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Appunti universitari

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Rilegature

NUMERO: 632

DATA: 03/10/2013

A P P U N T I

STUDENTE: Branca

MATERIA: Formulario di Gasdinamica

Prof. Iuso

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**ATTENZIONE: QUESTI APPUNTI SONO FATTI DA STUDENTIE NON SONO STATI VISIONATI DAL DOCENTE.
IL NOME DEL PROFESSORE, SERVE SOLO PER IDENTIFICARE IL CORSO.**

Formulario di Gasdinamica

Proprietà dei fluidi

$$\left\{ \begin{array}{l} \beta = -\frac{1}{v} \frac{dv}{dp} \left\{ \begin{array}{l} 5 \cdot 10^{-10} \Rightarrow \text{liquidi} \\ 1 \cdot 10^{-5} \Rightarrow \text{gas} \end{array} \right. \\ \beta_m = \frac{1}{\rho} \frac{d\rho}{dp} \Rightarrow d\rho = \rho \beta_m dp \end{array} \right.$$

$$\mathfrak{R} \left\{ \begin{array}{l} 8314 \frac{J}{Kg \cdot mol \cdot K} \\ 4,97 \cdot 10^4 \frac{ft \cdot lb}{slug \cdot mol \cdot R} \end{array} \right.$$

$$e = c_v T$$

$$h = c_p T = e + pv$$

$$c_p - c_v = R = \frac{\mathfrak{R}}{M}$$

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

$$\gamma = \frac{c_p}{c_v}$$

$$\left\{ \begin{array}{l} R = \frac{\mathfrak{R}}{M} = 287 \frac{J}{mol \cdot K} \\ R = Na \cdot Kb \end{array} \right.$$

$$R = Na \cdot Kb$$

$$C_i = \frac{m_i}{m_t}; \chi_i = \frac{n_i}{n_t} = \frac{\frac{C_i}{M_i}}{\sum \frac{C_i}{M_i}}$$

Termodinamica

$$dq + dw = de$$

$$\left\{ \begin{array}{l} ds \geq \frac{dq}{T} \\ ds \geq 0 \text{ sempre} \end{array} \right.$$

$$Re = \frac{V_\infty L \rho_\infty}{\mu_\infty}$$

$$Pr = \frac{\mu_\infty C_p}{\lambda} = \frac{2L + 4}{2L + 9} = \frac{4\gamma}{9\gamma - 5}$$

$$\frac{\delta}{\delta_T} = \sqrt{Pr}$$

$$\mu_\infty = S \frac{T^{\frac{3}{2}}}{\chi + T}$$

$$\frac{\mu}{\mu_\infty} = \left(\frac{T}{T_\infty} \right)^\omega$$

$$l = \frac{1}{d^2 n} \cdot \frac{1}{\sqrt{2\pi}}$$

$$E_T = \frac{3}{2} K_b T$$

$$V_{at} = \sqrt{\frac{2E_T}{m}}$$

$$\left\{ \begin{array}{l} L_v = 3n - L_t - L_r \\ L = L_t + L_r + 2L_v \end{array} \right.$$

$$h = e + \frac{v^2}{2}$$

$$\frac{a^2}{\gamma - 1} + \frac{u^2}{2} = \frac{\gamma + 1}{2(\gamma - 1)} a^{*2}$$

$$a^{*2} = u_1 \cdot u_2$$

Formula di Wilke

$$\mu_{misc} = \sum \mu_i \left(1 + \sum G_{i,k} \frac{\chi_k}{\chi_i} \right)^{-1}$$

Proprietà dei GAS									
n	Lt	Lr	Lv	L	e	h	Cp	Cv	Y
1	3	0	0	3	1,5	2,5	716,724	430,034	1,6667E+00
2	3	2	0	5	2,5	3,5	1003,41	716,724	1,4000E+00
2	3	3	6	6	3	4	1146,76	860,069	1,3333E+00
3	3	3	6	12	6	7	2006,83	1720,14	1,1667E+00
4	3	3	6	18	9	10	2866,9	2580,21	1,1111E+00

Formulario di Gasdinamica

Aria

$$\left\{ \begin{array}{l} C_v = 717 \frac{J}{Kg \cdot K} \\ C_p = 1003 \frac{J}{Kg \cdot K} \\ \gamma = 1,4 \\ M = 29 \frac{Kg}{mol} \end{array} \right.$$

$$\left\{ \begin{array}{l} Pr = 0,71 \\ S = 1,46 \cdot 10^{-6} \frac{Kg}{m \cdot s \cdot \sqrt{K}} \\ \chi = 110K \\ v = \frac{\mu_\infty}{\rho_\infty} = 1,45 \cdot 10^{-5} \frac{m^2}{s} \end{array} \right.$$

Conversioni

$$1lb_f = 4,448N$$

$$1ft = 0,3048m$$

$$1ft^2 = 0,093m^2$$

$$1lb = 0,45369Kg$$

$$1 \frac{lb}{ft^2} = 4,882 \frac{Kg}{m^2}$$

$$1 \frac{lb}{ft^3} = 16,018 \frac{Kg}{m^3}$$

$$1 \frac{lb}{in^2} (psi) = 6894,75Pa$$

$$1atm = 101325Pa$$

$$1BTU = 4,184J$$

$$1J = 0,239cal$$

$$BTU = 252cal$$

$$1^\circ C = [^\circ R - 491,67] \frac{5}{9}$$

$$1^\circ F = 1,8(^\circ C + 40^\circ) - 40^\circ$$

Formulario di Gasdinamica

Temperatura [K]	Sutherland	Monomia		
	μ_{∞}	μ - con riferimento ambiente		
		0,6	0,75	0,9
750	3,4870E-05	3,2028E-05	3,6783E-05	4,2245E-05
760	3,5160E-05	3,2283E-05	3,7151E-05	4,2752E-05
770	3,5449E-05	3,2537E-05	3,7517E-05	4,3258E-05
780	3,5736E-05	3,2790E-05	3,7881E-05	4,3763E-05
790	3,6021E-05	3,3042E-05	3,8245E-05	4,4268E-05
800	3,6303E-05	3,3292E-05	3,8608E-05	4,4772E-05
810	3,6584E-05	3,3541E-05	3,8969E-05	4,5275E-05
820	3,6863E-05	3,3789E-05	3,9329E-05	4,5778E-05
830	3,7140E-05	3,4036E-05	3,9688E-05	4,6280E-05
840	3,7415E-05	3,4281E-05	4,0046E-05	4,6781E-05
850	3,7689E-05	3,4525E-05	4,0404E-05	4,7282E-05
860	3,7960E-05	3,4769E-05	4,0759E-05	4,7783E-05
870	3,8230E-05	3,5011E-05	4,1114E-05	4,8283E-05
880	3,8498E-05	3,5251E-05	4,1468E-05	4,8782E-05
890	3,8765E-05	3,5491E-05	4,1821E-05	4,9280E-05
900	3,9030E-05	3,5730E-05	4,2173E-05	4,9778E-05
910	3,9293E-05	3,5968E-05	4,2524E-05	5,0276E-05
920	3,9555E-05	3,6204E-05	4,2874E-05	5,0773E-05
930	3,9815E-05	3,6440E-05	4,3223E-05	5,1269E-05
940	4,0073E-05	3,6674E-05	4,3571E-05	5,1765E-05
950	4,0330E-05	3,6908E-05	4,3919E-05	5,2261E-05
960	4,0586E-05	3,7141E-05	4,4265E-05	5,2755E-05
970	4,0840E-05	3,7372E-05	4,4610E-05	5,3250E-05
980	4,1093E-05	3,7603E-05	4,4955E-05	5,3743E-05
990	4,1344E-05	3,7833E-05	4,5298E-05	5,4237E-05
1000	4,1594E-05	3,8062E-05	4,5641E-05	5,4730E-05
1010	4,1842E-05	3,8290E-05	4,5983E-05	5,5222E-05
1020	4,2090E-05	3,8517E-05	4,6324E-05	5,5714E-05
1030	4,2335E-05	3,8743E-05	4,6664E-05	5,6205E-05
1040	4,2580E-05	3,8968E-05	4,7003E-05	5,6696E-05
1050	4,2823E-05	3,9192E-05	4,7342E-05	5,7186E-05
1060	4,3065E-05	3,9416E-05	4,7680E-05	5,7676E-05
1070	4,3306E-05	3,9639E-05	4,8017E-05	5,8166E-05
1080	4,3545E-05	3,9860E-05	4,8353E-05	5,8655E-05
1090	4,3784E-05	4,0081E-05	4,8688E-05	5,9143E-05
1100	4,4021E-05	4,0302E-05	4,9023E-05	5,9632E-05
1110	4,4257E-05	4,0521E-05	4,9357E-05	6,0119E-05
1120	4,4491E-05	4,0740E-05	4,9690E-05	6,0606E-05
1130	4,4725E-05	4,0958E-05	5,0022E-05	6,1093E-05
1140	4,4957E-05	4,1175E-05	5,0354E-05	6,1580E-05
1150	4,5189E-05	4,1391E-05	5,0685E-05	6,2066E-05
1160	4,5419E-05	4,1607E-05	5,1015E-05	6,2551E-05
1170	4,5648E-05	4,1821E-05	5,1345E-05	6,3036E-05
1180	4,5876E-05	4,2036E-05	5,1673E-05	6,3521E-05
1190	4,6103E-05	4,2249E-05	5,2001E-05	6,4005E-05
1200	4,6329E-05	4,2462E-05	5,2329E-05	6,4489E-05
1210	4,6554E-05	4,2674E-05	5,2656E-05	6,4972E-05
1220	4,6778E-05	4,2885E-05	5,2982E-05	6,5456E-05

Formulario di Gasdinamica

Flusso Unidimensionale

* *Continuità* $\rho_1 u_1 = \rho_2 u_2$

* *QdM* $p_1 + \rho_1 u_1^2 = p_2 + \rho_2 u_2^2$

* *Energia* $h_1 + \rho_1 \frac{u_1^2}{2} = h_2 + \rho_2 \frac{u_2^2}{2}$

Flusso Isentropico

$$\left\{ \begin{array}{l} \frac{T_2}{T_1} = 1 + \frac{\gamma-1}{2} M_1^2 \\ \frac{p_2}{p_1} = \left(\frac{T_2}{T_1} \right)^{\frac{\gamma}{\gamma-1}} = \left(1 + \frac{\gamma-1}{2} M_1^2 \right)^{\frac{\gamma}{\gamma-1}} \\ \frac{\rho_2}{\rho_1} = \left(\frac{T_2}{T_1} \right)^{\frac{1}{\gamma-1}} = \left(1 + \frac{\gamma-1}{2} M_1^2 \right)^{\frac{1}{\gamma-1}} \end{array} \right.$$

$$\left\{ \begin{array}{l} \frac{T_0}{T_\infty} = 1 + \frac{\gamma-1}{2} M_\infty^2 \\ \frac{p_0}{p_\infty} = \left(\frac{T_0}{T_\infty} \right)^{\frac{\gamma}{\gamma-1}} = \left(1 + \frac{\gamma-1}{2} M_\infty^2 \right)^{\frac{\gamma}{\gamma-1}} \\ \frac{\rho_0}{\rho_\infty} = \left(\frac{T_0}{T_\infty} \right)^{\frac{1}{\gamma-1}} = \left(1 + \frac{\gamma-1}{2} M_\infty^2 \right)^{\frac{1}{\gamma-1}} \end{array} \right.$$

Formulario di Gasdinamica

FLUSSO ISENTROPICO				
Mach In	T0/T	P0/P	ρ_0/ρ	A/A*
1,00E+00	1,2000E+00	1,8929E+00	1,5774E+00	1,0000E+00
1,02E+00	1,2081E+00	1,9379E+00	1,6041E+00	1,0003E+00
1,04E+00	1,2163E+00	1,9846E+00	1,6316E+00	1,0013E+00
1,06E+00	1,2247E+00	2,0330E+00	1,6599E+00	1,0029E+00
1,08E+00	1,2333E+00	2,0831E+00	1,6891E+00	1,0051E+00
1,10E+00	1,2420E+00	2,1351E+00	1,7191E+00	1,0079E+00
1,12E+00	1,2509E+00	2,1890E+00	1,7500E+00	1,0113E+00
1,14E+00	1,2599E+00	2,2449E+00	1,7818E+00	1,0153E+00
1,16E+00	1,2691E+00	2,3028E+00	1,8145E+00	1,0198E+00
1,18E+00	1,2785E+00	2,3628E+00	1,8481E+00	1,0248E+00
1,20E+00	1,2880E+00	2,4250E+00	1,8827E+00	1,0304E+00
1,22E+00	1,2977E+00	2,4894E+00	1,9183E+00	1,0366E+00
1,24E+00	1,3075E+00	2,5560E+00	1,9549E+00	1,0432E+00
1,26E+00	1,3175E+00	2,6251E+00	1,9925E+00	1,0504E+00
1,28E+00	1,3277E+00	2,6967E+00	2,0311E+00	1,0581E+00
1,30E+00	1,3380E+00	2,7707E+00	2,0708E+00	1,0663E+00
1,32E+00	1,3485E+00	2,8474E+00	2,1116E+00	1,0750E+00
1,34E+00	1,3591E+00	2,9269E+00	2,1535E+00	1,0842E+00
1,36E+00	1,3699E+00	3,0091E+00	2,1965E+00	1,0940E+00
1,38E+00	1,3809E+00	3,0942E+00	2,2407E+00	1,1042E+00
1,40E+00	1,3920E+00	3,1823E+00	2,2861E+00	1,1149E+00
1,42E+00	1,4033E+00	3,2734E+00	2,3327E+00	1,1262E+00
1,44E+00	1,4147E+00	3,3678E+00	2,3805E+00	1,1379E+00
1,46E+00	1,4263E+00	3,4654E+00	2,4296E+00	1,1501E+00
1,48E+00	1,4381E+00	3,5665E+00	2,4800E+00	1,1629E+00
1,50E+00	1,4500E+00	3,6710E+00	2,5317E+00	1,1762E+00
1,52E+00	1,4621E+00	3,7792E+00	2,5848E+00	1,1899E+00
1,54E+00	1,4743E+00	3,8911E+00	2,6392E+00	1,2042E+00
1,56E+00	1,4867E+00	4,0068E+00	2,6951E+00	1,2190E+00
1,58E+00	1,4993E+00	4,1266E+00	2,7524E+00	1,2344E+00
1,60E+00	1,5120E+00	4,2504E+00	2,8111E+00	1,2502E+00
1,62E+00	1,5249E+00	4,3785E+00	2,8714E+00	1,2666E+00
1,64E+00	1,5379E+00	4,5110E+00	2,9332E+00	1,2836E+00
1,66E+00	1,5511E+00	4,6479E+00	2,9965E+00	1,3010E+00
1,68E+00	1,5645E+00	4,7896E+00	3,0614E+00	1,3190E+00
1,70E+00	1,5780E+00	4,9360E+00	3,1280E+00	1,3376E+00
1,72E+00	1,5917E+00	5,0874E+00	3,1962E+00	1,3567E+00
1,74E+00	1,6055E+00	5,2439E+00	3,2662E+00	1,3764E+00
1,76E+00	1,6195E+00	5,4057E+00	3,3378E+00	1,3967E+00
1,78E+00	1,6337E+00	5,5729E+00	3,4113E+00	1,4175E+00
1,80E+00	1,6480E+00	5,7458E+00	3,4865E+00	1,4390E+00
1,82E+00	1,6625E+00	5,9244E+00	3,5636E+00	1,4610E+00
1,84E+00	1,6771E+00	6,1091E+00	3,6426E+00	1,4836E+00
1,86E+00	1,6919E+00	6,2998E+00	3,7235E+00	1,5069E+00
1,88E+00	1,7069E+00	6,4970E+00	3,8063E+00	1,5308E+00
1,90E+00	1,7220E+00	6,7006E+00	3,8912E+00	1,5553E+00
1,92E+00	1,7373E+00	6,9111E+00	3,9781E+00	1,5804E+00
1,94E+00	1,7527E+00	7,1284E+00	4,0671E+00	1,6062E+00
1,96E+00	1,7683E+00	7,3530E+00	4,1582E+00	1,6326E+00

Formulario di Gasdinamica

FLUSSO ISENTROPICO				
Mach In	T0/T	P0/P	ρ_0/ρ	A/A*
4,40E+00	4,8720E+00	2,5526E+02	5,2392E+01	1,5210E+01
4,45E+00	4,9605E+00	2,7186E+02	5,4804E+01	1,5873E+01
4,50E+00	5,0500E+00	2,8941E+02	5,7310E+01	1,6562E+01
4,55E+00	5,1405E+00	3,0798E+02	5,9912E+01	1,7277E+01
4,60E+00	5,2320E+00	3,2759E+02	6,2614E+01	1,8018E+01
4,65E+00	5,3245E+00	3,4832E+02	6,5418E+01	1,8786E+01
4,70E+00	5,4180E+00	3,7020E+02	6,8328E+01	1,9583E+01
4,75E+00	5,5125E+00	3,9330E+02	7,1346E+01	2,0408E+01
4,80E+00	5,6080E+00	4,1766E+02	7,4477E+01	2,1264E+01
4,85E+00	5,7045E+00	4,4337E+02	7,7722E+01	2,2150E+01
4,90E+00	5,8020E+00	4,7046E+02	8,1086E+01	2,3067E+01
4,95E+00	5,9005E+00	4,9901E+02	8,4571E+01	2,4017E+01
5,00E+00	6,0000E+00	5,2909E+02	8,8182E+01	2,5000E+01
5,10E+00	6,2020E+00	5,9410E+02	9,5792E+01	2,7070E+01
5,20E+00	6,4080E+00	6,6608E+02	1,0395E+02	2,9283E+01
5,30E+00	6,6180E+00	7,4566E+02	1,1267E+02	3,1649E+01
5,40E+00	6,8320E+00	8,3352E+02	1,2200E+02	3,4175E+01
5,50E+00	7,0500E+00	9,3038E+02	1,3197E+02	3,6869E+01
5,60E+00	7,2720E+00	1,0370E+03	1,4260E+02	3,9740E+01
5,70E+00	7,4980E+00	1,1543E+03	1,5394E+02	4,2797E+01
5,80E+00	7,7280E+00	1,2830E+03	1,6602E+02	4,6050E+01
5,90E+00	7,9620E+00	1,4242E+03	1,7888E+02	4,9507E+01
6,00E+00	8,2000E+00	1,5789E+03	1,9255E+02	5,3180E+01
6,10E+00	8,4420E+00	1,7481E+03	2,0707E+02	5,7077E+01
6,20E+00	8,6880E+00	1,9329E+03	2,2248E+02	6,1210E+01
6,30E+00	8,9380E+00	2,1347E+03	2,3884E+02	6,5590E+01
6,40E+00	9,1920E+00	2,3547E+03	2,5617E+02	7,0227E+01
6,50E+00	9,4500E+00	2,5942E+03	2,7452E+02	7,5134E+01
6,60E+00	9,7120E+00	2,8548E+03	2,9395E+02	8,0323E+01
6,70E+00	9,9780E+00	3,1380E+03	3,1449E+02	8,5805E+01
6,80E+00	1,0248E+01	3,4454E+03	3,3620E+02	9,1594E+01
6,90E+00	1,0522E+01	3,7787E+03	3,5913E+02	9,7702E+01
7,00E+00	1,0800E+01	4,1398E+03	3,8332E+02	1,0414E+02
7,10E+00	1,1082E+01	4,5307E+03	4,0883E+02	1,1093E+02
7,20E+00	1,1368E+01	4,9533E+03	4,3572E+02	1,1808E+02
7,30E+00	1,1658E+01	5,4098E+03	4,6405E+02	1,2560E+02
7,40E+00	1,1952E+01	5,9026E+03	4,9386E+02	1,3352E+02
7,50E+00	1,2250E+01	6,4339E+03	5,2522E+02	1,4184E+02
7,60E+00	1,2552E+01	7,0064E+03	5,5819E+02	1,5058E+02
7,70E+00	1,2858E+01	7,6227E+03	5,9283E+02	1,5977E+02
7,80E+00	1,3168E+01	8,2855E+03	6,2922E+02	1,6940E+02
7,90E+00	1,3482E+01	8,9979E+03	6,6740E+02	1,7951E+02
8,00E+00	1,3800E+01	9,7629E+03	7,0745E+02	1,9011E+02
9,00E+00	1,7200E+01	2,1103E+04	1,2269E+03	3,2719E+02
1,00E+01	2,1000E+01	4,2439E+04	2,0209E+03	5,3594E+02
1,10E+01	2,5200E+01	8,0334E+04	3,1879E+03	8,4191E+02
1,20E+01	2,9800E+01	1,4446E+05	4,8478E+03	1,2762E+03
1,30E+01	3,4800E+01	2,4862E+05	7,1441E+03	1,8761E+03
1,40E+01	4,0200E+01	4,1190E+05	1,0246E+04	2,6854E+03

Formulario di Gasdinamica

Urto Retto

$$\left\{ \begin{array}{l} M_2 < 1 \leq M_1 \\ \frac{\rho_2}{\rho_1} \geq 1 \\ \frac{p_2}{p_1} \geq 1 \end{array} \right. \left\{ \begin{array}{l} \frac{T_2}{T_1} \geq 1 \\ T_{01} = T_{02} \\ P_{01} > P_{02} \end{array} \right.$$

$$\left\{ \begin{array}{l} M_2^2 = \frac{1 + \frac{\gamma-1}{2} M_1^2}{\gamma M_1^2 - \frac{\gamma-1}{2}} \\ \frac{\rho_2}{\rho_1} = \frac{u_1}{u_2} = \frac{(\gamma+1) M_1^2}{2 + (\gamma-1) M_1^2} \\ \frac{p_2}{p_1} = 1 + \frac{2\gamma}{\gamma+1} (M_1^2 - 1) \\ \frac{T_2}{T_1} = \frac{p_2}{p_1} \cdot \frac{\rho_1}{\rho_2} = \left[1 + \frac{2\gamma}{\gamma+1} \cdot (M_1^2 - 1) \right] \left[\frac{2 + (\gamma-1) M_1^2}{(\gamma+1) M_1^2} \right] \\ s_2 - s_1 = C_p \ln \frac{T_2}{T_1} - R \ln \frac{p_2}{p_1} = C_p \ln \frac{T_{02}}{T_{01}} - R \ln \frac{p_{02}}{p_{01}} \\ \frac{p_{02}}{p_{01}} = e^{-\frac{s_2 - s_1}{R}} \end{array} \right.$$

Formulario di Gasdinamica

URTO RETTO							
Mach in	Mach out	P2/P1	ρ_2/ρ_1	T2/T1	P02/P01	P02/p1	s2-s1
1,98E+00	5,808E-01	4,407E+00	2,637E+00	1,671E+00	7,302E-01	5,539E+00	9,024E+01
2,00E+00	5,774E-01	4,500E+00	2,667E+00	1,688E+00	7,209E-01	5,640E+00	9,393E+01
2,05E+00	5,691E-01	4,736E+00	2,740E+00	1,729E+00	6,975E-01	5,900E+00	1,034E+02
2,10E+00	5,613E-01	4,978E+00	2,812E+00	1,770E+00	6,742E-01	6,165E+00	1,131E+02
2,15E+00	5,540E-01	5,226E+00	2,882E+00	1,813E+00	6,511E-01	6,438E+00	1,232E+02
2,20E+00	5,471E-01	5,480E+00	2,951E+00	1,857E+00	6,281E-01	6,716E+00	1,335E+02
2,25E+00	5,406E-01	5,740E+00	3,019E+00	1,901E+00	6,055E-01	7,002E+00	1,440E+02
2,30E+00	5,344E-01	6,005E+00	3,085E+00	1,947E+00	5,833E-01	7,294E+00	1,547E+02
2,35E+00	5,286E-01	6,276E+00	3,149E+00	1,993E+00	5,615E-01	7,592E+00	1,656E+02
2,40E+00	5,231E-01	6,553E+00	3,212E+00	2,040E+00	5,401E-01	7,897E+00	1,768E+02
2,45E+00	5,179E-01	6,836E+00	3,273E+00	2,088E+00	5,193E-01	8,208E+00	1,881E+02
2,50E+00	5,130E-01	7,125E+00	3,333E+00	2,138E+00	4,990E-01	8,526E+00	1,995E+02
2,55E+00	5,083E-01	7,420E+00	3,392E+00	2,187E+00	4,793E-01	8,850E+00	2,111E+02
2,60E+00	5,039E-01	7,720E+00	3,449E+00	2,238E+00	4,601E-01	9,181E+00	2,228E+02
2,65E+00	4,996E-01	8,026E+00	3,505E+00	2,290E+00	4,416E-01	9,519E+00	2,346E+02
2,70E+00	4,956E-01	8,338E+00	3,559E+00	2,343E+00	4,236E-01	9,862E+00	2,465E+02
2,75E+00	4,918E-01	8,656E+00	3,612E+00	2,397E+00	4,062E-01	1,021E+01	2,585E+02
2,80E+00	4,882E-01	8,980E+00	3,664E+00	2,451E+00	3,895E-01	1,057E+01	2,706E+02
2,85E+00	4,847E-01	9,310E+00	3,714E+00	2,507E+00	3,733E-01	1,093E+01	2,828E+02
2,90E+00	4,814E-01	9,645E+00	3,763E+00	2,563E+00	3,577E-01	1,130E+01	2,950E+02
2,95E+00	4,782E-01	9,986E+00	3,811E+00	2,621E+00	3,428E-01	1,168E+01	3,073E+02
3,00E+00	4,752E-01	1,033E+01	3,857E+00	2,679E+00	3,283E-01	1,206E+01	3,196E+02
3,05E+00	4,723E-01	1,069E+01	3,902E+00	2,738E+00	3,145E-01	1,245E+01	3,320E+02
3,10E+00	4,695E-01	1,105E+01	3,947E+00	2,799E+00	3,012E-01	1,285E+01	3,444E+02
3,15E+00	4,669E-01	1,141E+01	3,990E+00	2,860E+00	2,885E-01	1,325E+01	3,568E+02
3,20E+00	4,643E-01	1,178E+01	4,031E+00	2,922E+00	2,762E-01	1,366E+01	3,692E+02
3,25E+00	4,619E-01	1,216E+01	4,072E+00	2,985E+00	2,645E-01	1,407E+01	3,817E+02
3,30E+00	4,596E-01	1,254E+01	4,112E+00	3,049E+00	2,533E-01	1,449E+01	3,941E+02
3,35E+00	4,573E-01	1,293E+01	4,151E+00	3,114E+00	2,425E-01	1,492E+01	4,066E+02
3,40E+00	4,552E-01	1,332E+01	4,188E+00	3,180E+00	2,322E-01	1,535E+01	4,190E+02
3,45E+00	4,531E-01	1,372E+01	4,225E+00	3,247E+00	2,224E-01	1,579E+01	4,315E+02
3,50E+00	4,512E-01	1,412E+01	4,261E+00	3,315E+00	2,129E-01	1,624E+01	4,439E+02
3,55E+00	4,492E-01	1,454E+01	4,296E+00	3,384E+00	2,039E-01	1,670E+01	4,563E+02
3,60E+00	4,474E-01	1,495E+01	4,330E+00	3,454E+00	1,953E-01	1,716E+01	4,687E+02
3,65E+00	4,456E-01	1,538E+01	4,363E+00	3,525E+00	1,871E-01	1,762E+01	4,811E+02
3,70E+00	4,439E-01	1,580E+01	4,395E+00	3,596E+00	1,792E-01	1,810E+01	4,934E+02
3,75E+00	4,423E-01	1,624E+01	4,426E+00	3,669E+00	1,717E-01	1,857E+01	5,058E+02
3,80E+00	4,407E-01	1,668E+01	4,457E+00	3,743E+00	1,645E-01	1,906E+01	5,180E+02
3,85E+00	4,392E-01	1,713E+01	4,487E+00	3,817E+00	1,576E-01	1,955E+01	5,303E+02
3,90E+00	4,377E-01	1,758E+01	4,516E+00	3,893E+00	1,510E-01	2,005E+01	5,425E+02
3,95E+00	4,363E-01	1,804E+01	4,544E+00	3,969E+00	1,448E-01	2,056E+01	5,547E+02
4,00E+00	4,350E-01	1,850E+01	4,571E+00	4,047E+00	1,388E-01	2,107E+01	5,668E+02
4,05E+00	4,336E-01	1,897E+01	4,598E+00	4,125E+00	1,330E-01	2,159E+01	5,789E+02
4,10E+00	4,324E-01	1,944E+01	4,624E+00	4,205E+00	1,276E-01	2,211E+01	5,910E+02
4,15E+00	4,311E-01	1,993E+01	4,650E+00	4,285E+00	1,223E-01	2,264E+01	6,030E+02
4,20E+00	4,299E-01	2,041E+01	4,675E+00	4,367E+00	1,173E-01	2,318E+01	6,150E+02
4,25E+00	4,288E-01	2,091E+01	4,699E+00	4,449E+00	1,126E-01	2,372E+01	6,269E+02
4,30E+00	4,277E-01	2,140E+01	4,723E+00	4,532E+00	1,080E-01	2,427E+01	6,388E+02
4,35E+00	4,266E-01	2,191E+01	4,746E+00	4,616E+00	1,036E-01	2,483E+01	6,506E+02

Formulario di Gasdinamica

URTO RETTO							
Mach in	Mach out	P2/P1	ρ_2/ρ_1	T2/T1	P02/P01	P02/p1	s2-s1
8,70E+00	3,906E-01	8,814E+01	5,628E+00	1,566E+01	5,799E-03	9,792E+01	1,478E+03
8,80E+00	3,903E-01	9,018E+01	5,636E+00	1,600E+01	5,504E-03	1,002E+02	1,493E+03
8,90E+00	3,901E-01	9,225E+01	5,644E+00	1,634E+01	5,226E-03	1,024E+02	1,508E+03
9,00E+00	3,898E-01	9,433E+01	5,651E+00	1,669E+01	4,964E-03	1,048E+02	1,523E+03
9,10E+00	3,895E-01	9,645E+01	5,658E+00	1,704E+01	4,718E-03	1,071E+02	1,537E+03
9,20E+00	3,893E-01	9,858E+01	5,665E+00	1,740E+01	4,486E-03	1,094E+02	1,552E+03
9,30E+00	3,891E-01	1,007E+02	5,672E+00	1,776E+01	4,267E-03	1,118E+02	1,566E+03
9,40E+00	3,888E-01	1,029E+02	5,679E+00	1,812E+01	4,061E-03	1,142E+02	1,580E+03
9,50E+00	3,886E-01	1,051E+02	5,685E+00	1,849E+01	3,866E-03	1,167E+02	1,594E+03
9,60E+00	3,884E-01	1,074E+02	5,691E+00	1,886E+01	3,683E-03	1,191E+02	1,608E+03
9,70E+00	3,882E-01	1,096E+02	5,697E+00	1,924E+01	3,510E-03	1,216E+02	1,622E+03
9,80E+00	3,880E-01	1,119E+02	5,703E+00	1,962E+01	3,346E-03	1,241E+02	1,636E+03
9,90E+00	3,878E-01	1,142E+02	5,709E+00	2,000E+01	3,191E-03	1,267E+02	1,650E+03
1,00E+01	3,876E-01	1,165E+02	5,714E+00	2,039E+01	3,045E-03	1,292E+02	1,663E+03
1,10E+01	3,859E-01	1,410E+02	5,762E+00	2,447E+01	1,945E-03	1,563E+02	1,792E+03
1,20E+01	3,847E-01	1,678E+02	5,799E+00	2,894E+01	1,287E-03	1,859E+02	1,910E+03
1,30E+01	3,837E-01	1,970E+02	5,828E+00	3,380E+01	8,771E-04	2,181E+02	2,020E+03
1,40E+01	3,829E-01	2,285E+02	5,851E+00	3,905E+01	6,138E-04	2,528E+02	2,123E+03
1,50E+01	3,823E-01	2,623E+02	5,870E+00	4,469E+01	4,395E-04	2,902E+02	2,218E+03
1,60E+01	3,817E-01	2,985E+02	5,885E+00	5,072E+01	3,212E-04	3,301E+02	2,308E+03
1,70E+01	3,813E-01	3,370E+02	5,898E+00	5,714E+01	2,390E-04	3,726E+02	2,393E+03
1,80E+01	3,810E-01	3,778E+02	5,909E+00	6,394E+01	1,807E-04	4,176E+02	2,474E+03
1,90E+01	3,806E-01	4,210E+02	5,918E+00	7,114E+01	1,386E-04	4,653E+02	2,550E+03
2,00E+01	3,804E-01	4,665E+02	5,926E+00	7,872E+01	1,078E-04	5,155E+02	2,622E+03
2,20E+01	3,800E-01	5,645E+02	5,939E+00	9,506E+01	6,741E-05	6,236E+02	2,757E+03
2,40E+01	3,796E-01	6,718E+02	5,948E+00	1,129E+02	4,388E-05	7,421E+02	2,880E+03
2,60E+01	3,794E-01	7,885E+02	5,956E+00	1,324E+02	2,953E-05	8,709E+02	2,993E+03
2,80E+01	3,792E-01	9,145E+02	5,962E+00	1,534E+02	2,046E-05	1,010E+03	3,099E+03
3,00E+01	3,790E-01	1,050E+03	5,967E+00	1,759E+02	1,453E-05	1,159E+03	3,197E+03
3,20E+01	3,789E-01	1,194E+03	5,971E+00	2,001E+02	1,055E-05	1,319E+03	3,289E+03
3,40E+01	3,788E-01	1,348E+03	5,974E+00	2,257E+02	7,804E-06	1,489E+03	3,375E+03
3,60E+01	3,787E-01	1,512E+03	5,977E+00	2,529E+02	5,874E-06	1,669E+03	3,457E+03
3,80E+01	3,786E-01	1,684E+03	5,979E+00	2,817E+02	4,488E-06	1,860E+03	3,534E+03
4,00E+01	3,786E-01	1,866E+03	5,981E+00	3,121E+02	3,477E-06	2,061E+03	3,607E+03
4,20E+01	3,785E-01	2,058E+03	5,983E+00	3,439E+02	2,727E-06	2,272E+03	3,677E+03
4,40E+01	3,785E-01	2,258E+03	5,985E+00	3,774E+02	2,163E-06	2,493E+03	3,744E+03
4,60E+01	3,784E-01	2,468E+03	5,986E+00	4,124E+02	1,733E-06	2,725E+03	3,807E+03
4,80E+01	3,784E-01	2,688E+03	5,987E+00	4,489E+02	1,402E-06	2,967E+03	3,868E+03
5,00E+01	3,784E-01	2,916E+03	5,988E+00	4,871E+02	1,144E-06	3,219E+03	3,926E+03

Formulario di Gasdinamica

Flusso di Rayleigh					
Mach in	P/P*	T/T*	ρ/ρ^*	P0/P0*	T0/T0*
2,00E-02	2,3987E+00	2,3014E-03	1,0423E+03	1,2675E+00	1,9180E-03
4,00E-02	2,3946E+00	9,1749E-03	2,6100E+02	1,2665E+00	7,6482E-03
6,00E-02	2,3880E+00	2,0529E-02	1,1632E+02	1,2647E+00	1,7119E-02
8,00E-02	2,3787E+00	3,6212E-02	6,5688E+01	1,2623E+00	3,0215E-02
1,00E-01	2,3669E+00	5,6020E-02	4,2250E+01	1,2591E+00	4,6777E-02
1,20E-01	2,3526E+00	7,9698E-02	2,9519E+01	1,2554E+00	6,6606E-02
1,40E-01	2,3359E+00	1,0695E-01	2,1842E+01	1,2510E+00	8,9471E-02
1,60E-01	2,3170E+00	1,3743E-01	1,6859E+01	1,2461E+00	1,1511E-01
1,80E-01	2,2959E+00	1,7078E-01	1,3443E+01	1,2406E+00	1,4324E-01
2,00E-01	2,2727E+00	2,0661E-01	1,1000E+01	1,2346E+00	1,7355E-01
2,20E-01	2,2477E+00	2,4452E-01	9,1921E+00	1,2281E+00	2,0574E-01
2,40E-01	2,2209E+00	2,8411E-01	7,8171E+00	1,2213E+00	2,3948E-01
2,60E-01	2,1925E+00	3,2496E-01	6,7470E+00	1,2140E+00	2,7446E-01
2,80E-01	2,1626E+00	3,6667E-01	5,8980E+00	1,2064E+00	3,1035E-01
3,00E-01	2,1314E+00	4,0887E-01	5,2130E+00	1,1985E+00	3,4686E-01
3,20E-01	2,0991E+00	4,5119E-01	4,6523E+00	1,1904E+00	3,8369E-01
3,40E-01	2,0657E+00	4,9327E-01	4,1877E+00	1,1822E+00	4,2056E-01
3,60E-01	2,0314E+00	5,3482E-01	3,7984E+00	1,1737E+00	4,5723E-01
3,80E-01	1,9964E+00	5,7553E-01	3,4688E+00	1,1652E+00	4,9346E-01
4,00E-01	1,9608E+00	6,1515E-01	3,1875E+00	1,1566E+00	5,2903E-01
4,20E-01	1,9247E+00	6,5346E-01	2,9454E+00	1,1480E+00	5,6376E-01
4,40E-01	1,8882E+00	6,9025E-01	2,7355E+00	1,1394E+00	5,9748E-01
4,60E-01	1,8515E+00	7,2538E-01	2,5525E+00	1,1308E+00	6,3007E-01
4,80E-01	1,8147E+00	7,5871E-01	2,3918E+00	1,1224E+00	6,6139E-01
5,00E-01	1,7778E+00	7,9012E-01	2,2500E+00	1,1141E+00	6,9136E-01
5,20E-01	1,7409E+00	8,1955E-01	2,1243E+00	1,1059E+00	7,1990E-01
5,40E-01	1,7043E+00	8,4695E-01	2,0122E+00	1,0979E+00	7,4695E-01
5,60E-01	1,6678E+00	8,7227E-01	1,9120E+00	1,0901E+00	7,7249E-01
5,80E-01	1,6316E+00	8,9552E-01	1,8219E+00	1,0826E+00	7,9648E-01
6,00E-01	1,5957E+00	9,1670E-01	1,7407E+00	1,0753E+00	8,1892E-01
6,20E-01	1,5603E+00	9,3584E-01	1,6673E+00	1,0682E+00	8,3983E-01
6,40E-01	1,5253E+00	9,5298E-01	1,6006E+00	1,0615E+00	8,5920E-01
6,60E-01	1,4908E+00	9,6816E-01	1,5399E+00	1,0550E+00	8,7708E-01
6,80E-01	1,4569E+00	9,8144E-01	1,4844E+00	1,0489E+00	8,9350E-01
7,00E-01	1,4235E+00	9,9290E-01	1,4337E+00	1,0431E+00	9,0850E-01
7,20E-01	1,3907E+00	1,0026E+00	1,3871E+00	1,0376E+00	9,2212E-01
7,40E-01	1,3585E+00	1,0106E+00	1,3442E+00	1,0325E+00	9,3442E-01
7,60E-01	1,3270E+00	1,0171E+00	1,3047E+00	1,0278E+00	9,4546E-01
7,80E-01	1,2961E+00	1,0220E+00	1,2682E+00	1,0234E+00	9,5528E-01
8,00E-01	1,2658E+00	1,0255E+00	1,2344E+00	1,0193E+00	9,6395E-01
8,20E-01	1,2362E+00	1,0276E+00	1,2030E+00	1,0157E+00	9,7152E-01
8,40E-01	1,2073E+00	1,0285E+00	1,1738E+00	1,0124E+00	9,7807E-01
8,60E-01	1,1791E+00	1,0283E+00	1,1467E+00	1,0095E+00	9,8363E-01
8,80E-01	1,1515E+00	1,0269E+00	1,1214E+00	1,0070E+00	9,8828E-01
9,00E-01	1,1246E+00	1,0245E+00	1,0977E+00	1,0049E+00	9,9207E-01
9,20E-01	1,0984E+00	1,0212E+00	1,0756E+00	1,0031E+00	9,9506E-01
9,40E-01	1,0728E+00	1,0170E+00	1,0549E+00	1,0017E+00	9,9729E-01
9,60E-01	1,0479E+00	1,0121E+00	1,0354E+00	1,0008E+00	9,9883E-01
9,80E-01	1,0236E+00	1,0064E+00	1,0172E+00	1,0002E+00	9,9971E-01
1,00E+00	1,0000E+00	1,0000E+00	1,0000E+00	1,0000E+00	1,0000E+00
1,02E+00	9,7698E-01	9,9304E-01	9,8382E-01	1,0002E+00	9,9973E-01
1,04E+00	9,5456E-01	9,8554E-01	9,6857E-01	1,0008E+00	9,9895E-01

Formulario di Gasdinamica

Flusso di Rayleigh					
Mach in	P/P*	T/T*	ρ/ρ^*	P0/P0*	T0/T0*
2,25E+00	2,9675E-01	4,4582E-01	6,6564E-01	1,8128E+00	7,4768E-01
2,30E+00	2,8551E-01	4,3122E-01	6,6210E-01	1,8860E+00	7,3954E-01
2,35E+00	2,7487E-01	4,1723E-01	6,5878E-01	1,9634E+00	7,3173E-01
2,40E+00	2,6478E-01	4,0384E-01	6,5567E-01	2,0451E+00	7,2421E-01
2,45E+00	2,5522E-01	3,9100E-01	6,5275E-01	2,1311E+00	7,1699E-01
2,50E+00	2,4615E-01	3,7870E-01	6,5000E-01	2,2218E+00	7,1006E-01
2,55E+00	2,3754E-01	3,6691E-01	6,4741E-01	2,3173E+00	7,0340E-01
2,60E+00	2,2936E-01	3,5561E-01	6,4497E-01	2,4177E+00	6,9700E-01
2,65E+00	2,2158E-01	3,4478E-01	6,4267E-01	2,5233E+00	6,9084E-01
2,70E+00	2,1417E-01	3,3439E-01	6,4049E-01	2,6343E+00	6,8494E-01
2,75E+00	2,0712E-01	3,2442E-01	6,3843E-01	2,7508E+00	6,7926E-01
2,80E+00	2,0040E-01	3,1486E-01	6,3648E-01	2,8731E+00	6,7380E-01
2,85E+00	1,9399E-01	3,0568E-01	6,3463E-01	3,0014E+00	6,6855E-01
2,90E+00	1,8788E-01	2,9687E-01	6,3288E-01	3,1359E+00	6,6350E-01
2,95E+00	1,8205E-01	2,8841E-01	6,3121E-01	3,2768E+00	6,5865E-01
3,00E+00	1,7647E-01	2,8028E-01	6,2963E-01	3,4245E+00	6,5398E-01
3,05E+00	1,7114E-01	2,7246E-01	6,2812E-01	3,5790E+00	6,4949E-01
3,10E+00	1,6604E-01	2,6495E-01	6,2669E-01	3,7408E+00	6,4516E-01
3,15E+00	1,6117E-01	2,5773E-01	6,2533E-01	3,9101E+00	6,4100E-01
3,20E+00	1,5649E-01	2,5078E-01	6,2402E-01	4,0871E+00	6,3699E-01
3,25E+00	1,5202E-01	2,4410E-01	6,2278E-01	4,2721E+00	6,3313E-01
3,30E+00	1,4773E-01	2,3766E-01	6,2159E-01	4,4655E+00	6,2940E-01
3,35E+00	1,4361E-01	2,3146E-01	6,2046E-01	4,6674E+00	6,2582E-01
3,40E+00	1,3966E-01	2,2549E-01	6,1938E-01	4,8783E+00	6,2236E-01
3,45E+00	1,3587E-01	2,1974E-01	6,1834E-01	5,0984E+00	6,1902E-01
3,50E+00	1,3223E-01	2,1419E-01	6,1735E-01	5,3280E+00	6,1580E-01
3,55E+00	1,2873E-01	2,0885E-01	6,1640E-01	5,5676E+00	6,1270E-01
3,60E+00	1,2537E-01	2,0369E-01	6,1548E-01	5,8173E+00	6,0970E-01
3,65E+00	1,2213E-01	1,9871E-01	6,1461E-01	6,0776E+00	6,0681E-01
3,70E+00	1,1901E-01	1,9390E-01	6,1377E-01	6,3488E+00	6,0401E-01
3,75E+00	1,1601E-01	1,8926E-01	6,1296E-01	6,6314E+00	6,0131E-01
3,80E+00	1,1312E-01	1,8478E-01	6,1219E-01	6,9256E+00	5,9870E-01
3,85E+00	1,1034E-01	1,8045E-01	6,1144E-01	7,2318E+00	5,9617E-01
3,90E+00	1,0765E-01	1,7627E-01	6,1073E-01	7,5505E+00	5,9373E-01
3,95E+00	1,0506E-01	1,7222E-01	6,1004E-01	7,8820E+00	5,9137E-01
4,00E+00	1,0256E-01	1,6831E-01	6,0938E-01	8,2268E+00	5,8909E-01
4,05E+00	1,0015E-01	1,6453E-01	6,0874E-01	8,5853E+00	5,8687E-01
4,10E+00	9,7823E-02	1,6086E-01	6,0812E-01	8,9579E+00	5,8473E-01
4,15E+00	9,5574E-02	1,5732E-01	6,0753E-01	9,3451E+00	5,8266E-01
4,20E+00	9,3400E-02	1,5388E-01	6,0695E-01	9,7473E+00	5,8065E-01
4,25E+00	9,1298E-02	1,5056E-01	6,0640E-01	1,0165E+01	5,7870E-01
4,30E+00	8,9266E-02	1,4734E-01	6,0587E-01	1,0599E+01	5,7682E-01
4,35E+00	8,7300E-02	1,4421E-01	6,0535E-01	1,1049E+01	5,7499E-01
4,40E+00	8,5397E-02	1,4119E-01	6,0486E-01	1,1516E+01	5,7322E-01
4,45E+00	8,3555E-02	1,3825E-01	6,0437E-01	1,2000E+01	5,7149E-01
4,50E+00	8,1772E-02	1,3540E-01	6,0391E-01	1,2502E+01	5,6982E-01
4,55E+00	8,0044E-02	1,3264E-01	6,0346E-01	1,3023E+01	5,6820E-01
4,60E+00	7,8370E-02	1,2996E-01	6,0302E-01	1,3563E+01	5,6663E-01
4,65E+00	7,6747E-02	1,2736E-01	6,0260E-01	1,4122E+01	5,6510E-01
4,70E+00	7,5174E-02	1,2483E-01	6,0220E-01	1,4702E+01	5,6362E-01
4,75E+00	7,3648E-02	1,2238E-01	6,0180E-01	1,5302E+01	5,6218E-01
4,80E+00	7,2167E-02	1,2000E-01	6,0142E-01	1,5923E+01	5,6078E-01

Formulario di Gasdinamica

Flusso di Rayleigh					
Mach in	P/P*	T/T*	ρ/ρ^*	P0/P0*	T0/T0*
2,70E+01	2,3493E-03	4,0234E-03	5,8390E-01	4,7570E+04	4,9219E-01
2,80E+01	2,1846E-03	3,7416E-03	5,8386E-01	5,6965E+04	4,9202E-01
2,90E+01	2,0367E-03	3,4885E-03	5,8383E-01	6,7793E+04	4,9187E-01
3,00E+01	1,9033E-03	3,2601E-03	5,8380E-01	8,0212E+04	4,9174E-01
3,10E+01	1,7825E-03	3,0535E-03	5,8377E-01	9,4390E+04	4,9161E-01
3,20E+01	1,6729E-03	2,8659E-03	5,8374E-01	1,1051E+05	4,9150E-01
3,30E+01	1,5732E-03	2,6951E-03	5,8372E-01	1,2877E+05	4,9140E-01
3,40E+01	1,4820E-03	2,5391E-03	5,8369E-01	1,4936E+05	4,9131E-01
3,50E+01	1,3986E-03	2,3962E-03	5,8367E-01	1,7252E+05	4,9122E-01
3,60E+01	1,3220E-03	2,2651E-03	5,8365E-01	1,9846E+05	4,9114E-01
3,70E+01	1,2516E-03	2,1444E-03	5,8364E-01	2,2745E+05	4,9107E-01
3,80E+01	1,1866E-03	2,0332E-03	5,8362E-01	2,5972E+05	4,9101E-01
3,90E+01	1,1265E-03	1,9303E-03	5,8361E-01	2,9557E+05	4,9094E-01
4,00E+01	1,0710E-03	1,8351E-03	5,8359E-01	3,3528E+05	4,9089E-01
4,10E+01	1,0194E-03	1,7467E-03	5,8358E-01	3,7914E+05	4,9084E-01
4,20E+01	9,7142E-04	1,6646E-03	5,8357E-01	4,2749E+05	4,9079E-01
4,30E+01	9,2678E-04	1,5882E-03	5,8356E-01	4,8065E+05	4,9074E-01
4,40E+01	8,8515E-04	1,5168E-03	5,8355E-01	5,3899E+05	4,9070E-01
4,50E+01	8,4626E-04	1,4502E-03	5,8354E-01	6,0285E+05	4,9066E-01
4,60E+01	8,0988E-04	1,3879E-03	5,8353E-01	6,7264E+05	4,9062E-01
4,70E+01	7,7580E-04	1,3295E-03	5,8352E-01	7,4875E+05	4,9059E-01
4,80E+01	7,4382E-04	1,2747E-03	5,8351E-01	8,3161E+05	4,9055E-01
4,90E+01	7,1378E-04	1,2233E-03	5,8351E-01	9,2165E+05	4,9052E-01
5,00E+01	6,8552E-04	1,1748E-03	5,8350E-01	1,0193E+06	4,9050E-01

Formulario di Gasdinamica

Flusso di Fanno					
Mach in	T/T*	P/P*	ρ/ρ^*	P0/P0*	4fL*/D
2,00E-02	1,1999E+00	5,4770E+01	4,5645E+01	2,8942E+01	1,7784E+03
4,00E-02	1,1996E+00	2,7382E+01	2,2825E+01	1,4481E+01	4,4035E+02
6,00E-02	1,1991E+00	1,8251E+01	1,5220E+01	9,6659E+00	1,9303E+02
8,00E-02	1,1985E+00	1,3684E+01	1,1418E+01	7,2616E+00	1,0672E+02
1,00E-01	1,1976E+00	1,0944E+01	9,1378E+00	5,8218E+00	6,6922E+01
1,20E-01	1,1966E+00	9,1156E+00	7,6182E+00	4,8643E+00	4,5408E+01
1,40E-01	1,1953E+00	7,8093E+00	6,5333E+00	4,1824E+00	3,2511E+01
1,60E-01	1,1939E+00	6,8291E+00	5,7200E+00	3,6727E+00	2,4198E+01
1,80E-01	1,1923E+00	6,0662E+00	5,0879E+00	3,2779E+00	1,8543E+01
2,00E-01	1,1905E+00	5,4554E+00	4,5826E+00	2,9635E+00	1,4533E+01
2,20E-01	1,1885E+00	4,9554E+00	4,1694E+00	2,7076E+00	1,1596E+01
2,40E-01	1,1863E+00	4,5383E+00	3,8255E+00	2,4956E+00	9,3865E+00
2,60E-01	1,1840E+00	4,1851E+00	3,5347E+00	2,3173E+00	7,6876E+00
2,80E-01	1,1815E+00	3,8820E+00	3,2857E+00	2,1656E+00	6,3572E+00
3,00E-01	1,1788E+00	3,6191E+00	3,0702E+00	2,0351E+00	5,2993E+00
3,20E-01	1,1759E+00	3,3887E+00	2,8818E+00	1,9219E+00	4,4467E+00
3,40E-01	1,1729E+00	3,1853E+00	2,7158E+00	1,8229E+00	3,7520E+00
3,60E-01	1,1697E+00	3,0042E+00	2,5684E+00	1,7358E+00	3,1801E+00
3,80E-01	1,1663E+00	2,8420E+00	2,4367E+00	1,6587E+00	2,7054E+00
4,00E-01	1,1628E+00	2,6958E+00	2,3184E+00	1,5901E+00	2,3085E+00
4,20E-01	1,1591E+00	2,5634E+00	2,2115E+00	1,5289E+00	1,9744E+00
4,40E-01	1,1553E+00	2,4428E+00	2,1145E+00	1,4740E+00	1,6915E+00
4,60E-01	1,1513E+00	2,3326E+00	2,0261E+00	1,4246E+00	1,4509E+00
4,80E-01	1,1471E+00	2,2313E+00	1,9451E+00	1,3801E+00	1,2453E+00
5,00E-01	1,1429E+00	2,1381E+00	1,8708E+00	1,3398E+00	1,0691E+00
5,20E-01	1,1384E+00	2,0519E+00	1,8024E+00	1,3034E+00	9,1742E-01
5,40E-01	1,1339E+00	1,9719E+00	1,7391E+00	1,2703E+00	7,8663E-01
5,60E-01	1,1292E+00	1,8975E+00	1,6805E+00	1,2403E+00	6,7357E-01
5,80E-01	1,1244E+00	1,8282E+00	1,6260E+00	1,2130E+00	5,7568E-01
6,00E-01	1,1194E+00	1,7634E+00	1,5753E+00	1,1882E+00	4,9082E-01
6,20E-01	1,1143E+00	1,7026E+00	1,5279E+00	1,1656E+00	4,1720E-01
6,40E-01	1,1091E+00	1,6456E+00	1,4836E+00	1,1451E+00	3,5330E-01
6,60E-01	1,1038E+00	1,5919E+00	1,4421E+00	1,1265E+00	2,9785E-01
6,80E-01	1,0984E+00	1,5413E+00	1,4032E+00	1,1097E+00	2,4978E-01
7,00E-01	1,0929E+00	1,4935E+00	1,3665E+00	1,0944E+00	2,0814E-01
7,20E-01	1,0873E+00	1,4482E+00	1,3320E+00	1,0806E+00	1,7215E-01
7,40E-01	1,0815E+00	1,4054E+00	1,2994E+00	1,0681E+00	1,4112E-01
7,60E-01	1,0757E+00	1,3647E+00	1,2686E+00	1,0570E+00	1,1447E-01
7,80E-01	1,0698E+00	1,3261E+00	1,2395E+00	1,0471E+00	9,1672E-02
8,00E-01	1,0638E+00	1,2893E+00	1,2119E+00	1,0382E+00	7,2290E-02
8,20E-01	1,0578E+00	1,2542E+00	1,1858E+00	1,0305E+00	5,5932E-02
8,40E-01	1,0516E+00	1,2208E+00	1,1609E+00	1,0237E+00	4,2256E-02
8,60E-01	1,0454E+00	1,1889E+00	1,1373E+00	1,0179E+00	3,0965E-02
8,80E-01	1,0391E+00	1,1583E+00	1,1148E+00	1,0129E+00	2,1795E-02
9,00E-01	1,0327E+00	1,1291E+00	1,0934E+00	1,0089E+00	1,4512E-02
9,20E-01	1,0263E+00	1,1011E+00	1,0730E+00	1,0056E+00	8,9133E-03
9,40E-01	1,0198E+00	1,0743E+00	1,0535E+00	1,0031E+00	4,8154E-03
9,60E-01	1,0132E+00	1,0485E+00	1,0348E+00	1,0014E+00	2,0571E-03
9,80E-01	1,0066E+00	1,0238E+00	1,0170E+00	1,0003E+00	4,9470E-04
1,00E+00	1,0000E+00	1,0000E+00	1,0000E+00	1,0000E+00	0,0000E+00
1,02E+00	9,9331E-01	9,7711E-01	9,8369E-01	1,0003E+00	4,5869E-04
1,04E+00	9,8658E-01	9,5507E-01	9,6805E-01	1,0013E+00	1,7685E-03

Formulario di Gasdinamica

Flusso di Fanno					
Mach in	T/T*	P/P*	ρ/ρ^*	P0/P0*	4fL*/D
2,25E+00	5,9627E-01	3,4319E-01	5,7557E-01	2,0964E+00	3,7378E-01
2,30E+00	5,8309E-01	3,3200E-01	5,6938E-01	2,1931E+00	3,8623E-01
2,35E+00	5,7021E-01	3,2133E-01	5,6353E-01	2,2953E+00	3,9826E-01
2,40E+00	5,5762E-01	3,1114E-01	5,5798E-01	2,4031E+00	4,0989E-01
2,45E+00	5,4533E-01	3,0141E-01	5,5272E-01	2,5168E+00	4,2112E-01
2,50E+00	5,3333E-01	2,9212E-01	5,4772E-01	2,6367E+00	4,3198E-01
2,55E+00	5,2163E-01	2,8323E-01	5,4298E-01	2,7630E+00	4,4246E-01
2,60E+00	5,1020E-01	2,7473E-01	5,3846E-01	2,8960E+00	4,5259E-01
2,65E+00	4,9906E-01	2,6658E-01	5,3417E-01	3,0359E+00	4,6237E-01
2,70E+00	4,8820E-01	2,5878E-01	5,3007E-01	3,1830E+00	4,7182E-01
2,75E+00	4,7761E-01	2,5131E-01	5,2617E-01	3,3377E+00	4,8095E-01
2,80E+00	4,6729E-01	2,4414E-01	5,2245E-01	3,5001E+00	4,8976E-01
2,85E+00	4,5723E-01	2,3726E-01	5,1890E-01	3,6707E+00	4,9828E-01
2,90E+00	4,4743E-01	2,3066E-01	5,1551E-01	3,8498E+00	5,0652E-01
2,95E+00	4,3788E-01	2,2431E-01	5,1227E-01	4,0376E+00	5,1447E-01
3,00E+00	4,2857E-01	2,1822E-01	5,0918E-01	4,2346E+00	5,2216E-01
3,05E+00	4,1951E-01	2,1236E-01	5,0621E-01	4,4410E+00	5,2959E-01
3,10E+00	4,1068E-01	2,0672E-01	5,0337E-01	4,6573E+00	5,3678E-01
3,15E+00	4,0208E-01	2,0130E-01	5,0065E-01	4,8838E+00	5,4372E-01
3,20E+00	3,9370E-01	1,9608E-01	4,9804E-01	5,1210E+00	5,5044E-01
3,25E+00	3,8554E-01	1,9105E-01	4,9554E-01	5,3691E+00	5,5694E-01
3,30E+00	3,7760E-01	1,8621E-01	4,9314E-01	5,6286E+00	5,6323E-01
3,35E+00	3,6986E-01	1,8154E-01	4,9084E-01	5,9000E+00	5,6932E-01
3,40E+00	3,6232E-01	1,7704E-01	4,8862E-01	6,1837E+00	5,7521E-01
3,45E+00	3,5498E-01	1,7270E-01	4,8650E-01	6,4801E+00	5,8091E-01
3,50E+00	3,4783E-01	1,6851E-01	4,8445E-01	6,7896E+00	5,8643E-01
3,55E+00	3,4086E-01	1,6446E-01	4,8248E-01	7,1128E+00	5,9178E-01
3,60E+00	3,3408E-01	1,6055E-01	4,8059E-01	7,4501E+00	5,9695E-01
3,65E+00	3,2747E-01	1,5678E-01	4,7877E-01	7,8020E+00	6,0197E-01
3,70E+00	3,2103E-01	1,5313E-01	4,7701E-01	8,1691E+00	6,0684E-01
3,75E+00	3,1475E-01	1,4961E-01	4,7532E-01	8,5517E+00	6,1155E-01
3,80E+00	3,0864E-01	1,4620E-01	4,7368E-01	8,9506E+00	6,1612E-01
3,85E+00	3,0269E-01	1,4290E-01	4,7211E-01	9,3661E+00	6,2055E-01
3,90E+00	2,9688E-01	1,3971E-01	4,7059E-01	9,7990E+00	6,2485E-01
3,95E+00	2,9123E-01	1,3662E-01	4,6912E-01	1,0250E+01	6,2902E-01
4,00E+00	2,8571E-01	1,3363E-01	4,6771E-01	1,0719E+01	6,3306E-01
4,05E+00	2,8034E-01	1,3073E-01	4,6634E-01	1,1207E+01	6,3699E-01
4,10E+00	2,7510E-01	1,2793E-01	4,6502E-01	1,1715E+01	6,4080E-01
4,15E+00	2,7000E-01	1,2521E-01	4,6374E-01	1,2243E+01	6,4451E-01
4,20E+00	2,6502E-01	1,2257E-01	4,6250E-01	1,2792E+01	6,4810E-01
4,25E+00	2,6016E-01	1,2001E-01	4,6131E-01	1,3362E+01	6,5159E-01
4,30E+00	2,5543E-01	1,1753E-01	4,6015E-01	1,3955E+01	6,5499E-01
4,35E+00	2,5081E-01	1,1513E-01	4,5903E-01	1,4571E+01	6,5828E-01
4,40E+00	2,4631E-01	1,1279E-01	4,5794E-01	1,5210E+01	6,6149E-01
4,45E+00	2,4191E-01	1,1053E-01	4,5689E-01	1,5873E+01	6,6460E-01
4,50E+00	2,3762E-01	1,0833E-01	4,5587E-01	1,6562E+01	6,6763E-01
4,55E+00	2,3344E-01	1,0619E-01	4,5488E-01	1,7277E+01	6,7058E-01
4,60E+00	2,2936E-01	1,0411E-01	4,5393E-01	1,8018E+01	6,7345E-01
4,65E+00	2,2537E-01	1,0209E-01	4,5300E-01	1,8786E+01	6,7624E-01
4,70E+00	2,2148E-01	1,0013E-01	4,5210E-01	1,9583E+01	6,7895E-01
4,75E+00	2,1769E-01	9,8225E-02	4,5122E-01	2,0408E+01	6,8159E-01
4,80E+00	2,1398E-01	9,6371E-02	4,5037E-01	2,1264E+01	6,8417E-01

Formulario di Gasdinamica

Flusso di Fanno					
Mach in	T/T*	P/P*	ρ/ρ^*	P0/P0*	4fL*/D
2,70E+01	8,1744E-03	3,3486E-03	4,0965E-01	6,7806E+04	8,1663E-01
2,80E+01	7,6046E-03	3,1144E-03	4,0955E-01	8,1212E+04	8,1697E-01
2,90E+01	7,0922E-03	2,9040E-03	4,0946E-01	9,6663E+04	8,1728E-01
3,00E+01	6,6298E-03	2,7141E-03	4,0938E-01	1,1439E+05	8,1755E-01
3,10E+01	6,2112E-03	2,5423E-03	4,0931E-01	1,3462E+05	8,1780E-01
3,20E+01	5,8309E-03	2,3863E-03	4,0924E-01	1,5763E+05	8,1803E-01
3,30E+01	5,4845E-03	2,2442E-03	4,0918E-01	1,8369E+05	8,1824E-01
3,40E+01	5,1680E-03	2,1144E-03	4,0913E-01	2,1309E+05	8,1843E-01
3,50E+01	4,8780E-03	1,9955E-03	4,0908E-01	2,4615E+05	8,1860E-01
3,60E+01	4,6118E-03	1,8864E-03	4,0904E-01	2,8319E+05	8,1876E-01
3,70E+01	4,3668E-03	1,7860E-03	4,0899E-01	3,2457E+05	8,1891E-01
3,80E+01	4,1408E-03	1,6934E-03	4,0895E-01	3,7065E+05	8,1904E-01
3,90E+01	3,9318E-03	1,6078E-03	4,0892E-01	4,2184E+05	8,1916E-01
4,00E+01	3,7383E-03	1,5285E-03	4,0889E-01	4,7853E+05	8,1928E-01
4,10E+01	3,5587E-03	1,4550E-03	4,0885E-01	5,4117E+05	8,1939E-01
4,20E+01	3,3917E-03	1,3866E-03	4,0883E-01	6,1021E+05	8,1949E-01
4,30E+01	3,2362E-03	1,3230E-03	4,0880E-01	6,8613E+05	8,1958E-01
4,40E+01	3,0912E-03	1,2636E-03	4,0878E-01	7,6943E+05	8,1967E-01
4,50E+01	2,9557E-03	1,2081E-03	4,0875E-01	8,6064E+05	8,1975E-01
4,60E+01	2,8289E-03	1,1562E-03	4,0873E-01	9,6031E+05	8,1982E-01
4,70E+01	2,7100E-03	1,1076E-03	4,0871E-01	1,0690E+06	8,1989E-01
4,80E+01	2,5985E-03	1,0620E-03	4,0869E-01	1,1873E+06	8,1996E-01
4,90E+01	2,4938E-03	1,0191E-03	4,0867E-01	1,3159E+06	8,2002E-01
5,00E+01	2,3952E-03	9,7882E-04	4,0866E-01	1,4555E+06	8,2008E-01

Formulario di Gasdinamica

Espansione di Prandtl-Meyer

$$\left\{ \begin{array}{l} 1 \leq M_1 < M_2 \\ \frac{\rho_2}{\rho_1} < 1 \\ \frac{p_2}{p_1} < 1 \end{array} \right. \left\{ \begin{array}{l} \frac{T_2}{T_1} < 1 \\ T_{01} = T_{02} \\ P_{01} = P_{02} \end{array} \right.$$

$$\left\{ \begin{array}{l} d\theta = \sqrt{M^2 - 1} \frac{dV}{V} \\ v(\theta) = \frac{\sqrt{\frac{\gamma+1}{\gamma-1}}}{\tan \sqrt{\frac{\gamma-1}{\gamma+1}} (M^2 - 1)} - \frac{1}{\tan \sqrt{M^2 - 1}} \\ \Rightarrow \theta_2 = v(M_2) - v(M_1) \\ \Delta\mu = \mu_1 - (\mu_2 - \theta) \end{array} \right.$$

$$\frac{l}{h} = M_1 \left[\frac{1 + \frac{(\gamma-1)}{2} M_2^2}{1 + \frac{(\gamma-1)}{2} M_1^2} \right]^{\left(\frac{1}{\gamma-1} + \frac{1}{2}\right)}$$

$$\left\{ \begin{array}{l} \frac{T_2}{T_1} = 1 + \frac{\gamma-1}{2} M_1^2 \\ \frac{p_2}{p_1} = \left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}} = \left(1 + \frac{\gamma-1}{2} M_1^2\right)^{\frac{\gamma}{\gamma-1}} \\ \frac{\rho_2}{\rho_1} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}} = \left(1 + \frac{\gamma-1}{2} M_1^2\right)^{\frac{1}{\gamma-1}} \end{array} \right.$$

$$\left\{ \begin{array}{l} \frac{T_0}{T_\infty} = 1 + \frac{\gamma-1}{2} M_\infty^2 \\ \frac{p_0}{p_\infty} = \left(\frac{T_0}{T_\infty}\right)^{\frac{\gamma}{\gamma-1}} = \left(1 + \frac{\gamma-1}{2} M_\infty^2\right)^{\frac{\gamma}{\gamma-1}} \\ \frac{\rho_0}{\rho_\infty} = \left(\frac{T_0}{T_\infty}\right)^{\frac{1}{\gamma-1}} = \left(1 + \frac{\gamma-1}{2} M_\infty^2\right)^{\frac{1}{\gamma-1}} \end{array} \right.$$

Formulario di Gasdinamica

Espansione di Prandtl-Meyer								
Mach	v [deg]	μ [deg]	Mach	v [deg]	μ [deg]	Mach	v [deg]	μ [deg]
12,00	1,069E+02	4,780E+00						
13,00	1,087E+02	4,412E+00						
14,00	1,102E+02	4,096E+00						
15,00	1,115E+02	3,823E+00						
16,00	1,127E+02	3,583E+00						
17,00	1,137E+02	3,372E+00						
18,00	1,146E+02	3,185E+00						
19,00	1,155E+02	3,017E+00						
20,00	1,162E+02	2,866E+00						
22,00	1,175E+02	2,605E+00						
24,00	1,186E+02	2,388E+00						
26,00	1,195E+02	2,204E+00						
28,00	1,202E+02	2,047E+00						
30,00	1,209E+02	1,910E+00						
32,00	1,215E+02	1,791E+00						
34,00	1,220E+02	1,685E+00						
36,00	1,225E+02	1,592E+00						
38,00	1,229E+02	1,508E+00						
40,00	1,233E+02	1,433E+00						
42,00	1,236E+02	1,364E+00						
44,00	1,239E+02	1,302E+00						
46,00	1,242E+02	1,246E+00						
48,00	1,245E+02	1,194E+00						
50,00	1,247E+02	1,146E+00						

Formulario di Gasdinamica

Campo Transonico $[0,8 \leq M \leq 1,2]$

$$(1 - M_\infty^2) \frac{\partial u'}{\partial x} + \frac{\partial v'}{\partial y} + \frac{\partial w}{\partial z} = M_\infty^2 \left[(\gamma - 1) \frac{u'}{V_\infty} \right] \frac{\partial u'}{\partial x}$$

Campo ipersonico $[M \geq 5]$

$$\left\{ \begin{aligned} \frac{\rho_2}{\rho_1} &= \frac{(\gamma + 1)}{(\gamma - 1)} \\ \frac{p_2}{p_1} &= \frac{2\gamma}{\gamma + 1} M_1^2 \\ \frac{T_2}{T_1} &= \frac{p_2}{p_1} \frac{\rho_1}{\rho_2} = \frac{2\gamma(\gamma - 1)}{(\gamma + 1)^2} M_1^2 \\ s_2 - s_1 &= C_p \ln \frac{T_2}{T_1} - R \ln \frac{p_2}{p_1} = C_p \ln \frac{T_{02}}{T_{01}} - R \ln \frac{p_{02}}{p_{01}} \\ \frac{p_{02}}{p_{01}} &= e^{-\frac{s_2 - s_1}{R}} \end{aligned} \right.$$

$$\left\{ \begin{aligned} \frac{u_2}{V_\infty} &= 1 - \frac{2(M_{n1}^2 - 1)}{(\gamma + 1)M_{n1}^2} \approx 1 - \frac{2 \sin^2 \beta}{(\gamma + 1)} \\ \frac{v_2}{V_\infty} &= 1 - \frac{2(M_{n1}^2 - 1) \cot \beta}{(\gamma + 1)M_{n1}^2} \approx \frac{\sin 2\beta}{(\gamma + 1)} \\ C_p &= \frac{2}{\gamma M_\infty^2} \left(\frac{P}{P_\infty} - 1 \right) \approx \frac{2}{\gamma M_\infty^2} \left(\frac{2\gamma}{\gamma + 1} M_{n1}^2 - 1 \right) \\ &= \frac{4}{\gamma + 1} \left(\sin^2 \beta - \frac{1}{M_\infty} \right) \\ \tan \theta &= \frac{2}{\tan \beta} \left(\frac{M_1^2 \sin^2 \beta - 1}{M_1^2 (\gamma + \cos 2\beta) + 2} \right) \approx \frac{\beta}{\theta} = \frac{\gamma + 1}{2} \end{aligned} \right.$$

$$\beta = 1, 2\theta \left\{ \begin{aligned} \sin \beta &\approx \beta \\ \cos 2\beta &\approx 1 \\ \tan \theta &\approx \sin \theta \approx \theta \end{aligned} \right.$$

Teoria Newtoniana

$$\left. \begin{aligned} F_N &= \rho_\infty V_\infty A \sin \alpha (V_\infty \sin \alpha) \\ \frac{F_N}{A} &= \rho_\infty V_\infty^2 \sin^2 \alpha = P - P_\infty \end{aligned} \right\} C_p = \frac{P - P_\infty}{\frac{1}{2} \rho_\infty V_\infty^2} = 2 \sin^2 \theta$$

$$\text{Placca Piana} \left\{ \begin{aligned} C_L &= 2 \sin^2 \alpha \cos \alpha \\ C_D &= 2 \sin^3 \alpha \end{aligned} \right.$$

$$C_p = \frac{4}{\gamma + 1} \left(\sin^2 \beta - \frac{1}{M_\infty} \right) \frac{M_\infty \rightarrow \infty}{\gamma \rightarrow 1} \rightarrow C_p = 2 \sin^2 \beta$$

Resistenza D'onda

$$C_d = \frac{4\alpha^2}{\sqrt{M_\infty^2 - 1}} + \frac{2}{c\sqrt{M_\infty^2 - 1}} \int_0^c \left[\left(\frac{dy}{dx} \right)_u^2 + \left(\frac{dy}{dx} \right)_l^2 \right] dx$$

Formulario di Gasdinamica

$$\left\{ \begin{array}{l} \frac{u^2}{2} \rightarrow R \frac{u^2}{2} \\ \frac{V_\infty^2}{2} \rightarrow R \frac{V_\infty^2}{2} \\ T \rightarrow T_{rec} \end{array} \right. \quad \left\{ \begin{array}{l} \frac{u}{V_\infty} = \frac{T + R \frac{u^2}{2C_p} - T_w}{T_\infty + R \frac{u^2}{2C_p} - T_w} \\ \left\{ \begin{array}{l} T_w = T_{rec} \Rightarrow T = T_w (1 - \varphi) + T_\infty \varphi^2 + T_{rec} (\varphi - \varphi^2) \\ T_w = T_\infty \Rightarrow T = T_\infty + (T_{rec} - T_\infty) (\varphi - \varphi^2) \end{array} \right. \end{array} \right.$$

Formulario di Gasdinamica

Profili di Temperatura						
φ	Adiabatico			Non Adiabatico		
	T @ Pr=1	T @ Pr≠1		T @ Pr=1	T @ Pr≠1	
		Laminare	Turbolento		SemiAdiabatico Tw=Trec	Isothermo Tw=T∞
0	5,2841E+02	4,9215E+02	5,0355E+02	4,0000E+02	5,3640E+02	2,9800E+02
0,01	5,2839E+02	4,9213E+02	5,0353E+02	4,0134E+02	5,3638E+02	3,0036E+02
0,02	5,2832E+02	4,9207E+02	5,0347E+02	4,0263E+02	5,3630E+02	3,0267E+02
0,03	5,2821E+02	4,9198E+02	5,0337E+02	4,0388E+02	5,3619E+02	3,0494E+02
0,04	5,2804E+02	4,9184E+02	5,0323E+02	4,0507E+02	5,3602E+02	3,0715E+02
0,05	5,2784E+02	4,9166E+02	5,0304E+02	4,0622E+02	5,3580E+02	3,0932E+02
0,06	5,2758E+02	4,9145E+02	5,0281E+02	4,0733E+02	5,3554E+02	3,1145E+02
0,07	5,2728E+02	4,9120E+02	5,0255E+02	4,0838E+02	5,3523E+02	3,1352E+02
0,08	5,2694E+02	4,9091E+02	5,0224E+02	4,0939E+02	5,3487E+02	3,1555E+02
0,09	5,2655E+02	4,9058E+02	5,0189E+02	4,1034E+02	5,3447E+02	3,1752E+02
0,1	5,2611E+02	4,9021E+02	5,0150E+02	4,1126E+02	5,3402E+02	3,1946E+02
0,11	5,2563E+02	4,8980E+02	5,0107E+02	4,1212E+02	5,3352E+02	3,2134E+02
0,12	5,2510E+02	4,8935E+02	5,0059E+02	4,1294E+02	5,3297E+02	3,2318E+02
0,13	5,2452E+02	4,8887E+02	5,0008E+02	4,1370E+02	5,3237E+02	3,2496E+02
0,14	5,2390E+02	4,8834E+02	4,9953E+02	4,1442E+02	5,3173E+02	3,2670E+02
0,15	5,2323E+02	4,8778E+02	4,9893E+02	4,1510E+02	5,3104E+02	3,2840E+02
0,16	5,2251E+02	4,8718E+02	4,9829E+02	4,1572E+02	5,3030E+02	3,3004E+02
0,17	5,2175E+02	4,8654E+02	4,9761E+02	4,1630E+02	5,2951E+02	3,3164E+02
0,18	5,2095E+02	4,8586E+02	4,9689E+02	4,1683E+02	5,2868E+02	3,3319E+02
0,19	5,2010E+02	4,8514E+02	4,9613E+02	4,1731E+02	5,2779E+02	3,3469E+02
0,2	5,1920E+02	4,8438E+02	4,9533E+02	4,1774E+02	5,2686E+02	3,3614E+02
0,21	5,1825E+02	4,8359E+02	4,9449E+02	4,1813E+02	5,2589E+02	3,3755E+02
0,22	5,1726E+02	4,8275E+02	4,9361E+02	4,1847E+02	5,2486E+02	3,3891E+02
0,23	5,1622E+02	4,8188E+02	4,9268E+02	4,1876E+02	5,2379E+02	3,4022E+02
0,24	5,1514E+02	4,8097E+02	4,9171E+02	4,1900E+02	5,2267E+02	3,4148E+02
0,25	5,1401E+02	4,8002E+02	4,9071E+02	4,1920E+02	5,2150E+02	3,4270E+02
0,26	5,1284E+02	4,7903E+02	4,8966E+02	4,1935E+02	5,2028E+02	3,4387E+02
0,27	5,1162E+02	4,7800E+02	4,8857E+02	4,1945E+02	5,1902E+02	3,4499E+02
0,28	5,1035E+02	4,7693E+02	4,8744E+02	4,1950E+02	5,1771E+02	3,4606E+02
0,29	5,0904E+02	4,7582E+02	4,8627E+02	4,1951E+02	5,1635E+02	3,4709E+02
0,3	5,0768E+02	4,7468E+02	4,8505E+02	4,1946E+02	5,1494E+02	3,4806E+02
0,31	5,0627E+02	4,7349E+02	4,8380E+02	4,1937E+02	5,1349E+02	3,4899E+02
0,32	5,0482E+02	4,7227E+02	4,8251E+02	4,1924E+02	5,1199E+02	3,4988E+02
0,33	5,0332E+02	4,7101E+02	4,8117E+02	4,1905E+02	5,1044E+02	3,5071E+02
0,34	5,0178E+02	4,6971E+02	4,7979E+02	4,1882E+02	5,0884E+02	3,5150E+02
0,35	5,0019E+02	4,6837E+02	4,7837E+02	4,1854E+02	5,0720E+02	3,5224E+02
0,36	4,9855E+02	4,6699E+02	4,7691E+02	4,1821E+02	5,0550E+02	3,5293E+02
0,37	4,9687E+02	4,6557E+02	4,7541E+02	4,1783E+02	5,0376E+02	3,5357E+02
0,38	4,9514E+02	4,6411E+02	4,7387E+02	4,1741E+02	5,0198E+02	3,5417E+02
0,39	4,9337E+02	4,6262E+02	4,7229E+02	4,1694E+02	5,0014E+02	3,5472E+02
0,4	4,9155E+02	4,6109E+02	4,7067E+02	4,1642E+02	4,9826E+02	3,5522E+02
0,41	4,8968E+02	4,5951E+02	4,6900E+02	4,1585E+02	4,9632E+02	3,5567E+02
0,42	4,8777E+02	4,5790E+02	4,6729E+02	4,1523E+02	4,9435E+02	3,5607E+02
0,43	4,8581E+02	4,5625E+02	4,6555E+02	4,1457E+02	4,9232E+02	3,5643E+02

Formulario di Gasdinamica

Profili di Temperatura						
φ	Adiabatico			Non Adiabatico		
	T @ Pr=1	T @ Pr≠1		T @ Pr=1	T @ Pr≠1	
		Laminare	Turbolento		SemiAdiabatico Tw=Trec	Isotermo Tw=T∞
0,89	3,4590E+02	3,3836E+02	3,4073E+02	3,3256E+02	3,4756E+02	3,2134E+02
0,9	3,4178E+02	3,3489E+02	3,3706E+02	3,2966E+02	3,4330E+02	3,1946E+02
0,91	3,3761E+02	3,3137E+02	3,3333E+02	3,2670E+02	3,3898E+02	3,1752E+02
0,92	3,3339E+02	3,2782E+02	3,2957E+02	3,2371E+02	3,3462E+02	3,1555E+02
0,93	3,2913E+02	3,2423E+02	3,2577E+02	3,2066E+02	3,3021E+02	3,1352E+02
0,94	3,2482E+02	3,2060E+02	3,2193E+02	3,1757E+02	3,2575E+02	3,1145E+02
0,95	3,2047E+02	3,1693E+02	3,1804E+02	3,1442E+02	3,2124E+02	3,0932E+02
0,96	3,1606E+02	3,1322E+02	3,1412E+02	3,1123E+02	3,1669E+02	3,0715E+02
0,97	3,1162E+02	3,0947E+02	3,1015E+02	3,0800E+02	3,1209E+02	3,0494E+02
0,98	3,0712E+02	3,0569E+02	3,0614E+02	3,0471E+02	3,0744E+02	3,0267E+02
0,99	3,0259E+02	3,0186E+02	3,0209E+02	3,0138E+02	3,0274E+02	3,0036E+02

Analogia di Reynolds

- **Pr=1**

$$\frac{u}{V_\infty} = \frac{\left(h + \frac{u^2}{2}\right) - h_w}{\left(h_\infty + \frac{u_\infty^2}{2}\right) - h_w};$$

$$\frac{1}{V_\infty} \left(\frac{\partial u}{\partial y}\right)_{y=0} = \left(\frac{\partial h}{\partial y}\right)_{y=0} \frac{1}{h_\infty + \frac{u_\infty^2}{2} - h_w} \Rightarrow \begin{cases} \left(\frac{\partial u}{\partial y}\right)_{y=0} = \frac{\tau_w}{\mu} \\ \left(\frac{\partial h}{\partial y}\right)_{y=0} = C_p \left(\frac{\partial T}{\partial y}\right)_{y=0} \end{cases}$$

$$\begin{cases} \frac{\tau_w}{\mu V_\infty} = C_p \left(\frac{\partial T}{\partial y}\right)_{y=0} \frac{1}{h_\infty + \frac{u_\infty^2}{2} - h_w} \\ q_w = -\lambda \left(\frac{\partial T}{\partial y}\right)_{y=0} \end{cases} \Rightarrow \begin{cases} \frac{\tau_w}{V_\infty} = -\frac{\mu C_p}{\lambda} \frac{q_w}{h_\infty + \frac{u_\infty^2}{2} - h_w} \\ = -Pr \frac{q_w}{h_\infty + \frac{u_\infty^2}{2} - h_w} \end{cases}$$

- **Pr≠1**

$$\frac{\tau_w}{V_\infty} = -\frac{Aq_w}{h_\infty + \frac{Ru_\infty^2}{2} - h_w}$$

$$H = h_\infty + R \frac{u^2}{2}$$

$$A \begin{cases} Pr \text{ Moto Couette} \\ Pr^{2/3} \text{ Moto Laminare} \\ Pr^{3/5} \text{ Moto Turbolento} \\ 1 \text{ Trubolento } \infty \end{cases}$$

$$R \begin{cases} Pr \rightarrow \text{Flusso alla couette} \\ Pr^{1/2} \rightarrow \text{Flusso La minare} \\ Pr^{1/3} \rightarrow \text{Flusso Turbolento} \end{cases}$$

Formulario di Gasdinamica

Turbolento basso [$\omega = 0,75$]

$$\bar{\tau}_w = 0,036\rho_\infty V_\infty^2 \left(\frac{v_\infty}{V_\infty L} \right)^{1/5} \quad \left\{ \begin{array}{l} \chi_T = \left(\frac{T^*}{T_\infty} \right)^{\frac{\omega-4}{5}} \\ \chi_T = \left[\frac{T_w + T_\infty}{2T_\infty} + R \frac{\gamma-1}{2} \frac{M_\infty^2}{4} \right]^{\frac{\omega-4}{5}} \end{array} \right.$$

Cono

Se $\left\{ \begin{array}{l} \theta < 55^\circ \\ M > 1,2 \end{array} \right.$

$$\left\{ \begin{array}{l} T_{w_C} = T_{w_{PP}} \\ Re_{x_C} = Re_{x_{PP}} \\ M_{\infty_C} = M_{\infty_{PP}} \\ \left(\frac{T_w}{T_e} \right)_C = \left(\frac{T_w}{T_e} \right)_{PP} \end{array} \right.$$

Localmente

attrito

$$\begin{aligned} L \rightarrow C_{f_c}(x) &= \sqrt{3} C_{f_{PP}}(x) \\ T \rightarrow C_{f_c}(x) &= [1,1 \div 1,15] C_{f_{PP}}(x) \end{aligned}$$

Flusso di calore

$$\left\{ \begin{array}{l} Pr_C = Pr_{PP} \\ q_{w_C} = \sqrt{3} q_{w_{PP}} \end{array} \right.$$

Formulario di Gasdinamica

$$\frac{P - P_\infty}{\rho_\infty V_\infty^2} = \sin^2 \theta = \cos^2 \phi$$

A

$$\frac{dP}{dx} = -\rho_e u_e \frac{du_e}{dx} = -\rho_e K^2 x$$

B

$$\begin{cases} \frac{dP}{dx} = -2\rho_\infty V_\infty^2 \cos\phi \sin\phi \frac{d\phi}{dx} \\ \phi = 0 \Rightarrow \frac{dP}{dx} = -2\rho_\infty V_\infty^2 \frac{2x}{D} \frac{2}{D} = -8 \frac{\rho_\infty V_\infty^2 x}{D^2} \end{cases}$$

$$-\rho_e K^2 x = -8 \frac{\rho_\infty V_\infty^2 x}{D^2} \Rightarrow \frac{KD}{V_\infty} = \sqrt{8 \frac{\rho_\infty}{\rho_e}}$$

$$\frac{\rho_\infty}{\rho_e} = \frac{(\gamma + 1) M_1^2}{2 + (\gamma - 1) M_1^2} \left[1 + \frac{\gamma - 1}{2} M_2^2 \right]^{\frac{1}{\gamma - 1}}$$

Metodo Approssimato

$$q_w = \frac{\tau_w C_p}{C_p u_e(x)} (T_{rec} - T_w) \begin{cases} u_e(x) = 2u_e \sin\left(\frac{x}{R}\right) \\ \left(\frac{du_e}{dx}\right) = \frac{2u_e}{R} \cos\left(\frac{x}{R}\right) \end{cases}$$

Roming

$$q_w = 0,0145 M_\infty^{3,1} \sqrt{\frac{P_\infty}{R}} = \left[\frac{Btu}{ft^2} \right]$$

$$\begin{cases} \varphi(T_{max}) = \frac{T_{rec} - T_w}{2(T_{rec} - T_\infty)} \\ T_{max} = T_w + \frac{1}{4} \frac{(T_{rec} - T_w)^2}{(T_{rec} - T_\infty)^2} \end{cases}$$