

APPROXIMATE CALCULATION OF THE PRESSURE CHANGES IN TWO-DIMENSIONAL SUPERSONIC FLOW

1. NOTATION AND UNITS

		SI	British
C_1, C_2	first- and second-order Busemann coefficients, see Section 2		
C_p	pressure coefficient, $(p - p_0)/\frac{1}{2}\rho_0 V_0^2$		
M_0	free-stream Mach number		
p	local static pressure	N/m ²	lbf/ft ²
p_0	free-stream static pressure	N/m ²	lbf/ft ²
V_0	free-stream velocity	m/s	ft/s
δ	flow deflection angle (positive for compression)	rad	rad
γ	ratio of specific heat capacity at constant pressure to specific heat capacity at constant volume, taken as 1.4 for air		
ρ_0	free-stream density	kg/m ³	slug/ft ³

2. NOTES

If a supersonic air stream moving with Mach number M_0 is deflected through an angle δ , the resultant pressure coefficient may be written to second-order accuracy as

$$C_p = C_1 \delta + C_2 \delta^2, \quad (2.1)$$

where
$$C_1 = \frac{2}{(M_0^2 - 1)^{1/2}} \quad (2.2)$$

and
$$C_2 = \frac{(\gamma + 1)M_0^4 - 4(M_0^2 - 1)}{2(M_0^2 - 1)^2}. \quad (2.3)$$

Values of the coefficients C_1 and C_2 and of the ratio C_2/C_1 (which is useful in calculating the flow past aerofoils) are given in Table 2.1 for values of M_0 between 1.2 and 4.0.

Pressure changes may be calculated fairly accurately using the above equation provided that the flow deflection is not large. In first-order theory, the term in δ^2 is omitted.

Sketch 2.1 shows the Mach numbers and deflections at which the values of the pressure coefficient calculated by first- and second-order theory depart by 5% from the results of exact theory (Derivation 1).

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TABLE 2.1 Busemann Coefficients

M_0	C_1	C_2	C_2/C_1	M_0	C_1	C_2	C_2/C_1	M_0	C_1	C_2	C_2/C_1	M_0	C_1	C_2	C_2/C_1
1.20	3.0151	8.3074	2.7553	1.84	1.2949	1.5785	1.2190	2.48	0.8813	1.3229	1.5011	3.12	0.6767	1.2615	1.8642
1.22	2.8618	7.0498	2.4634	1.86	1.2753	1.5610	1.2240	2.50	0.8729	1.3197	1.5119	3.14	0.6719	1.2604	1.8759
1.24	2.7277	6.0962	2.2349	1.88	1.2563	1.5447	1.2296	2.52	0.8646	1.3167	1.5229	3.16	0.6672	1.2594	1.8876
1.26	2.6091	5.3563	2.0529	1.90	1.2380	1.5294	1.2354	2.54	0.8566	1.3137	1.5336	3.18	0.6625	1.2583	1.8993
1.28	2.5031	4.7710	1.9060	1.92	1.2202	1.5152	1.2418	2.56	0.8487	1.3109	1.5446	3.20	0.6580	1.2573	1.9108
1.30	2.4077	4.3002	1.7860	1.94	1.2031	1.5019	1.2484	2.58	0.8409	1.3082	1.5557				
1.32	2.3212	3.9160	1.6871	1.96	1.1864	1.4894	1.2554	2.60	0.8333	1.3056	1.5668				
1.34	2.2422	3.5986	1.6049	1.98	1.1703	1.4777	1.2627	2.62	0.8259	1.3031	1.5778	3.25	0.6468	1.2550	1.9403
1.36	2.1698	3.3333	1.5362	2.00	1.1547	1.4667	1.2702	2.64	0.8186	1.3007	1.5889	3.30	0.6360	1.2527	1.9696
1.38	2.1030	3.1094	1.4786	2.02	1.1395	1.4563	1.2780	2.66	0.8114	1.2983	1.6001	3.35	0.6255	1.2506	1.9993
1.40	2.0412	2.9188	1.4299	2.04	1.1248	1.4466	1.2861	2.68	0.8044	1.2961	1.6113	3.40	0.6155	1.2486	2.0286
1.42	1.9838	2.7551	1.3888	2.06	1.1105	1.4374	1.2944	2.70	0.7975	1.2939	1.6224	3.45	0.6057	1.2468	2.0584
1.44	1.9302	2.6137	1.3541	2.08	1.0966	1.4287	1.3028	2.72	0.7907	1.2918	1.6337	3.50	0.5963	1.2450	2.0879
1.46	1.8801	2.4906	1.3247	2.10	1.0831	1.4205	1.3115	2.74	0.7840	1.2898	1.6452	3.55	0.5872	1.2434	2.1175
1.48	1.8331	2.3829	1.2999	2.12	1.0699	1.4127	1.3204	2.76	0.7775	1.2878	1.6563	3.60	0.5783	1.2418	2.1473
1.50	1.7889	2.2880	1.2790	2.14	1.0571	1.4054	1.3276	2.78	0.7710	1.2860	1.6680	3.65	0.5697	1.2404	2.1773
1.52	1.7471	2.2041	1.2616	2.16	1.0446	1.3984	1.3387	2.80	0.7647	1.2841	1.6792	3.70	0.5614	1.2390	2.2070
1.54	1.7077	2.1295	1.2470	2.18	1.0325	1.3918	1.3480	2.82	0.7585	1.2824	1.6907	3.75	0.5534	1.2377	2.2365
1.56	1.6704	2.0629	1.2350	2.20	1.0206	1.3855	1.3575	2.84	0.7524	1.2806	1.7020	3.80	0.5455	1.2364	2.2674
1.58	1.6350	2.0032	1.2252	2.22	1.0091	1.3796	1.3672	2.86	0.7464	1.2790	1.7136	3.85	0.5379	1.2352	2.2963
1.60	1.6013	1.9495	1.2174	2.24	0.9978	1.3739	1.3769	2.88	0.7405	1.2774	1.7251	3.90	0.5306	1.2341	2.3258
1.62	1.5692	1.9010	1.2114	2.26	0.9868	1.3685	1.3868	2.90	0.7347	1.2758	1.7365	3.95	0.5234	1.2330	2.3558
1.64	1.5386	1.8571	1.2070	2.28	0.9761	1.3634	1.3968	2.92	0.7290	1.2743	1.7480	4.00	0.5164	1.2320	2.3857
1.66	1.5094	1.8172	1.2039	2.30	0.9656	1.3584	1.4068	2.94	0.7234	1.2729	1.7596				
1.68	1.4815	1.7808	1.2020	2.32	0.9554	1.3538	1.4170	2.96	0.7179	1.2715	1.7711				
1.70	1.4548	1.7476	1.2013	2.34	0.9454	1.3493	1.4272	2.98	0.7125	1.2701	1.7826				
1.72	1.4292	1.7171	1.2014	2.36	0.9356	1.3450	1.4376	3.00	0.7071	1.2688	1.7944				
1.74	1.4046	1.6892	1.2026	2.38	0.9260	1.3409	1.4481	3.02	0.7018	1.2675	1.8061				
1.76	1.3809	1.6634	1.2046	2.40	0.9167	1.3370	1.4585	3.04	0.6967	1.2662	1.8174				
1.78	1.3582	1.6397	1.2073	2.42	0.9076	1.3332	1.4689	3.06	0.6916	1.2650	1.8291				
1.80	1.3363	1.6177	1.2106	2.44	0.8986	1.3297	1.4797	3.08	0.6865	1.2638	1.8409				
1.82	1.3152	1.5974	1.2146	2.46	0.8898	1.3262	1.4904	3.10	0.6816	1.2626	1.8524				