Appendix-A Tables of Collected Experimental Data of Skin Friction Coefficient in a Compressible Turbulent Boundary Layer.

Table A1 **Experimental Data of Skin Friction Coefficient at Various Reynolds Numbers and Mach Numbers**

(For Adiabatic Wall Case)

Authors and Years	M_α	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks.
H.W. Spivak (1950) [33]	2·8	9600		0·00187		Flat wall of a 2-D nozzle	$c_f/2$ to $d\delta_2/dx$; $\bar{c}_f/2$ to δ_2/x	——
	2·8	9300		0·00182				
	2·8	10800		0·00180				
	2·8	11700		0·00177				
	2·8	12000		0·00171				
	2·8	12300		0·00170				
	2·8	13400		0·00169				
	2·8	13600		0·00168				
	2·8		7·6	0·00187	0·00246			
	2·8		8·0	0·00182	0·00244			
	2·8		8·9	0·00180	0·00237			
	2·8		10·0	0·00177	0·00230			
	2·8		10·0	0·00171	0·00237			
	2·8		10·8	0·00170	0·00226			
	2·8		12·0	0·00169	0·00227			
	2·8		12·5	0·00168	0·00222			

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
R.E. Wilson	1.897		3.1		0.0033	Flat Plate	$\bar{c}_f/2$ to δ_2/x	x is the effective
(1950)	1.897		5.8		0.0026			length which was
[redacted]	1.897		11.1		0.00238			determined by
	1.897		13.8		0.00242			extrapolating δ_2
	1.897		16.6		0.00230			to zero.
	2.121		0.93		0.00350			
	2.121		8.3		0.00240			
	2.121		11		0.00220			
	2.121		13.5		0.00218			
	2.003		2.83		0.00310			
	2.003		5.45		0.00258			
	2.003		10.6		0.00234			
	2.003		13.3		0.00230			
	2.003		16.0		0.00220			
	2.186		8		0.00240			
	2.186		10.5		0.00219			
	2.186		12.8		0.00218			
	2.186		15.4		0.00212			
	2.186		0.82		0.00390			

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Rema
M. W. Rubesin,	2.5		3.14		0.00266	Flat Plate	$\bar{c}_f/2$ to δ_2/x.	x is the
R. C. Maydew, and	2.5		3.49		0.00255			length w
S. A. Varga (1951)	2.5		3.63		0.00255			determin
[8]	2.5		4.13		0.00246			extrapola
	2.5		4.13		0.00253			to zero
	2.5		4.73		0.00241			
	2.5		4.73		0.00242			
	2.5		5.45		0.00241			
	2.5		6.09		0.00231			
	2.5		2.70		0.00247			
	2.5		3.21		0.00264			
	2.5		3.56		0.00250			
	2.5		3.69		0.00251			
	2.5		4.20		0.00244			
	2.5		4.22		0.00250			
	2.5		4.80		0.00241			
	2.5		4.83		0.00238			
	2.5		5.48		0.00239			
	2.5		6.17		0.00229			

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
P.F. Brinich and	3.05	2130		0.00206		Cylindrical testing	Measurements of	———
N.S. Diaconis	3.05	2600		0.00199		model placed co-	velocity profile at	
(1952)	3.05	3030		0.00190		axially in a	the outer surface of	
[redacted]	3.05	4400		0.00174		circular section	the model and $c_f/2$	
	3.05	7800		0.00146		tunnel.	to the slope of δ_2	
	3.05	10300		0.00142			vs x.	
	3.05	13000		0.00129				
	3.05	14500		0.00128				
W.F. Cope	2.5	2565		0.00250		Flat plate	Shear stress to the	———
(1952)	2.5	2720		0.00210			velocity gradient at	
[redacted]	2.5	5655		0.00210			the wall.	
S. Dahwan	0.352		1	0.00346		Flat plate	Direct force	x is the di
(1952)	0.63		1	0.00340			measurement on	from the lea
[redacted]	0.764		1	0.00329			a floating element	edge of the
	1.24		1	0.00296				
	1.26		1	0.00296				
	1.37		1	0.00282				
	1.44		1	0.00279				
	1.45		1	0.00272				

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
R.J. Monaghan and	2.43	1072	0.596	0.00295	0.00360	Flat plate	Velocity profiles;	x is the effective
J.E. Johnson (1952)	2.43	1307	0.772	0.00280	0.00338		$\bar{c}_f/2$ to δ_2/x;	length which was
[redacted]	2.43	1451	0.824	0.00272	0.00352		$c_f/2$ to the slope	determined by
	2.43	1792	1.187	0.00250	0.00302		of δ_2 vs x.	extrapolating δ_2 to
	2.43	2521	1.93	0.00237	0.00298			zero.
	2.43	3268	2.36	0.00227	0.00277			
	2.43	3950	2.93	0.00218	0.00270			
R.J. Monaghan and	2.82	886	0.490	0.00272	0.00359	Ditto	Ditto	Ditto
J.R. Cooke (1953)	2.82	1493	0.945	0.00243	0.00316			
[redacted]	2.82	1777	1.346	0.00219	0.00264			
	2.82	2180	1.570	0.00203	0.00278			
	2.82	2660	1.860	0.00196	0.00286			
	2.82	2789	2.178	0.00193	0.00256			
D.R. Chapman and	0.81		4.04		0.00308	Cylindrical Model	Direct measurement	x is the effective
R.H. Kester (1954)	0.81		4.82		0.00293	with air flowing	of total force on	length which was
[redacted]	0.81		6.20		0.00280	axially at the	the cylinder.	determined by
	0.81		6.68		0.00288	outer surface of		extrapolating δ_2 to
	0.81		7.42		0.00282	the model		zero.
	0.81		7.78		0.00279			

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
D.R. Chapman and R.H. Kesler (Cont.)	0.81		8.20		0.00269			
	0.81		9.00		0.00276			
	0.81		9.80		0.00268			
	0.81		10.9		0.00261			
	0.81		11.9		0.00263			
	0.81		12.0		0.00264			
	0.81		13.25		0.00260			
	0.81		13.5		0.00261			
	0.81		15.0		0.00256			
	0.81		15.4		0.00250			
	0.81		17.6		0.00250			
	0.81		17.3		0.00251			
	0.81		18.0		0.00250			
	0.81		20.7		0.00243			
	0.81		23.3		0.00240			
	0.81		26.9		0.00237			
	0.81		31.8		0.00232			
	2.5		5.78		0.00216			
	2.5		6.98		0.00202			

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
D.R. Chapman and	2.5		7.70		0.00202			
R.H. Kester (Cont.)	2.5		9.00		0.00195			
	2.5		9.30		0.00195			
	2.5		11.2		0.00191			
	2.5		11.3		0.00189			
	2.5		12.4		0.00190			
	2.5		14.3		0.00190			
	2.5		14.4		0.00188			
	2.5		16.0		0.00182			
	2.5		16.0		0.00182			
	2.5		17.9		0.00183			
	2.5		18.0		0.00179			
	2.5		21.0		0.00174			
	2.5		24.2		0.00170			
	2.5		26.4		0.00168			
	2.5		28.3		0.00163			
	2.5		31.2		0.00167			
	3.6		6.25		0.00170			
	3.6		9.46		0.00163			

Authors and Years	M_∞	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks.
R.D. Chapman and	3·6		10·0		0·00165			
R.H. Kester (Cont.)	3·6		16·2		0·00153			
	3·6		17·5		0·00154			
	3·6		18·3		0·00151			
D.Coles	2·6	6600	6·08	0·00181		Flat plate	Direct force measure-	x is the distanc
(1954)	2·6	10200	10·26	0·00166			ment on a floating	from a tripping
[redacted]	3·7	4100	3·98	0·00162			element.	device.
	3·7	7560	8·63	0·00138				
	4·5	2900	2·81	0·00155				
	4·5	3470	3·57	0·00148				
	4·5	5240	6·20	0·00126				
	4·5	6590	8·17	0·00122				
R.M. O'Donell	2·41	1530		0·00240		Cylindrical model	Velocity profiles at	x is the effective
(1954)	2·41	2140		0·00240		with air flowing	the outer surface of	length which wa
[redacted]	2·41	2200		0·00223		axially.	the model.	determined by
	2·41	3000		0·00236			$c_f/2$ to the slope	trapolating δ_2 t
	2·41	3600		0·00190			of δ_2 vs x, $\bar{c}_f/2$	zero.
	2·41	3820		0·00200			to δ_2/x.	
	2·41	4100		0·00180				

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
R.M. O'Donell (Cont.)	2.41	5360		0.00173				
	2.41		0.59		0.00360			
	2.41		0.93		0.00326			
	2.41		1.42		0.00300			
	2.41		2.12		0.00372			
	2.41		2.41		0.00291			
	2.41		2.90		0.00268			
	2.41		3.26		0.00260			
R.J. Hakkinen	0.18		0.33	0.00417		Flat plate	Direct force measurement on a floating element.	x is the distance from a tripping device.
(1955)	0.20		0.36	0.00409				
[redacted]	0.26		0.48	0.00395				
	0.27		0.48	0.00380				
	0.31		0.55	0.00384				
	0.33		0.59	0.00374				
	0.37		0.63	0.00366				
	0.46		0.76	0.00340				
	0.49		0.82	0.00344				
	0.56		0.90	0.00336				
	0.57		0.90	0.00337				

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks.
R.J. Hakkinen (Cont.)	0.65		1.00	0.00330				
	0.75		1.03	0.00301				
	0.85		1.12	0.00301				
	0.97		1.20	0.00300				
	1.45		1.04	0.00300				
	1.48		1.04	0.00294				
	1.49		1.04	0.00300				
	1.50		1.02	0.00291				
	1.50		1.04	0.00302				
	1.50		1.02	0.00302				
	1.50		1.03	0.00302				
	1.50		1.03	0.00292				
	1.52		1.02	0.00309				
	1.52		1.02	0.00307				
	1.52		1.01	0.00309				
	1.52		1.01	0.00307				
	1.71		0.68	0.00324				
	1.72		0.67	0.00321				
	1.73		0.66	0.00321				

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
R.J. Hakkinen (Cont.)	1.74		0.67	0.00323				
	1.75		0.67	0.00323				
	1.73		0.84	0.00313				
	1.74		0.85	0.00319				
	1.74		0.85	0.00319				
	1.76		0.84	0.00310				
	1.76		0.84	0.00312				
R.H. Korkegi	5.787	2477		0.001316		Flat plate	Direct force measure-	——
(1956)	5.770	2780		0.001275			ment on a floating	
[redacted]	5.792	3429		0.001223			element.	
	5.805	4040		0.001179				
F.E. Goddard	0.7		1.89		0.00412	Cylindrical model	Direct measurement	x is the effective
(1959)	0.7		3.80		0.00340	with air flowing	of the force on the	length which was
[redacted]	0.7		5.71		0.00327	axially at the	cylinder	determined by
	0.7		7.21		0.00328	outer surface of		extrapolating δ_2
	3.07		2.54		0.00193	the model		to zero.
	3.07		2.79		0.00189			
	3.07		3.41		0.00182			
	3.07		4.30		0.00172			

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
F.E. Goddard (cont.)	3.07		5.30		0.00169			
	3.7		3.68		0.00169			
	3.7		4.40		0.00158			
	3.7		5.05		0.00150			
	4.54		4.23		0.00150			
	4.54		4.42		0.00140			
	4.54		4.45		0.00135			
	4.54		4.55		0.00149			
	4.54		4.90		0.00142			
	4.54		5.20		0.00140			
	4.54		5.40		0.00139			
	4.54		6.20		0.00140			
	4.54		6.40		0.00133			
	4.54		6.40		0.00129			
	4.54		7.10		0.00140			
	4.54		7.40		0.00130			
	4.54		7.40		0.00123			
	4.54		7.90		0.00127			
	4.54		8.20		0.00130			

A

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
F.W. Matting,	2.95		6.18	0.00160		Flat wall of a	Direct force measure-	x is the dist
D.R. Chapman,	2.95		8.30	0.00155		2-D nozzle.	ment on a floating	measured fr
J.R. Nyholm,	2.95		9.01	0.00154			element.	the transition
and A.G. Thomas	2.95		10.50	0.00150				
(1961)	2.95		12.00	0.00146				
[redacted]	2.95		13.0	0.00145				
	2.95		14.8	0.00142				
	2.95		17.2	0.00140				
	2.95		19.9	0.00136				
	2.95		21.9	0.00134				
	2.95		24.6	0.00133				
	2.95		26.0	0.00130				
	2.95		27.5	0.00130				
	2.95		30.5	0.00130				
	2.95		34.0	0.00126				
	2.95		35.5	0.00129				
	2.95		37.5	0.00124				
	2.95		42.0	0.00123				
	2.95		54.0	0.00120				

Authors and Years	M_G	Re_{S_2}	$R_{0x} \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
F. W. Matting et al	2.95		65.0	0.00119				
(Cont.)	4.2		4.63	0.00132				
	4.2		5.90	0.00130				
	4.2		6.64	0.00126				
	4.2		7.53	0.00125				
	4.2		8.0	0.00120				
	4.2		9.12	0.00118				
	4.2		9.80	0.00115				
	4.2		11.2	0.00114				
	4.2		12.6	0.00110				
	4.2		14.0	0.00109				
	4.2		15.4	0.00107				
	4.2		17.5	0.00105				
	4.2		19.5	0.00104				
	4.2		22.5	0.00101				
	4.2		25.0	0.000995				
	4.2		27.5	0.000975				
	4.2		30.2	0.000960				
	4.2		34.8	0.000948				

Authors and Years	M_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
F.W. Matting et al (Cont.)	4.2		37.6	0.000928				
	4.2		42.0	0.000922				
	4.2		48.0	0.000920				
	4.2		55.0	0.000898				
	4.2		61.0	0.000880				
	4.2		68.2	0.000860				
	4.2		75.0	0.000855				
	4.2		84.0	0.000840				
	4.2		95.2	0.000828				
	6.7		7.17	0.00068				
	6.7		7.64	0.00066				
	6.7		9.60	0.000634				
	6.7		14.8	0.000610				
	6.7		18.6	0.000600				
	6.7		27.8	0.000530				
	6.7		33.0	0.000572				
	6.7		45.0	0.000570				
	6.7		46.8	0.000529				
	9.9		14.7	0.000331				
	9.9		20.4	0.000325				

Table A2 Experimental Data of Skin Friction Coefficient at Various Reynolds Numbers, Mach Numbers and Temperature R

(For the Case of Heat Transfer)

Authors and Years	M_G	T_s/T_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Model	Measurements	Remarks
I.H. Abbot	3.9	1		5		0.00239	Cylindrical	Drag from rate of	———
(1953)	7.25	1.8		5		0.00116	model	decceleration	
[45]	7.25	1.8		7.5		0.00104			
R.J. Monaghan and	2.82	3.5	1944	1.343	0.00221	0.00290	Flat plate	c_f from the slope of δ_2 vs x; and $\bar{c}_f/2$ from δ_2/x	x is the effecti length which wa determined by trapolating δ_2 zero
J.R. Cooke (1953)	2.82	3.5	2464	1.731	0.00206	0.00285			
[38]	2.82	3.5	3107	2.426	0.00198	0.00256			
	2.82	3.5	3391	2.897	0.00196	0.00234			
R.J. Monaghan and	2.43	2.94	1898	0.98	0.00300	0.00388	Ditto	Ditto	Ditto
J.R. Cooke (1953)	2.43	2.94	2278	1.40	0.00273	0.00326			
[46]	2.43	2.94	3270	2.10	0.00232	0.00313			
	2.43	2.94	3516	2.51	0.00200	0.00279			
	2.43	2.94	4525	3.20	0.00188	0.00281			
	2.43	3.42	2239	1.42	0.00248	0.00315			
	2.43	3.42	3003	2.12	0.00232	0.00280			
	2.43	3.42	3568	2.71	0.00218	0.00265			
	2.43	3.42	4556	3.70	0.00209	0.00245			
	2.43	3.42	5581	4.39	0.00195	0.00255			

Authors and Years	M_G	T_s/T_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
C.C. Pappas	1·69	1·7		0·807		0·00369	Flat plate	$\bar{c}_f/2$ to $\delta_2/2$	x is the effective
(1954)	1·69	1·7		1·50		0·00321			length which was
[47]	1·69	1·7		2·20		0·00316			determined by ex-
	1·69	1·7		2·89		0·00292			trapolating δ_2 to
	1·69	1·7		3·55		0·00280			zero.
	1·69	1·65		2·74		0·00318			
	1·69	1·65		3·80		0·00300			
	1·69	1·65		6·00		0·00276			
	1·69	1·63		1·89		0·00336			
	1·69	1·63		1·92		0·00337			
	1·69	1·63		2·92		0·00310			
	1·69	1·63		3·00		0·00316			
	1·69	1·63		4·01		0·00283			
	1·69	1·63		4·09		0·00271			
	1·69	1·63		5·42		0·00279			
	1·69	1·61		3·62		0·00273			
	1·69	1·61		5·45		0·00255			
	1·69	1·61		7·18		0·00256			
	1·69	1·61		7·21		0·00240			

Authors and Years	M_G	T_S/T_G	Re_{S_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c_f}$	Models	Measurements	Remarks.
C.C. Pappas	1.69	1.61		8.98		0.00235			
(cont.)	2.27	2.18		0.94		0.00342			
	2.27	2.18		1.95		0.00307			
	2.27	2.18		2.88		0.00286			
	2.27	2.18		3.90		0.00270			
	2.27	2.18		4.80		0.00270			
	2.27	2.19		1.48		0.00340			
	2.27	2.19		2.35		0.00290			
	2.27	2.19		4.30		0.00268			
	2.27	2.19		5.50		0.00254			
	2.27	2.12		3.56		0.00273			
	2.27	2.12		4.90		0.00250			
	2.27	2.12		6.40		0.00250			
	2.27	2.12		7.80		0.00230			
S.C. Sommer and	2.81	1.03		3.00		0.00312	Free flight tests	Drag from rate	x is the effective
B.J. Short (1955)	3.82	1.05		4.07		0.00250	on a tubular	of decceleration.	length which was de-
[20]	5.63	1.29		4.71		0.00187	model		termined by ex- trapolating δ_2 to zero.
	6.90	1.70		4.06		0.00138			
	6.90	1.70		6.09		0.00144			

Authors and Years	M_G	T_s/T_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
S.C. Sommer and	7.00	1.75		6.06		0.00126			
B. J. Short (Cont.)	7.00	1.75		9.92		0.00132			
	3.78	1.05		4.94		0.00229			
	3.67	1.05		3.78		0.00251			
F.K. Hill	8.99	7.68	1245		0.000790		Axially symmetrical	Shear stress to the	——
(1956)	9.04	7.97	1607		0.000891		nozzle using dry	velocity gradient	
~~[48]~~	9.07	8.28	1908		0.000851		N_2 as mainstream	at the wall	
	9.10	8.69	2287		0.000800		gas		
	8.22	7.17	2081		0.000924				
	8.25	7.26	2498		0.000910				
	8.27	7.34	2885		0.000870				
	8.29	7.37	3202		0.000820				
	8.29	7.41	3451		0.000771				
F.K. Hill	8.25	6.12	2200		0.000910		Ditto	Ditto	——
(1959)	8.27	6.17	2505		0.000840				
~~[49]~~	8.28	6.25	2760		0.000796				
	8.29	6.18	2965		0.000734				
	9.04	8.07	1936		0.000913				
	9.07	8.30	2276		0.000870				

Authors and Years	M_G	T_s/T_G	Re_{δ_2}	$Re_x \times 10^{-6}$	c_f	$\bar{c}_f$	Models	Measurements	Remarks
S.C. Sommer and	7.00	1.75		6.06		0.00126			
B. J. Short (Cont.)	7.00	1.75		9.92		0.00132			
	3.78	1.05		4.94		0.00229			
	3.67	1.05		3.78		0.00251			
F. K. Hill	8.99	7.68	1245		0.000790		Axially symmetrical	Shear stress to the	——
(1956)	9.04	7.97	1607		0.000891		nozzle using dry	velocity gradient	
[48]	9.07	8.28	1908		0.000851		N_2 as mainstream	at the wall	
	9.10	8.69	2287		0.000800		gas		
	8.22	7.17	2081		0.000924				
	8.25	7.26	2498		0.000910				
	8.27	7.34	2885		0.000870				
	8.29	7.37	3202		0.000820				
	8.29	7.41	3451		0.000771				
F. K. Hill	8.25	6.12	2200		0.000910		Ditto	Ditto	——
(1959)	8.27	6.17	2505		0.000840				
[49]	8.28	6.25	2760		0.000796				
	8.29	6.18	2965		0.000734				
	9.04	8.07	1936		0.000913				
	9.07	8.30	2276		0.000870				

Authors and Years	M_G	T_S/T_G	Re_{δ_2}	$Re_x \times 10^{-6}$	C_f	$\bar{C}_f$	Models	Measurements	Remarks
F. K. Hill (Cont.)	9.10	8.65	2710		0.000805				
	10.03	9.76	1300		0.000841				
	10.04	9.32	1450		0.000761				
	10.05	8.91	1680		0.000696				
	10.06	8.99	1700		0.000673				
E. M. Winkler (1961) [26]	5.21	5.15	2099	2.72	0.00147	0.00154	Flat plate	Shear stress to the velocity gradient at the wall.	x is the length from the leading edge of the plate.
	5.14	5.50	2936	3.36	0.00139	0.00175			
	5.20	5.38	3173	4.07	0.00143	0.00156			
	5.26	5.52	3880	5.04	0.00135	0.00154			
	5.29	5.57	4300	5.94	0.00131	0.00145			
	4.98	4.51	1900	2.29	0.00134	0.00166			
	5.19	4.74	1782	2.58	0.00161	0.00138			
	5.20	4.83	2960	3.81	0.00135	0.00155			
	5.24	5.02	3455	4.88	0.00115	0.00152			
	5.24	4.97	3799	5.11	0.00106	0.00148			
	5.17	3.89	1055	2.01	0.00147	0.00133			
	5.16	3.71	1652	2.57	0.00132	0.00129			
	5.10	3.58	1735	2.73	0.00134	0.00127			
	5.11	3.52	2488	2.27	0.00124	0.00153			
	5.20	3.77	2482	3.27	0.00120	0.00137			
	5.12	3.78	3256	3.57	0.00105	0.00182			