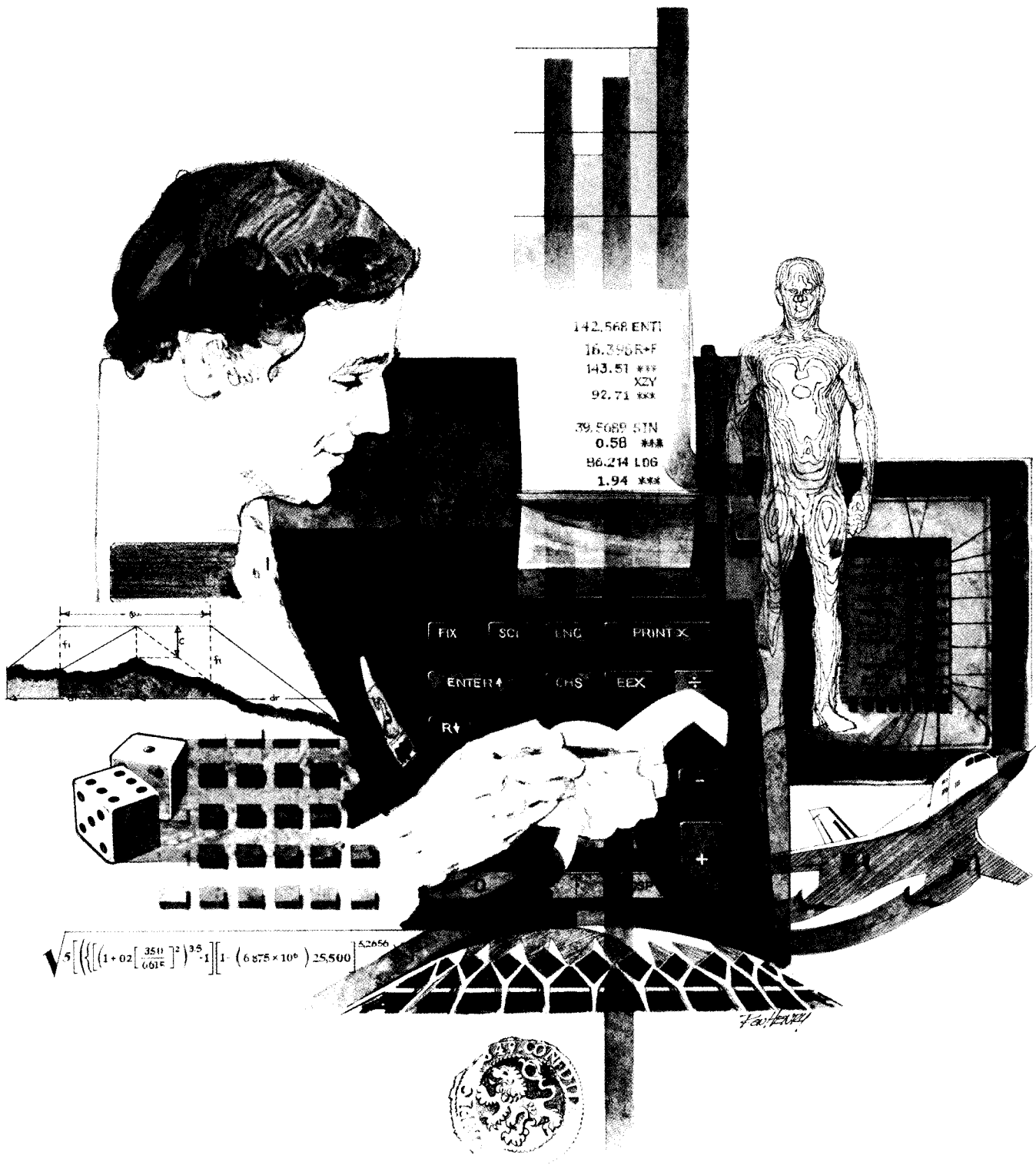


HEWLETT-PACKARD

HP-67/HP-97

Users' Library Solutions
Aeronautical Engineering



INTRODUCTION

In an effort to provide continued value to its customers, Hewlett-Packard is introducing a unique service for the HP fully programmable calculator user. This service is designed to save you time and programming effort. As users are aware, Programmable Calculators are capable of delivering tremendous problem solving potential in terms of power and flexibility, but the real genie in the bottle is program solutions. HP's introduction of the first handheld programmable calculator in 1974 immediately led to a request for program **solutions** — hence the beginning of the HP-65 Users' Library. In order to save HP calculator customers time, users wrote their own programs and sent them to the Library for the benefit of other program users. In a short period of time over 5,000 programs were accepted and made available. This overwhelming response indicated the value of the program library and a Users' Library was then established for the HP-67/97 users.

To extend the value of the Users' Library, Hewlett-Packard is introducing a unique service—a service designed to save you time and money. The Users' Library has collected the best programs in the most popular categories from the HP-67/97 and HP-65 Libraries. These programs have been packaged into a series of low-cost books, resulting in substantial savings for our valued HP-67/97 users.

We feel this new software service will extend the capabilities of our programmable calculators and provide a great benefit to our HP-67/97 users.

A WORD ABOUT PROGRAM USAGE

Each program contained herein is reproduced on the standard forms used by the Users' Library. Magnetic cards are not included. The Program Description I page gives a basic description of the program. The Program Description II page provides a sample problem and the keystrokes used to solve it. The User Instructions page contains a description of the keystrokes used to solve problems in general and the options which are available to the user. The Program Listing I and Program Listing II pages list the program steps necessary to operate the calculator. The comments, listed next to the steps, describe the reason for a step or group of steps. Other pertinent information about data register contents, uses of labels and flags and the initial calculator status mode is also found on these pages. Following the directions in your HP-67 or HP-97 **Owners' Handbook and Programming Guide**, "Loading a Program" (page 134, HP-67; page 119, HP-97), key in the program from the Program Listing I and Program Listing II pages. A number at the top of the Program Listing indicates on which calculator the program was written (HP-67 or HP-97). If the calculator indicated differs from the calculator you will be using, consult Appendix E of your **Owner's Handbook** for the corresponding keycodes and keystrokes converting HP-67 to HP-97 keycodes and vice versa. No program conversion is necessary. The HP-67 and HP-97 are totally compatible, but some differences do occur in the keycodes used to represent some of the functions.

A program loaded into the HP-67 or HP-97 is not permanent—once the calculator is turned off, the program will not be retained. You can, however, permanently save any program by recording it on a blank magnetic card, several of which were provided in the Standard Pac that was shipped with your calculator. Consult your **Owner's Handbook** for full instructions. A few points to remember:

The Set Status section indicates the status of flags, angular mode, and display setting. After keying in your program, review the status section and set the conditions as indicated before using or permanently recording the program.

REMEMBER! To save the program permanently, **clip** the corners of the magnetic card once you have recorded the program. This simple step will protect the magnetic card and keep the program from being inadvertently erased.

As a part of HP's continuing effort to provide value to our customers, we hope you will enjoy our newest concept.

TABLE OF CONTENTS

PROPERTIES OF AIR	1
This program computes the following properties of air at low pressures for a given temperature: specific heat ratio, specific heat at constant pressure, specific heat at constant volume, coefficient of viscosity, and absolute Rankine temperature.	
THEORETICAL U.S. STANDARD ATMOSPHERE TEMPERATURE AND PRESSURE BELOW 35,332 FT.	5
The program computes the theoretical U.S. Standard Atmosphere values for temperature and pressure at any altitude from -16,500 to 35,332 feet or by converting to metric units in the formula, -5,000 to 11,000 meters. Temperature is provided in absolute and thermometer standards. Pressure results are in Hg, psf, psi and mb.	
AIRCRAFT FLYOVER ACOUSTIC TONE DOPPLER SHIFT	9
Computes Doppler shift of an aircraft flyover acoustic source frequency observed on the ground. Also determines the 1/3 octave-band filter, and location within the filter, of the observed frequency. Inputs are flight path speed and angle, air temperature, source frequency, and aircraft elevation angle.	
ISENTROPIC FLOW FOR IDEAL GASES	13
The card replaces isentropic flow tables for a specified specific heat ratio k . Inputs and outputs are interchangeable with the exception of k .	
NORMAL AND OBLIQUE SHOCK PARAMETERS FOR COMPRESSIBLE FLOW	19
Knowing freestream Mach number, shock angle and ratio of specific heats (γ); computes mach number behind shock and the ratios across the shock for: static pressure, total pressure, density and temperature. Assumes adiabatic flow, perfect fluid.	
OBLIQUE SHOCK ANGLE FOR WEDGE	23
Given the upstream Mach number, the flow deflection angle, and the ratio of specific heats the program determines if an oblique shock is possible and finds the shock angle for the weak shock condition if the condition is possible.	
MACH NUMBER AND TRUE AIRSPEED	28
Converts calibrated airspeed and pressure altitude to Mach number and true airspeed.	
TAKE-OFF RUN VS DENSITY ALTITUDE	32
Computes actual take-off run required given sea level run at 15° C at full gross weight, pressure altitude, actual air temperature, and actual take-off weight.	
TRUE AIR TEMPERATURE AND DENSITY ALTITUDE	36
Converts indicated air temperature to true air temperature accounting for the temperature rise associated with high speed flight. Once a true temperature is established the density altitude can be calculated.	
AIRCRAFT CLIMB	40
This program permits one to determine the desirability of climbing from an altitude of high headwinds to an altitude with lower headwinds. Determine the minimum that must remain at the start of the climb to make the climb to higher altitude worthwhile. Program is good for non-supercharged aircraft only.	

Program Description I

1

Program Title	Properties of Air		
Contributor's Name	Hewlett-Packard		
Address	1000 N.E. Circle Blvd.		
City	Corvallis	State	Oregon
		Zip Code	97330

Program Description, Equations, Variables

This program computes properties of air at low pressures for a given temperature * in degrees Fahrenheit or Rankine.

The following properties are computed:

1. Specific heat ratio

$$k = 1/(1 - R/J C_p)$$

where:

R Universal gas constant

J Mechanical equivalent of heat

3. Specific heat at constant volume

$$C_v = C_p/k, \text{ Btu/lb.} - ^\circ\text{R}$$

4. Coefficient of viscosity

$$\mu = 7.4 \times 10^{-7} (T)^{1.5} / (T + 200),$$

lbm./ft. - sec.

2. Specific heat at constant pressure

$$C_p = 0.2478 - 4.2047 \times 10^{-5} T$$
$$+ 5.8 \times 10^{-8} T^2 - 1.49 \times 10^{-11} T^3,$$

Btu/lb. - $^\circ\text{R}$

5. Absolute Rankine temperature

$$T = 459.7 + (T, ^\circ\text{F}), ^\circ\text{R}$$

* If temperature is in degrees Centigrade or Kelvin, use Temperature Conversion program (STD - 08A) from Standard Pac to convert to degrees Fahrenheit or Rankine.

Operating Limits and Warnings

Properties k , C_p , C_v and μ are good for temperature and pressure ranges of 300 - 2000 $^\circ\text{R}$ and 0 - 300 psia respectively.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

[illegible]

Sample Problem(s)

Find the specific heat ratio, specific heat at constant pressure, specific heat at constant volume, coefficient of viscosity, and absolute Rankine temperature for air at a temperature of 300 degrees Fahrenheit.

$$k = 1.3930$$

$$C_p = 0.2428 \text{ Btu/lb. } ^\circ\text{R}$$

$$C_v = 0.1743 \text{ Btu/lb. } ^\circ\text{R}$$

$$u = 1.6146 \times 10^{-5} \text{ lbm./ft. -sec.}$$

$$T = 759.70^{\circ}\text{R}$$

Solution(s)

Keystrokes:

Outputs:

300[E] [A] -----> 1.3930

300[E] [B] -----> 0.2428

```
300[E] [C] -----> 0.1743
```

300[E] [D] -----> 1.6146 x 10⁻⁵

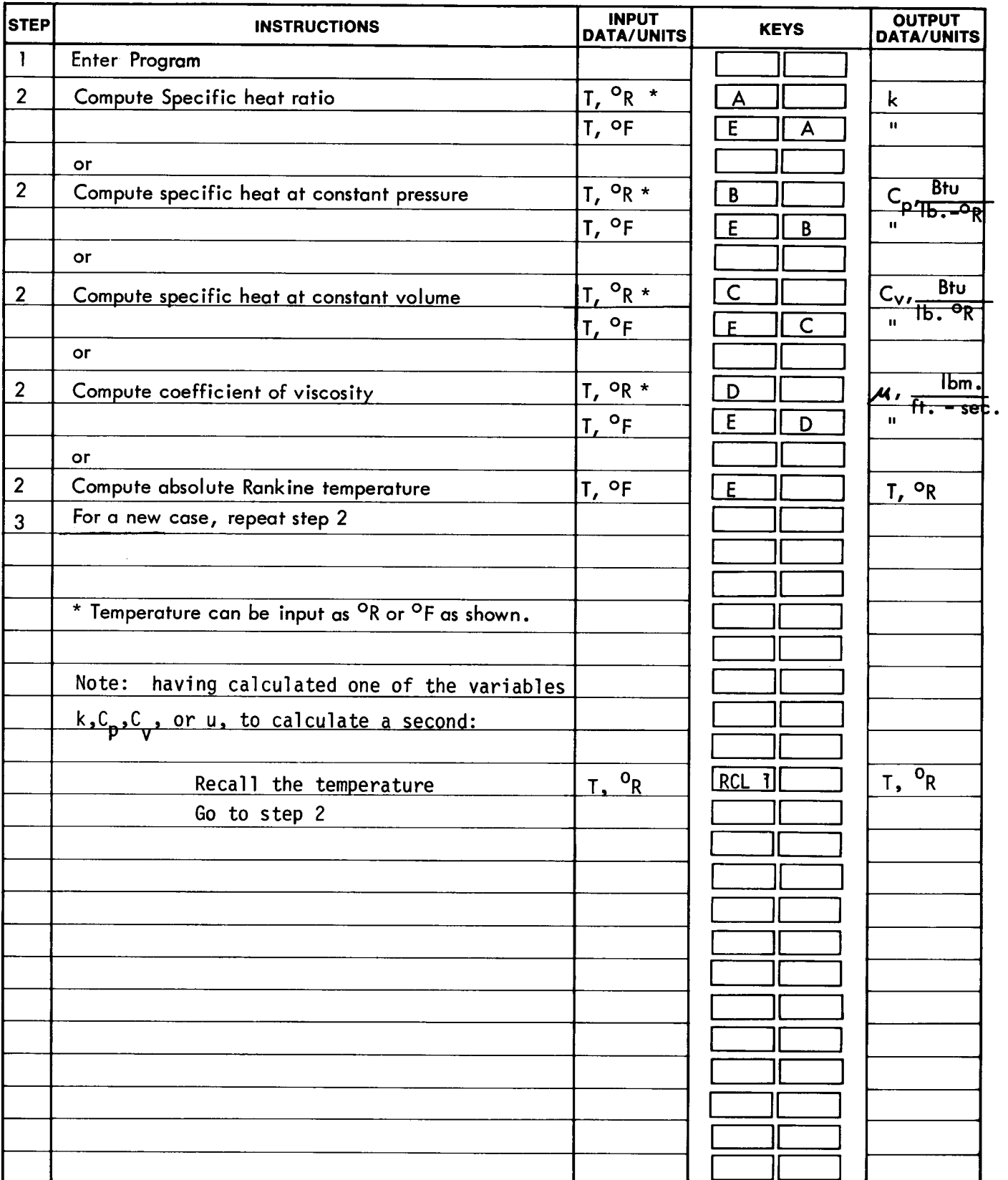
300[E] -----> 759.70

Reference(s)

Keenan and Kay, Gas Tables, fifth printing, John Wiley & Sons, Inc., March, 1956. Hall, Newman A., Thermodynamics of Fluid Flow, Prentice-Hall, Inc., 1951.

This program is a translation of the Users' Library program #01078A submitted by Paul. K. Shumpert.

3



97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS		
001	*LBLA	21 11	Compute k T, °R	057	RCL2	36 02	Compute C _v		
002	FIX	-11		058	RTN	24			
003	DSP4	-63 04		059	*LBLC	21 13			
004	ST01	35 01		060	GSBA	23 11			
005	ENT↑	-21		061	RCL2	36 02			
006	x	-35		062	X*Y	-41			
007	5	05		063	÷	-24			
008	.	-62		064	RTN	24			
009	8	08		065	*LBLD	21 14	Compute μ		
010	EEX	-23		066	ST01	35 01			
011	CHS	-22		067	1	01			
012	8	08		068	.	-62			
013	x	-35		069	5	05			
014	.	-62		070	Y*	31			
015	2	02		071	RCL1	36 01			
016	4	04		072	2	02			
017	7	07		073	0	00			
018	8	08		074	0	00			
019	+	-55		075	+	-55			
020	RCL1	36 01		076	÷	-24			
021	2	02		077	7	07			
022	3	03		078	.	-62			
023	7	07		079	4	04			
024	8	08		080	EEX	-23	Compute T, °R		
025	3	03		081	CHS	-22			
026	÷	-24		082	7	07			
027	-	-45		083	x	-35			
028	1	01		084	SCI	-12			
029	4	04		085	RTN	24			
030	9	09		086	*LBLE	21 15			
031	EEX	-23		087	ENT↑	-21			
032	CHS	-22		088	4	04			
033	1	01		089	5	05			
034	3	03	090	9	09				
035	RCL1	36 01	091	.	-62				
036	3	03	092	7	07				
037	Y*	31	093	+	-55				
038	x	-35	094	FIX	-11				
039	-	-45	095	RTN	24				
040	ST02	35 02							
041	1	01							
042	ENT↑	-21							
043	1	01							
044	ENT↑	-21	100						
045	.	-62							
046	0	00							
047	6	06							
048	8	08							
049	5	05							
050	RCL2	36 02							
051	÷	-24							
052	-	-45							
053	÷	-24							
054	RTN	24	110						
055	*LBLB	21 12							
056	GSBA	23 11							
			C _p						
			Compute C _p						
REGISTERS									
0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	I				

Compute C_v

Compute μ

Compute T, °R

C_pCompute C_p

SET STATUS

FLAGS

TRIG

DISP

ON OFF

0 ☐ ☒1 ☐ ☒2 ☐ ☒3 ☐ ☒DEG ☒GRAD ☐RAD ☐FIX ☒SCI ☐ENG ☐

n 4

Program Description I

5

Program Title Standard Atmosphere Below 35,322 Feet

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle

City Corvallis State Oregon Zip Code 97330

Program Description, Equations, Variables This program computes the theoretical U.S. Standard Atmosphere temperature and pressure in English and Metric units at altitudes below 35,332 feet and 11,000 meters. Additionally, the actual mean sea level values, at a specific time, can be placed in the program for prediction of altitude temperature and pressure based on the following formulas:

$$P = \frac{P_0}{\left(\frac{T_0}{T_0 - aZ}\right)^n} \quad T = T_0 - aZ \quad t = T - T \text{ abs reference}$$

P = Pressure at altitude above/below mean sea level.

P₀ = Standard air pressure at mean sea level.

T₀ = Standard absolute temperature at mean sea level in Rankine/Kelvin.

a = Temperature lapse rate per foot of altitude in °F/per meter °C.

Z = Altitude above/below mean sea level in feet/meters.

n = Constant G/aR = 5.2561

T = Temperature absolute at altitude in Rankine/Kelvin.

T abs ref. = 459.688 °R/ 273.16 °K.

t = Temperature at altitude in Fahrenheit/Centigrade

Operating Limits and Warnings 1. The program will accurately reproduce the theoretical U.S. Standard Atmosphere tables of temperature and pressure within the limits of -16,500 to 35,332 feet or -5,000 to 11,000 meters.

2. The correct temperature and pressure cannot be predicted under actual conditions when the temperature gradient is not linear, i.e. the lapse rate is not linear per foot of altitude.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

Sketch(es)



Sample Problem(s)

1. What is the theoretical U.S. Standard Atmosphere pressure in inches of mercury, pounds per square foot, pounds per square inch, temperature in degrees Fahrenheit and degrees Rankine at an altitude of 30,000 feet?
2. What is the theoretical U.S. Standard Atmosphere pressure in millibars temperature in degrees centigrade and degrees Kelvin at an altitude of 11,000 meters?

Solution(s) **Keystrokes:**

Outputs:

- ```

1. [RTN] [f] [a] 30000[D] -----> 8.885413
 [E] -----> 47.984800
 [RCL] [6] -----> 411.703200
 [f] [b] 3000[D] -----> 4.364107
2. 1013.25[A] 288.16[B] .0065[C] 273.16[STO] [7]
 11000[D] -----> 226.319813
 [E] -----> -56.5000
 [RCL] [6] -----> 216.6600

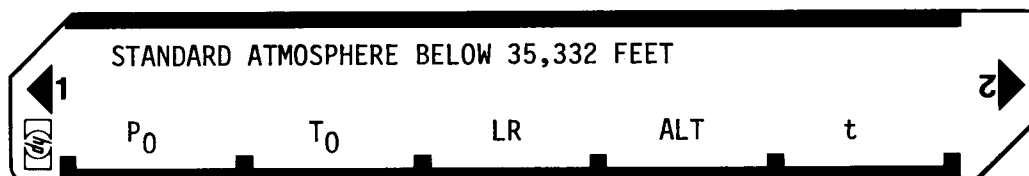
```

### Reference(s)

This program is a translation of the HP-65 Users' Library program #01148A submitted by William D. Staton.

# User Instructions

7



| STEP | INSTRUCTIONS                                                                                                                          | INPUT DATA/UNITS | KEYS                                                                  | OUTPUT DATA/UNITS |
|------|---------------------------------------------------------------------------------------------------------------------------------------|------------------|-----------------------------------------------------------------------|-------------------|
| 1    | Enter Program                                                                                                                         |                  | <input type="button" value="RTN"/> <input type="button" value="R/S"/> | 0.00              |
| 2    | Initialize                                                                                                                            |                  | <input type="button" value="RTN"/> <input type="button" value="R/S"/> | 0.000000          |
| 3    | Automatic input of U.S. Standard Atmosphere mean sea level values of Hg, temperature, lapse rate plus reference temperature absolute. |                  | <input type="button" value="GTO"/> <input type="button" value="1"/>   |                   |
|      |                                                                                                                                       |                  | <input type="button" value="R/S"/> <input type="button" value="1"/>   | 459.688000        |
| 4    | Input altitude and compute Hg.                                                                                                        | Feet             | <input type="button" value="D"/> <input type="button" value="1"/>     | Hg                |
| 5    | Compute temperature °F at altitude.                                                                                                   |                  | <input type="button" value="E"/> <input type="button" value="1"/>     | °F                |
| 6    | Recall °R at altitude.                                                                                                                |                  | <input type="button" value="RCL"/> <input type="button" value="6"/>   | °R                |
| 7    | To recall input altitude in step 4                                                                                                    |                  | <input type="button" value="RCL"/> <input type="button" value="5"/>   | Feet              |
| 8    | For new case change altitude input in step 4                                                                                          |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
| 9    | Convert program to compute LBS/IN <sup>2</sup> at altitude.                                                                           |                  | <input type="button" value="GTO"/> <input type="button" value="2"/>   |                   |
|      |                                                                                                                                       |                  | <input type="button" value="R/S"/> <input type="button" value="1"/>   | 14.695949         |
| 10   | Repeat steps 4 thru 8                                                                                                                 |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
| 11   | Convert program to compute LBS/FT <sup>2</sup> at altitude.                                                                           | 2116.216         | <input type="button" value="A"/> <input type="button" value="1"/>     | 2116.216          |
| 12   | Repeat steps 4 thru 8                                                                                                                 |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
| 13   | To compute pressure and temperature based upon other than U.S. Standard Atmosphere, input pressure reference at mean sea level.       | Hg               | <input type="button" value="A"/> <input type="button" value="1"/>     | Hg                |
|      |                                                                                                                                       |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
| 14   | Input temperature reference at MSL.                                                                                                   | °R               | <input type="button" value="B"/> <input type="button" value="1"/>     | °R                |
| 15   | Input temperature lapse rate per foot of altitude in °F.                                                                              | °F/FT.           | <input type="button" value="C"/> <input type="button" value="1"/>     | °F/FT.            |
| 16   | Repeat steps 4 thru 8.                                                                                                                |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
| 17   | To compute the Standard Atmosphere in metric units, input millibars at MSL.                                                           | 1013.25          | <input type="button" value="A"/> <input type="button" value="1"/>     | 1013.25           |
|      |                                                                                                                                       |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
| 18   | Input temperature reference at MSL in °K.                                                                                             | 288.16           | <input type="button" value="B"/> <input type="button" value="1"/>     | 288.16            |
| 19   | Input lapse rate per meter in °C.                                                                                                     | .0065            | <input type="button" value="C"/> <input type="button" value="1"/>     | 0.0065            |
| 20   | Input temperature abs reference in °K                                                                                                 | 273.16           | <input type="button" value="STO"/> <input type="button" value="7"/>   | 273.16            |
| 21   | Input altitude and compute pressure.                                                                                                  | meters           | <input type="button" value="D"/> <input type="button" value="1"/>     | mb                |
| 22   | Compute temperature °C at altitude.                                                                                                   |                  | <input type="button" value="E"/> <input type="button" value="1"/>     | °C                |
| 23   | Recall °K at altitude.                                                                                                                |                  | <input type="button" value="RCL"/> <input type="button" value="6"/>   | °K                |
| 24   | For new case change altitude input in step 21.                                                                                        |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
|      |                                                                                                                                       |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
|      |                                                                                                                                       |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
|      |                                                                                                                                       |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |
|      |                                                                                                                                       |                  | <input type="button" value="D"/> <input type="button" value="1"/>     |                   |

# 97 Program Listing I

| STEP | KEY ENTRY      | KEY CODE | COMMENTS                                                                             | STEP | KEY ENTRY   | KEY CODE | COMMENTS                                                 |
|------|----------------|----------|--------------------------------------------------------------------------------------|------|-------------|----------|----------------------------------------------------------|
| 001  | *LBLA 21 16 11 |          |                                                                                      | 057  | ST02        | 35 02    | Input MSL ref. temperature                               |
| 002  | 2              | 02       | Inputs U.S. Standards in program                                                     | 058  | RTN         | 24       |                                                          |
| 003  | 9              | 09       |                                                                                      | 059  | *LBLC 21 13 |          | Input temperature rate.                                  |
| 004  | .              | -62      |                                                                                      | 060  | ST03        | 35 03    |                                                          |
| 005  | 9              | 09       |                                                                                      | 061  | RTN         | 24       |                                                          |
| 006  | 2              | 02       |                                                                                      | 062  | *LBLD 21 14 |          | Input altitude for desired pressure and computes $P_A$ . |
| 007  | 1              | 01       |                                                                                      | 063  | ST05        | 35 05    |                                                          |
| 008  | 2              | 02       |                                                                                      | 064  | RCL2        | 36 02    |                                                          |
| 009  | 6              | 06       |                                                                                      | 065  | ENT↑        | -21      |                                                          |
| 010  | ST01           | 35 01    | Temperature at MSL in °R                                                             | 066  | ENT↑        | -21      |                                                          |
| 011  | 5              | 05       |                                                                                      | 067  | RCL3        | 36 03    |                                                          |
| 012  | 1              | 01       |                                                                                      | 068  | RCL5        | 36 05    |                                                          |
| 013  | 8              | 08       |                                                                                      | 069  | X           | -35      |                                                          |
| 014  | .              | -62      |                                                                                      | 070  | -           | -45      |                                                          |
| 015  | 6              | 06       |                                                                                      | 071  | ST06        | 35 06    |                                                          |
| 016  | 8              | 08       |                                                                                      | 072  | ÷           | -24      |                                                          |
| 017  | 8              | 08       |                                                                                      | 073  | 5           | 05       |                                                          |
| 018  | ST02           | 35 02    | Temperature lapse rate in °F per foot of H.                                          | 074  | .           | -62      |                                                          |
| 019  | .              | -62      |                                                                                      | 075  | 2           | 02       |                                                          |
| 020  | 0              | 00       |                                                                                      | 076  | 5           | 05       |                                                          |
| 021  | 0              | 00       |                                                                                      | 077  | 6           | 06       |                                                          |
| 022  | 3              | 03       |                                                                                      | 078  | 1           | 01       |                                                          |
| 023  | 5              | 05       |                                                                                      | 079  | Y*          | 31       |                                                          |
| 024  | 6              | 06       |                                                                                      | 080  | RCL1        | 36 01    |                                                          |
| 025  | 6              | 06       |                                                                                      | 081  | X*Y         | -41      |                                                          |
| 026  | 1              | 01       |                                                                                      | 082  | ÷           | -24      |                                                          |
| 027  | 6              | 06       |                                                                                      | 083  | RTN         | 24       |                                                          |
| 028  | ST03           | 35 03    | Temperature absolute at the melting point of ice under 29.92126 Hg minus 32 degrees. | 084  | *LBLE 21 15 |          | Computes °F or °C at altitude.                           |
| 029  | 4              | 04       |                                                                                      | 085  | RCL6        | 36 06    |                                                          |
| 030  | 5              | 05       |                                                                                      | 086  | RCL7        | 36 07    |                                                          |
| 031  | 9              | 09       |                                                                                      | 087  | -           | -45      |                                                          |
| 032  | .              | -62      |                                                                                      | 088  | RTN         | 24       |                                                          |
| 033  | 6              | 06       |                                                                                      |      |             |          |                                                          |
| 034  | 8              | 08       |                                                                                      |      |             |          |                                                          |
| 035  | 8              | 08       |                                                                                      |      |             |          |                                                          |
| 036  | ST07           | 35 07    |                                                                                      |      |             |          |                                                          |
| 037  | DSP6           | -63 06   |                                                                                      |      |             |          |                                                          |
| 038  | RTN            | 24       |                                                                                      |      |             |          |                                                          |
| 039  | *LBLB 21 16 12 |          |                                                                                      |      |             |          |                                                          |
| 040  | 1              | 01       | Input lbs/in <sup>2</sup> for MSL reference pressure                                 |      |             |          |                                                          |
| 041  | 4              | 04       |                                                                                      |      |             |          |                                                          |
| 042  | .              | -62      |                                                                                      |      |             |          |                                                          |
| 043  | 6              | 06       |                                                                                      |      |             |          |                                                          |
| 044  | 9              | 09       |                                                                                      |      |             |          |                                                          |
| 045  | 5              | 05       |                                                                                      |      |             |          |                                                          |
| 046  | 9              | 09       |                                                                                      |      |             |          |                                                          |
| 047  | 4              | 04       |                                                                                      |      |             |          |                                                          |
| 048  | 8              | 08       |                                                                                      |      |             |          |                                                          |
| 049  | 6              | 06       |                                                                                      |      |             |          |                                                          |
| 050  | 1              | 01       |                                                                                      |      |             |          |                                                          |
| 051  | ST01           | 35 01    |                                                                                      |      |             |          |                                                          |
| 052  | RTN            | 24       |                                                                                      |      |             |          |                                                          |
| 053  | *LBLA 21 11    |          | Input MSL ref. pressure.                                                             |      |             |          |                                                          |
| 054  | ST01           | 35 01    |                                                                                      |      |             |          |                                                          |
| 055  | RTN            | 24       |                                                                                      |      |             |          |                                                          |
| 056  | *LBLB 21 12    |          |                                                                                      |      |             |          |                                                          |

| REGISTERS |                       |                       |              |    |          |                    |              |    |    |
|-----------|-----------------------|-----------------------|--------------|----|----------|--------------------|--------------|----|----|
| 0         | 1 P <sub>0</sub> Ref. | 2 T <sub>0</sub> Ref. | 3 Lapse Rate | 4  | 5 Alt.-H | 6 Temp. at H °R/°K | 7 T abs ref. | 8  | 9  |
| S0        | S1                    | S2                    | S3           | S4 | S5       | S6                 | S7           | S8 | S9 |
| A         | B                     | C                     | D            | E  | I        |                    |              |    |    |

| SET STATUS                                                     |                                          |                                         |
|----------------------------------------------------------------|------------------------------------------|-----------------------------------------|
| FLAGS                                                          | TRIG                                     | DISP                                    |
| ON OFF                                                         |                                          |                                         |
| 0 <input type="checkbox"/> <input checked="" type="checkbox"/> | DEG <input checked="" type="checkbox"/>  | FIX <input checked="" type="checkbox"/> |
| 1 <input type="checkbox"/> <input checked="" type="checkbox"/> | GRAD <input checked="" type="checkbox"/> | SCI <input type="checkbox"/>            |
| 2 <input type="checkbox"/> <input checked="" type="checkbox"/> | RAD <input checked="" type="checkbox"/>  | ENG <input type="checkbox"/>            |
| 3 <input type="checkbox"/> <input checked="" type="checkbox"/> |                                          | n <u>4</u>                              |

# Program Description I

9

Program Title Aircraft Flyover Acoustic Tone Doppler Shift

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis

State Oregon

Zip Code 97330

**Program Description, Equations, Variables** Computes doppler shift of an aircraft flyover acoustic source frequency observed on the ground. Also determines the 1/3 octave-band filter, and location within the filter, of the observed frequency. Inputs are flight path speed and angle, air temperature, source frequency, and aircraft elevation angle. Any input frequency can be located in the A.N.S.I.\* 1/3 octave-band filters. Equations: See sketch on next page.

Doppler shift  $f_0/f_s = 1/(1-M \cos \beta)$  where  $\begin{cases} f_0 \text{ is observed freq.} \\ f_s \text{ is source freq.} \\ M \text{ is Mach Number of source} \\ \beta = \text{Source angle to observe} \end{cases}$

Source angle  $\beta = \theta + \alpha$

Mach number  $Mach = V/(29.04\sqrt{t+459})$  where  $\begin{cases} V = \text{Flt. path speed, kts} \\ T = \text{Air temp, } ^\circ\text{F} \end{cases}$

\*Mid-frequency of 1/3 oct-band  $f_m = 10^{N/10}$ , N any integer

\*Upper frequency of 1/3 oct-band  $f_2 = 1.1225 f_m$   
(nominal band edge)

\*American National Standards Institute

**Operating Limits and Warnings** 1/3 octave band filters start at  $f_m = 50H_z$  which corresponds to  $N=17$ , ANSI convention. Minimum input frequency of 45  $H_z$ .

$f_m$ 's are exact preferred frequencies, which are within 0.7% of nominal preferred frequencies.

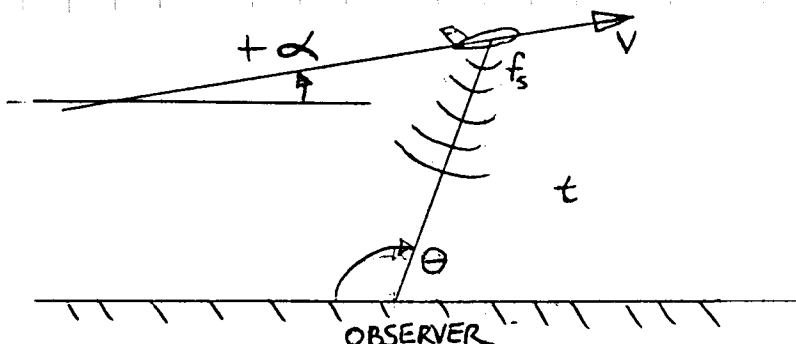
The time required for filter band location is a function of the band no., 3 sec < time < 34 sec for 17 < N < 40.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

# Program Description II

Sketch(es)



Sample Problem(s) Air temperature  $t = 77^\circ\text{F}$

Given: Flight path angle  $\alpha = -3^\circ$

Source tone frequency  $f_s = 687 \text{ Hz}$

Flight path speed  $V = 155 \text{ kts. (re to observer)}$

Calculate the Doppler shift, the observed frequency, the 1/3 oct. band filter position ( $f_0/f_m$ ), the band number, and the filter mid-frequency for the following aircraft elevation angles.

$\theta_1 = 45 \text{ degrees}$

$\theta_2 = 90 \text{ degrees}$

$\theta_3 = 135 \text{ degrees}$

| Aircraft Elev. Angle | $\theta_1 = 45^\circ$ | $\theta_2 = 90^\circ$ | $\theta_3 = 135^\circ$ |
|----------------------|-----------------------|-----------------------|------------------------|
| $f_0/f_s$            | 1.21                  | 1.01                  | 0.87                   |
| $f_0, \text{Hz}$     | 829                   | 695                   | 595                    |
| $f_0/f_m$            | 1.04                  | 1.10                  | 0.94                   |
| Band No.             | 29                    | 28                    | 28                     |
| $f_m, \text{Hz}$     | $7.9 \times 10^2$     | $6.3 \times 10^2$     | $6.3 \times 10^2$      |
|                      | (nominal of 800)      |                       |                        |

Solutions:

Keystrokes:

Output

77[ENT+] 3[CHS] [A] 687[ENT+] 155[B]

45[C] ---->1.21[R/S] ---->829.04[D] ---->1.04[R/S] 29[R/S]  $7.9 \times 10^2$

etc.

Reference(s)

1. Wood, A.B., A Textbook of Sound, pages 370B-372, G. Bell & Sons, London, 1957.
2. S1.11-1966, Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, page 12, American National Standards Institute, New York, 1966.

This program is a translation of the HP-65 Users' Library program #01291A submitted Edgar L. Zwieback.

## 11

[illegible]

# 97 Program Listing I

| STEP      | KEY ENTRY | KEY CODE | COMMENTS                                                       | STEP   | KEY ENTRY            | KEY CODE             | COMMENTS                      |                          |                                     |      |                                     |     |                                     |
|-----------|-----------|----------|----------------------------------------------------------------|--------|----------------------|----------------------|-------------------------------|--------------------------|-------------------------------------|------|-------------------------------------|-----|-------------------------------------|
| 001       | *LBLA     | 21 11    | Input t, α                                                     | 057    | 0                    | 00                   |                               |                          |                                     |      |                                     |     |                                     |
| 002       | ST02      | 35 02    |                                                                | 058    | =                    | -24                  |                               |                          |                                     |      |                                     |     |                                     |
| 003       | X→Y       | -41      |                                                                | 059    | 10×                  | 16 33                |                               |                          |                                     |      |                                     |     |                                     |
| 004       | ST04      | 35 04    |                                                                | 060    | ST07                 | 35 07                |                               |                          |                                     |      |                                     |     |                                     |
| 005       | X→Y       | -41      |                                                                | 061    | 1                    | 01                   |                               |                          |                                     |      |                                     |     |                                     |
| 006       | RTN       | 24       | Input f <sub>s</sub> , V                                       | 062    | .                    | -62                  |                               |                          |                                     |      |                                     |     |                                     |
| 007       | *LBLB     | 21 12    |                                                                | 063    | 1                    | 01                   |                               |                          |                                     |      |                                     |     |                                     |
| 008       | ST03      | 35 03    |                                                                | 064    | 2                    | 02                   |                               |                          |                                     |      |                                     |     |                                     |
| 009       | X→Y       | -41      |                                                                | 065    | 2                    | 02                   |                               |                          |                                     |      |                                     |     |                                     |
| 010       | ST06      | 35 06    |                                                                | 066    | 5                    | 05                   |                               |                          |                                     |      |                                     |     |                                     |
| 011       | RTN       | 24       | Input & calc.<br>f <sub>0</sub> /f <sub>s</sub>                | 067    | ×                    | -35                  | Compare f with f <sub>z</sub> |                          |                                     |      |                                     |     |                                     |
| 012       | *LBLC     | 21 13    |                                                                | 068    | RCL5                 | 36 05                |                               |                          |                                     |      |                                     |     |                                     |
| 013       | FIX       | -11      |                                                                | 069    | X→Y?                 | 16-34                |                               |                          |                                     |      |                                     |     |                                     |
| 014       | DSP2      | -63 02   |                                                                | 070    | GT01                 | 22 01                |                               |                          |                                     |      |                                     |     |                                     |
| 015       | ST01      | 35 01    |                                                                | 071    | RCL7                 | 36 07                |                               |                          |                                     |      |                                     |     |                                     |
| 016       | RCL4      | 36 04    |                                                                | 072    | RCL5                 | 36 05                | f/f <sub>m</sub>              |                          |                                     |      |                                     |     |                                     |
| 017       | 4         | 04       |                                                                | 073    | X→Y                  | -41                  |                               |                          |                                     |      |                                     |     |                                     |
| 018       | 5         | 05       |                                                                | 074    | =                    | -24                  |                               |                          |                                     |      |                                     |     |                                     |
| 019       | 9         | 09       |                                                                | 075    | R/S                  | 51                   |                               |                          |                                     |      |                                     |     |                                     |
| 020       | +         | -55      |                                                                | 076    | RCL1                 | 36 46                | Band no.                      |                          |                                     |      |                                     |     |                                     |
| 021       | IX        | 54       | 077                                                            | CHS    | -22                  |                      |                               |                          |                                     |      |                                     |     |                                     |
| 022       | 2         | 02       | 078                                                            | 1      | 01                   |                      |                               |                          |                                     |      |                                     |     |                                     |
| 023       | 9         | 09       | 079                                                            | 6      | 06                   |                      |                               |                          |                                     |      |                                     |     |                                     |
| 024       | .         | -62      | 080                                                            | +      | -55                  |                      |                               |                          |                                     |      |                                     |     |                                     |
| 025       | 0         | 00       | f <sub>0</sub> /f <sub>s</sub> Doppler shift                   | 081    | R/S                  | 51                   | f <sub>m</sub>                |                          |                                     |      |                                     |     |                                     |
| 026       | 4         | 04       |                                                                | 082    | RCL7                 | 36 07                |                               |                          |                                     |      |                                     |     |                                     |
| 027       | ×         | -35      |                                                                | 083    | SCI                  | -12                  |                               |                          |                                     |      |                                     |     |                                     |
| 028       | RCL3      | 36 03    |                                                                | 084    | DSP1                 | -63 01               |                               |                          |                                     |      |                                     |     |                                     |
| 029       | X→Y       | -41      |                                                                | 085    | RTN                  | 24                   |                               |                          |                                     |      |                                     |     |                                     |
| 030       | =         | -24      |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 031       | RCL1      | 36 01    |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 032       | RCL2      | 36 02    |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 033       | +         | -55      |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 034       | COS       | 42       |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 035       | ×         | -35      | f <sub>0</sub> /f <sub>s</sub> Doppler shift                   |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 036       | CHS       | -22      |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 037       | 1         | 01       |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 038       | +         | -55      |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 039       | 1/X       | 52       |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 040       | R/S       | 51       |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 041       | RCL6      | 36 06    |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 042       | ×         | -35      |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 043       | ST05      | 35 05    |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 044       | RTN       | 24       |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 045       | *LBLD     | 21 14    |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 046       | ST05      | 35 05    |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 047       | 0         | 00       |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 048       | ST01      | 35 46    |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 049       | *LBL1     | 21 01    |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 050       | DSZI      | 16 25 46 | Calc. upper freq.<br>f <sub>z</sub> of 1/3 oct-<br>ban filters |        |                      |                      | SET STATUS                    |                          |                                     |      |                                     |     |                                     |
| 051       | RCL1      | 36 46    |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 052       | CHS       | -22      |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 053       | 1         | 01       |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 054       | 6         | 06       |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 055       | +         | -55      |                                                                |        |                      |                      | ON OFF                        |                          |                                     |      |                                     |     |                                     |
| 056       | 1         | 01       |                                                                |        |                      |                      | 0                             | <input type="checkbox"/> | <input checked="" type="checkbox"/> | DEG  | <input checked="" type="checkbox"/> | FIX | <input checked="" type="checkbox"/> |
|           |           |          |                                                                |        |                      |                      | 1                             | <input type="checkbox"/> | <input checked="" type="checkbox"/> | GRAD | <input type="checkbox"/>            | SCI | <input type="checkbox"/>            |
|           |           |          |                                                                |        |                      |                      | 2                             | <input type="checkbox"/> | <input checked="" type="checkbox"/> | RAD  | <input type="checkbox"/>            | ENG | <input type="checkbox"/>            |
|           |           |          |                                                                |        |                      |                      | 3                             | <input type="checkbox"/> | <input checked="" type="checkbox"/> |      |                                     | n   | 2                                   |
| REGISTERS |           |          |                                                                |        |                      |                      |                               |                          |                                     |      |                                     |     |                                     |
| 0         | 1 θ,deg   | 2 α,deg  | 3 V,kts                                                        | 4 t,°F | 5 f <sub>0</sub> /Hz | 6 f <sub>s</sub> ,Hz | 7 f <sub>m</sub> ,Hz          | 8 N                      | 9                                   |      |                                     |     |                                     |
| S0        | S1        | S2       | S3                                                             | S4     | S5                   | S6                   | S7                            | S8                       | S9                                  |      |                                     |     |                                     |
| A         | B         | C        | D                                                              | E      | I                    |                      |                               |                          |                                     |      |                                     |     |                                     |

# Program Description I

Program Title **ISENTROPIC FLOW FOR IDEAL GASES**

Contributor **HEWLETT-PACKARD**  
 Address **1000 N. E. Circle Blvd.**  
**Corvallis, Oregon 97339**  
 City \_\_\_\_\_

State \_\_\_\_\_ Zip Code \_\_\_\_\_

## Program D

This card replaces isentropic flow tables for a specified specific heat ratio  $k$ . Inputs and outputs are interchangeable with the exception of  $k$ .

The following values are correlated:

$M$  is the Mach number;

$T/T_0$  is the ratio of flow temperature  $T$  to stagnation or zero velocity temperature  $T_0$ ;

$P/P_0$  is the ratio of flow pressure  $P$  to stagnation pressure  $P_0$ ;

$\rho/\rho_0$  is the ratio of flow density  $\rho$  to stagnation density  $\rho_0$ ;

$A/A^*_{\text{sub}}$  and  $A/A^*_{\text{sup}}$  are the ratios of flow area  $A$  to the throat area  $A^*$  in converging—diverging passages.  $A/A^*_{\text{sub}}$  refers to subsonic flow while  $A/A^*_{\text{sup}}$  refers to supersonic flow.

### Equations:

$$T/T_0 = \frac{2}{2 + (k - 1) M^2}$$

$$P/P_0 = (T/T_0)^{k/(k-1)}$$

$$\rho/\rho_0 = (T/T_0)^{1/(k-1)}$$

$$A/A^* = \frac{1}{M} \left[ \left( \frac{2}{k+1} \right) \left( 1 + \frac{k-1}{2} M^2 \right) \right]^{\frac{k+1}{2(k-1)}}$$

In the last equation  $M^2$  is determined using Newton's method. The initial guess used is as follows with a positive exponent for supersonic flow:

$$M_0^2 = (\sqrt{\text{Frac}(A/A^*)} + A/A^*)^{\pm 3}$$

### Operating Limits

### Remarks:

After an input of  $A/A^*$ , the program begins to iterate to find  $M^2$  for future use. This iteration will normally take less than one minute, but may take longer on occasion. For extreme values of  $k$  (1.4 is optimum) the routine may fail to converge at all. An "Error" message will eventually halt the routine if it goes out of control.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.



# Program Description I

Program Title \_\_\_\_\_

Contributor's Name \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_

State \_\_\_\_\_

Zip Code \_\_\_\_\_

## Program Description, Equations, Variables

A/A\* values of 1.00 are illegal inputs. Instead, input an M of 1.00.

The calculator uses flag 3 to decide whether to store or calculate a value. If you use the data input keys (setting flag 3) and then wish to calculate a parameter based on a prior input, clear flag 3 before pressing the appropriate user definable keys.

Registers  $R_0$ ,  $R_5$  and  $R_{S0}-R_I$  are available for user storage.

## Operating Limits and Warnings

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

# Program Description II

15

Sketch(es)

## Example 1:

A pilot is flying at Mach 0.93 and reads on air temperature of 15 degrees Celsius (288 K) on a thermometer that reads stagnation temperature  $T_0$ . What is the true temperature assuming that  $k = 1.38$ ?

### Keystrokes:

1.38 **f** **A** →  
 .93 **A** →  
**B** →  
 288 **x** →  
 273 **-** →

### Outputs:

1.380  
 0.930  
 0.859 ( $T/T_0$ )  
 247.352 ( $T$ , K)  
 -25.648 ( $T$ , °C)

If the same pilot reads a stagnation pressure  $P_0$  of 700 millimeters of mercury, what is the true air pressure?

(Since the data input flag was set when 288 was keyed in, we must either clear it, or input 0.93 again.)

.93 **A** **C** →  
 700 **x** →

0.575 ( $P/P_0$ )  
 402.843 (mm Hg)

## Example 2:

A converging, diverging passage has supersonic flow in the diverging section. At an area ratio  $A/A^*$  of 1.60, what are the isentropic flow ratios for temperature, pressure and density? What is the Mach number?  $k = 1.74$ .

### Keystrokes:

1.74 **f** **A** →  
 1.60 **f** **E** →  
**B** →  
**C** →  
**D** →

### Outputs:

1.740  
 2.105 (M)  
 0.379 ( $T/T_0$ )  
 0.102 ( $P/P_0$ )  
 0.269 ( $\rho/\rho_0$ )

or, alternatively, using automatic output.

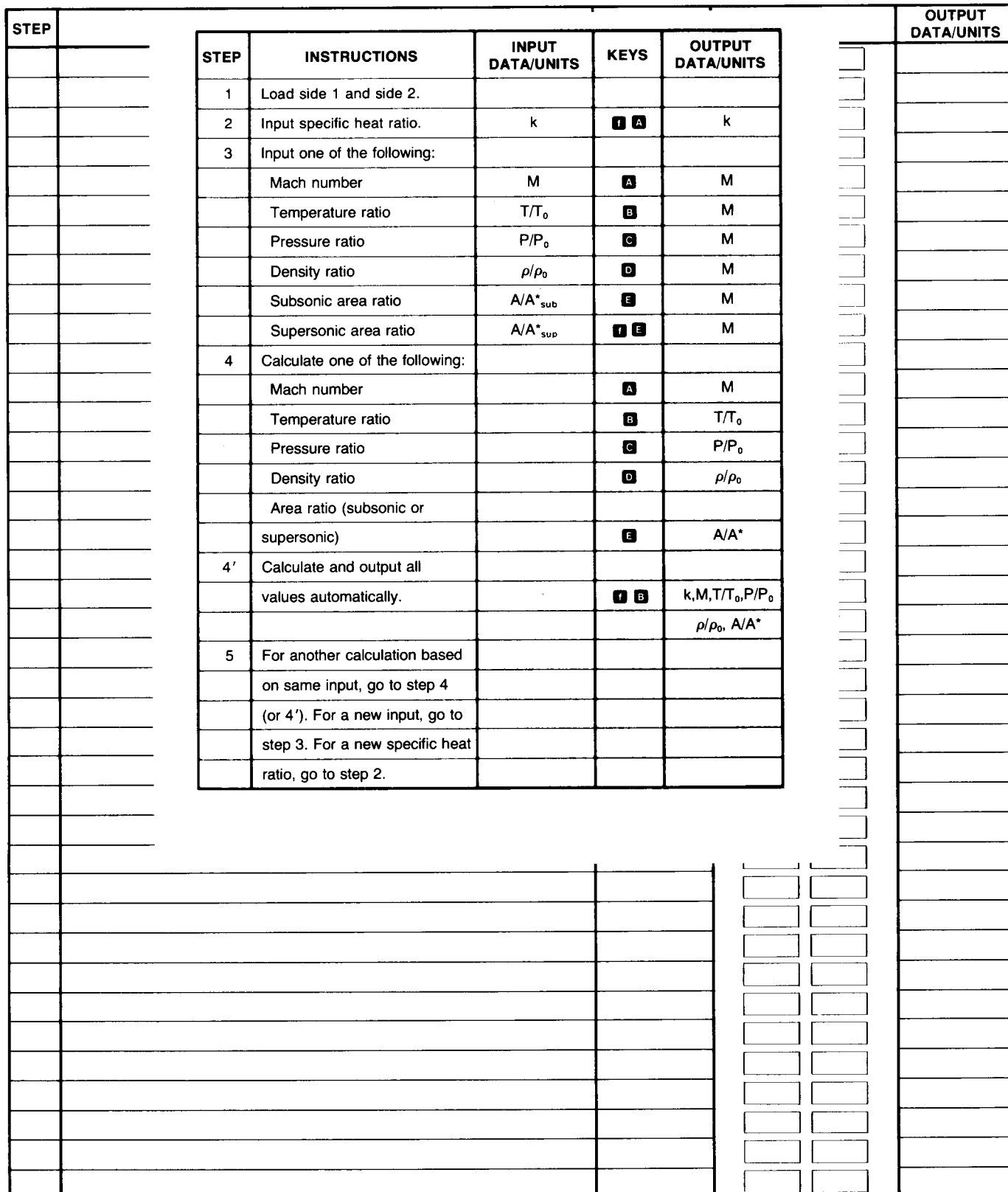
**f** **B** →

1.740 \*\*\* (k)  
 2.105 \*\*\* (M)  
 0.379 \*\*\* ( $T/T_0$ )  
 0.102 \*\*\* ( $P/P_0$ )  
 0.269 \*\*\* ( $\rho/\rho_0$ )  
 1.600 \*\*\* ( $A/A^*$ )

Sample Problem(s)

Solution(s)

Reference(s)



# 97 Program Listing I

17

| STEP | KEY ENTRY      | KEY CODE | COMMENTS                                  | STEP | KEY ENTRY | KEY CODE | COMMENTS                                                            |
|------|----------------|----------|-------------------------------------------|------|-----------|----------|---------------------------------------------------------------------|
| 001  | *LBLA          | 21 16 11 | Store $k-1, 1/(k-1)$                      | 057  | SF3       | 16 21 03 | Output $\rho/\rho_0$ .                                              |
| 002  | ST02           | 35 02    |                                           | 058  | GT08      | 22 12    |                                                                     |
| 003  | 1              | 01       |                                           | 059  | *LBLD     | 21 14    |                                                                     |
| 004  | -              | -45      |                                           | 060  | F3?       | 16 23 03 |                                                                     |
| 005  | ST03           | 35 03    |                                           | 061  | GT00      | 22 00    |                                                                     |
| 006  | 1/X            | 52       | Output M.                                 | 062  | GSBB      | 23 12    | Convert $\rho/\rho_0$ to $T/T_0$ and $GT_0 B$ .                     |
| 007  | ST04           | 35 04    |                                           | 063  | RCL4      | 36 04    |                                                                     |
| 008  | RCL2           | 36 02    |                                           | 064  | Y*        | 31       |                                                                     |
| 009  | RTN            | 24       |                                           | 065  | RTN       | 24       |                                                                     |
| 010  | *LBLA          | 21 11    |                                           | 066  | *LBL0     | 21 00    |                                                                     |
| 011  | F3?            | 16 23 03 | Store $M^2$ .                             | 067  | SF3       | 16 21 03 | Set -3 in display for subsonic guess.                               |
| 012  | GT00           | 22 00    |                                           | 068  | RCL3      | 36 03    |                                                                     |
| 013  | RCL1           | 36 01    |                                           | 069  | Y*        | 31       |                                                                     |
| 014  | JX             | 54       |                                           | 070  | GT08      | 22 12    |                                                                     |
| 015  | RTN            | 24       |                                           | 071  | *LBLE     | 21 15    |                                                                     |
| 016  | *LBL0          | 21 00    | Output $T/T_0$ .                          | 072  | 3         | 03       | Make guess of $M^2$ .                                               |
| 017  | X <sup>2</sup> | 53       |                                           | 073  | CHS       | -22      |                                                                     |
| 018  | ST01           | 35 01    |                                           | 074  | X*Y       | -41      |                                                                     |
| 019  | JX             | 54       |                                           | 075  | F3?       | 16 23 03 |                                                                     |
| 020  | RTN            | 24       |                                           | 076  | GT01      | 22 01    | Iterate by Newton's method to find $M^2$ corresponding to $A/A^*$ . |
| 021  | *LBLB          | 21 12    | Convert $T/T_0$ to $M^2$ .                | 077  | GT03      | 22 03    |                                                                     |
| 022  | F3?            | 16 23 03 |                                           | 078  | *LBL1     | 21 01    |                                                                     |
| 023  | GT00           | 22 00    |                                           | 079  | ENT↑      | -21      |                                                                     |
| 024  | 2              | 02       |                                           | 080  | ST06      | 35 06    |                                                                     |
| 025  | RCL1           | 36 01    | Output $P/P_0$ .                          | 081  | FRC       | 16 44    |                                                                     |
| 026  | RCL3           | 36 03    |                                           | 082  | JX        | 54       |                                                                     |
| 027  | X              | -35      |                                           | 083  | +         | -55      |                                                                     |
| 028  | 2              | 02       |                                           | 084  | X*Y       | -41      |                                                                     |
| 029  | +              | -55      |                                           | 085  | Y*        | 31       |                                                                     |
| 030  | ÷              | -24      | Convert $P/P_0$ to $T/T_0$ and $GT_0 B$ . | 086  | ST01      | 35 01    |                                                                     |
| 031  | RTN            | 24       |                                           | 087  | *LBL2     | 21 02    |                                                                     |
| 032  | *LBL0          | 21 00    |                                           | 088  | RCL6      | 36 06    |                                                                     |
| 033  | 2              | 02       |                                           | 089  | GSB3      | 23 03    |                                                                     |
| 034  | X*Y            | -41      |                                           | 090  | ÷         | -24      |                                                                     |
| 035  | ÷              | -24      | Output $P/P_0$ .                          | 091  | 1         | 01       |                                                                     |
| 036  | 2              | 02       |                                           | 092  | -         | -45      |                                                                     |
| 037  | -              | -45      |                                           | 093  | .         | -62      |                                                                     |
| 038  | RCL3           | 36 03    |                                           | 094  | 5         | 05       |                                                                     |
| 039  | ÷              | -24      |                                           | 095  | RCL8      | 36 08    |                                                                     |
| 040  | ST01           | 35 01    | Convert $P/P_0$ to $T/T_0$ and $GT_0 B$ . | 096  | ÷         | -24      |                                                                     |
| 041  | JX             | 54       |                                           | 097  | .         | -62      |                                                                     |
| 042  | RTN            | 24       |                                           | 098  | 5         | 05       |                                                                     |
| 043  | *LBLC          | 21 13    |                                           | 099  | RCL1      | 36 01    |                                                                     |
| 044  | F3?            | 16 23 03 |                                           | 100  | ÷         | -24      |                                                                     |
| 045  | GT00           | 22 00    | Convert $P/P_0$ to $T/T_0$ and $GT_0 B$ . | 101  | -         | -45      |                                                                     |
| 046  | GSBB           | 23 12    |                                           | 102  | ÷         | -24      |                                                                     |
| 047  | RCL2           | 36 02    |                                           | 103  | ST+1      | 35-55 01 |                                                                     |
| 048  | RCL3           | 36 03    |                                           | 104  | RCL1      | 36 01    |                                                                     |
| 049  | ÷              | -24      |                                           | 105  | ÷         | -24      |                                                                     |
| 050  | Y*             | 31       | Convert $P/P_0$ to $T/T_0$ and $GT_0 B$ . | 106  | ABS       | 16 31    |                                                                     |
| 051  | RTN            | 24       |                                           | 107  | EEX       | -23      |                                                                     |
| 052  | *LBL0          | 21 00    |                                           | 108  | CHS       | -22      |                                                                     |
| 053  | RCL3           | 36 03    |                                           | 109  | 4         | 04       |                                                                     |
| 054  | RCL2           | 36 02    |                                           | 110  | X<Y?      | 16-35    |                                                                     |
| 055  | ÷              | -24      | Convert $P/P_0$ to $T/T_0$ and $GT_0 B$ . | 111  | GT02      | 22 02    |                                                                     |
| 056  | Y*             | 31       |                                           | 112  | RCL1      | 36 01    |                                                                     |

## REGISTERS

|    |       |    |     |       |    |      |    |      |      |
|----|-------|----|-----|-------|----|------|----|------|------|
| 0  | 1     | 2  | 3   | 4     | 5  | 6    | 7  | 8    | 9    |
|    | $M^2$ | k  | k-1 | 1/k-1 |    | A/A* |    | Used | Used |
| S0 | S1    | S2 | S3  | S4    | S5 | S6   | S7 | S8   | S9   |
| A  | B     | C  | D   | E     | I  |      |    |      |      |

## 97 Program Listing II

| STEP | KEY ENTRY         | KEY CODE | COMMENTS                       | STEP | KEY ENTRY | KEY CODE | COMMENTS |
|------|-------------------|----------|--------------------------------|------|-----------|----------|----------|
| 113  | JX                | 54       |                                |      |           |          |          |
| 114  | RTN               | 24       |                                |      |           |          |          |
| 115  | *LBL 21           | 16 15    | Set +3 in display              |      |           |          |          |
| 116  | 3                 | 03       | for supersonic                 |      |           |          |          |
| 117  | X $\rightarrow$ Y | -41      | guess                          |      |           |          |          |
| 118  | F3?               | 16 23 03 |                                |      |           |          |          |
| 119  | GT01              | 22 01    |                                |      |           |          |          |
| 120  | *LBL 21           | 03       |                                |      |           |          |          |
| 121  | 2                 | 02       | Convert M <sup>2</sup> to A/A* |      |           |          |          |
| 122  | RCL 2             | 36 02    |                                |      |           |          |          |
| 123  | 1                 | 01       |                                |      |           |          |          |
| 124  | +                 | -55      |                                |      |           |          |          |
| 125  | =                 | -24      |                                |      |           |          |          |
| 126  | RCL 3             | 36 03    |                                |      |           |          |          |
| 127  | LSTX              | 16-63    |                                |      |           |          |          |
| 128  | =                 | -24      |                                |      |           |          |          |
| 129  | ST07              | 35 07    |                                |      |           |          |          |
| 130  | RCL 1             | 36 01    |                                |      |           |          |          |
| 131  | x                 | -35      |                                |      |           |          |          |
| 132  | +                 | -55      |                                |      |           |          |          |
| 133  | ST08              | 35 08    |                                |      |           |          |          |
| 134  | RCL 7             | 36 07    |                                |      |           |          |          |
| 135  | 2                 | 02       |                                |      |           |          |          |
| 136  | x                 | -35      |                                |      |           |          |          |
| 137  | 1/X               | 52       |                                |      |           |          |          |
| 138  | Yx                | 31       |                                |      |           |          |          |
| 139  | RCL 1             | 36 01    |                                |      |           |          |          |
| 140  | JX                | 54       |                                |      |           |          |          |
| 141  | =                 | -24      |                                |      |           |          |          |
| 142  | RTN               | 24       |                                |      |           |          |          |
| 143  | *LBL 21           | 16 12    | Output values                  |      |           |          |          |
| 144  | SPC               | 16-11    |                                |      |           |          |          |
| 145  | CF3               | 16 22 03 |                                |      |           |          |          |
| 146  | RCL 2             | 36 02    |                                |      |           |          |          |
| 147  | PRTX              | -14      |                                |      |           |          |          |
| 148  | SPC               | 16-11    |                                |      |           |          |          |
| 149  | GSBA              | 23 11    |                                |      |           |          |          |
| 150  | PRTX              | -14      |                                |      |           |          |          |
| 151  | GSBB              | 23 12    |                                |      |           |          |          |
| 152  | PRTX              | -14      |                                |      |           |          |          |
| 153  | GSBC              | 23 13    |                                |      |           |          |          |
| 154  | PRTX              | -14      |                                |      |           |          |          |
| 155  | GSBD              | 23 14    |                                |      |           |          |          |
| 156  | PRTX              | -14      |                                |      |           |          |          |
| 157  | GSBE              | 23 15    |                                |      |           |          |          |
| 158  | PRTX              | -14      |                                |      |           |          |          |
| 159  | RTN               | 24       |                                |      |           |          |          |

**LABELS**

|                     |                                        |                                    |                                    |                                       |
|---------------------|----------------------------------------|------------------------------------|------------------------------------|---------------------------------------|
| A M $\rightarrow$ M | B T/T <sub>0</sub> $\rightarrow$ M     | C P/P <sub>0</sub> $\rightarrow$ M | D p/p <sub>0</sub> $\rightarrow$ M | E A/A* <sub>sub</sub> $\rightarrow$ M |
| a k                 | b $\rightarrow$ k, M, T/T <sub>0</sub> | c                                  | d                                  | e A/A* <sub>sup</sub> $\rightarrow$ M |
| 0 Used              | 1 M <sup>2</sup> guess                 | 2 M <sup>2</sup> iter              | 3 A/A                              | 4                                     |
| 5                   | 6                                      | 7                                  | 8                                  | 9                                     |

**FLAGS**

|                                     |                                     |                                     |                                     |
|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| 0                                   | 1                                   | 2                                   | 3                                   |
| <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            | <input type="checkbox"/>            |
| <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Data?                               |                                     |                                     |                                     |

**SET STATUS**

|                            |                                         |                                         |
|----------------------------|-----------------------------------------|-----------------------------------------|
| <b>FLAGS</b>               | <b>TRIG</b>                             | <b>DISP</b>                             |
| ON OFF                     | DEG <input checked="" type="checkbox"/> | FIX <input checked="" type="checkbox"/> |
| 0 <input type="checkbox"/> | GRAD <input type="checkbox"/>           | SCI <input type="checkbox"/>            |
| 1 <input type="checkbox"/> | RAD <input type="checkbox"/>            | ENG <input type="checkbox"/>            |
| 2 <input type="checkbox"/> |                                         | n <u>3</u>                              |
| 3 <input type="checkbox"/> |                                         |                                         |

# Program Description I

Program Title Normal and Oblique Shock Parameters for Compressible Flow

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis

State Oregon

Zip Code 97330

## Program Description, Equations, Variables

Given the values for: free stream Mach number ( $M_1$ ), the ratio of specific heats ( $\gamma$ ), and the shock angle ( $\theta$ ); the program computes:

$$M_2 = \left[ \frac{(\gamma+1)^2 M_1^4 \sin^2 \theta - 4(M_1^2 \sin^2 \theta - 1)(\gamma M_1^2 \sin^2 \theta + 1)}{2\gamma M_1^2 \sin^2 \theta - (\gamma - 1)} \right]^{1/2} \quad \text{Mach No. behind shock}$$

$$\frac{P_2}{P_1} = \frac{2\gamma M_1^2 \sin^2 \theta - (\gamma - 1)}{\gamma + 1} \quad \text{Static pressure ratio}$$

$$\frac{\rho_2}{\rho_1} = \frac{(\gamma + 1) M_1^2 \sin^2 \theta}{(\gamma - 1) M_1^2 \sin^2 \theta + 2} \quad \text{Density ratio}$$

$$\frac{T_2}{T_1} = \frac{[2\gamma M_1^2 \sin^2 \theta - (\gamma - 1)][(\gamma - 1) M_1^2 \sin^2 \theta + 2]}{(\gamma + 1)^2 M_1^2 \sin^2 \theta} \quad \text{Temperature ratio}$$

$$\frac{P_{T_2}}{P_{T_1}} = \left[ \frac{(\gamma + 1) M_1^2 \sin^2 \theta}{(\gamma - 1) M_1^2 \sin^2 \theta + 2} \right]^{\frac{\gamma}{\gamma - 1}} \left[ \frac{\gamma + 1}{2\gamma M_1^2 \sin^2 \theta - (\gamma - 1)} \right]^{\frac{1}{\gamma - 1}} \quad \text{Total pressure ratio}$$

Where the 1 subscript denotes the value upstream of the shock, and the 2 subscript denotes the value downstream of the shock.

## Operating Limits and Warnings

Assumes calorically perfect ( $C_p$  and  $C_v$  are constant) and thermally perfect ( $P = \rho RT$ ) gas, and adiabatic flow. Only solutions where

$$M_2 < M_1; \frac{P_2}{P_1}, \frac{\rho_2}{\rho_1}, \frac{T_2}{T_1} > 1$$

and  $P_{T_2}/P_{T_1} < 1$  are valid. If any one of these conditions is satisfied, the other four are satisfied.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

# Program Description II

## Sketch(es)

## Sample Problem(s)

1. Find the Mach number and static pressure behind an oblique shock where  $M_1 = 2.5$ ,  $\theta = 70^\circ$ ,  $\gamma = 1.4$  and  $P_1 = 85$  psi. Also find the ratios across the shock for density, temperature and total pressure. (See Fig. 1)
2. Find the temperature, Mach number and total pressure behind a normal shock ( $\theta = 90^\circ$ ) where  $M_1 = 6.23$ ,  $\gamma = 1.4$ ,  $P_{T1} = 64$  psi and  $T_1 = 624^\circ R$  (See Fig. 2)

## Solution(s)

1. 1.4[+] 70[+] 2.5[f] [a] [A] ----- 0.80 (M)  
 [B] ----- 6.27 ( $P_2/P_1$ )  
 85[X] ----- 533.12 (psi) ( $P_2$ )  
 [C] ----- 3.15 ( $P_2/P_1$ )  
 [D] ----- 1.99 ( $T_2/T_1$ )  
 [E] ----- 0.56 ( $P_{T2}/P_{T1}$ )
2. 6.23 [ST0] [ ] 90 [ST0] [2] [GT0] [0] [R/S] [D] ----- 8.49 ( $T_2/T_1$ )  
 624 [X] ----- 5296.40 ( $^\circ R$ ) ( $T_2$ )  
 [A] ----- 0.40 ( $M_2$ )  
 [E] ----- .30 ( $P_{T2}/P_{T1}$ )  
 64 [X] ----- 1.62 (psi) ( $P_{T2}$ )

## Reference(s)

National Advisory Committee for Aeronautics, Report 1135, Equations, Tables and Charts for Compressible Flow, By Ames Research Staff, pgs. 7,8, U.S. Government Printing Office, 1953.

This program is a translation of the HP-65 Users' Library program #01303A submitted by Glenn D. Rambach.

## 21

[illegible]



| STEP | KEY ENTRY      | KEY CODE | COMMENTS                                                                   | STEP                                     | KEY ENTRY | KEY CODE | COMMENTS                                       |                                                |  |
|------|----------------|----------|----------------------------------------------------------------------------|------------------------------------------|-----------|----------|------------------------------------------------|------------------------------------------------|--|
| 001  | *LBLA          | 21 16 11 | Store $M_1$ in $R_1$<br>Store $\theta$ in $R_2$<br>Store $\gamma$ in $R_3$ | 057                                      | *LBLB     | 21 12    | Compute $P_2/P_1$                              |                                                |  |
| 002  | ST01           | 35 01    |                                                                            | 058                                      | RCL3      | 36 03    |                                                |                                                |  |
| 003  | R4             | -31      |                                                                            | 059                                      | RCL4      | 36 04    |                                                |                                                |  |
| 004  | ST02           | 35 02    |                                                                            | 060                                      | x         | -35      | Display $P_2/P_1$<br>Compute $\rho_2/\rho_1$   |                                                |  |
| 005  | R4             | -31      |                                                                            | 061                                      | 2         | 02       |                                                |                                                |  |
| 006  | ST03           | 35 03    |                                                                            | 062                                      | x         | -35      |                                                |                                                |  |
| 007  | 1              | 01       |                                                                            | Initial point for<br>repeated operations | 063       | RCL7     | 36 07                                          | Display $\rho_2/\rho_1$<br>Compute $T_2/T_1$   |  |
| 008  | -              | -45      |                                                                            |                                          | 064       | -        | -45                                            |                                                |  |
| 009  | ST07           | 35 07    |                                                                            |                                          | 065       | RCL8     | 36 08                                          |                                                |  |
| 010  | 2              | 02       |                                                                            |                                          | 066       | =        | -24                                            | Display $T_2/T_1$<br>Compute $P_{T_2}/P_{T_1}$ |  |
| 011  | +              | -55      | 067                                                                        |                                          | RTN       | 24       |                                                |                                                |  |
| 012  | ST08           | 35 08    | 068                                                                        |                                          | *LBLC     | 21 13    |                                                |                                                |  |
| 013  | *LBL0          | 21 00    | 069                                                                        |                                          | RCL5      | 36 05    | Display $P_{T_2}/P_{T_1}$                      |                                                |  |
| 014  | RCL2           | 36 02    | 070                                                                        |                                          | RCL6      | 36 06    |                                                |                                                |  |
| 015  | SIN            | 41       | 071                                                                        |                                          | 2         | 02       |                                                |                                                |  |
| 016  | RCL1           | 36 01    | Compute $M_2$                                                              |                                          | 072       | +        | -55                                            | Display $P_{T_2}/P_{T_1}$                      |  |
| 017  | x              | -35      |                                                                            | 073                                      | =         | -24      |                                                |                                                |  |
| 018  | X <sup>2</sup> | 53       |                                                                            | 074                                      | RTN       | 24       |                                                |                                                |  |
| 019  | ST04           | 35 04    |                                                                            | 075                                      | *LBLD     | 21 14    | Display $T_2/T_1$<br>Compute $P_{T_2}/P_{T_1}$ |                                                |  |
| 020  | RCL8           | 36 08    |                                                                            | 076                                      | GSBB      | 23 12    |                                                |                                                |  |
| 021  | x              | -35      |                                                                            | 077                                      | GSBC      | 23 13    |                                                |                                                |  |
| 022  | ST05           | 35 05    |                                                                            | 078                                      | =         | -24      | Display $T_2/T_1$<br>Compute $P_{T_2}/P_{T_1}$ |                                                |  |
| 023  | RCL7           | 36 07    |                                                                            | 079                                      | RTN       | 24       |                                                |                                                |  |
| 024  | RCL4           | 36 04    |                                                                            | 080                                      | *LBLE     | 21 15    |                                                |                                                |  |
| 025  | x              | -35      |                                                                            | Display $M_2$                            | 081       | GSEC     | 23 13                                          | Display $P_{T_2}/P_{T_1}$                      |  |
| 026  | ST06           | 35 06    | 082                                                                        |                                          | GSBB      | 23 12    |                                                |                                                |  |
| 027  | R/S            | 51       | 083                                                                        |                                          | =         | -24      |                                                |                                                |  |
| 028  | *LBLA          | 21 11    | 084                                                                        |                                          | RCL7      | 36 07    | Display $P_{T_2}/P_{T_1}$                      |                                                |  |
| 029  | RCL5           | 36 05    | 085                                                                        |                                          | 1/X       | 52       |                                                |                                                |  |
| 030  | RCL8           | 36 08    | 086                                                                        |                                          | Y*        | 31       |                                                |                                                |  |
| 031  | x              | -35      | 090                                                                        |                                          | 087       | GSBC     | 23 13                                          | Display $P_{T_2}/P_{T_1}$                      |  |
| 032  | RCL1           | 36 01    |                                                                            |                                          | 088       | x        | -35                                            |                                                |  |
| 033  | X <sup>2</sup> | 53       |                                                                            |                                          | 089       | RTN      | 24                                             |                                                |  |
| 034  | x              | -35      |                                                                            |                                          |           |          |                                                |                                                |  |
| 035  | RCL4           | 36 04    |                                                                            |                                          |           |          |                                                |                                                |  |
| 036  | RCL3           | 36 03    |                                                                            |                                          |           |          |                                                |                                                |  |
| 037  | x              | -35      |                                                                            |                                          |           |          |                                                |                                                |  |
| 038  | 1              | 01       |                                                                            |                                          |           |          |                                                |                                                |  |
| 039  | +              | -55      |                                                                            |                                          |           |          |                                                |                                                |  |
| 040  | 4              | 04       |                                                                            |                                          |           |          |                                                |                                                |  |
| 041  | x              | -35      |                                                                            |                                          |           |          |                                                |                                                |  |
| 042  | RCL4           | 36 04    |                                                                            |                                          |           |          |                                                |                                                |  |
| 043  | 1              | 01       |                                                                            |                                          |           |          |                                                |                                                |  |
| 044  | -              | -45      |                                                                            |                                          |           |          |                                                |                                                |  |
| 045  | x              | -35      |                                                                            |                                          |           |          |                                                |                                                |  |
| 046  | -              | -45      |                                                                            |                                          |           |          |                                                |                                                |  |
| 047  | GSBC           | 23 13    |                                                                            |                                          |           |          |                                                |                                                |  |
| 048  | x              | -35      |                                                                            |                                          |           |          |                                                |                                                |  |
| 049  | GSBB           | 23 12    |                                                                            |                                          |           |          |                                                |                                                |  |
| 050  | =              | -24      |                                                                            |                                          |           |          |                                                |                                                |  |
| 051  | RCL8           | 36 08    |                                                                            |                                          |           |          |                                                |                                                |  |
| 052  | =              | -24      |                                                                            |                                          |           |          |                                                |                                                |  |
| 053  | RCL5           | 36 05    |                                                                            |                                          |           |          |                                                |                                                |  |
| 054  | =              | -24      |                                                                            |                                          |           |          |                                                |                                                |  |
| 055  | JX             | 54       |                                                                            |                                          |           |          |                                                |                                                |  |
| 056  | RTN            | 24       | Display $M_2$                                                              |                                          |           |          |                                                |                                                |  |

090

|  |    |  |
|--|----|--|
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  |    |  |
|  | </ |  |

# Program Description I

|                    |                               |          |        |
|--------------------|-------------------------------|----------|--------|
| Program Title      | Oblique Shock Angle for Wedge |          |        |
| Contributor's Name | Hewlett-Packard               |          |        |
| Address            | 1000 N.E. Circle Blvd.        |          |        |
| City               | Corvallis                     | State    | Oregon |
|                    |                               | Zip Code | 97330  |

## Program Description, Equations, Variables

When the upstream Mach number, the deflection angle and the specific heat ratio are given the compressible flow equation will give at most three values for the shock angle. This program calculates the weak oblique shock angle when it is possible.

The equation which must be solved is

$$\sin^6 \sigma + b \sin^4 \sigma + c \sin^2 \sigma + d = 0$$

where

$$b = - \frac{M_1^2 + 2}{M_1^2} - k \sin^2 \delta$$

$$c = \frac{2M_1^2 + 1}{M_1^4} + \left[ \frac{(k+1)^2}{4} + \frac{k-1}{M_1^2} \right] \sin^2 \delta$$

$$d = - \frac{\cos^2 \delta}{M_1^4}$$

$M_1$  = Upstream Mach number > 1.0

$\delta$  = Deflection angle (deg)

$k$  = Specific heat ratio

$\sigma$  = Shock angle (D.M.S.)

## Operating Limits and Warnings

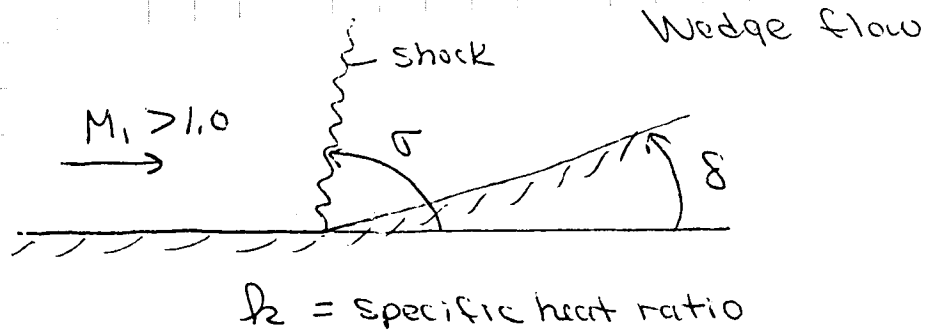
If no shock condition is possible, i.e., if the shock must detach from the corner, then the first program card stops with a blinking display. If  $\delta$  approaches  $\delta_{\max}$  for the flow the program takes some time (1 min or so) to converge. I have never had the program fail to converge, although it may be possible. Should convergence not occur, change the calculator to the DEG mode after the iteration is stopped.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

# Program Description II

## Sketch(es)



## Sample Problem(s) Given

$$M_1 = 2.0$$

$$\delta = 10^\circ$$

$$k = 1.4$$

$$\sigma = 39.3139 \text{ Deg}$$

## Solution(s)

Keystrokes:

Outputs:

2[x2] [STO] [1] 10 [STO] [2] 1.4 [STO] [3] [A] -----> 39.3139

**Reference(s)** 1. Introductory Gas Dynamics, A.J. Chapman and W.F. Walker, HRW Series in Mech. Engineering.

This program is a translation of the HP-65 Users' Library program #00630A submitted by Harry W. Townes.

## 25

[illegible]

# 97 Program Listing I

| STEP | KEY ENTRY | KEY CODE | COMMENTS | STEP | KEY ENTRY | KEY CODE | COMMENTS                                                                                   |
|------|-----------|----------|----------|------|-----------|----------|--------------------------------------------------------------------------------------------|
| 001  | *LBLA     | 21 11    |          | 057  | ENT↑      | -21      |                                                                                            |
| 002  | RCL2      | 36 02    |          | 058  | X         | -35      |                                                                                            |
| 003  | SIN       | 41       |          | 059  | -         | -45      |                                                                                            |
| 004  | ENT↑      | -21      |          | 060  | ST07      | 35 07    |                                                                                            |
| 005  | X         | -35      |          | 061  | RCL4      | 36 04    |                                                                                            |
| 006  | ST07      | 35 07    |          | 062  | RCL5      | 36 05    |                                                                                            |
| 007  | RCL3      | 36 03    |          | 063  | X         | -35      |                                                                                            |
| 008  | X         | -35      |          | 064  | 3         | 03       |                                                                                            |
| 009  | RCL1      | 36 01    |          | 065  | X         | -35      |                                                                                            |
| 010  | 2         | 02       |          | 066  | RCL6      | 36 06    |                                                                                            |
| 011  | +         | -55      |          | 067  | -         | -45      |                                                                                            |
| 012  | RCL1      | 36 01    |          | 068  | 2         | 02       |                                                                                            |
| 013  | ÷         | -24      |          | 069  | ÷         | -24      |                                                                                            |
| 014  | +         | -55      |          | 070  | RCL4      | 36 04    |                                                                                            |
| 015  | CHS       | -22      |          | 071  | ENT↑      | -21      |                                                                                            |
| 016  | 3         | 03       |          | 072  | ENT↑      | -21      |                                                                                            |
| 017  | ÷         | -24      |          | 073  | X         | -35      |                                                                                            |
| 018  | ST04      | 35 04    | b/3 R4   | 074  | X         | -35      |                                                                                            |
| 019  | RCL3      | 36 03    |          | 075  | -         | -45      |                                                                                            |
| 020  | 1         | 01       |          | 076  | ST08      | 35 08    |                                                                                            |
| 021  | +         | -55      |          | 077  | RCL7      | 36 07    |                                                                                            |
| 022  | ENT↑      | -21      |          | 078  | ENT↑      | -21      |                                                                                            |
| 023  | X         | -35      |          | 079  | ENT↑      | -21      |                                                                                            |
| 024  | 4         | 04       |          | 080  | X         | -35      |                                                                                            |
| 025  | ÷         | -24      |          | 081  | X         | -35      |                                                                                            |
| 026  | RCL3      | 36 03    |          | 082  | ST06      | 35 06    |                                                                                            |
| 027  | 1         | 01       |          | 083  | RCL8      | 36 08    |                                                                                            |
| 028  | -         | -45      |          | 084  | ENT↑      | -21      |                                                                                            |
| 029  | RCL1      | 36 01    |          | 085  | X         | -35      |                                                                                            |
| 030  | ÷         | -24      |          | 086  | +         | -55      |                                                                                            |
| 031  | +         | -55      |          | 087  | 0         | 00       |                                                                                            |
| 032  | RCL7      | 36 07    |          | 088  | X≠Y?      | 16-35    | Test for existance<br>of weak shock<br><br>Blinking display<br>for no solution<br>possible |
| 033  | X         | -35      |          | 089  | 1/X       | 52       |                                                                                            |
| 034  | RCL1      | 36 01    |          | 090  | RCL2      | 36 02    |                                                                                            |
| 035  | 2         | 02       |          | 091  | TAN       | 43       |                                                                                            |
| 036  | X         | -35      |          | 092  | ST02      | 35 02    |                                                                                            |
| 037  | 1         | 01       |          | 093  | RAD       | 16-22    |                                                                                            |
| 038  | +         | -55      |          | 094  | RCL8      | 36 08    |                                                                                            |
| 039  | RCL1      | 36 01    |          | 095  | RCL6      | 36 06    |                                                                                            |
| 040  | ENT↑      | -21      |          | 096  | CHS       | -22      |                                                                                            |
| 041  | X         | -35      |          | 097  | JX        | 54       |                                                                                            |
| 042  | ÷         | -24      |          | 098  | ÷         | -24      |                                                                                            |
| 043  | +         | -55      |          | 099  | COS↑      | 16 42    |                                                                                            |
| 044  | 3         | 03       |          | 100  | Pi        | 16-24    |                                                                                            |
| 045  | ÷         | -24      |          | 101  | 4         | 04       |                                                                                            |
| 046  | ST05      | 35 05    | C/3 R5   | 102  | X         | -35      |                                                                                            |
| 047  | RCL2      | 36 02    |          | 103  | +         | -55      |                                                                                            |
| 048  | COS       | 42       |          | 104  | 3         | 03       |                                                                                            |
| 049  | RCL1      | 36 01    |          | 105  | ÷         | -24      |                                                                                            |
| 050  | ENT↑      | -21      |          | 106  | COS       | 42       |                                                                                            |
| 051  | X         | -35      |          | 107  | RCL7      | 36 07    |                                                                                            |
| 052  | ÷         | -24      |          | 108  | CHS       | -22      |                                                                                            |
| 053  | CHS       | -22      |          | 109  | JX        | 54       |                                                                                            |
| 054  | ST06      | 35 06    | d R6     | 110  | X         | -35      |                                                                                            |
| 055  | RCL5      | 36 05    |          | 111  | 2         | 02       |                                                                                            |
| 056  | RCL4      | 36 04    |          | 112  | X         | -35      |                                                                                            |

## REGISTERS

|    |                    |               |     |        |        |        |        |            |    |
|----|--------------------|---------------|-----|--------|--------|--------|--------|------------|----|
| 0  | 1 M <sub>1</sub> 2 | 2 δ and ton δ | 3 k | 4 Used | 5 Used | 6 Used | 7 Used | 8 σ in RAD | 9  |
| S0 | S1                 | S2            | S3  | S4     | S5     | S6     | S7     | S8         | S9 |
| A  | B                  | C             | D   | E      | I      |        |        |            |    |

# 97Program Listing II

27

| STEP | KEY ENTRY         | KEY CODE | COMMENTS                                                                                                               | STEP | KEY ENTRY | KEY CODE | COMMENTS |
|------|-------------------|----------|------------------------------------------------------------------------------------------------------------------------|------|-----------|----------|----------|
| 113  | RCL4              | 36 04    | σ in RAD from direct solution of the equation. Iteration improves accuracy. A R/S in step 30 would eliminate iteration | 169  | SIN       | 41       |          |
| 114  | -                 | -45      |                                                                                                                        | 170  | -         | -45      |          |
| 115  | JX                | 54       |                                                                                                                        | 171  | ÷         | -24      |          |
| 116  | SIN <sup>-1</sup> | 16 41    |                                                                                                                        | 172  | CHS       | -22      |          |
| 117  | ST08              | 35 08    |                                                                                                                        | 173  | RCL1      | 36 01    |          |
| 118  | .                 | -62      |                                                                                                                        | 174  | -         | -45      |          |
| 119  | 0                 | 00       |                                                                                                                        | 175  | RTN       | 24       |          |
| 120  | 1                 | 01       |                                                                                                                        |      |           |          |          |
| 121  | ST06              | 35 06    |                                                                                                                        |      |           |          |          |
| 122  | RCL8              | 36 08    |                                                                                                                        |      |           |          |          |
| 123  | +                 | -55      |                                                                                                                        | 180  |           |          |          |
| 124  | GSB0              | 23 00    |                                                                                                                        |      |           |          |          |
| 125  | ST07              | 35 07    |                                                                                                                        |      |           |          |          |
| 126  | RCL8              | 36 08    |                                                                                                                        |      |           |          |          |
| 127  | GSB0              | 23 00    |                                                                                                                        |      |           |          |          |
| 128  | RCL7              | 36 07    |                                                                                                                        |      |           |          |          |
| 129  | X <sup>2</sup> Y  | -41      |                                                                                                                        |      |           |          |          |
| 130  | -                 | -45      |                                                                                                                        |      |           |          |          |
| 131  | RCL6              | 36 06    |                                                                                                                        |      |           |          |          |
| 132  | ÷                 | -24      |                                                                                                                        |      |           |          |          |
| 133  | ST07              | 35 07    |                                                                                                                        | 190  |           |          |          |
| 134  | *LBL1             | 21 01    |                                                                                                                        |      |           |          |          |
| 135  | RCL8              | 36 08    |                                                                                                                        |      |           |          |          |
| 136  | GSB0              | 23 00    |                                                                                                                        |      |           |          |          |
| 137  | RCL7              | 36 07    |                                                                                                                        |      |           |          |          |
| 138  | ÷                 | -24      |                                                                                                                        |      |           |          |          |
| 139  | ST-8              | 35-45 08 |                                                                                                                        |      |           |          |          |
| 140  | RCL8              | 36 08    |                                                                                                                        |      |           |          |          |
| 141  | ÷                 | -24      |                                                                                                                        |      |           |          |          |
| 142  | ABS               | 16 31    |                                                                                                                        |      |           |          |          |
| 143  | EEX               | -23      | σ in deg after convergence                                                                                             | 200  |           |          |          |
| 144  | CHS               | -22      |                                                                                                                        |      |           |          |          |
| 145  | 6                 | 06       |                                                                                                                        |      |           |          |          |
| 146  | X <sup>2</sup> Y? | 16-35    |                                                                                                                        |      |           |          |          |
| 147  | GT01              | 22 01    |                                                                                                                        |      |           |          |          |
| 148  | RCL8              | 36 08    |                                                                                                                        |      |           |          |          |
| 149  | R→D               | 16 46    |                                                                                                                        |      |           |          |          |
| 150  | RTN               | 24       |                                                                                                                        |      |           |          |          |
| 151  | *LBL0             | 21 00    |                                                                                                                        |      |           |          |          |
| 152  | ST05              | 35 05    |                                                                                                                        |      |           |          |          |
| 153  | TAN               | 43       |                                                                                                                        | 210  |           |          |          |
| 154  | 1/X               | 52       |                                                                                                                        |      |           |          |          |
| 155  | RCL2              | 36 02    |                                                                                                                        |      |           |          |          |
| 156  | +                 | -55      |                                                                                                                        |      |           |          |          |
| 157  | 2                 | 02       |                                                                                                                        |      |           |          |          |
| 158  | x                 | -35      |                                                                                                                        |      |           |          |          |
| 159  | RCL5              | 36 05    |                                                                                                                        |      |           |          |          |
| 160  | 2                 | 02       |                                                                                                                        |      |           |          |          |
| 161  | x                 | -35      |                                                                                                                        |      |           |          |          |
| 162  | ST05              | 35 05    |                                                                                                                        |      |           |          |          |
| 163  | COS               | 42       |                                                                                                                        | 220  |           |          |          |
| 164  | RCL3              | 36 03    |                                                                                                                        |      |           |          |          |
| 165  | +                 | -55      |                                                                                                                        |      |           |          |          |
| 166  | RCL2              | 36 02    |                                                                                                                        |      |           |          |          |
| 167  | x                 | -35      |                                                                                                                        |      |           |          |          |
| 168  | RCL5              | 36 05    |                                                                                                                        |      |           |          |          |

| LABELS |   |   |   |   | FLAGS | SET STATUS                                                     |                                         |                                         |
|--------|---|---|---|---|-------|----------------------------------------------------------------|-----------------------------------------|-----------------------------------------|
| A      | B | C | D | E | 0     | FLAGS                                                          | TRIG                                    | DISP                                    |
| σ      |   |   |   |   |       | ON OFF                                                         |                                         |                                         |
| a      | b | c | d | e | 1     | 0 <input type="checkbox"/> <input checked="" type="checkbox"/> | DEG <input checked="" type="checkbox"/> | FIX <input checked="" type="checkbox"/> |
| 0      | 1 | 2 | 3 | 4 | 2     | 1 <input type="checkbox"/> <input checked="" type="checkbox"/> | GRAD <input type="checkbox"/>           | SCI <input type="checkbox"/>            |
| 5      | 6 | 7 | 8 | 9 | 3     | 2 <input type="checkbox"/> <input checked="" type="checkbox"/> | RAD <input type="checkbox"/>            | ENG <input type="checkbox"/>            |
|        |   |   |   |   |       | 3 <input type="checkbox"/> <input checked="" type="checkbox"/> |                                         | n <u>4</u>                              |

# Program Description I

|                    |                               |       |        |
|--------------------|-------------------------------|-------|--------|
| Program Title      | Mach Number and True Airspeed |       |        |
| Contributor's Name | Hewlett-Packard               |       |        |
| Address            | 1000 N.E. Circle Blvd.        |       |        |
| City               | Corvallis                     | State | Oregon |
| Zip Code           | 97330                         |       |        |

## Program Description, Equations, Variables, etc.

This program converts calibrated airspeed (CAS) to mach number and true airspeed (TAS). Pressure altitude (PALT) must be known to calculate mach number (M). Aircraft recovery coefficient ( $C_T$ ) and indicated air temperature (IT) must also be known to calculate true airspeed. The recovery coefficient varies from 0.6 to 1.0 but is around 0.8 for most aircraft.

$$\text{Pressure ratio } \left( \frac{P}{P_0} \right) = \left[ \frac{518.67 - 3.566 \times 10^{-3} \text{ PALT}}{518.67} \right]^{5.2563}$$

$$M^2 = 5 \left[ \left( \frac{P_0}{P} \right) \left\{ \left[ 1 + 0.2 \left( \frac{\text{CAS}}{661.5} \right)^2 \right]^{3.5} - 1 \right\} + 1 \right]^{0.286}$$

$$\text{TAS} = 39M \sqrt{(IT + 273) \left[ C_T \left( \frac{1}{(1 + 0.2 M^2)} - 1 \right) + 1 \right]}$$

## Operating Limits and Warnings

Accuracy degenerates for mach numbers in excess of one.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

## Program Description II

### Sketch(es)

A full-page view of a blank sheet of graph paper. The grid consists of small squares formed by thin black lines. There are approximately 20 columns and 15 rows of squares. A thicker vertical line runs down the page about one-fifth of the way from the left edge, creating a narrow margin. Similarly, a thicker horizontal line runs across the page about one-fifth of the way from the top edge, creating a header space. These two lines intersect at a point near the top-left corner.

### Sample Problem(s)

For a pressure altitude of 25,500 feet, a calibrated airspeed of 350 knots, a recovery factor of 0.8, and an indicated air temperature of 5 degrees Celsius, what is the flight mach number and the true airspeed?

### Solution(s)

$$M = 0.84$$

**TAS = 515.76 knots**

## Keystrokes

25500 **A** 350 **B**

**.8 C 5 D**

**See Displayed**

0.84

**515.76**

### Reference(s)

This program is a translation of the HP-65 Users' Library program  
#00531B submitted by Hewlett-Packard.



# User Instructions

**MACH NUMBER AND TRUE AIRSPEED**

1

**PALT**  
→ P/P<sub>0</sub>

**CAS**  
→ M

**C<sub>T</sub>**

**T (°C)**  
→ TAS

2

| STEP | INSTRUCTIONS                    | INPUT DATA/UNITS | KEYS                                        | OUTPUT DATA/UNITS |
|------|---------------------------------|------------------|---------------------------------------------|-------------------|
| 1    | Enter program*                  |                  | <input type="text"/> <input type="text"/>   |                   |
| 2    | Input pressure altitude         | PALT             | <input type="text"/> A <input type="text"/> | P/P <sub>0</sub>  |
| 3    | Input calibrated airspeed in    |                  | <input type="text"/> <input type="text"/>   |                   |
|      | knots and calculate mach        |                  | <input type="text"/> <input type="text"/>   |                   |
|      | number                          | CAS              | <input type="text"/> B <input type="text"/> | M                 |
| 4    | Input recovery coefficient      |                  | <input type="text"/> <input type="text"/>   |                   |
|      | (.8 for most aircraft)          | C <sub>T</sub>   | <input type="text"/> C <input type="text"/> | C <sub>T</sub>    |
| 5    | Input indicated air temperature |                  | <input type="text"/> <input type="text"/>   |                   |
|      | and calculate true airspeed     |                  | <input type="text"/> <input type="text"/>   |                   |
|      | in knots                        | IT (°C)          | <input type="text"/> D <input type="text"/> | TAS               |
| 6    | For same aircraft at same       |                  | <input type="text"/> <input type="text"/>   |                   |
|      | PALT go to step 3 and skip      |                  | <input type="text"/> <input type="text"/>   |                   |
|      | step 4. For different PALT go   |                  | <input type="text"/> <input type="text"/>   |                   |
|      | to step 2 and skip step 4. For  |                  | <input type="text"/> <input type="text"/>   |                   |
|      | totally new case go to step 2.  |                  | <input type="text"/> <input type="text"/>   |                   |

\*For pressure altitudes above 36089 feet, calculate P/P<sub>0</sub> using *Standard Atmosphere*.

# 97 Program Listing I

31

| STEP | KEY ENTRY | KEY CODE | COMMENTS                                    | STEP  | KEY ENTRY | KEY CODE | COMMENTS                   |
|------|-----------|----------|---------------------------------------------|-------|-----------|----------|----------------------------|
| 001  | *LBLA     | 21 11    | Convert pressure altitude to pressure ratio | 057   | ST04      | 35 04    | Input recovery coefficient |
| 002  | 3         | 03       |                                             | 058   | RTN       | 24       |                            |
| 003  | 5         | 05       |                                             | 059   | *LBLC     | 21 13    |                            |
| 004  | 6         | 06       |                                             | 060   | ST03      | 35 03    |                            |
| 005  | 6         | 06       |                                             | 061   | RTN       | 24       |                            |
| 006  | EEX       | -23      |                                             | 062   | *LBLD     | 21 14    |                            |
| 007  | CHS       | -22      |                                             | 063   | 2         | 02       |                            |
| 008  | 6         | 06       |                                             | 064   | 7         | 07       |                            |
| 009  | X         | -35      |                                             | 065   | 3         | 03       |                            |
| 010  | CHS       | -22      |                                             | 066   | +         | -55      |                            |
| 011  | 5         | 05       |                                             | 067   | ST05      | 35 05    | Calculate TAS              |
| 012  | 1         | 01       |                                             | 068   | RCL4      | 36 04    |                            |
| 013  | 8         | 08       |                                             | 069   | GSBE      | 23 15    |                            |
| 014  | .         | -62      |                                             | 070   | ÷         | -24      |                            |
| 015  | 6         | 06       |                                             | 071   | RCL5      | 36 05    |                            |
| 016  | 7         | 07       |                                             | 072   | -         | -45      |                            |
| 017  | +         | -55      |                                             | 073   | RCL3      | 36 03    |                            |
| 018  | LSTX      | 16-63    |                                             | 074   | X         | -35      |                            |
| 019  | ÷         | -24      |                                             | 075   | RCL5      | 36 05    |                            |
| 020  | 5         | 05       |                                             | 076   | +         | -55      |                            |
| 021  | .         | -62      |                                             | 077   | JX        | 54       |                            |
| 022  | 2         | 02       |                                             | 078   | 3         | 03       |                            |
| 023  | 5         | 05       |                                             | 079   | 5         | 09       |                            |
| 024  | 6         | 06       |                                             | 080   | X         | -35      |                            |
| 025  | 3         | 03       |                                             | 081   | RCL4      | 36 04    |                            |
| 026  | Y*        | 31       |                                             | 082   | X         | -35      |                            |
| 027  | ST06      | 35 06    | 083                                         | RTN   | 24        |          |                            |
| 028  | RTN       | 24       | 084                                         | *LBLE | 21 15     |          |                            |
| 029  | *LBLB     | 21 12    | 085                                         | ENT↑  | -21       |          |                            |
| 030  | 6         | 06       | 086                                         | X     | -35       |          |                            |
| 031  | 6         | 06       | 087                                         | .     | -62       |          |                            |
| 032  | 1         | 01       | 088                                         | 2     | 02        |          |                            |
| 033  | .         | -62      | 089                                         | X     | -35       |          |                            |
| 034  | 5         | 05       | 090                                         | 1     | 01        |          |                            |
| 035  | ÷         | -24      | 091                                         | +     | -55       |          |                            |
| 036  | GSBE      | 23 15    | 092                                         | RTN   | 24        |          |                            |
| 037  | 3         | 03       |                                             |       |           |          |                            |
| 038  | .         | -62      |                                             |       |           |          |                            |
| 039  | 5         | 05       |                                             |       |           |          |                            |
| 040  | Y*        | 31       |                                             |       |           |          |                            |
| 041  | 1         | 01       |                                             |       |           |          |                            |
| 042  | -         | -45      |                                             |       |           |          |                            |
| 043  | RCL6      | 36 06    |                                             |       |           |          |                            |
| 044  | ÷         | -24      | 100                                         |       |           |          |                            |
| 045  | 1         | 01       |                                             |       |           |          |                            |
| 046  | +         | -55      |                                             |       |           |          |                            |
| 047  | .         | -62      |                                             |       |           |          |                            |
| 048  | 2         | 02       |                                             |       |           |          |                            |
| 049  | 8         | 08       |                                             |       |           |          |                            |
| 050  | 6         | 06       |                                             |       |           |          |                            |
| 051  | Y*        | 31       |                                             |       |           |          |                            |
| 052  | 1         | 01       |                                             |       |           |          |                            |
| 053  | -         | -45      | 110                                         |       |           |          |                            |
| 054  | 5         | 05       |                                             |       |           |          |                            |
| 055  | X         | -35      |                                             |       |           |          |                            |
| 056  | JX        | 54       |                                             |       |           |          |                            |

SET STATUS

| FLAGS |                                     | TRIG                                    | DISP                                    |
|-------|-------------------------------------|-----------------------------------------|-----------------------------------------|
| ON    | OFF                                 |                                         |                                         |
| 0     | <input checked="" type="checkbox"/> | DEG <input checked="" type="checkbox"/> | FIX <input checked="" type="checkbox"/> |
| 1     | <input type="checkbox"/>            | GRAD <input type="checkbox"/>           | SCI <input type="checkbox"/>            |
| 2     | <input checked="" type="checkbox"/> | RAD <input type="checkbox"/>            | ENG <input type="checkbox"/>            |
| 3     | <input checked="" type="checkbox"/> |                                         | n <u>2</u>                              |

| REGISTERS |    |    |                  |     |     |                    |    |    |    |
|-----------|----|----|------------------|-----|-----|--------------------|----|----|----|
| 0         | 1  | 2  | 3 C <sub>T</sub> | 4 M | 5 T | 6 P/P <sub>0</sub> | 7  | 8  | 9  |
| S0        | S1 | S2 | S3               | S4  | S5  | S6                 | S7 | S8 | S9 |
| A         |    | B  |                  | C   |     | D                  |    | E  |    |

## REGISTERS

|    |    |    |                  |     |     |                    |    |    |    |
|----|----|----|------------------|-----|-----|--------------------|----|----|----|
| 0  | 1  | 2  | 3 C <sub>T</sub> | 4 M | 5 T | 6 P/P <sub>0</sub> | 7  | 8  | 9  |
| S0 | S1 | S2 | S3               | S4  | S5  | S6                 | S7 | S8 | S9 |
| A  | B  | C  | D                | E   | I   |                    |    |    |    |

# Program Description I

**Program Title** TAKE-OFF RUN VS. DENSITY ALTITUDE  
**Contributor's Name** Hewlett-Packard, Corvallis Division  
**Address** 1000 N. E. Circle Blvd.  
**City** Corvallis **State** OR **Zip Code** 97330

## Program Description, Equations, Variables

$$A_D = 145366 \left[ 1 - \left( \frac{\rho}{\rho_0} \right)^{0.235} \right] \quad \text{Density altitude}$$

$$\rho/\rho_0 = (288/T_{0K}) (1 - 6.87 \times 10^{-6} A_p)^{5.256}$$

where  $A_p$  = Pressure altitude (Ft)

$$F = 1 + 2.18 \times 10^{-5} A_D + 2.032 \times 10^{-8} A_D^2$$

$$D_A = (D_{STD}/W_G) \cdot W_A \cdot F$$

where

$D_A$  = Actual take-off run (Ft)

$D_{STD}$  = Sea level take-off run at 15°C and full gross weight

$W_G$  = Gross weight

$W_A$  = Actual take-off weight

**Operating Limits and Warnings** Computed value of  $D_A$  is an approximation to be tempered by caution and good sense. It depends on runway surface condition, aircraft condition, pilot skill; assumes zero wind. No provision for obstructions.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

# Program Description II

33

Sketch(es)

**Sample Problem(s)** Land performance of a popular twin engine amphibian is a ground run of 965 feet (sea level) at 15°C at full gross weight of 6,000 lbs.

How much runway will it require at Laramie, Wyoming (elev. 7300 ft.) on a summer day when outside air temperature is 35°C (95°F) and plane is loaded to 5750 lbs?

**Solution(s)**  $965/6000 = .1608$  - Aircraft parameter to be inserted in program at LBL 1.

$A_D$  (density altitude) = 11094 ft

$D_A$  (actual take-off distance) = 3461 ft

Outpoints:

Keystrokes: 965[ENT +] 6000[+][STD][O] 35[ENT +] 7300[ENT +] 5750[A] → 11094

[B] → 3461

**Reference(s)** 1) HP-65 Users' Library Program #532A

2) "AOPA Handbook for Pilots - 1974", page 15 (F VS  $A_D$ )

3) "Aerodynamics of the airplane", Millikan, John Wiley & Sons, 1941, page 132.

[illegible]

# 97 Program Listing I

35

| STEP | KEY ENTRY | KEY CODE | COMMENTS                       | STEP | KEY ENTRY | KEY CODE | COMMENTS                                           |
|------|-----------|----------|--------------------------------|------|-----------|----------|----------------------------------------------------|
| 001  | *LBLA     | 21 11    |                                | 057  | ENT↑      | -21      |                                                    |
| 002  | DSP0      | -63 00   |                                | 058  | 2         | 02       |                                                    |
| 003  | ST01      | 35 01    | W <sub>A</sub> (Take off Wt.)  | 059  | .         | -62      |                                                    |
| 004  | R↓        | -31      |                                | 060  | 1         | 01       |                                                    |
| 005  | ST02      | 35 02    | A <sub>P</sub> (Pressure Alt.) | 061  | 8         | 08       |                                                    |
| 006  | R↓        | -31      |                                | 062  | EEX       | -23      |                                                    |
| 007  | 2         | 02       |                                | 063  | CHS       | -22      |                                                    |
| 008  | 7         | 07       |                                | 064  | 5         | 05       |                                                    |
| 009  | 3         | 03       |                                | 065  | x         | -35      |                                                    |
| 010  | ST03      | 35 03    |                                | 066  | 1         | 01       |                                                    |
| 011  | +         | -55      |                                | 067  | +         | -55      |                                                    |
| 012  | ST04      | 35 04    | Temp. °k                       | 068  | XZY       | -41      |                                                    |
| 013  | 6         | 06       |                                | 069  | ENT↑      | -21      |                                                    |
| 014  | .         | -62      |                                | 070  | x         | -35      | A <sub>D</sub> <sup>2</sup>                        |
| 015  | 8         | 08       |                                | 071  | 2         | 02       |                                                    |
| 016  | 7         | 07       |                                | 072  | .         | -62      |                                                    |
| 017  | 6         | 06       |                                | 073  | 0         | 00       |                                                    |
| 018  | EEX       | -23      |                                | 074  | 3         | 03       |                                                    |
| 019  | CHS       | -22      |                                | 075  | 2         | 02       |                                                    |
| 020  | 6         | 06       |                                | 076  | EEX       | -23      |                                                    |
| 021  | RCL2      | 36 02    |                                | 077  | CHS       | -22      |                                                    |
| 022  | x         | -35      |                                | 078  | 8         | 08       |                                                    |
| 023  | CHS       | -22      |                                | 079  | x         | -35      |                                                    |
| 024  | 1         | 01       |                                | 080  | +         | -55      |                                                    |
| 025  | +         | -55      |                                | 081  | RCL0      | 36 00    |                                                    |
| 026  | 5         | 05       |                                | 082  | x         | -35      |                                                    |
| 027  | .         | -62      |                                | 083  | RCL1      | 36 01    |                                                    |
| 028  | 2         | 02       |                                | 084  | x         | -35      | D <sub>A</sub> (Actual Take-<br>Off Distance, Ft.) |
| 029  | 5         | 05       |                                | 085  | RTN       | 24       |                                                    |
| 030  | 6         | 06       |                                | 086  | R/S       | 51       |                                                    |
| 031  | Y*        | 31       |                                |      |           |          |                                                    |
| 032  | RCL3      | 36 03    |                                |      |           |          |                                                    |
| 033  | 1         | 01       |                                |      |           |          |                                                    |
| 034  | 5         | 05       |                                | 090  |           |          |                                                    |
| 035  | +         | -55      |                                |      |           |          |                                                    |
| 036  | x         | -35      |                                |      |           |          |                                                    |
| 037  | RCL4      | 36 04    |                                |      |           |          |                                                    |
| 038  | ÷         | -24      |                                |      |           |          |                                                    |
| 039  | .         | -62      |                                |      |           |          |                                                    |
| 040  | 2         | 02       |                                |      |           |          |                                                    |
| 041  | 3         | 03       |                                |      |           |          |                                                    |
| 042  | 5         | 05       |                                |      |           |          |                                                    |
| 043  | Y*        | 31       |                                |      |           |          |                                                    |
| 044  | CHS       | -22      |                                | 100  |           |          |                                                    |
| 045  | 1         | 01       |                                |      |           |          |                                                    |
| 046  | +         | -55      |                                |      |           |          |                                                    |
| 047  | 1         | 01       |                                |      |           |          |                                                    |
| 048  | 4         | 04       |                                |      |           |          |                                                    |
| 049  | 5         | 05       |                                |      |           |          |                                                    |
| 050  | 3         | 03       |                                |      |           |          |                                                    |
| 051  | 6         | 06       |                                |      |           |          |                                                    |
| 052  | 6         | 06       |                                |      |           |          |                                                    |
| 053  | x         | -35      | A <sub>D</sub>                 |      |           |          |                                                    |
| 054  | RTN       | 24       |                                | 110  |           |          |                                                    |
| 055  | *LBLB     | 21 12    |                                |      |           |          |                                                    |
| 056  | ENT↑      | -21      |                                |      |           |          |                                                    |

| SET STATUS                                                     |                                         |                                         |
|----------------------------------------------------------------|-----------------------------------------|-----------------------------------------|
| FLAGS                                                          | TRIG                                    | DISP                                    |
| ON OFF                                                         |                                         |                                         |
| 0 <input type="checkbox"/> <input checked="" type="checkbox"/> | DEG <input checked="" type="checkbox"/> | FIX <input checked="" type="checkbox"/> |
| 1 <input type="checkbox"/> <input checked="" type="checkbox"/> | GRAD <input type="checkbox"/>           | SCI <input type="checkbox"/>            |
| 2 <input type="checkbox"/> <input checked="" type="checkbox"/> | RAD <input type="checkbox"/>            | ENG <input type="checkbox"/>            |
| 3 <input type="checkbox"/> <input checked="" type="checkbox"/> |                                         | n <u>0</u>                              |

| REGISTERS |                |                |     |     |    |    |    |    |    |
|-----------|----------------|----------------|-----|-----|----|----|----|----|----|
| 0         | 1              | 2              | 3   | 4   | 5  | 6  | 7  | 8  | 9  |
|           | W <sub>A</sub> | A <sub>P</sub> | 273 | T°k |    |    |    |    |    |
| S0        | S1             | S2             | S3  | S4  | S5 | S6 | S7 | S8 | S9 |
| A         | B              | C              | D   | E   | I  |    |    |    |    |

# Program Description I

**Program Title** TRUE AIR TEMPERATURE AND DENSITY ALTITUDE

**Contributor's Name** Hewlett-Packard, Corvallis Division

**Address** 1000 N. E. Circle Blvd.

**City** Corvallis

**State** OR

**Zip Code** 97330

**Program Description, Equations, Variables** This program accounts for the compressibility effects of high speed flight. Given the mach number (M) and the aircraft recovery coefficient ( $C_T = 0.8$  for most aircraft), indicated air temperature (IT) is converted to true air temperature (T). True air temperature and pressure altitude are then converted to density altitude. For low flight mach numbers, compressibility effects are small. In such cases only temperature and pressure altitude (PALT) are needed to calculate density altitude (DALT).

$$T(K) = C_T \left( \frac{IT(K)}{0.205 M^2 + 1} - IT \right) + IT(K)$$

$$DALT = 145366 \left[ 1 - \left( \frac{\rho}{\rho_0} \right)^{0.235} \right]$$

where

$$\frac{\rho}{\rho_0} = \frac{288.15}{T(K)} \left[ 1 - 6.879 \times 10^{-6} PALT \right]^{5.256}$$

## Operating Limits and Warnings

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

# Program Description II

37

**Sketch(es)****Sample Problem(s)**

1.  $M = 0.87$   
 $C_T = 0.80$   
 $IT = 8^\circ\text{C}$   
 $PALT = 10,000 \text{ ft}$
2. For a low speed aircraft  
 $T = 12^\circ\text{C}$   
 $PALT = 9,000 \text{ ft}$

**Solution(s)**

1.  $T = -22.21^\circ\text{C}$   
 $DALT = 7852.96 \text{ ft}$
2.  $DALT = 10,703.11 \text{ ft}$

Keystrokes [f][a]

See Displayed

1. .87[A]8[C]

-22.21

10000[E]

7852.96

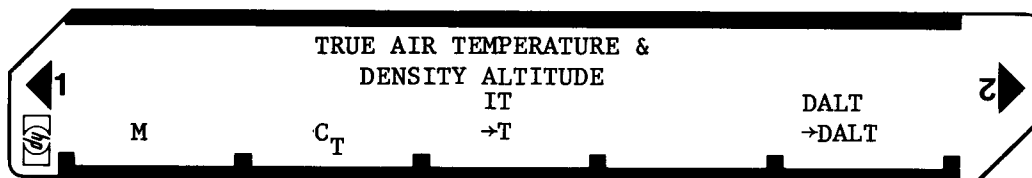
2. 12[D]9000[E]

10703.11

**Reference(s)** This program is a translation of the HP-65 Users' Library Program  
#00532A Submitted by User's Library.



## User Instructions

[illegible]

# 97 Program Listing I

39

| STEP | KEY ENTRY | KEY CODE | COMMENTS   | STEP | KEY ENTRY | KEY CODE                   | COMMENTS                   |                                     |
|------|-----------|----------|------------|------|-----------|----------------------------|----------------------------|-------------------------------------|
| 001  | *LBLA     | 21 16 11 | Initialize | 057  | 1         | 01                         | Calculate density altitude |                                     |
| 002  | .         | -62      |            | 058  | +         | -55                        |                            |                                     |
| 003  | 8         | 08       |            | 059  | 5         | 05                         |                            |                                     |
| 004  | ST03      | 35 03    |            | 060  | .         | -62                        |                            |                                     |
| 005  | RTN       | 24       |            | 061  | 2         | 02                         |                            |                                     |
| 006  | *LBLA     | 21 11    |            | 062  | 5         | 05                         |                            | Input mach number                   |
| 007  | ST04      | 35 04    |            | 063  | 6         | 06                         |                            |                                     |
| 008  | RTN       | 24       |            | 064  | Y*        | 31                         |                            |                                     |
| 009  | *LBLB     | 21 12    |            | 065  | RCL6      | 36 06                      |                            |                                     |
| 010  | ST03      | 35 03    |            | 066  | 1         | 01                         |                            |                                     |
| 011  | RTN       | 24       | 067        | 5    | 05        | Input recovery factor      |                            |                                     |
| 012  | *LBLC     | 21 13    | 068        | +    | -55       |                            |                            |                                     |
| 013  | GSBD      | 23 14    | 069        | x    | -35       |                            |                            |                                     |
| 014  | RCL4      | 36 04    | 070        | RCL5 | 36 05     |                            |                            |                                     |
| 015  | ENT1      | -21      | 071        | =    | -24       |                            |                            |                                     |
| 016  | x         | -35      | 072        | .    | -62       |                            |                            | Calculate true temperature          |
| 017  | .         | -62      | 073        | 2    | 02        |                            |                            |                                     |
| 018  | 2         | 02       | 074        | 3    | 03        |                            |                            |                                     |
| 019  | 0         | 00       | 075        | 5    | 05        |                            |                            |                                     |
| 020  | 5         | 05       | 076        | Y*   | 31        |                            |                            |                                     |
| 021  | x         | -35      | 077        | CHS  | -22       | Calculate density altitude |                            |                                     |
| 022  | 1         | 01       | 078        | 1    | 01        |                            |                            |                                     |
| 023  | +         | -55      | 079        | +    | -55       |                            |                            |                                     |
| 024  | =         | -24      | 080        | 1    | 01        |                            |                            |                                     |
| 025  | RCL5      | 36 05    | 081        | 4    | 04        |                            |                            |                                     |
| 026  | -         | -45      | 082        | 5    | 05        |                            |                            |                                     |
| 027  | RCL3      | 36 03    | 083        | 3    | 03        |                            |                            |                                     |
| 028  | x         | -35      | 084        | 6    | 06        |                            |                            |                                     |
| 029  | RCL5      | 36 05    | 085        | 6    | 06        |                            |                            |                                     |
| 030  | +         | -55      | 086        | x    | -35       |                            |                            | Convert T(°C) to T(K) and store it. |
| 031  | ST05      | 35 05    | 087        | RTN  | 24        |                            |                            |                                     |
| 032  | RCL6      | 36 06    |            |      |           |                            |                            |                                     |
| 033  | -         | -45      |            |      |           |                            |                            |                                     |
| 034  | RTN       | 24       |            |      |           |                            |                            |                                     |
| 035  | *LBLD     | 21 14    |            |      |           |                            |                            |                                     |
| 036  | 2         | 02       |            |      |           |                            |                            |                                     |
| 037  | 7         | 07       |            |      |           |                            |                            |                                     |
| 038  | 3         | 03       |            |      |           |                            |                            |                                     |
| 039  | .         | -62      |            |      |           |                            |                            |                                     |
| 040  | 1         | 01       |            |      |           |                            |                            |                                     |
| 041  | 5         | 05       |            |      |           |                            |                            |                                     |
| 042  | ST06      | 35 06    |            |      |           |                            |                            |                                     |
| 043  | +         | -55      |            |      |           |                            |                            |                                     |
| 044  | ST05      | 35 05    |            |      |           |                            |                            |                                     |
| 045  | RTN       | 24       |            |      |           |                            |                            |                                     |
| 046  | *LBLE     | 21 15    |            |      |           |                            |                            |                                     |
| 047  | 6         | 06       |            |      |           |                            |                            |                                     |
| 048  | .         | -62      |            |      |           |                            |                            |                                     |
| 049  | 8         | 08       |            |      |           |                            |                            |                                     |
| 050  | 7         | 07       |            |      |           |                            |                            |                                     |
| 051  | 9         | 09       |            |      |           |                            |                            |                                     |
| 052  | EEX       | -23      |            |      |           |                            |                            |                                     |
| 053  | CHS       | -22      |            |      |           |                            |                            |                                     |
| 054  | 6         | 06       |            |      |           |                            |                            |                                     |
| 055  | x         | -35      |            |      |           |                            |                            |                                     |
| 056  | CHS       | -22      |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |
|      |           |          |            |      |           |                            |                            |                                     |

# Program Description I

Program Title Aircraft Climb

Contributor's Name Carroll F. Lam

Address 4411 Random Ct.

City Annadale

State VA

Zip Code 22003

## Program Description, Equations, Variables

Given current and new higher altitudes,  $A_1$  and  $A_2$ , and associated headwinds at these altitudes,  $W_1$  and  $W_2$ , this program will compute the following:

$$1. D_{\min} = [(V_{cr} - V_{cl}) + (\frac{W_1 - W_2}{2})] (\frac{V_{cr} - W_1}{W_1 - W_2}) T_C$$

where:  $V_{cr}$  = cruise air speed  
 $V_{cc}$  = climb air speed  
 $T_c$  = time to climb,  $A_1$  to  $A_2$

$$2. T_{\text{climb}} = \frac{A_m}{ROC_{\max}} \ln \left( \frac{A_m - A_1}{A_m - A_2} \right)$$

where:  $A_m$  = aircraft ceiling  
 $ROC_{\max}$  = sea level rate-of-climb

$$3. T_{\text{act}} = \frac{D_{\text{act}} - [V_{cl} - (\frac{W_1 + W_2}{2})] T_c}{V_{cr} - W_2} + T_c$$

$$4. T_{\text{save}} = \frac{D_{\text{act}}}{V_{cr} - W_1} - T_{\text{act}}$$

## Operating Limits and Warnings

$$W_1, W_2 \geq 0$$

$$A_2 > A_1$$

$$D_{\text{act}} > D_{\min} \text{ if steps 9,10,11 are to be used.}$$

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

# Program Description I

41

Program Title Aircraft Climb

Contributor's Name Carroll F. Lam

Address 4411 Random Ct.

City Annandale

State VA

Zip Code 22003

## Program Description, Equations, Variables (con't)

The equation for  $D_{\min}$  is derived by setting up an equation for the two time possibilities for traveling between points A and  $B_1$  and solving for the D that assures that the travel time based on climbing to a higher altitude with a smaller headwind component is less than the travel time that would result from remaining at altitude  $A_1$ .

Although the program doesn't incorporate it, there would in general be an additional benefit in climbing to a higher altitude, namely a higher true airspeed will generally result.

## Operating Limits and Warnings

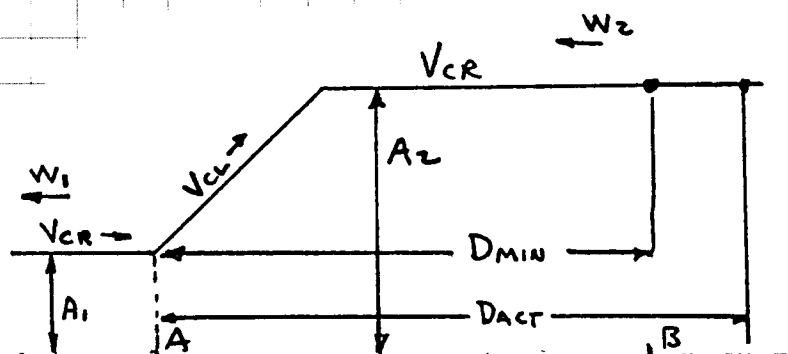
See previous page.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

# Program Description II

Sketch(es)



## Sample Problem(s)

Assumed aircraft parameters:  $V_{cr} = 150$  mph  
 $V_{cl} = 85$  mph  
 $ROC_{max} = 850$  ft/min  
 $A_{max} = 18.5$  kft

Given: Current Altitude ( $A_1$ ) = 3.5 kft  
 Current Headwind Component ( $W_1$ ) = 38 mph  
 Potential Altitude ( $A_2$ ) = 11.5 kft  
 Headwind Component at  $A_2$  ( $W_2$ ) = 10 mph  
 Distance Remaining ( $D_{act}$ ) = 185 miles

Find: 1. Distance required for climb to breakeven  
 2. Time to fly distance remaining if climb is made  
 3. Time saved by climbing to higher altitude  
 4. Time to climb to new altitude

**Solution(s)**

|          |         |         |                                 |       |       |     |                      |     |
|----------|---------|---------|---------------------------------|-------|-------|-----|----------------------|-----|
| 150[STO] | [1]     | 85[STO] | [2]                             | [850] | [STO] | [3] | 18.5 [STO]           | [4] |
| 11.5     | [ENTER] | -----   | Store $A_2$                     |       |       |     | 11.50                |     |
| 10       | [ENTER] | -----   | Store $W_2$                     |       |       |     | 10.50                |     |
| 3.5      | [ENTER] | -----   | Store $A_1$                     |       |       |     | 3.50                 |     |
| 38       | [A]     | -----   | Store $W_1$                     |       |       |     | 11.50                |     |
| 1.       | [B]     | -----   | Compute $D_{min}$               |       |       |     | 87.54                |     |
| 2.       | 185 [C] | -----   | Compute $T_{act}$ for 185 miles |       |       |     | 1.28 (1 hr, 28 mins) |     |
| 3.       | [R/S]   | -----   | Compute $T_{saved}$             |       |       |     | 0.10 (10 mins)       |     |
| 4.       | [D]     | -----   | Compute $T_{climb}$             |       |       |     | 0.16 (16 mins)       |     |

**Reference(s)** Equations (1), (2), and (4) are submitter's own derivations based on the geometry of the problem.

Equation (3) is based on an assumption that ROC varies lineary with altitude  $[ROC(A) = A_{max} (1 - \frac{A}{A_{max}})]$  and straight forward integration. See any good aeronautical engineering text.

This program is a translation of the HP-65 Users Library program # 01815A submitted by Carroll F. Lam.

## 43

[illegible]



## **Hewlett-Packard Software**

In terms of power and flexibility, the problem-solving potential of the Hewlett-Packard line of fully programmable calculators is nearly limitless. And in order to see the practical side of this potential, we have several different types of software to help save you time and programming effort. Every one of our software solutions has been carefully selected to effectively increase your problem-solving potential. Chances are, we already have the solutions you're looking for.

### **Application Pacs**

To increase the versatility of your fully programmable Hewlett-Packard calculator, HP has an extensive library of "Application Pacs". These programs transform your HP-67 and HP-97 into specialized calculators in seconds. Each program in a pac is fully documented with commented program listing, allowing the adoption of programming techniques useful to each application area. The pacs contain 20 or more programs in the form of prerecorded cards, a detailed manual, and a program card holder. Every Application Pac has been designed to extend the capabilities of our fully programmable models to increase your problem-solving potential.

You can choose from:

**Statistics**  
**Mathematics**  
**Electrical Engineering**  
**Business Decisions**  
**Clinical Lab and Nuclear Medicine**

**Mechanical Engineering**  
**Surveying**  
**Civil Engineering**  
**Navigation**

### **Users' Library**

The main objective of our Users' Library is dedicated to making selected program solutions contributed by our HP-67 and HP-97 users available to you. By subscribing to our Users' Library, you'll have at your fingertips, literally hundreds of different programs. No longer will you have to: research the application; program the solution; debug the program; or complete the documentation. Simply key your program to obtain your solution. In addition, programs from the library may be used as a source of programming techniques in your application area.

A one-year subscription to the Library costs \$9.00. You receive: a catalog of contributed programs; catalog updates; and coupons for three programs of your choice (a \$9.00 value).

### **Users' Library Solutions Books**

Hewlett-Packard recently added a unique problem-solving contribution to its existing software line. The new series of software solutions are a collection of programs provided by our programmable calculator users. Hewlett-Packard has currently accepted over 6,000 programs for our Users' Libraries. The best of these programs have been compiled into 40 Library Solutions Books covering 39 application areas (including two game books).

Each of the Books, containing up to 15 programs without cards, is priced at \$10.00, a savings of up to \$35.00 over single copy cost.

The Users' Library Solutions Books will compliment our other applications of software and provide you with a valuable new tool for program solutions.

**Options/Technical Stock Analysis**  
**Portfolio Management/Bonds & Notes**  
**Real Estate Investment**  
**Taxes**  
**Home Construction Estimating**  
**Marketing/Sales**  
**Home Management**  
**Small Business**  
**Antennas**  
**Butterworth and Chebyshev Filters**  
**Thermal and Transport Sciences**  
**EE (Lab)**  
**Industrial Engineering**  
**Aeronautical Engineering**  
**Control Systems**  
**Beams and Columns**  
**High-Level Math**  
**Test Statistics**  
**Geometry**  
**Reliability/QA**

**Medical Practitioner**  
**Anesthesia**  
**Cardiac**  
**Pulmonary**  
**Chemistry**  
**Optics**  
**Physics**  
**Earth Sciences**  
**Energy Conservation**  
**Space Science**  
**Biology**  
**Games**  
**Games of Chance**  
**Aircraft Operation**  
**Aviation**  
**Calendars**  
**Photo Dark Room**  
**COGO-Surveying**  
**Astrology**  
**Forestry**



## **AERONAUTICAL ENGINEERING**

Includes programs in several areas for Aeronautical Engineering, such as calculations for properties of air and atmosphere, behavior of gas flows, calibration of temperature and speed, and also some aircraft maneuvering.

PROPERTIES OF AIR

THEORETICAL U.S. STANDARD ATMOSPHERE TEMPERATURE  
AND PRESSURE BELOW 35,332 FT.

AIRCRAFT FLYOVER ACOUSTIC TONE DOPPLER SHIFT

ISENTROPIC FLOW FOR IDEAL GASES

NORMAL AND OBLIQUE SHOCK PARAMETERS FOR  
COMPRESSIBLE FLOW

OBLIQUE SHOCK ANGLE FOR WEDGE

MACH NUMBER AND TRUE AIRSPEED

TAKE-OFF RUN VS DENSITY ALTITUDE

TRUE AIR TEMPERATURE AND DENSITY ALTITUDE

AIRCRAFT CLIMB



**1000 N.E. Circle Blvd., Corvallis, OR 97330**

Reorder No. 00097-14036 Printed in U.S.A. 00097-90211