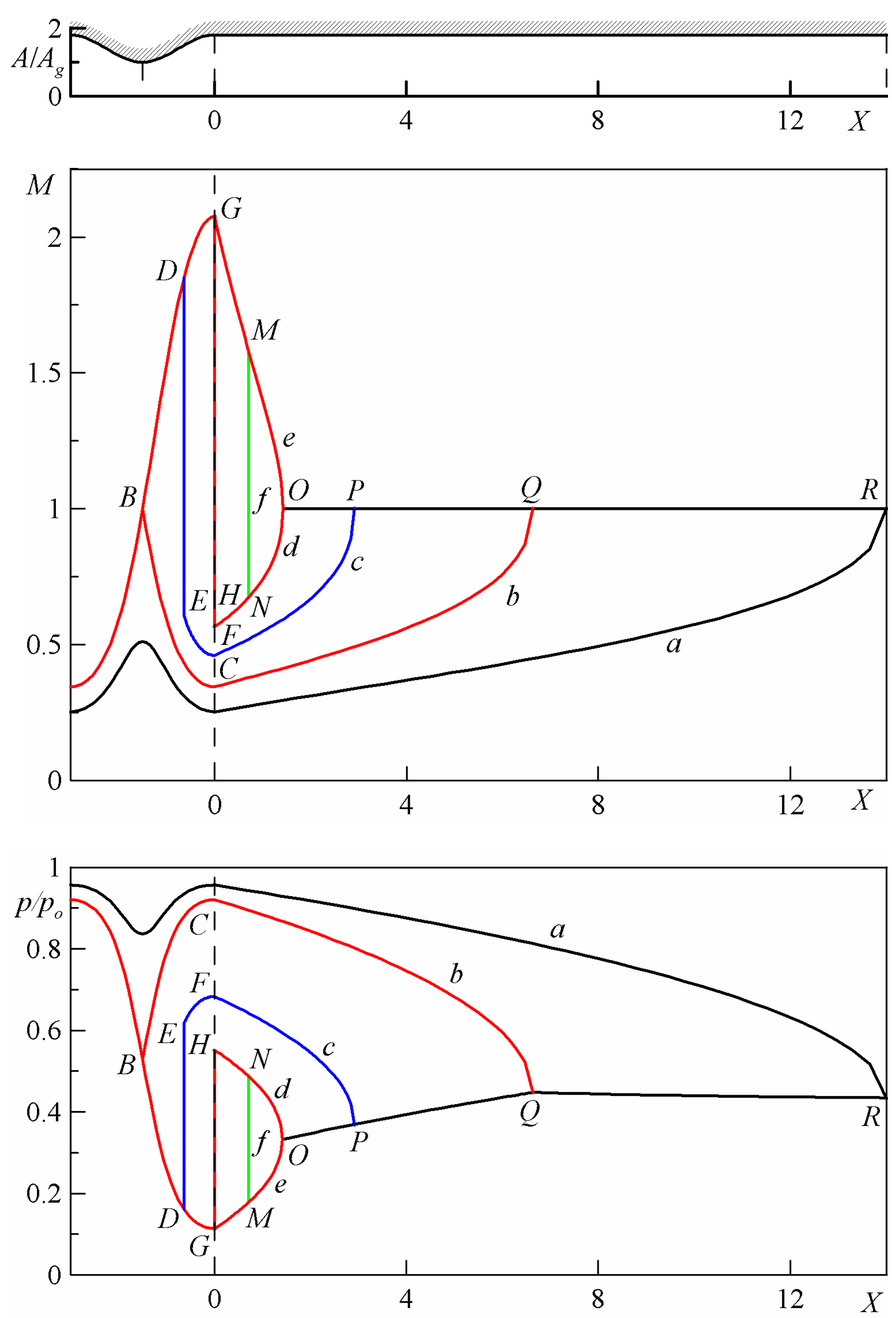

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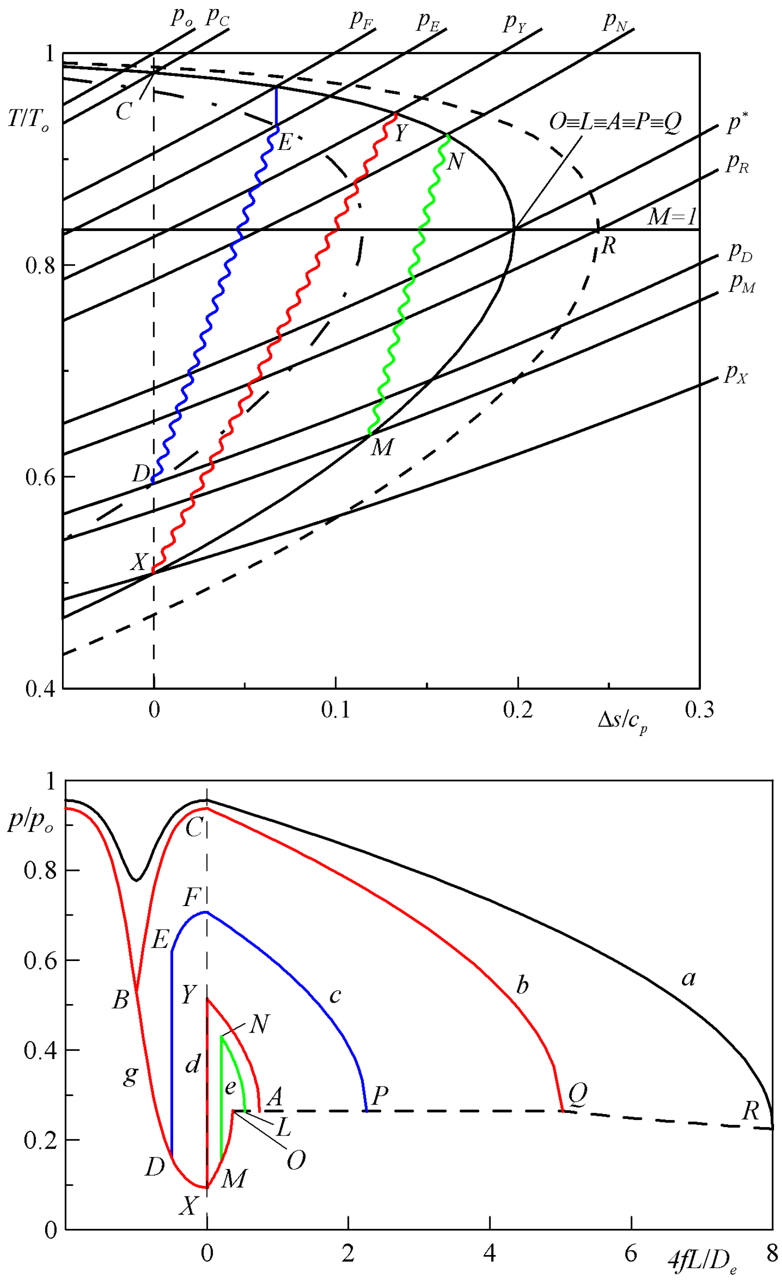

RAYLEIGH