HEWLETT-PACKARD

HP-67/HP-97

Users' Library Solutions

Thermal and Transport Sciences

INTRODUCTION

In an effort to provide continued value to it's 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

Program Description I

Program Title PSYCHROMETRIC PROPERTIES

Contributor's Name Donald H. Madsen

Address 1315 Whiting Avenue Court

City Iowa City **State** Iowa **Zip Code** 52240

Program Description, Equations, Variables This program outputs dry bulb temperature, wet bulb temperature, dew point temperature (unless the vapor pressure is zero), total pressure, vapor pressure, specific humidity, relative humidity, enthalpy and specific volume.

The input is dry bulb temperature and
wet bulb temperature or relative humidity or vapor pressure.

With wet bulb temperature input the total time required is approximately 22 seconds. With relative humidity or vapor pressure input an iterative solution results and it usually requires $1\frac{1}{2}$ to 2 minutes.

The data required for English or SI units are given on page 9.

Temperatures °F or °C   Relative humidity %
Pressures psi or kPa   Specific humidity lb_m/lb_m dry air or kg/kg dry air   Enthalpy Btu/lb_m dry air or kJ/kg dry air
Specific volume ft^3/lb_m dry air or dm^3/kg dry air

Operating Limits and Warnings Temperatures -40 °F to 300 °F or -40 °C to 150 °C (temperatures less than 32 °F or 0 °C, vapor in equilibrium with ice).

Total pressure 1 psia to 50 psia or 7 kPa to 345 kPa.

Relative humidity 0 to 100%

Specific humidity less than 0.2 lb_m/lb_m dry air or 0.2 kg/kg dry air.

Helpful program diagnosis follows on page 10

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.

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Program Description I

Program Title PSYCHROMETRIC PROPERTIES

Contributor's Name

Address

City **State** **Zip Code**

Program Description, Equations, Variables

$$\omega = \frac{c_{p,a}(t_{wb} - t_{db}) + \omega_{sat,wb}(h_{g,wb} - h_{f,wb})}{h_{v,db} - h_{f,wb}}$$

$$c_{p,a} = 0.240 \text{ Btu/lb}_m {}^\circ\text{F} = 1.0048 \text{ kJ/kg} {}^\circ\text{C}$$

$h_v = h_g = a + bt$ $\qquad a = 1061.0 \text{ Btu/lb}_m = 2501.0 \text{ kJ/kg}$ *

$\qquad b = 0.445 \text{ Btu/lb}_m {}^\circ\text{F} = 1.8631 \text{ kJ/kg} {}^\circ\text{C}$

$t \geqq 32^\circ\text{F or } 0^\circ\text{C}$ $\qquad h_f = (t - c)d$

$\qquad c = 32^\circ\text{F} = 0^\circ\text{C}$

$\qquad d = 1 \text{ Btu/lb}_m {}^\circ\text{F} = 4.1868 \text{ kJ/kg} {}^\circ\text{C}$

$t < 32^\circ\text{F or } 0^\circ\text{C}$ $\qquad h_f = h_i = [(t - c)0.467 + e]d$

$\qquad e = -143.956^\circ\text{F} = -79.97556^\circ\text{C}$ **

$h = c_{p,a}t_{db} + \omega h_{v,db}$ ***

Operating Limits and Warnings

* constants do not directly convert because of different zero point for enthalpy.

** constants for empirical equation do not convert. (÷1.8)

*** note that the enthalpy of the mixture does not convert directly because of a different zero point for the enthalpy of air.

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Program Description I

Program Title PSYCHROMETRIC PROPERTIES

Contributor's Name

Address

City **State** **Zip Code**

Program Description, Equations, Variables

$$\omega = \frac{R_{air}}{R_{vapor}} \frac{P_{vapor}}{P_{total} - P_{vapor}} \qquad \frac{R_{air}}{R_{vapor}} = 0.622$$

(also used to calculate P_{vapor})

$$P_{sat} = f\, e^{g/(t+h)}$$

t = temperature, °F or °C

$e = 2.718282$

$t \geqq 32\,°F$ or $0\,°C$

$f = 2.04466 \cdot 10^6$ psi $= 1.40974 \cdot 10^7$ kPa

$g = -7071.3\,°F = -3928.5\,°C$ *

$h = 385\,°F = 231.667\,°C$ **

$t < 32\,°F$ or $0\,°C$

$f' = 5.24506 \cdot 10^8$ psi $= 3.61633 \cdot 10^9$ kPa

$g' = -11{,}071\,°F = -6150.6\,°C$ *

$h' = 460\,°F = 273.33\,°C$ **

$$v = \frac{R_{air}\, T}{P_{total} - P_{vapor}}$$

$$\varphi = P_{vapor}/P_{sat,db}$$

Operating Limits and Warnings

* temperatures do not convert. (÷1.8)

** temperatures do not convert because of different zero point.

P_{sat} is within 0.33% of the liquid-vapor values given in the ASME Steam Tables and the solid-vapor values of Keenan and Keyes Tables.

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Program Description II

Sketch(es)

Sample Problem(s)

English Units

(1) P_{total} = 14.696 psia dry bulb 70 °F wet bulb 60 °F

(2) P_{total} = 25.0 psia dry bulb 70 °F relative humidity 50 %

(3) t = 212 °F, find P_{sat}

Solutions

	(1) 14.696 A 70 ↑ 60 B	(2) 25.0 A 70 ↑ 50 C
t_{db}, °F	70.0 ***	70.0 ***
t_{wb}, °F	60.0 ***	60.8 ***
t_{dp}, °F	53.7 ***	50.6 ***
P_{total}, psi	14.7 ***	25.0 ***
P_{vapor}, psi	0.2040 ***	0.1820 ***
ω, lb_m/lb_m dry air	0.0088 ***	0.0046 ***
φ, %	56.0 ***	50.0 ***
h, Btu/lb_m dry air	26.4 ***	21.8 ***
v, ft^3/lb_m dry air	13.5 ***	7.9 ***

(3) 212 E Output 14.7

Reference(s)

Program Description II

Sketch(es)

Sample Problem(s)

SI Units

(4) P_{total} = 101.325 kPa dry bulb 25 °C wet bulb 20 °C

(5) P_{total} = 200 kPa dry bulb 50 °C vapor pressure 4 kPa

(6) t = 100 °C, find P_{sat}

Solutions	(4) 101.325 A 25 ↑ 20 B	(5) 200 A 50 ↑ 4 D
t_{db}, °C	25.0 ***	50.0 ***
t_{wb}, °C	20.0 ***	35.7 ***
t_{dp}, °C	17.6 ***	28.9 ***
P_{total}, kPa	101.3 ***	200.0 ***
P_{vapor}, kPa	2.0166 ***	4.0000 ***
ω, kg/kg dry air	0.0126 ***	0.0127 ***
φ, %	63.5 ***	32.4 ***
h, kJ/kg dry air	57.3 ***	83.2 ***
v, dm^3/kg dry air	860.7 ***	472.7 ***

(6) 100 E Output 101.2

Reference(s)

User Instructions

PSYCHROMETRIC PROPERTIES

1 ◀ ▶ 2

P_{total} | $t_{db} \uparrow t_{wb}$ | $t_{db} \uparrow \varphi$ | $t_{db} \uparrow P_v$ | $t \rightarrow P_{sat}$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2 Program card			
2	Load side 1 and side 2 English or			
	SI Data card			
3	If only Psat is needed skip to step 8			
4	Input Ptotal (if changed from	P_{total}	A	P_{total}
	previous value)			
5	Input dry bulb temperature	t_{db}	ENT↑	t_{db}
6	Input:			
	wet bulb temperature	t_{wb}	B	
	or relative humidity	φ	C	
	or vapor pressure	P_{vapor}	D	
				t_{db}
				t_{wb}
				t_{dp} *
				P_{total}
				P_{vapor}
				ω
				φ
				h
				v
7	For a new case go to step 3			
8	Input temperature	t	E	P_{sat}
	* omitted if P_{vapor} = 0			
	In case of difficulty see Program			
	Diagnosis sheet, page 10			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBL A	21 11	Store pressure
	STO A	35 11	
	RTN	24	
	*LBL B	21 12	Enter dry bulb and wet bulb temperatures
	GSB 2	23 02	
	STO 0	35 00	
	GSB E	23 15	
	GSB 3	23 03	
	X<0 ?	16-45	
010	R/S	51	
	GSB 4	23 04	
	X<0 ?	16-45	
	R/S	51	
	STO C	35 13	
	.	-62	
	2	02	
	X≤Y ?	16-35	
	R/S	51	
	R↓	-31	
020	RCL A	36 11	
	x	-35	
	RCL C	36 13	
	RCL 3	36 03	
	+	-55	
	÷	-24	
	GSB 5	23 05	
	GTO 8	22 08	
	*LBL C	21 13	Enter dry bulb temperature and relative humidity
	GSB 2	23 02	
030	STO D	35 14	
	RCL B	36 12	
	GSB E	23 15	
	X⇄Y	-41	
	%	55	
	STO E	35 15	
	GTO 0	22 00	
	*LBL D	21 14	Enter dry bulb temperature and vapor pressure
	GSB 2	23 02	
	GSB 5	23 05	
040	RCL E	36 15	
	*LBL 0	21 00	
	GSB 3	23 03	
	X<0 ?	16-45	
	R/S	51	
	STO C	35 13	
	.	-62	
	2	02	
	X≤Y ?	16-35	
	R/S	51	
050	DSP 5	-63 05	
	RCL I	36 46	
	STO 1	35 01	
	*LBL 1	21 01	
	RCL 1	36 01	
	F2 ?	16 23 02	
	CHS	-22	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	ST-0	35-45 00	
	2	02	
	ST÷1	35-24 01	
060	RCL 0	36 00	
	GSB E	23 15	
	GSB 3	23 03	
	X<0 ?	16-45	
	GTO 1	22 01	
	GSB 4	23 04	
	RCL C	36 13	
	-	-45	
	RND	16 24	
	X=0 ?	16-43	
070	GTO 8	22 08	
	X<0 ?	16-45	
	SF 2	16 21 02	
	GTO 1	22 01	
	*LBL E	21 15	Calculate saturation pressure. Temperature in X register
	RCL 5	36 05	
	X>Y ?	16-34	
	P⇄S	16-51	
	X>Y ?	16-34	
	SF 2	16 21 02	
080	R↓	-31	
	RCL 9	36 09	
	+	-55	
	1/X	52	
	RCL 8	36 08	
	x	-35	
	e^x	33	
	RCL 7	36 07	
	x	-35	
	F2 ?	16 23 02	
090	P⇄S	16-51	
	RTN	24	
	*LBL 2	21 02	Initialize
	SPC	16-11	
	CF 2	16 22 02	
	DSP 1	-63 01	
	RCL 6	36 06	
	X<0 ?	16-45	
	P⇄S	16-51	
	R↓	-31	
100	X⇄Y	-41	
	STO B	35 12	
	STO 0	35 00	
	PRT X	-14	
	X⇄Y	-41	
	RTN	24	
	*LBL 3	21 03	Calculate specific humidity. Vapor pressure in X, total pressure in A
	RCL 3	36 03	
	X⇄Y	-41	
	x	-35	
110	RCL A	36 11	
	LST X	16-63	
	-	-45	

REGISTERS

0	1	2	3	4	5	6	7	8	9
t_{wb}	Δt_{wb}	$c_{p,a}$	R_a/R_v	R_a	t_{ip}	$t_{abs}-t_{com}$	f	g	h
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
	d	t_{ip}	b	a	0.467	e	f'	g'	h'

A	B	C	D	E	I
p_{tot}	t_{db}	ω	ϕ	p_v	Engl. 140 SI 80

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
	÷	-24	
	RTN	24	
	*LBL 4	21 04	Calculate specific humidity. Wet bulb in register 0, dry bulb in register B
	RCL 0	36 00	
	RCL 0	36 00	
	GSB 6	23 06	
	x	-35	
120	RCL 0	36 00	
	RCL B	36 12	
	-	-45	
	RCL 2	36 02	
	x	-35	
	+	-55	
	RCL 0	36 00	
	RCL B	36 12	
	GSB 6	23 06	
	÷	-24	
130	RTN	24	
	*LBL 5	21 05	Calculate relative humidity. Vapor pressure in X, dry bulb in register B
	STO E	35 15	
	RCL B	36 12	
	GSB E	23 15	
	÷	-24	
	1	01	
	X⇄Y	-41	
	X>Y ?	16-34	
	R/S	51	
140	EEX	-23	
	2	02	
	x	-35	
	STO D	35 14	
	RTN	24	
	*LBL 6	21 06	Calculate difference in enthalpy, ice or water to vapor. Ice or water temperature in Y, vapor temperature in X.
	P⇄S	16-51	
	RCL 3	36 03	
	x	-35	
	RCL 4	36 04	
150	+	-55	
	X⇄Y	-41	
	RCL 2	36 02	
	-	-45	
	X<0 ?	16-45	
	GSB 7	23 07	
	RCL 1	36 01	
	x	-35	
	-	-45	
	P⇄S	16-51	
160	RTN	24	
	*LBL 7	21 07	
	RCL 5	36 05	
	x	-35	
	RCL 6	36 06	
	+	-55	
	RTN	24	
	*LBL 8	21 08	Print results
	DSP 1	-63 01	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	RCL 0	36 00	
170	PRT X	-14	
	RCL E	36 15	
	X=0 ?	16-43	If vapor pressure is zero, dew point does not exist.
	GTO 9	22 09	
	RCL 5	36 05	
	GSB E	23 15	
	X>Y ?	16-34	
	P⇄S	16-51	
	RCL E	36 15	
	RCL 7	36 07	
180	÷	-24	
	LN	32	
	1/X	52	
	RCL 8	36 08	
	x	-35	
	RCL 9	36 09	
	-	-45	
	PRT X	-14	
	RCL 6	36 06	
	X<0 ?	16-45	
190	P⇄S	16-51	
	*LBL 9	21 09	
	SPC	16-11	
	RCL A	36 11	
	PRT X	-14	
	DSP 4	-63 04	
	RCL E	36 15	
	PRT X	-14	
	SPC	16-11	
	RCL C	36 13	
200	PRT X	-14	
	DSP 1	-63 01	
	RCL D	36 14	
	PRT X	-14	
	RCL B	36 12	
	RCL 2	36 02	
	x	-35	
	RCL 5	36 05	
	RCL B	36 12	
	GSB 6	23 06	
210	RCL C	36 13	
	x	-35	
	+	-55	
	PRT X	-14	
	RCL B	36 12	
	RCL 6	36 06	
	+	-55	
	RCL 4	36 04	
	x	-35	
	RCL A	36 11	
220	RCL E	36 15	
	-	-45	
	÷	-24	
	PRT X	-14	
	RTN	24	

LABELS

A P_{tot}	B $t_{db} \uparrow t_{wb}$	C $t_{db} \uparrow \varphi$	D $t_{db} \uparrow P_v$	E $t \to P_{sat}$
a	b	c	d	e
0 Used	1 Used	2 Initial	3 $P_v \to \omega$	4 $\to \omega$
5 $\to \varphi$	6 $\to \Delta h$	7 Used	8 Print	9 Used

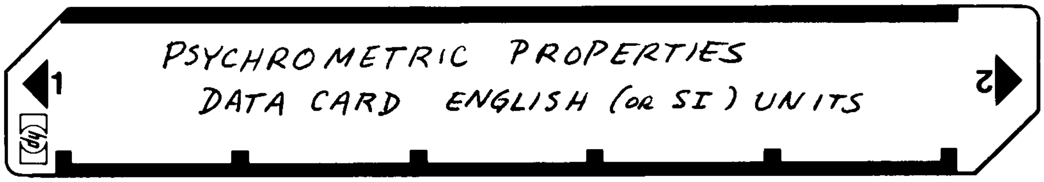
FLAGS

0	
1	
2	Used
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	1

DATA CARD



English Units	SI Units
.24 STO 2	1.0048 STO 2
.622 STO 3	.622 STO 3
.3701 STO 4	286.7 STO 4
32 STO 5	0 STO 5
459.67 STO 6	273.15 STO 6
2.04466 EEX 6 STO 7	1.40974 EEX 7 STO 7
7071.3 CHS STO 8	3928.5 CHS STO 8
385 STO 9	231.667 STO 9
14.696 STO A	101.325 STO A
140 STO I	80 STO I
f P⇄S	f P⇄S
1 STO 1	4.1868 STO 1
32 STO 2	0 STO 2
.445 STO 3	1.8631 STO 3
1061 STO 4	2501 STO 4
.467 STO 5	.467 STO 5
143.956 CHS STO 6	79.97556 CHS STO 6
5.24506 EEX 8 STO 7	3.61633 EEX 9 STO 7
11071 CHS STO 8	6150.6 CHS STO 8
460 STO 9	273.33 STO 9
f WDTA	f WDTA

PROGRAM DIAGNOSIS

IF EXECUTION STOPS using GSB B

Display	Step	Reason
Negative	11	Wet bulb too high
Negative	14	Wet bulb too low
0.2	19	Specific humidity ≧ 0.2
ERROR	113	Wet bulb saturation pressure equals total prssure
Positive	140	Wet bulb > Dry bulb

IF EXECUTION STOPS using GSB C or GSB D

Display	Step	Reason
Negative	45	Vapor pressure > total pressure
0.2	50	Specific humidity ≧ 0.2
ERROR	113	Vapor pressure equals total pressure
Positive	140	Vapor pressure > dry bulb saturation pressure

EXECUTION MAY CONTINUE INDEFINITELY UNDER CERTAIN CONDITIONS

Example: Relative humidity entered greater than 100%.

Program Description I

Program Title PSYCHROMETRIC CALCULATIONS FOR WATER IN AIR

Contributor's Name James V. Clore
Address 4900 Richardson Rd.
City Howell State Michigan Zip Code 48843

Program Description, Equations, Variables Given dry bulb temperature, wet bulb temperature and barometric pressure the program will calculate: Vapor Pressure, Absolute Humidity, Relative Humidity and Dew Point for dry bulb temperatures between 32°F and 105°F. Calculations can be made in either English or Metric units.

UNITS

Temperature	F°	C°
Pressure	inches of Mercury	millimeters of Mercury
Humidity	Grains of Water Per Pound Dry Air	Grams of Water Per Kilogram Dry Air

Program constants are stored between step 173 and step 222. After initialization the area between step 173 and step 224 is available for users' program. Registers 9, 50 → 59, A, E are available to the user.

Operating Limits and Warnings Over the range 32°F to 105°F dry bulb temperature, Dew Point is calculated to within 1 degree F, Humidity within one grain of water per pound dry air.

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.

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Program Description II

Sketch(es)

Sample Problem(s)

Problem 1

English Units

Barometric Pressure 29.92 in. Hg

Wet bulb Temp. 64° F

Dry bulb Temp. 77° F

Problem 2

Metric Units

Barometric Pressure 760 mm Hg

Wet bulb Temp. 18° C

Dry bulb Temp 25° C

Solution(s) Solution 1

Keystrokes	Display	
[f] [a]	0.	
29.92 [f] [c]	29.92	
64 [ENTER↑] 77 [A]	0.4567	Vapor Pres.
[C]	68	Abs. Humidity
[D]	49	% Rel. Humidity
[E]	57	Dew Point F°

Solution 2

Keystrokes	Display	
[f] [a]	0.	
[f] [b]	1.	
760 [f] [c]	29.92	
18 [ENTER↑] 25 [A]	11.93	Vapor Pres.
[C]	10	Abs. Humidity
[D]	50	% Rel. Humidity
[E]	14	DewPoint C°

Reference(s) PSYCHROMETRIC CHART

User Instructions

PSYCHROMETRIC CALCULATIONS FOR WATER IN AIR

1	INITIALIZE	ENG/MET	BAROMETER		2
	CALC	VAP PRES	ABS. HUM.	REL HUM	DEW PNT

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	LOAD SIDE 1 AND SIDE 2				
2	INITIALIZE CONSTANTS		f	a	0.
	BAROMETRIC PRESSURE IS INITIALIZED				
	TO 30 inches Mercury. UNITS INTIALIZED				
	TO ENGLISH.				
3	SELECT ALTERNATE UNITS		f	b	
	ENGLISH — DISPLAY ⇒ 0.				
	METRIC — DISPLAY ⇒ 1.				
4	INPUT BAROMETRIC PRESSURE	PB	f	c	PBE
	DISPLAY OUTPUT SHOWS BAROMETRIC PRESSURE PBE				
	IN ENGLISH UNITS.				
5	INPUT WET BULB TEMPERATURE WB	WB	ENTER ↑		
6	INPUT DRY BULB TEMPERATURE DB	DB			
7	CALCULATE VALUES		A		PV
	VAPOR PRESSURE PV IS DISPLAYED				
8	RESULTS				
	VAPOR PRESSURE PV		B		PV
	ABSOLUTE HUMIDITY H		C		H
	RELATIVE HUMIDITY RH		D		RH
	DEW POINT DP		E		DP
9	FOR NEW CALCULATION WITH DIFFERENT				
	TEMPERATURES GO TO STEP 5.				
10	FOR NEW BAROMETRIC PRESSURE				
	GO TO STEP 4.				
11	TO CHANGE UNITS ENGLISH OR				
	METRIC GO TO STEP 3.				
12	TO SHOW CURRENT RESULTS IN				
	COMPLEMENTARY UNITS DO STEP 3				
	THEN STEP 8. FOR A NEW CALCULATION				
	GO TO STEP 3.				

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBL c	32 25 13	
	1/x	35 62	
	F0?	35 71 00	
	GSB 4	31 22 04	
	1/x	35 62	
	STO 0	33 00	
	DSP 2	23 02	
	RTN	35 22	
	*LBL A	31 25 11	
010	STO 6	33 06	
	R↓	35 53	
	STO 7	33 07	
	F?0	35 71 00	
	GSB 9	31 22 09	
	STO 8	33 08	
	GSB 1	31 22 01	
	RCL 6	34 06	
	RCL 7	34 07	
	−	51	
020	2	02	
	7	07	
	0	00	
	0	00	
	÷	81	
	RCL 0	34 00	
	×	71	
	−	51	
	STO B	33 12	VAPOR PRESSURE
	7	07	
030	EEX	43	
	3	03	
	×	71	
	1	01	
	.	83	
	6	06	
	÷	81	
	RCL 0	34 00	
	RCL B	34 12	
	−	51	
040	÷	81	
	STO C	33 13	ABS. HUMIDITY
	RCL 6	34 06	
	STO 8	33 08	
	STO 7	33 07	
	GSB 1	31 22 01	
	RCL B	34 12	
	X⇄Y	35 52	
	÷	81	
	EEX	43	
050	2	02	
	×	71	
	STO D	33 14	REL. HUMIDITY
	*LBL B	31 25 12	DISPLAY VAPOR PRESSURE
	RCL B	34 12	
	F0?	35 71 00	
	GTO 4	22 04	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	DSP 4	23 04	
	RTN	35 22	
	*LBL C	31 25 13	DISPLAY ABSOLUTE HUMIDITY
060	RCL C	34 13	
	F0?	35 71 00	
	GSB 5	31 22 05	
	*LBL 8	31 25 08	
	DSP 0	23 00	
	RTN	35 22	
	*LBL D	31 25 14	DISPLAY RELATIVE HUMIDITY
	RCL D	34 14	
	GTO 8	22 08	
	*LBL 9	31 25 09	TEMPERATURE CONVERSION
070	6	06	
	ST I	35 33	
	GSB 2	31 22 02	
	ISZ	31 34	
	GSB 2	31 22 02	
	RTN	35 22	
	*LBL 2	31 25 02	
	RCL (i)	34 24	
	1	01	
	.	83	
080	8	08	
	×	71	
	3	03	
	2	02	
	+	61	
	STO (i)	33 24	
	RTN	35 22	
	*LBL 1	31 25 01	
	4	04	
	ST I	35 33	
090	RCL 5	34 05	
	*LBL 6	31 25 06	
	RCL (i)	34 24	
	RCL 8	34 08	
	×	71	
	+	61	
	RCL 7	34 07	
	STO × 8	33 71 08	
	R↓	35 53	
	DSZ	31 33	
100	GTO 6	22 06	
	RTN	35 22	
	*LBL b	32 25 12	METRIC/ENGLISH
	F0?	35 71 00	
	GTO 3	22 03	
	SF0	35 51 00	
	1	01	
	GTO 8	22 08	
	*LBL 3	31 25 03	
	CF0	35 61 00	
110	0	00	
	GTO 8	22 08	
	*LBL 4	31 25 04	INCHES Hg → mm Hg

REGISTERS

0	1	2	3	4	5	6	7	8	9
BARO. PRESSURE	K4	K3	K2	K1	KØ	DB	WB	INTER. RESULTS	

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
	VAPOR PRESSURE	ABSOLUTE HUMIDITY	RELATIVE HUMIDITY		COUNTER

67 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
	2	02	
	5	05	
	•	83	
	4	04	
	x	71	
	DSP 2	23 02	
	RTN	35 22	
120	*LBL 5	31 25 05	GRAINS PER POUND
	•	83	TO GRAMS PER
	1	01	KILOGRAM
	4	04	
	3	03	
	x	71	
	RTN	35 22	
	*LBL E	31 25 15	DEW POINT
	RCL C	34 13	
	7	07	
130	•	83	
	7	07	
	4	04	
	7	07	
	÷	81	
	LN	31 52	
	•	83	
	0	00	
	3	03	
	8	08	
140	6	06	
	÷	81	
	3	03	
	•	83	
	8	08	
	EEX	43	
	CHS	42	
	5	05	
	RCL C	34 13	
	x^2	32 54	
150	x	71	
	+	61	
	8	08	
	•	83	
	5	05	
	EEX	43	
	CHS	42	
	3	03	
	RCL C	34 13	
	x	71	
160	+	61	
	F0?	35 71 00	
	GTO 7	22 07	
	GTO 8	22 08	
	*LBL 7	31 25 07	
	3	03	
	2	02	
	−	51	
	1	01	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	•	83	
170	8	08	
	÷	81	
	GTO 8	22 08	
173	*LBL a	32 25 11	INITIALIZE
	•	83	CONSTANTS
	1	01	
	1	01	
	5	05	
	4	04	
	STO 5	33 05	
180	2	02	
	•	83	
	6	06	
	4	04	
	CHS	42	
	EEX	43	
	CHS	42	
	3	03	
	STO 4	33 04	
	1	01	
190	•	83	
	7	07	
	3	03	
	4	04	
	EEX	43	
	CHS	42	
	4	04	
	STO 3	33 03	
	1	01	
	•	83	
200	2	02	
	0	00	
	9	09	
	CHS	42	
	EEX	43	
	CHS	42	
	6	06	
	STO 2	33 02	
	1	01	
	•	83	
210	5	05	
	5	05	
	6	06	
	EEX	43	
	CHS	42	
	8	08	
	STO 1	33 01	
	3	03	
	0	00	
	STO Ø	33 00	
220	CF0	35 61 00	
	0	00	
222	GTO 8	22 08	

LABELS

A	B	C	D	E
CALC	PV	SH	RH	DP
a INITIALIZE	b ENG/MET	c BAROMETER	d	e
0	1 ✓	2 ✓	3 ✓	4 ✓
5 ✓	6 ✓	7 ✓	8 ✓	9 ✓

FLAGS

0	METRIC = 1
1	
2	
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☑
1	☐	☑
2	☐	☑
3	☐	☑

TRIG	
DEG	☑
GRAD	☐
RAD	☐

DISP	
FIX	☑
SCI	☐
ENG	☐
n	____

Program Description I

Program Title EQUATIONS OF STATE

Contributor's Name

Address

City **State**

HEWLETT-PACKARD
1000 N. E. Circle Blvd.
Corvallis, Oregon 97330

Program Description

This card provides both ideal gas and Redlich-Kwong equations of state. Given four of the five state variables, the fifth is calculated. For the Redlich-Kwong solution, the critical pressure and temperature of the gas must be known. They are not needed for ideal gas solutions.

Values of the Universal Gas Constants

Value of R	Units of R	Units of P	Units of V	Units of T
8.314	N - m/g mole - K	N/m^2	m^3/g mole	K
83.14	cm^3 - bar/g mole - K	bar	cm^3/g mole	K
82.05	cm^3 - atm/g mole - K	atm	cm^3/g mole	K
0.7302	atm - ft^3/lb mole - °R	atm	ft^3/lb mole	°R
10.73	psi - ft^3/lb mole - °R	psi	ft^3/lb mole	°R
1545	psf - ft^3/lb mole - °R	psf	ft^3/lb mole	°R

Critical Temperatures and Pressures

Substance	T_c, K	T_c, °R	P_c, ATM
Ammonia	405.6	730.1	112.5
Argon	151	272	48.0
Carbon dioxide	304.2	547.6	72.9
Carbon monoxide	133	239	34.5
Chlorine	417	751	76.1
Helium	5.3	9.5	2.26
Hydrogen	33.3	59.9	12.8
Nitrogen	126.2	227.2	33.5
Oxygen	154.8	278.6	50.1
Water	647.3	1165.1	218.2
Dichlorodifluoromethane	384.7	692.5	39.6
Dichlorofluoromethane	451.7	813.1	51.0
Ethane	305.5	549.9	48.2
Ethanol	516.3	929.3	63
Methanol	513.2	923.8	78.5
n-Butane	425.2	765.4	37.5
n-Hexane	507.9	914.2	29.9
n-Pentane	469.5	845.1	33.3
n-Octane	568.6	1023.5	24.6
Trichlorofluoromethane	471.2	848.1	43.2

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.

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Program Description I

Program Title

Contributor's Name

Address

City

Equations:

Ideal gas:

$$PV = nRT$$

Redlich-Kwong:

$$P = \frac{nRT}{(V - b)} - \frac{a}{T^{1/2}\, V\,(V + b)}$$

$$a = 4.934\ b\ nRT_c^{1.5}$$

$$b = 0.0867 \frac{nRT_c}{P_c}$$

where:

P is the absolute pressure;

V is the volume;

n is the number of moles present;

R is the universal gas constant;

T is the absolute temperature;

T_c is the critical temperature;

P_c is the critical pressure.

Program Description

Remarks:

P, V, n and T must have units compatible with R.

At low temperatures or high pressures, the ideal gas law does not represent the behavior of real gases.

No equation of state is valid for all substances nor over an infinite range of conditions. The Redlich-Kwong equation gives moderate to good accuracy for a variety of substances over a wide range of conditions. Results should be used with caution and tempered by experience.

Operating Limits

Solutions for V, n, R and T, using the Redlich-Kwong equation, require an iterative technique. Newton's method is employed using the ideal gas law to generate the initial guess. Iteration time is generally a function of the amount of deviation from ideal gas behavior. For extreme cases, the routine may fail to converge entirely, resulting in an ''error''.

Registers R_0, R_1 and R_{S0}—R_{S9} are available for user storage.

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.

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Program Description II

Sketch(es)

Sample Problem

Solution(s)

Reference(s)

Example 1:

0.63 g moles of air are enclosed in a 25,000 cm^3 space at 1200 K. What is the pressure in bars? Assume an ideal gas.

Keystrokes:	Outputs:	
Select ideal gas by pressing f A until 0.00 is displayed.		
f A f A ⟶	0.00	
25000 B .63 C 83.14 D		
1200 E A ⟶	2.51	(bars)

Example 2:

What is the specific volume (ft^3/lb) of a gas at atmospheric pressure and at a temperature of 513°R? The molecular weight is 29. Assume an ideal gas.

Keystrokes:	Outputs:	
f A ⟶	0.00	
513 E 29 1/x C 0.7302		
D 1 A B ⟶	12.92	(ft^3/lb)
What is the density?		
1/x ⟶	0.08	(lb/ft^3)
What is the density at 1.32 atmospheres and 555°R?		
1.32 A 555 E B 1/x ⟶	0.09	(lb/ft^3)

Example 3:

The specific volume of a gas in a container is 800 cm^3/g mole. The temperature will reach 400 K. What will the pressure be according to the Redlich-Kwong relation?

P_c = 48.2 atm

T_c = 305.5 K

R = 82.05 cm^3 - atm/g mole-K

Keystrokes:	Outputs:	
f A ⟶	1.00	
305.5 f B 48.2 f C 82.05		
D 1 C 400 E 800 B A ⟶	36.27	(atm)

Example 4:

6 gram moles of carbon dioxide gas are held at a pressure of 50 atmospheres, and at a temperature of 500 K. What is the volume in cubic centimeters? Use the Redlich-Kwong relation.

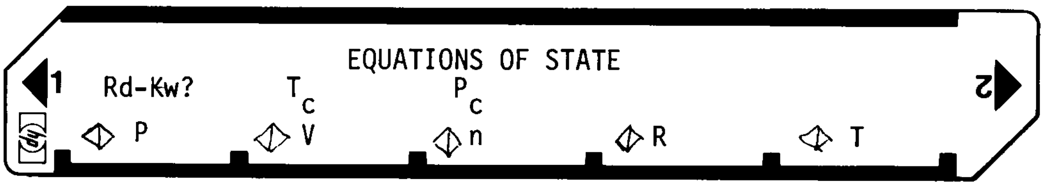
T_c = 304.2 K

P_c = 72.9 atm

R = 82.05 cm^3 - atm/g mole - K

Keystrokes:	Outputs:	
f A ⟶	1.00	
72.9 f C 304.2 f B 82.05		
D 6 C 50 A 500 E B ⟶	4695.86	(cm^3)
How many moles could be contained at this temperature and pressure in 5 liters?		
5000 B C ⟶	6.39	(g moles)

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Select Redlich-Kwong (1.00) or			
	ideal gas (0.00) using mode			
	toggle.		f A	1.00/0.00
3	If you selected ideal gas in			
	step 2, skip to step 5.			
4	Input critical temperature	T_c	f B	T_c
	and critical pressure.	P_c	f C	P_c
5	Input four of the following:			
	Absolute pressure	P	A	P
	Volume	V	B	V
	Number of moles	n	C	n
	Universal gas constant	R	D	R
	Absolute temperature	T	E	T
6	Calculate remaining value:			
	Absolute pressure		A	P
	Volume		B	V
	Number of moles		C	n
	Universal gas constant		D	R
	Absolute temperature		E	T
7	For a new case, go to steps 2,			
	4, or 5 and change values or			
	mode.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	
002	F0?	16 23 00	Redlich-Kwong ideal
003	GTO0	22 00	gas toggle.
004	0	00	
005	SF0	16 21 00	
006	RTN	24	
007	*LBL0	21 00	
008	1	01	
009	CF0	16 22 00	
010	RTN	24	
011	*LBLb	21 16 12	Store T_c.
012	CF3	16 22 03	
013	STOC	35 13	
014	RTN	24	
015	*LBLc	21 16 13	Store P_c.
016	CF3	16 22 03	
017	STOD	35 14	
018	RTN	24	
019	*LBLA	21 11	P code.
020	5	05	
021	GTO0	22 00	
022	*LBLB	21 12	V code.
023	6	06	
024	GTO0	22 00	
025	*LBLC	21 13	n code.
026	7	07	
027	GTO0	22 00	
028	*LBLD	21 14	R code.
029	8	08	
030	GTO0	22 00	
031	*LBLE	21 15	T code.
032	9	09	
033	*LBL0	21 00	
034	CF1	16 22 01	Store input.
035	STOI	35 46	
036	R↓	-31	
037	STOi	35 45	
038	F3?	16 23 03	
039	RTN	24	
040	1	01	
041	STOi	35 45	Dummy 1.00 for un-
042	GTOi	22 45	known and GTO ideal
043	*LBL5	21 05	gas.
044	*LBL6	21 06	Ideal gas solution
045	RCL7	36 07	for P and V.
046	RCL8	36 08	
047	×	-35	
048	RCL9	36 09	
049	×	-35	
050	RCL5	36 05	
051	RCL6	36 06	
052	×	-35	
053	÷	-24	
054	STOi	35 45	
055	GTO0	22 00	
056	*LBL7	21 07	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	*LBL8	21 08	Ideal gas solution
058	SF1	16 21 01	for n, R and T.
059	*LBL9	21 09	
060	RCL5	36 05	
061	RCL6	36 06	
062	×	-35	
063	RCL7	36 07	
064	÷	-24	
065	RCL8	36 08	
066	÷	-24	
067	RCL9	36 09	
068	÷	-24	
069	STOi	35 45	
070	*LBL0	21 00	Stop if ideal gas
071	F0?	16 23 00	is desired.
072	RTN	24	
073	GSB1	23 01	Calculate P by
074	GTO0	22 00	Redlich-Kwong
075	*LBL2	21 02	
076	F1?	16 23 01	
077	GSB1	23 01	
078	*LBL0	21 00	
079	RCLE	36 15	
080	RCL9	36 09	
081	×	-35	
082	RCL6	36 06	
083	RCLB	36 12	
084	-	-45	
085	STO4	35 04	
086	÷	-24	
087	RCLA	36 11	
088	RCL9	36 09	
089	√X	54	
090	÷	-24	
091	STO2	35 02	
092	RCL6	36 06	
093	÷	-24	
094	LSTX	16-63	
095	RCLB	36 12	
096	+	-55	
097	STO3	35 03	
098	÷	-24	
099	-	-45	
100	RCL5	36 05	
101	-	-45	Calculate f(P).
102	GSBi	23 45	
103	÷	-24	Calculate f'(P).
104	ST-i	35-45 45	
105	RCLi	36 45	Loop again?
106	÷	-24	
107	ABS	16 31	
108	EEX	-23	
109	CHS	-22	
110	4	04	
111	X≤Y?	16-35	
112	GTO2	22 02	

REGISTERS

0	1	2	3	4	5	6	7	8	9
		$a/T^{1/2}$	(V+b)	(V-b)	P	V	n	R	T
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
a	b	T_c	P_c	nR	Control

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	RCLi	36 45	Display result of iteration
114	RTN	24	
115	*LBL6	21 06	$\frac{\partial P}{\partial V}$
116	RCL6	36 06	
117	ENT↑	-21	
118	+	-55	
119	RCLB	36 12	
120	+	-55	
121	RCL2	36 02	
122	x	-35	
123	RCL3	36 03	
124	RCL6	36 06	
125	x	-35	
126	X²	53	
127	÷	-24	
128	RCLE	36 15	
129	RCL9	36 09	
130	x	-35	
131	RCL4	36 04	
132	X²	53	
133	÷	-24	
134	-	-45	
135	RTN	24	
136	*LBL9	21 09	$\frac{\partial P}{\partial T}$
137	RCLE	36 15	
138	RCL4	36 04	
139	÷	-24	
140	RCL2	36 02	
141	2	02	
142	÷	-24	
143	RCL9	36 09	
144	÷	-24	
145	RCL6	36 06	
146	÷	-24	
147	RCL3	36 03	
148	÷	-24	
149	+	-55	
150	RTN	24	
151	*LBL7	21 07	$\frac{\partial P}{\partial n}$ or $\frac{\partial P}{\partial R}$
152	*LBL8	21 08	
153	RCL9	36 09	
154	RCL6	36 06	
155	x	-35	
156	RCL4	36 04	
157	X²	53	
158	÷	-24	
159	RCL6	36 06	
160	ENT↑	-21	
161	+	-55	
162	RCLB	36 12	
163	+	-55	
164	RCLE	36 15	
165	÷	-24	
166	RCL6	36 06	
167	÷	-24	
168	RCL3	36 03	

STEP	KEY ENTRY	KEY CODE	COMMENTS
169	X²	53	
170	÷	-24	
171	RCL2	36 02	
172	x	-35	
173	-	-45	
174	RCLE	36 15	
175	x	-35	
176	RCLi	36 45	
177	÷	-24	
178	RTN	24	
179	*LBL5	21 05	Display P.
180	LSTX	16-63	
181	+	-55	
182	STO5	35 05	
183	R/S	51	
184	*LBL1	21 01	Calculate a and b.
185	RCL7	36 07	
186	RCL8	36 08	
187	x	-35	
188	STOE	35 15	
189	.	-62	
190	0	00	
191	8	08	
192	6	06	
193	7	07	
194	RCLD	36 14	
195	÷	-24	
196	X⇄Y	-41	
197	RCLC	36 13	
198	x	-35	
199	x	-35	
200	STOB	35 12	
201	LSTX	16-63	
202	x	-35	
203	RCLC	36 13	
204	√X	54	
205	x	-35	
206	4	04	
207	.	-62	
208	9	09	
209	3	03	
210	4	04	
211	x	-35	
212	STOA	35 11	
213	RTN	24	

LABELS

A	B	C	D	E
↔P	↔V	↔n	↔R	↔T
a R-K?	b T_C	c P_C	d	e
0 Used	1 a,b	2 Iter	3	4
5 P	6 V	7 n	8 R	9 T

FLAGS

0	R-K
1	a,b
2	
3	Calc

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☑	DEG	☑	FIX	☑
1	☐	☑	GRAD	☐	SCI	☐
2	☐	☑	RAD	☐	ENG	☐
3	☐	☑			n	2

Program Description I

Program Title ISENTROPIC FLOW FOR IDEAL GASES

Contributor HEWLETT-PACKARD
Address 1000 N. E. Circle Blvd.
City Corvallis, Oregon **State** **Zip Code** 97330

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;

ρ/ρ_0 is the ratio of flow density ρ to stagnation density ρ_0;

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

Operating Limits

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

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.

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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

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Program Description II

Sketch(es)

Sample Problem(s)

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:	Outputs:	
1.38 f A →	1.380	
.93 A →	0.930	
B →	0.859	(T/T_0)
288 × →	247.352	(T, K)
273 − →	−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 →	0.575	(P/P_0)
700 × →	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:	Outputs:	
1.74 f A →	1.740	
1.60 f E →	2.105	(M)
B →	0.379	(T/T_0)
C →	0.102	(P/P_0)
D →	0.269	(ρ/ρ_0)

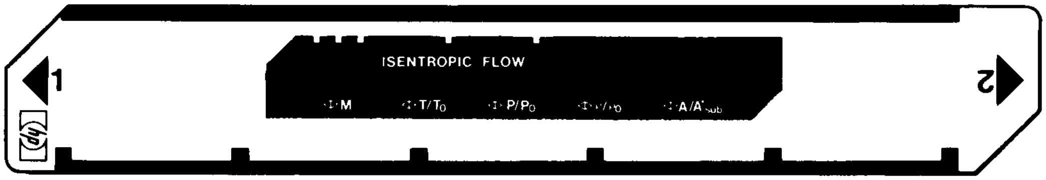
Solution(s)

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 ***	(ρ/ρ_0)
	1.600 ***	(A/A*)

Reference(s)

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input specific heat ratio.	k	f A	k
3	Input one of the following:			
	Mach number	M	A	M
	Temperature ratio	T/T_0	B	M
	Pressure ratio	P/P_0	C	M
	Density ratio	ρ/ρ_0	D	M
	Subsonic area ratio	A/A^*_{sub}	E	M
	Supersonic area ratio	A/A^*_{sup}	f E	M
4	Calculate one of the following:			
	Mach number		A	M
	Temperature ratio		B	T/T_0
	Pressure ratio		C	P/P_0
	Density ratio		D	ρ/ρ_0
	Area ratio (subsonic or			
	supersonic)		E	A/A^*
4′	Calculate and output all			
	values automatically.		f B	$k, M, T/T_0, P/P_0$
				ρ/ρ_0, A/A^*
5	For another calculation based			
	on same input, go to step 4			
	(or 4′). For a new input, go to			
	step 3. For a new specific heat			
	ratio, go to step 2.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	Store k-1,1/(k-1)
002	STO2	35 02	
003	1	01	
004	-	-45	
005	STO3	35 03	
006	1/X	52	
007	STO4	35 04	
008	RCL2	36 02	
009	RTN	24	Output M.
010	*LBLA	21 11	
011	F3?	16 23 03	
012	GTO0	22 00	
013	RCL1	36 01	
014	√X	54	
015	RTN	24	
016	*LBL0	21 00	
017	X^2	53	Store M^2.
018	STO1	35 01	
019	√X	54	
020	RTN	24	
021	*LBLB	21 12	
022	F3?	16 23 03	Output T/T_0.
023	GTO0	22 00	
024	2	02	
025	RCL1	36 01	
026	RCL3	36 03	
027	×	-35	
028	2	02	
029	+	-55	
030	÷	-24	
031	RTN	24	
032	*LBL0	21 00	Convert T/T_0 to M^2.
033	2	02	
034	X⇄Y	-41	
035	÷	-24	
036	2	02	
037	-	-45	
038	RCL3	36 03	
039	÷	-24	
040	STO1	35 01	
041	√X	54	
042	RTN	24	
043	*LBLC	21 13	
044	F3?	16 23 03	Output P/P_0.
045	GTO0	22 00	
046	GSBB	23 12	
047	RCL2	36 02	
048	RCL3	36 03	
049	÷	-24	
050	Y^x	31	
051	RTN	24	
052	*LBL0	21 00	
053	RCL3	36 03	Convert P/P_0 to
054	RCL2	36 02	T/T_0 and GTO B.
055	÷	-24	
056	Y^x	31	
057	SF3	16 21 03	
058	GTOB	22 12	
059	*LBLD	21 14	Output ρ/ρ_0.
060	F3?	16 23 03	
061	GTO0	22 00	
062	GSBB	23 12	
063	RCL4	36 04	
064	Y^x	31	
065	RTN	24	
066	*LBL0	21 00	
067	SF3	16 21 03	Convert ρ/ρ_0 to
068	RCL3	36 03	T/T_0 and
069	Y^x	31	GTO B.
070	GTOB	22 12	
071	*LBLE	21 15	
072	3	03	Set -3 in display
073	CHS	-22	for subsonic guess.
074	X⇄Y	-41	
075	F3?	16 23 03	
076	GTO1	22 01	
077	GTO3	22 03	
078	*LBL1	21 01	
079	ENT↑	-21	
080	STO6	35 06	Make guess of M^2.
081	FRC	16 44	
082	√X	54	
083	+	-55	
084	X⇄Y	-41	
085	Y^x	31	
086	STO1	35 01	
087	*LBL2	21 02	
088	RCL6	36 06	Iterate by Newton's
089	GSB3	23 03	method to find M^2
090	÷	-24	Corresponding to
091	1	01	A/A*.
092	-	-45	
093	.	-62	
094	5	05	
095	RCL8	36 08	
096	÷	-24	
097	.	-62	
098	5	05	
099	RCL1	36 01	
100	÷	-24	
101	-	-45	
102	÷	-24	
103	ST+1	35-55 01	
104	RCL1	36 01	
105	÷	-24	
106	ABS	16 31	
107	EEX	-23	
108	CHS	-22	
109	4	04	
110	X≤Y?	16-35	
111	GTO2	22 02	
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
113	√X	54	
114	RTN	24	
115	*LBLe	21 16 15	Set +3 in display for supersonic guess
116	3	03	
117	X⇄Y	-41	
118	F3?	16 23 03	
119	GTO1	22 01	
120	*LBL3	21 03	
121	2	02	Convert M^2 to A/A*
122	RCL2	36 02	
123	1	01	
124	+	-55	
125	÷	-24	
126	RCL3	36 03	
127	LSTX	16-63	
128	÷	-24	
129	STO7	35 07	
130	RCL1	36 01	
131	x	-35	
132	+	-55	
133	STO8	35 08	
134	RCL7	36 07	
135	2	02	
136	x	-35	
137	1/X	52	
138	Y^x	31	
139	RCL1	36 01	
140	√X	54	
141	÷	-24	
142	RTN	24	
143	*LBLb	21 16 12	Output values
144	SPC	16-11	
145	CF3	16 22 03	
146	RCL2	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 $M \to M$	B $T/T_0 \to M$	C $P/P_0 \to M$	D $\rho/\rho_0 \to M$	E $A/A^*_{sub} \to M$
a k	b →k,M,T/T_0…	c	d	e $A/A^*_{sup} \to M$
0 Used	1 M^2 guess	2 M^2 iter	3 A/A	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	Data?

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	3

Program Description I

Program Title SATURATED STEAM PROPERTIES

Contributor's Name DON R. BUNTIN

Address 345 JOHNSON DRIVE

City CASTLE ROCK **State** COLORADO **Zip Code** 80104

Program Description, Equations, Variables THE PROGRAM CALCULATES SATURATED LIQUID ENTHALPY AND SPECIFIC VOLUME, SATURATED VAPOR ENTHALPY AND SPECIFIC VOLUME AND TEMPERATURE OF SATURATED STEAM GIVEN THE ABSOLUTE PRESSURE. THE ABSOLUTE PRESSURE OF SATURATED STEAM IS CALCULATED GIVEN THE TEMPERATURE.

EQUATIONS USED ARE:

TEMPERATURE OF SATURATED STEAM (°F)

$$T = (8576.65/(15.47538 - \ln P)) - 459.216 + P(-0.023719 + P(0.84219E\text{-}4 + P(-0.70854E\text{-}7)))$$

ENTHALPY OF SATURATED LIQUID (Btu/lb.)

$$H_L = (6473.878/(14.01875 - \ln P)) - 391.6063 + 0.022915\,P$$

ENTHALPY OF SATURATED VAPOR (Btu/lb.)

$$H_V = 1142.342 + P(0.76833 + P(-0.004194 + P(0.11642E\text{-}4 + P(-0.157E\text{-}7 + P(0.8086E\text{-}11)))))$$

Operating Limits and Warnings

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Program Description I

Program Title SATURATED STEAM PROPERTIES

Contributor's Name DON R. BUNTIN

Address 345 JOHNSON DRIVE

City CASTLE ROCK **State** COLORADO **Zip Code** 80104

Program Description, Equations, Variables

SPECIFIC VOLUME OF SATURATED VAPOR (cu.ft./lb.)

$SV = (430.8419/(P+1.66)) + 0.2031 - (0.000258\ P)$

SPECIFIC VOLUME OF SATURATED LIQUID (cu.ft./lb.)

$SL = 0.01655 + P(0.150326E{-4} + P(-0.40488E{-7}$
$+ P(0.665584E{-10} + P(-0.4053E{-13}))))$

PRESSURE OF SATURATED STEAM (PSIA)
TRIAL AND ERROR METHOD BASED ON TEMPERATURE CALCULATION.

P = PSIA
LN = NATURAL LOGARITHM
E = POWER OF TEN (ie. $E{-7} = 10^{-7}$)

Operating Limits and Warnings $20\ PSIA \leq P \leq 600\ PSIA$

PRESSURE	0.90 %	MAXIMUM	ERROR
TEMPERATURE	0.18 "	"	"
LIQUID ENTHALPY	0.23 "	"	"
VAPOR ENTHALPY	0.23 "	"	"
LIQUID SPECIFIC VOLUME	0.97 "	"	"
VAPOR SPECIFIC VOLUME	0.35 "	"	"

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Program Description II

Sketch(es)

Sample Problem(s)

1) WHAT IS THE TEMPERATURE, LIQUID ENTHALPY, VAPOR ENTHALPY, SPECIFIC VOLUME OF LIQUID, AND SPECIFIC VOLUME OF VAPOR OF SATURATED STEAM AT 250 PSIA?

2) WHAT IS THE PRESSURE OF SATURATED STEAM AT A TEMPERATURE OF 300°F?

3) WHAT IS THE PRESSURE, LIQUID ENTHALPY AND VAPOR ENTHALPY OF SATURATED STEAM AT A TEMPERATURE OF 350°F?

Solution(s) KEYSTROKES:

1) 250 [A] → 250.00
[B] → 400.65°F
[C] → 376.001 Btu/lb.
[D] → 1200.774 Btu/lb.
[E] → 0.0187 cu.ft/lb.
[R/S] → 1.8506 cu.ft/lb.

2) 300 [f][A] → 66.4~~8~~7 PSIA

3) 350 [f][A] → 134.39 PSIA
[C] → 321.485 Btu/lb.
[D] → 1193.342 Btu/lb

Reference(s)

User Instructions

CARD ONE

SATURATED STEAM PROPERTIES

DATA CARD REQD.

$^\circ F \rightarrow P$				
P	$\rightarrow {}^\circ F$	$\rightarrow H_L$	$\rightarrow H_V$	$\rightarrow SL;SV$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	LOAD SIDE 1 AND SIDE TWO OF			
	PROGRAM CARD			
2	LOAD SIDE 1 AND SIDE TWO OF			
	DATA CARD			
3*	IF TEMPERATURE OF SATURATED STEAM			
	IS KNOWN; KEY IN °F AND PRESS [f][A]	°F	f A	PSIA
4	IF PRESSURE OF SATURATED STEAM			
	IS KNOWN; KEY IN PSIA AND PRESS [A]	PSIA	A	PSIA
5	TO COMPUTE THE FOLLOWING:			
	TEMPERATURE -------- PRESS [B]		B	°F
	LIQUID ENTHALPY ------ PRESS [C]		C	Btu/lb. LIQ.
	VAPOR ENTHALPY ------ PRESS [D]		D	Btu/lb. VAP.
	LIQUID SPECIFIC VOLUME -- PRESS [E]		E	cu.ft./lb. LIQ.
	& VAPOR SPECIFIC VOLUME -- THEN [R/S]		R/S	cu.ft./lb. VAP.
6	FOR NEW CASE GO TO STEP 3			
	*THIS STEP SHOULD BE OMITTED IF			
	THE PRESSURE IS KNOWN.			
	NOTE: STORAGE REGISTERS A, B, C,			
	P_0, P_1, P_2, S_0, S_1, AND S_2 ARE FREE			
	FOR USER USE.			

CARD TWO

SATURATED STEAM PROPERTIES

DATA CARD

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001 *	g LBL A	32-25-11	
002	STO D	33-14	
003	DSP 2	23-02	
004	2	02	
005	0	00	
006	0	00	
007	f LBL 1	31-25-01	
008	STO E	33-15	
009	f GSB B	31-22-12	
010	h ST I	35-33	
011	RCL D	34-14	
012	−	51	
013	h ABS	35-64	
014	.	83	
015	0	00	
016	0	00	
017	5	05	
018	g x>y	32-81	
019	GTO 2	22-02	
020	RCL E	34-15	
021	h RC I	35-34	
022	RCL D	34-14	
023	÷	81	
024	4	04	
025	.	83	
026	5	05	
027	6	06	
028	h y^x	35-63	
029	÷	81	
030	GTO 1	22-01	
031	f LBL 2	31-25-02	
032	RCL E	34-15	
033	h RTN	35-22	
034 *	f LBL A	31-25-11	
035	STO E	33-15	
036	DSP 2	23-02	
037	h RTN	35-22	
038 *	f LBL B	31-25-12	
039	f GSB 3	31-22-03	
040	f P⇄S	31-42	
041	8	08	
042	5	05	
043	7	07	
044	6	06	
045	.	83	
046	6	06	
047	5	05	
048	RCL 3	34-03	
049	RCL E	34-15	
050	f LN	31-52	
051	−	51	
052	÷	81	
053	4	04	
054	5	05	
055	9	09	
056	.	83	
057	2	02	
058	1	01	
059	6	06	
060	−	51	
061	RCL E	34-15	
062	.	83	
063	0	00	
064	2	02	
065	3	03	
066	7	07	
067	2	02	
068	×	71	
069	−	51	
070	RCL E	34-15	
071	g x^2	32-54	
072	RCL 4	34-04	
073	×	71	
074	+	61	
075	RCL E	34-15	
076	3	03	
077	h y^x	35-63	
078	RCL 5	34-05	
079	×	71	
080	−	51	
081	f P⇄S	31-42	
082	h RTN	35-22	
083 *	f LBL C	31-25-13	
084	DSP 3	23-03	
085	f GSB 3	31-22-03	
086	RCL 3	34-03	
087	RCL 4	34-04	
088	RCL E	34-15	
089	f LN	31-52	
090	−	51	
091	÷	81	
092	RCL 5	34-05	
093	−	51	
094	RCL E	34-15	
095	.	83	
096	0	00	
097	2	02	
098	2	02	
099	9	09	
100	1	01	
101	5	05	
102	×	71	
103	+	61	
104	h RTN	35-22	
105 *	f LBL D	31-25-14	
106	DSP 3	23-03	
107	f GSB 3	31-22-03	
108	RCL E	34-15	
109	5	05	
110	h y^x	35-63	
111	RCL 8	34-08	
112	×	71	

REGISTERS

0	1	2	3	4	5	6	7	8	9
			6473.878	14.01875	391.6036	1142.342	.1642E-4	.8086E-11	430.8419

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
			15.47538	.8422 E-4	.7085 E-7	.150326E-4	.40488 E-7	.665584E-10	.4053 E-13

A	B	C	D	E	I
			T INPUT OR SPEC. VOL. VAP.	PSIA OR PSIA TRIAL	T CALCULATED

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	RCL E	34-15	
114	4	04	
115	h Y^x	35-63	
116	.	83	
117	1	01	
118	5	05	
119	7	07	
120	EEX	43	
121	CHS	42	
122	7	07	
123	X	71	
124	−	51	
125	RCL E	34-15	
126	3	03	
127	h Y^x	35-63	
128	RCL 7	34-07	
129	X	71	
130	+	61	
131	RCL E	34-15	
132	g x^2	32-54	
133	.	83	
134	0	00	
135	0	00	
136	4	04	
137	1	01	
138	9	09	
139	4	04	
140	X	71	
141	−	51	
142	RCL E	34-15	
143	.	83	
144	7	07	
145	6	06	
146	8	08	
147	3	03	
148	3	03	
149	X	71	
150	+	61	
151	RCL 6	34-06	
152	+	61	
153	h RTN	35-22	
154 *	f LBL E	31-25-15	
155	DSP 4	23-04	
156	f GSB 3	31-22-03	
157	RCL 9	34-09	
158	RCL E	34-15	
159	1	01	
160	.	83	
161	6	06	
162	6	06	
163	+	61	
164	÷	81	
165	.	83	
166	2	02	
167	0	00	
168	3	03	

STEP	KEY ENTRY	KEY CODE	COMMENTS
169	1	01	
170	+	61	
171	RCL E	34-15	
172	2	02	
173	5	05	
174	8	08	
175	EEX	43	
176	CHS	42	
177	6	06	
178	X	71	
179	−	51	
180	STO D	33-14	
181	RCL E	34-15	
182	f P⇄S	31-42	
183	3	03	
184	h Y^x	35-63	
185	RCL 8	34-08	
186	X	71	
187	RCL E	34-15	
188	4	04	
189	h Y^x	35-63	
190	RCL 9	34-09	
191	X	71	
192	−	51	
193	RCL E	34-15	
194	g x^2	32-54	
195	RCL 7	34-07	
196	X	71	
197	−	51	
198	RCL E	34-15	
199	RCL 6	34-06	
200	X	71	
201	+	61	
202	.	83	
203	0	00	
204	1	01	
205	6	06	
206	5	05	
207	5	05	
208	+	61	
209	f P⇄S	31-42	
210	R/S	84	
211	RCL D	34-14	
212	h RTN	35-22	
213 *	f LBL 3	31-25-03	
214	1	01	
215	RCL 4	34-04	
216	g $x>y$	32-81	
217	h RTN	35-22	
218	f P⇄S	31-42	
219	h RTN	35-22	
220			

LABELS

A P	B →°F	C → H_L	D → H_V	E → SL; SV
a °F → P	b	c	d	e
0	1 CONVERGENCE LOOP	2 DISPLAY P	3 REGISTER PLACEMENT	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2,3,4

Program Description I

Program Title CONDUIT FLOW

Contributor's Name HEWLETT-PACKARD

Address 1000 N. E. Circle Blvd.

City Corvallis, **State** Oregon 97330

Program Description

This program solves for the average velocity, or the pressure drop for viscous, incompressible flow in conduits.

Equations:

$$v^2 = \frac{\Delta P/\rho}{2\left(f\frac{L}{D} + \frac{K_T}{4}\right)}$$

For laminar flow (Re < 2300)

$$f = 16/Re$$

For turbulent flow (Re > 2300)

$$\frac{1}{\sqrt{f}} = 1.737 \ln\frac{D}{\epsilon} + 2.28 - 1.737 \ln\left(4.67\frac{D}{\epsilon\, Re \sqrt{f}} + 1\right)$$

is solved by Newton's method.

$$\frac{1}{\sqrt{f_0}} = 1.737 \ln\frac{D}{\epsilon} + 2.28$$

is used as an initial guess in the iteration.

where:

Re is the Reynolds number, defined as $\rho Dv/\mu$;

D is the pipe diameter;

ϵ is the dimension of irregularities in the conduit surface (see table 2);

f is the Fanning friction factor for conduit flow;

ΔP is the pressure drop along the conduit;

ρ is the density of the fluid;

μ is the viscosity of the fluid;

ν is the kinematic viscosity of the fluid;

L is the conduit length;

v is the average fluid velocity;

K_T is the total of the applicable fitting coefficients in table 1.

Operating Limits and Warnings

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Program Description I

Program Title

Contributor's Name

Address

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Program Descriptic

Table 1
Fitting Coefficients

Fitting	K
Glove valve, wide open	7.5—10
Angle valve, wide open	3.8
Gate valve, wide open	0.15—0.19
Gate valve, ¾ open	0.85
Gate valve, ½ open	4.4
Gate valve, ¼ open	20
90° elbow	0.4—0.9
Standard 45° elbow	0.35—0.42
Tee, through side outlet	1.5
Tee, straight through	.4
180° bend	1.6
Entrance to circular pipe	0.25—0.50
Sudden expansion	$(1 - A_{up}/A_{dn})^2$*
Acceleration from $v = 0$ to $v = v_{entrance}$	1.0

*A_{up} is the upstream area and A_{dn} is the downstream area.

Table 2
Surface Irregularities

Material	ϵ (feet)	ϵ (meters)
Drawn or Smooth Tubing	5.0×10^{-6}	1.5×10^{-6}
Commercial Steel or Wrought Iron	1.5×10^{-4}	4.6×10^{-5}
Asphalted Cast Iron	4.0×10^{-4}	1.2×10^{-4}
Galvanized Iron	5.0×10^{-4}	1.5×10^{-4}
Cast Iron	8.3×10^{-4}	2.5×10^{-4}
Wood Stave	6.0×10^{-4} to 3.0×10^{-3}	1.8×10^{-4} to 9.1×10^{-4}
Concrete	1.0×10^{-3} to 1.0×10^{-2}	3.0×10^{-4} to 3.0×10^{-3}
Riveted Steel	3.0×10^{-3} to 3.0×10^{-2}	9.1×10^{-4} to 9.1×10^{-3}

Operating Limits a

Reference:

Welty, Wicks, Wilson; *Fundamentals of Momentum, Heat and Mass Transfer*, John Wiley and Sons, Inc., 1969.

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Program Description I

Program Title

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Address

City **State** **Zip Code**

Program Description, Equations, Variables

Remarks:

The correlation gives meaningless results in the region $2300 < Re < 4000$.

The solution requires an iterative procedure. The time for solution will range from 10 seconds for ΔP, to several minutes for v. The display setting is used to determine when the solution for v is adequately accurate. Time for solution of v is roughly proportional to the number or significant digits in the display setting.

If the conduit is not circular, an equivalent diameter may be calculated using the formula below:

$$D_{eq} = 4\frac{\text{cross sectional area}}{\text{wetted perimeter}}$$

Unitary consistency must be maintained with the exception of the pressure drop ΔP. If all length units are feet, time is measured in seconds and mass is given in pounds, pressure may be input or output in pounds per square inch, using the **f** **E** keys.

Operating Limits and Warnings

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Program Description II

Sketch(es)

Sample Problem

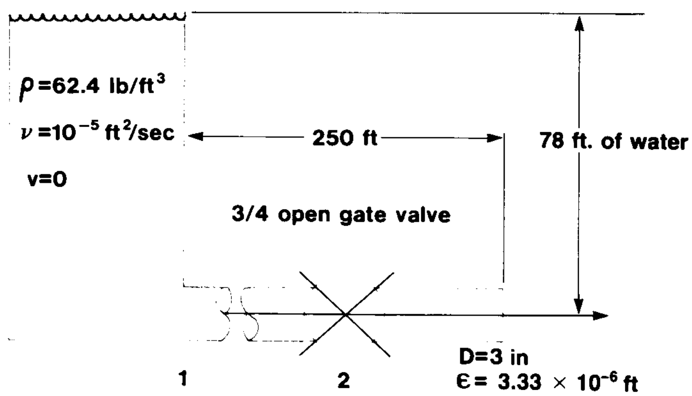
Example 1:

A heat exchanger has 20, 3 meter tube passes (60 m of pipe) with 180 degree bends connecting each pair of tubes (from table 1, $K_T = 10 \times 1.6$). The fluid is water ($\nu = 9.3 \times 10^{-7}$ m²/s, $\rho = 10^3$ kg/m³). The surface roughness is 3×10^{-4} m and the diameter is 2.54×10^{-2} m. If the fluid velocity is 3.05 m/s, what is the pressure loss? What is the Reynolds number? What is the Fanning friction factor?

Keystrokes:	Outputs:	
9.3 EEX CHS 7 f B EEX 3		
f C 3 EEX CHS 4 f D 60		
A 2.54 EEX CHS 2 B 16 C		
3.05 D E ⟶	522. 03	(ΔP, N/m²)
R↓ ⟶	83.3 03	(Re)
R↓ ⟶	10.2–03	(f)

Example 2:

For the system shown, what is the volume flow rate?



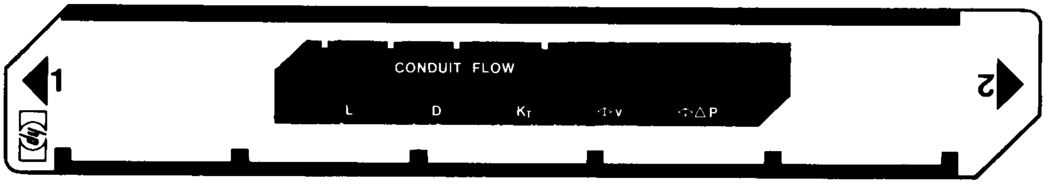
$$K_T = K_0 + K_1 + K_2$$
$$= 1 + .4 + 0.85 = 2.25$$

Solution(s)

Keystrokes:	Outputs:	
First calculate and store ΔP in psi from the given data.		
78 ENTER↑ 62.4 × 144 ÷		
f E ⟶	157. 03	(ΔP, psi)
Now store the other values.		
EEX CHS 5 f B 62.4 f		
C 3.33 EEX CHS 6 f D 250		
A 3 ENTER↑ 12 ÷ B 2.25		
C D ⟶	17.8 00	(v, ft/sec)
Calculate volume flow rate (v × Area).		
1.5 ENTER↑ 12 ÷ ENTER↑		
× π × × ⟶	873.–03	(ft³/sec)
What will the height of the water be when the velocity is 15 ft/sec?		
15 D f E ⟶	24.7 00	(ΔP, psi)
144 × 62.4 ÷ ⟶	57.0 00	(ft)

Reference(s)

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input the following in any order			
	(units must be consistent):			
	Viscosity of fluid	μ	f A	
	or			
	Kinematic viscosity of fluid	ν	f B	ν
	Density	ρ	f C	ρ
	Surface irregularity	ϵ	f D	ϵ
	Length of conduit	L	A	L
	Equivalent diameter of			
	passage	D	B	D
	Total fitting coefficient	K_T	C	$K_T/4$
3	Input one of the following:			
	Fluid velocity	v	D	v
	Pressure drop in compatible			
	units	ΔP	E	ΔP
	or			
	Pressure drop in psi	ΔP(psi)	f E	144gΔP
4	Calculate one of the following:			
	Fluid velocity		D	v
	Pressure drop in compatible			
	units		E	ΔP
	or			
	Pressure drop in psi		f E	ΔP(psi)
5	Optional: After calculation of			
	ΔP or v, display Reynolds			
	number		R↓	Re
	and Fanning friction factor.		R↓	f
6	For a new case, go to step 2 or			
	step 3 and change appropriate			
	inputs.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	Set divide by ρ flag
002	SF2	16 21 02	
003	GTO0	22 00	
004	*LBLb	21 16 12	Clear divide by ρ flag
005	CF2	16 22 02	
006	*LBL0	21 00	
007	STO9	35 09	Store μ or ν
008	GTO0	22 00	
009	*LBLc	21 16 13	Store ρ
010	STOA	35 11	
011	GTO0	22 00	
012	*LBLd	21 16 14	Store e
013	STOE	35 15	
014	GTO0	22 00	
015	*LBLA	21 11	Store L
016	STO3	35 03	
017	GTO0	22 00	
018	*LBLB	21 12	Store D
019	STOD	35 14	
020	GTO0	22 00	
021	*LBLC	21 13	Store $K_T/4$
022	4	04	
023	÷	-24	
024	STO8	35 08	
025	*LBL0	21 00	
026	CF3	16 22 03	Clean data input flag
027	RTN	24	
028	*LBLe	21 16 15	
029	4	04	
030	6	06	Convert input psi to lb/ft-sec and store
031	3	03	
032	2	02	
033	x	-35	
034	STO4	35 04	
035	F3?	16 23 03	
036	RTN	24	
037	GSBE	23 15	Convert lb/ft-sec^2 to psi and display
038	4	04	
039	6	06	
040	3	03	
041	2	02	
042	÷	-24	
043	RTN	24	
044	*LBLE	21 15	
045	STO4	35 04	Store pressure
046	F3?	16 23 03	
047	RTN	24	
048	CF0	16 22 00	
049	GSB9	23 09	Compute pressure drop
050	RCL2	36 02	
051	X²	53	
052	x	-35	
053	RCLA	36 11	
054	x	-35	
055	STO4	35 04	
056	RCL5	36 05	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	1/X	52	Set f and Re in Display
058	X²	53	
059	RCL1	36 01	
060	RCL4	36 04	
061	RTN	24	
062	*LBLD	21 14	Store velocity
063	STO2	35 02	
064	F3?	16 23 03	
065	RTN	24	
066	SF0	16 21 00	Guess v.
067	GSB9	23 09	
068	*LBL3	21 03	Iterate to find v
069	RND	16 24	
070	STO0	35 00	
071	GSB8	23 08	
072	RND	16 24	
073	RCL0	36 00	
074	X⇄Y	-41	
075	X≠Y?	16-32	
076	GTO3	22 03	Set f, Re and v in display
077	RCL5	36 05	
078	1/X	52	
079	X²	53	
080	RCL1	36 01	
081	RCL2	36 02	
082	RTN	24	
083	*LBL9	21 09	Calculate constants
084	RCLA	36 11	
085	F2?	16 23 02	
086	ST÷9	35-24 09	
087	RCLD	36 14	
088	RCLE	36 15	
089	÷	-24	
090	STO6	35 06	
091	LN	32	
092	1	01	
093	.	-62	
094	7	07	
095	3	03	
096	7	07	
097	STO7	35 07	
098	x	-35	
099	2	02	
100	.	-62	
101	2	02	
102	8	08	
103	+	-55	
104	STOC	35 13	
105	STO5	35 05	
106	F0?	16 23 00	
107	GTO7	22 07	
108	*LBL8	21 08	
109	1	01	Is flow turbulent?
110	6	06	
111	RCL2	36 02	
112	RCLD	36 14	

REGISTERS

0	1	2	3	4	5	6	7	8	9
v	Re	v	L	ΔP	$1/\sqrt{f}$	D/ε	1.737	$K_T/4$	ν,μ

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
ρ	Used	$1/\sqrt{f_o}$	D	ε	

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	x	-35	
114	RCL9	36 09	
115	÷	-24	
116	STO1	35 01	
117	2	02	
118	3	03	
119	0	00	
120	0	00	
121	X≤Y?	16-35	
122	GTO2	22 02	
123	R↓	-31	
124	÷	-24	
125	√X	54	
126	1/X	52	
127	GTO7	22 07	
128	*LBL2	21 02	
129	RCLC	36 13	Iterate to find $\frac{1}{\sqrt{f}}$ for turbulent flow
130	RCL5	36 05	
131	-	-45	
132	4	04	
133	.	-62	
134	6	06	
135	7	07	
136	RCL6	36 06	
137	x	-35	
138	RCL1	36 01	
139	÷	-24	
140	RCL5	36 05	
141	x	-35	
142	1	01	
143	+	-55	
144	STOB	35 12	
145	LN	32	
146	RCL7	36 07	
147	x	-35	
148	-	-45	
149	RCLB	36 12	
150	1/X	52	
151	CHS	-22	
152	1	01	
153	+	-55	
154	RCL7	36 07	
155	x	-35	
156	RCL5	36 05	
157	÷	-24	
158	1	01	
159	+	-55	
160	÷	-24	
161	ST+5	35-55 05	
162	RCL5	36 05	
163	÷	-24	
164	ABS	16 31	
165	EEX	-23	
166	CHS	-22	
167	3	03	
168	X≤Y?	16-35	

STEP	KEY ENTRY	KEY CODE	COMMENTS
169	GTO2	22 02	
170	*LBL7	21 07	
171	RCL5	36 05	Start calculation of ΔP or v
172	1/X	52	
173	X²	53	
174	RCL3	36 03	
175	x	-35	
176	RCLD	36 14	
177	÷	-24	
178	RCL8	36 08	
179	+	-55	
180	2	02	
181	x	-35	
182	RCL4	36 04	
183	RCLA	36 11	
184	÷	-24	
185	X⇄Y	-41	
186	F0?	16 23 00	
187	GTO0	22 00	
188	RTN	24	
189	*LBL0	21 00	Finish v calculation
190	÷	-24	
191	√X	54	
192	STO2	35 02	
193	RTN	24	
200			
210			
220			

LABELS

A L	B B	C K_T	D v	E ΔP
a μ	b ν	c ρ	d ε	e ΔP
0 Used	1	2 iter-$1/\sqrt{f}$	3 iter-v	4
5	6	7 calc.	8 turb?	9 → f

FLAGS

0	v calc.
1	
2	divide
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	2

Program Description I

Program Title **PARALLEL & COUNTER FLOW HEAT EXCHANGERS**

Contributc
Address HEWLETT-PACKARD
1000 N. E. Circle Blvd.
Corvallis, Oregon 97330
City **itate** **Zip Code**

Program Description, Equations, Variables

This two card set allows analysis of counter-flow, parallel-flow, parallel-counter flow, and cross-flow (both fluids unmixed) heat exchanges.

The program is organized in four segments. The first side of card 1 performs heat balance calculations and acts as controller for the three slave program segments. Slave program segment one, on side 2 of card 1, is applicable to parallel-flow and counter-flow heat exchanges. Counter-flow is selected by pressing f E until 1.00 appears. Parallel-flow is selected by pressing f E until 0.00 appears.

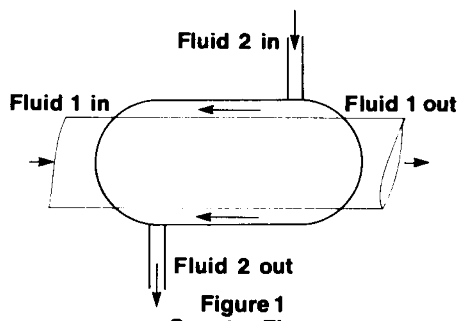


Figure 1
Counter-Flow

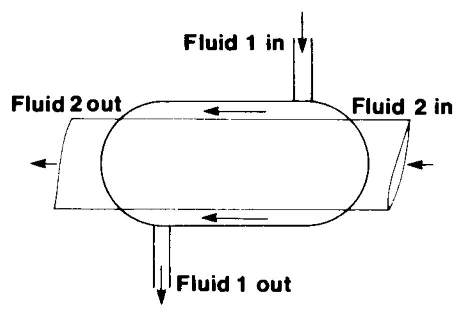


Figure 2
Parallel-Flow

Operating Limits ai

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Program Description I

Program Title

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Address

City

Program Description

Operating Limits an

The slave segment for **parallel-counter-flow** configuration (with an even number of tube passes) is on side 1 of card 2.

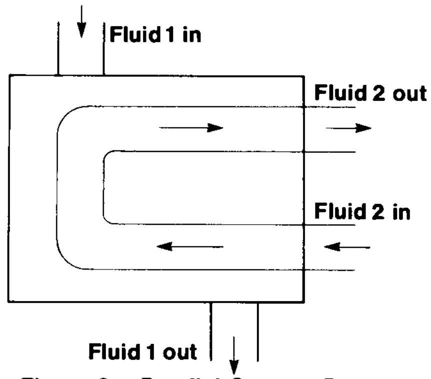

Figure 3 Parallel-Counter-Flow (Even Number Of Tube Passes)

The slave segment for **cross-flow** (with both fluids unmixed) is on side 2 of card 2.

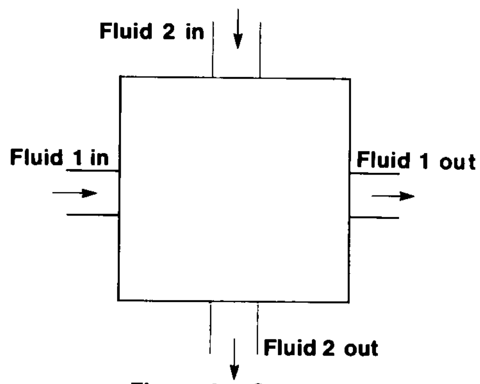

Figure 4 Cross Flow (Both Fluids Unmixed)

Equations:

Heat exchanger effectiveness E is the ratio of actual heat transfer to maximum possible heat transfer.

$$E = \frac{q}{C_{min}\,(T_{hin} - T_{cin})} = \frac{C_h\,(T_{hin} - T_{ho})}{C_{min}\,(T_{hin} - T_{cin})} = \frac{C_c\,(T_{co} - T_{cin})}{C_{min}\,(T_{hin} - T_{cin})}$$

where:

- q is the actual heat transfer;
- T_{hin} and T_{cin} are the inlet temperatures of the hot and cold fluids, respectively;
- T_{ho} and T_{co} are the outlet temperatures of the hot and cold fluids, respectively;
- C_h and C_c are the heat capacities of the hot and cold fluids, respectively, e.g., $C_h = m_h \times c_{ph}$, where m_h is the flow rate and c_{ph} is the specific heat capacity of the hot fluid;
- C_{min} and C_{max} (which are used later) are the smaller and larger values of C_h and C_c.

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Program Description I

Program Title

Contributor's Name

Address

City

Program Descriptioı

Effectiveness can be related to the product of the surface area of an exchanger and the overall transfer coefficient for specific geometries. This product is designated AU. The geometries considered in this pac have the following correlations:

Counter-Flow (See figure 1)

$$E = \frac{1 - e^{-\frac{AU}{C_{min}}\left(1 - \frac{C_{min}}{C_{max}}\right)}}{1 - (C_{min}/C_{max})\, e^{-\frac{AU}{C_{min}}\left(1 - \frac{C_{min}}{C_{max}}\right)}}$$

For $C_{min}/C_{max} = 1$

$$E = \frac{AU/C_{min}}{1 + AU/C_{min}}$$

Parallel-Flow (See figure 2)

$$E = \frac{1 - e^{-\frac{AU}{C_{min}}(1 + C_{min}/C_{max})}}{1 + C_{min}/C_{max}}$$

For $C_{min}/C_{max} = 0$, C_{min} is set to 1.

Parallel-Counter-Flow; Shell Mixed with an Even Number of Tube Passes (See figure 3)

$$E = \frac{2}{\left(1 + \frac{C_{min}}{C_{max}}\right) + \sqrt{1 + \left(\frac{C_{min}}{C_{max}}\right)^2}\left[\frac{1 + e^{-x}}{1 - e^{-x}}\right]}$$

where:

$$x = \frac{AU}{C_{min}}\sqrt{1 + \left(\frac{C_{min}}{C_{max}}\right)^2}$$

Cross-Flow; Both Fluids Unmixed (See figure 4)

No exact expression exists for this case, but the following is a very good approximation. Note that it cannot be stated explicitly in terms of AU and thus requires an iterative solution.

$$E = 1 - e^{\left(e^{\left(-\frac{AU}{C_{min}}\frac{C_{min}}{C_{max}}y\right)} - 1\right)\left(\frac{C_{max}}{C_{min}}\frac{1}{y}\right)}$$

Operating Limits and

where:

$$y = \left[\frac{C_{min}}{AU}\right]^{0.22}$$

References:

W.M. Kays and A.L. London, *Compact Heat Exchangers,* National Press, 1955.

Eckert and Drake, *Heat and Mass Transfer,* McGraw-Hill.

Remarks:

Registers R_{S0}-R_{S9}, R_C, R_E, and R_I are available for user storage.

Solution for AU, using the cross-flow slave card takes significantly longer than other solutions because of the iterative technique required.

You should always solve for all values (AU, q, T_{co}, T_{ho} and E). It is quite possible for the heat balance equations to yield meaningless solutions for a particular type of heat exchange. By calculating all results, you are assured that the configuration being used is capable of the performance specified. An error message during calculation of AU or q usually indicates a violation of the second law of thermodynamics.

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Program Description II

Sketch(es)

Sample Problem(s)

Solution(s)

Reference(s)

Example 1:

Water (c_p = 1 Btu/lb- °F) is used to cool an oil (c_p = .53 Btu/lb- °F) from 200°F to 110°F. The water flow rate is 20,000 pounds per hour while the oil flows at 37,000 pounds per hour. If the water inlet temperature is 55°F and U is 25 Btu/ft²-hr-°F for the heat exchangers being considered, what are the area requirements for counter-flow, parallel-flow, parallel-counter-flow and cross-flow?

Knowns:

c_{pc} = 1.0 Btu/lb-°F

$\dot{m}_c$ = 20,000 lb/hr

c_{ph} = 0.53 Btu/lb-°F

$\dot{m}_h$ = 37,000 lb/hr

T_{cin} = 55°F

T_{hin} = 200°F

T_{ho} = 110°F

U = 25 Btu/ft²-hr-°F

Keystrokes:	Outputs:	
Load side 1 and side 2 of card 1 and select counter-flow mode.		
55 f A 20000 ENTER↑ 1		
f B 200 f C 37000 ENTER↑		
.53 f D f E →	1.00	(Counter-flow mode on)
110 E →	0.62	(Effectiveness)
Since effectiveness is the same for all configurations, store it for later use.		
STO I →	0.62	
Calculate AU.		
A →	31587.76	(AU)
25 ÷ →	1263.51	(ft²)
Switch to parallel configuration.		
f E →	0.00	(parallel selected)
RCL I →	0.62	
A →	Error	(Violation of second law)
CL X →	-0.23	
Load parallel-counter flow configuration on side 1 of card 2 and clear display of "Crd."		
CL X →	-0.23	
RCL I A →	Error	(Violation of second law)
CL X →	-0.06	
Load cross-flow configuration on side 2 of card 2 and clear display of "Crd".		
CL X RCL I A →	39383.22	(AU)
25 ÷ →	1575.33	(ft²)

(Do not alter storage registers if you intend to continue with example 2.)

Program Description II

Sketch(es)

Sample Problem(s)

Example 2:

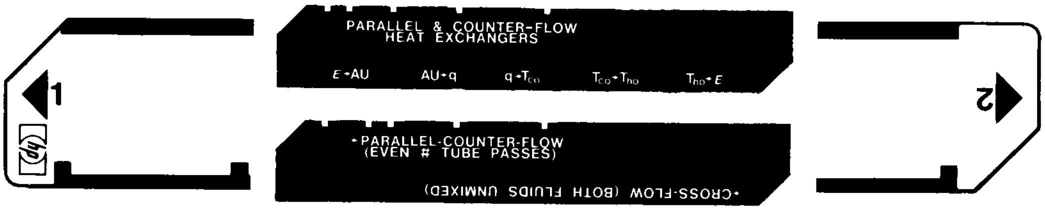
If a counter flow exchanger with an area of 1000 ft^2 and an overall heat transfer coefficient of 27 Btu/ft^2-hr-°F is available, how close will the outlet temperature of the oil be to 110°F? What will the total heat transfer and outlet water temperature be? All unspecified values remain the same as example 1.

Keystrokes:	**Outputs:**	
Load counter-flow routine on side 2 of card 1 and select counter flow mode.		
CL X f E ⟶	1.00	
Calculate AU product and calculate q.		
27 ENTER↑ 1000 × ⟶	27000.00	(AU)
B ⟶	1656452.69	(q, Btu/hr)
C ⟶	137.82	(T_{co})
D ⟶	115.53	(T_{ho})
E ⟶	0.58	(E)

Solution(s)

Reference(s)

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 of card 1.			
2	Select proper configuration card and side, and load:			
	a. Parallel or counter-flow exchangers→card 1, side 2.			
	b. Parallel-counter-flow (even number of tube passes)→card 2, side 1.			
	c. Cross-flow (both fluids unmixed→card 2, side 2.			
3	If display says "Crd" press [CLX].		[CLX]	0.00
4	If you loaded parallel/counter-flow configurations in step 2, select counter flow (1) or parallel-flow (0) using mode toggle.		[f] [E]	1.00/0.00
5	Input the following values			
	Cold fluid inlet temperature	T_{cin}	[f] [A]	T_{cin}
	Cold fluid density flow rate	$\dot{m}_c$	[ENTER↑]	m_c
	then			
	Cold fluid heat capacity	c_{pc}	[f] [B]	C_c
	and			
	Hot fluid inlet temperature	T_{hin}	[f] [C]	T_{hin}
	Hot fluid density flow rate	$\dot{m}_h$	[ENTER↑]	m_h
	then			
	Hot fluid heat capacity	c_{ph}	[f] [D]	C_h
6	If the remaining known is effectiveness, go to step 7. If area-conductance product, go to step 8. If heat transfer, go to step 9. If cold fluid outlet temperature, go to step 10. If hot fluid outlet temperature, go to step 11.			

User Instructions

STEP	INSTRUCTIONS			OUTPUT DATA/UNITS
7	With effectiveness displayed, calculate area-conductance product.	E	A	AU
8	With area-conductance product displayed, calculate heat transfer.	AU	B	q
9	With heat transfer displayed, calculate cold fluid outlet temperature.	q	C	T_{co}
10	With cold fluid outlet temperature displayed, calculate hot fluid outlet temperature.	T_{co}	D	T_{ho}
11	With hot fluid outlet temperature displayed, calculate effectiveness.	T_{ho}	E	E
12	Go back to step 6 and complete calculation of all outputs.			
13	For a new configuration, go to step 2. It is not necessary to repeat the input process if values remain unchanged.			
14	For new input values, go to step 5 and change appropriate variables.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	Store T_{cin}
002	STO2	35 02	
003	RTN	24	
004	*LBLb	21 16 12	Store C_c
005	x	-35	
006	STO3	35 03	
007	RTN	24	
008	*LBLc	21 16 13	Store T_{hin}
009	STO1	35 01	
010	RTN	24	
011	*LBLd	21 16 14	Store C_h
012	x	-35	
013	STO4	35 04	
014	RTN	24	
015	*LBLe	21 16 15	Clear flag 1 for counter flow, set for parallel flow
016	F1?	16 23 01	
017	GTO0	22 00	
018	0	00	
019	SF1	16 21 01	
020	RTN	24	
021	*LBL0	21 00	
022	1	01	
023	CF1	16 22 01	
024	RTN	24	
025	*LBLA	21 11	Calculate AU from E
026	STO5	35 05	
027	GSB1	23 01	
028	GSB0	23 00	
029	STO8	35 08	
030	RTN	24	
031	*LBLB	21 12	Calculate q from AU
032	STO8	35 08	
033	GSB1	23 01	
034	GSB2	23 02	
035	RCL7	36 07	
036	x	-35	
037	RCL1	36 01	
038	RCL2	36 02	
039	-	-45	
040	x	-35	
041	STO6	35 06	
042	RTN	24	
043	*LBLC	21 13	Calculate T_{co} from q
044	STO6	35 06	
045	RCL3	36 03	
046	÷	-24	
047	RCL2	36 02	
048	+	-55	
049	RTN	24	
050	*LBLD	21 14	Calculate T_{ho} from T_{co}
051	RCL2	36 02	
052	-	-45	
053	RCL3	36 03	
054	x	-35	
055	RCL4	36 04	
056	÷	-24	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	RCL1	36 01	
058	-	-45	
059	CHS	-22	
060	RTN	24	
061	*LBLE	21 15	Calculate E from T_{co}
062	STO5	35 05	
063	GSB1	23 01	
064	RCL4	36 04	
065	RCL7	36 07	
066	÷	-24	
067	RCL1	36 01	
068	RCL5	36 05	
069	-	-45	
070	x	-35	
071	RCL1	36 01	
072	RCL2	36 02	
073	-	-45	
074	÷	-24	
075	STO5	35 05	
076	RTN	24	
077	*LBL0	21 00	Calculate AU for C_{min}/C_{max} = 0
078	X≠0?	16-42	
079	GTO0	22 00	
080	1	01	
081	RCL5	36 05	
082	-	-45	
083	LN	32	
084	CHS	-22	
085	RTN	24	
086	*LBL2	21 02	Calculate E for C_{min}/C_{max} = 0
087	X≠0?	16-42	
088	GTO2	22 02	
089	1	01	
090	RCL8	36 08	
091	CHS	-22	
092	e^x	33	
093	-	-45	
094	RTN	24	
095	*LBL1	21 01	Store C_{min} and C_{min}/C_{max}
096	RCL3	36 03	
097	RCL4	36 04	
098	X>Y?	16-34	
099	X⇄Y	-41	
100	STO7	35 07	
101	X⇄Y	-41	
102	÷	-24	
103	STO0	35 00	
104	RTN	24	
110			

REGISTERS

0	1	2	3	4	5	6	7	8	9
C_{min}/C_{max}	T_{hin}	T_{cin}	C_c	C_h	E	q	C_{min}	AU	C_{max}
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	*LBL0	21 00	
114	F1?	16 23 01	Counter-flow AU calculations
115	GTO8	22 08	
116	RCL5	36 05	
117	1/X	52	
118	-	-45	
119	1	01	
120	LSTX	16-63	
121	-	-45	
122	÷	-24	
123	LN	32	
124	1	01	
125	RCL0	36 00	
126	-	-45	
127	X=0?	16-43	
128	GTO7	22 07	
129	÷	-24	
130	RCL7	36 07	
131	x	-35	
132	RTN	24	
133	*LBL7	21 07	
134	RCL5	36 05	Counter-flow for $C_{min}/C_{max} = 1$
135	1	01	
136	RCL5	36 05	
137	-	-45	
138	÷	-24	
139	RCL7	36 07	
140	x	-35	
141	RTN	24	
142	*LBL8	21 08	
143	RCL0	36 00	Parallel-flow AU calculation
144	1	01	
145	+	-55	
146	RCL5	36 05	
147	x	-35	
148	CHS	-22	
149	1	01	
150	+	-55	
151	LN	32	
152	CHS	-22	
153	1	01	
154	RCL0	36 00	
155	+	-55	
156	÷	-24	
157	RCL7	36 07	
158	x	-35	
159	RTN	24	
160	*LBL2	21 02	
161	F1?	16 23 01	Counter flow E calculation
162	GTO8	22 08	
163	1	01	
164	-	-45	
165	RCL8	36 08	
166	RCL7	36 07	
167	÷	-24	
168	x	-35	
169	e^x	33	
170	1	01	
171	X⇄Y	-41	
172	-	-45	
173	LSTX	16-63	
174	RCL0	36 00	
175	x	-35	
176	1	01	
177	X⇄Y	-41	
178	-	-45	
179	X=0?	16-43	
180	GTO9	22 09	
181	÷	-24	
182	RTN	24	
183	*LBL9	21 09	Counter-flow E calculation where $C_{min}/C_{max} = 1$
184	RCL8	36 08	
185	RCL7	36 07	
186	÷	-24	
187	ENT↑	-21	
188	ENT↑	-21	
189	1	01	
190	+	-55	
191	÷	-24	
192	RTN	24	
193	*LBL8	21 08	Parallel-flow E calculation
194	1	01	
195	+	-55	
196	RCL8	36 08	
197	RCL7	36 07	
198	÷	-24	
199	x	-35	
200	CHS	-22	
201	e^x	33	
202	CHS	-22	
203	1	01	
204	+	-55	
205	1	01	
206	RCL0	36 00	
207	+	-55	
208	÷	-24	
209	RTN	24	
210			
220			

LABELS

A $E \rightarrow AU$	B $AU \rightarrow q$	C $q \rightarrow T_{\infty}$	D $T_{\infty} \rightarrow T_{ho}$	E $T_{ho} \rightarrow E$
a T_{cin}	b $m_c{\dagger}c_{pc}$	c T_{hin}	d $m_h{\dagger}c_{ph}$	e CNT?
0 $E \rightarrow AU$	1 C_{min}	2 $AU \rightarrow E$	3	4
5	6	7 $C_{min}/C_{max} = 1$	8 parallel	9 $C_{min}/C_{max} = 1$

FLAGS

0	
1	CNT?
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

Parallel-Counter-Flow

97 Program Listing I

Card 2, side 1

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	*LBL0	21 00	
114	GSB6	23 06	
115	2	02	
116	×	-35	
117	RCL6	36 06	
118	2	02	
119	RCL5	36 05	
120	÷	-24	
121	+	-55	
122	RCL9	36 09	
123	-	-45	
124	÷	-24	
125	CHS	-22	
126	1	01	
127	+	-55	
128	LN	32	
129	RCL6	36 06	
130	÷	-24	
131	CHS	-22	
132	RCL7	36 07	
133	÷	-24	
134	LSTX	16-63	
135	ENT↑	-21	
136	×	-35	
137	×	-35	
138	RTN	24	
139	*LBL2	21 02	Calculate E for parallel-counter-flow
140	GSB6	23 06	
141	RCL8	36 08	
142	RCL7	36 07	
143	÷	-24	
144	RCL6	36 06	
145	×	-35	
146	CHS	-22	
147	e^x	33	
148	1	01	
149	X⇄Y	-41	
150	+	-55	
151	1	01	
152	LSTX	16-63	
153	-	-45	
154	÷	-24	
155	RCL6	36 06	
156	×	-35	
157	RCL9	36 09	
158	+	-55	
159	2	02	
160	X⇄Y	-41	
161	÷	-24	
162	RTN	24	
163	*LBL6	21 06	
164	RCL0	36 00	
165	1	01	
166	+	-55	
167	STO9	35 09	
168	RCL0	36 00	
169	X^2	53	
170	1	01	
171	+	-55	
172	√X	54	
173	STO6	35 06	
174	RTN	24	

REGISTERS

0	1	2	3	4	5	6	7	8	9
C_{min}/C_{max}	T_{hin}	T_{cin}	C_c	C_h	E	Used	C_{min}	AU_i	Used
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
AU_{i-1}	$F(AU_i)$		$F(AU_{i-1})$		

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	*LBL0	21 00	
114	FIX	-11	
115	0	00	
116	STOA	35 11	
117	1	01	
118	RCL5	36 05	
119	CHS	-22	
120	STOD	35 14	
121	+	-55	
122	LN	32	
123	CHS	-22	
124	STO8	35 08	
125	*LBL6	21 06	
126	RCL8	36 08	
127	GSB2	23 02	
128	RCL5	36 05	
129	-	-45	
130	STOB	35 12	
131	RCLA	36 11	
132	RCL8	36 08	
133	STOA	35 11	
134	-	-45	
135	RCLD	36 14	
136	RCLB	36 12	
137	STOD	35 14	
138	-	-45	
139	÷	-24	
140	×	-35	
141	ST-8	35-45 08	
142	RCL8	36 08	
143	÷	-24	
144	RND	16 24	
145	X≠0?	16-42	
146	GTO6	22 06	
147	RCL8	36 08	
148	RTN	24	
149	*LBL2	21 02	Calculate E for cross-flow.
150	RCL8	36 08	
151	RCL7	36 07	
152	÷	-24	
153	ENT↑	-21	
154	ENT↑	-21	
155	.	-62	
156	2	02	
157	2	02	
158	Y^x	31	
159	RCL0	36 00	
160	÷	-24	
161	÷	-24	
162	LSTX	16-63	
163	X⇄Y	-41	
164	CHS	-22	
165	e^x	33	
166	1	01	
167	-	-45	
168	×	-35	
169	e^x	33	
170	CHS	-22	
171	1	01	
172	+	-55	
173	RTN	24	

LABELS

A	B	C	D	E
a	b	c	d	e
0 E →AU	1	2 AU →E	3	4
5	6 iterate	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☐	DEG	☐	FIX	☐
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☐	ENG	☐
3	☐	☐			n ____	

Program Description I

Program Title ENERGY EQUATION FOR STEADY FLOW

Contributor's Name Hewlett-Packard

Address 19310 Pruneridge

City Cupertino **State** CA **Zip Code** 95014

Program Description, Equations, Variables Given any 8 terms out of 9 terms in energy equation for steady flow as shown in the figure, this program calculates the remaining term.

Energy Equation:

$$\frac{P_1}{W} + Z_1 + \frac{V_1^2}{2g} + H_p = \frac{P_2}{W} + Z_2 + \frac{V_1^2}{2g} + H_T + H_L$$

Where

H = total dynamic head, ft.

H_p = head added by pump, ft.

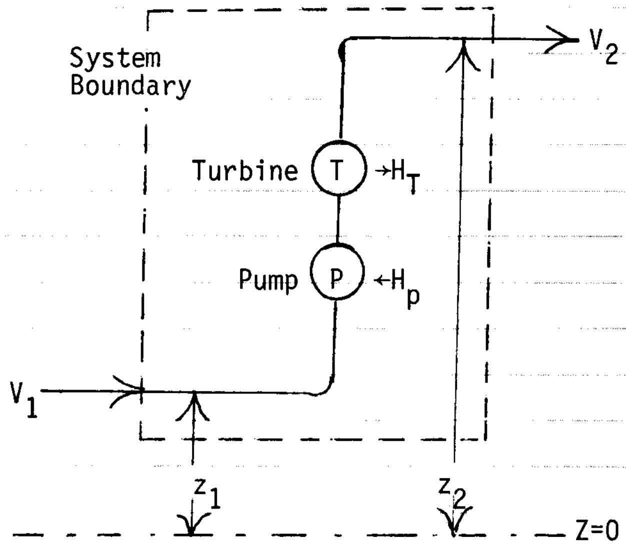
H_T = head extracted by turbine, ft.

H_L = head loss due to friction, ft.

$\frac{V^2}{2g}$ = velocity head, ft.

$\frac{P}{W}$ = pressure head, ft.

Z = potential head, ft.



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.

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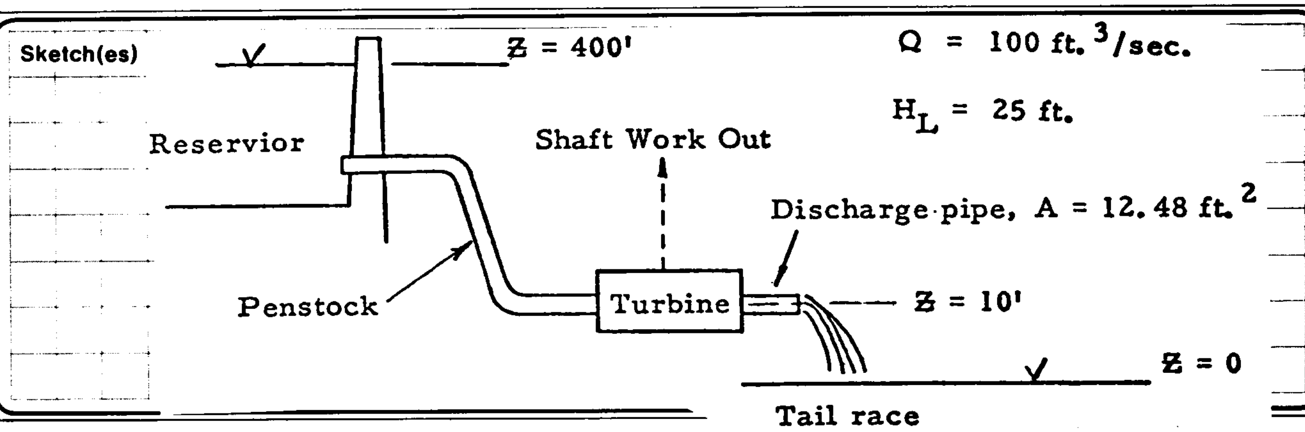
Program Description II

Sketch(es)



Sample Problem(s)

Find the head extracted by the turbine.

H_T = 364.00 ft.

```
          GSBa
   0.00   GSBb
 400.00   GSBc
   0.00   GSBd
          GSBe
          GSBA
  10.00   GSBB
 100.00   ENT↑
  12.48   ÷
          X²
  32.20   ÷
   2.00   ÷
          GSBC
  25.00   GSBE
   0.00   CF0
          GSBD
 364.00   ***
```

Solution(s) Load side 1 of the program, switch to [NORM].

[f] [A] , 0 [f] [B] , 400 [f] [C] . 0 [f] [D], [f] [E], [A] , 10 [B] , 100 [ENT] 12.48 [÷] [x^2] 32.2 [÷] 2 [÷] C , 25 [E] , 0 [f] [CLF] [0] [D] →364.00 (HT = 364.00 ft.)

Reference(s) Fluid Mechanics and Hydraulics, by Ronald V. Giles, Schaums Outline Series, McGraw-Hill Book Company, New York, 1962/

User Instructions

START	P_1/W	Z_1	$V_1^2/2g$	H_p
P_2/W	Z_2	$V_2^2/2g$	H_T	H_L

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 of the program			
2	Initialize		f A	0
3	Input any 8 of the 9 terms in the equation:			
	P_1/W	P_1/W	f B	P_1/W
	Z_1	Z_1	f C	Z_1
	$V_1^2/2g$	$V_1^2/2g$	f D	$V_1^2/2g$
	H_p	H_p	f E	H_p
	p_2/W	p_2/W	A	P_2/W
	Z_2	Z_2	B	Z_2
	$V_2^2/2g$	$V_2^2/2g$	C	$V_2^2/2g$
	H_T	H_T	D	H_T
	H_L	H_L	E	H_L
4	To calculate the remaining unknown,		0	
	first press:		f	
			CLF	
			0	
5	Then press the label key for the corresponding unknown term.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	Initialize
002	CLRG	16-53	
003	SF0	16 21 00	
004	0	00	
005	RTN	24	
006	*LBLb	21 16 12	P_1/W
007	STO1	35 01	
008	GSB3	23 03	
009	STO1	35 01	
010	GTO4	22 04	
011	*LBLc	21 16 13	Z_1
012	STO2	35 02	
013	GSB3	23 03	
014	STO2	35 02	
015	GTO4	22 04	
016	*LBLd	21 16 14	$V_1^2/2g$
017	STO3	35 03	
018	GSB3	23 03	
019	STO3	35 03	
020	GSB4	23 04	
021	*LBLe	21 16 15	H_p
022	STO4	35 04	
023	GSB3	23 03	
024	STO3	35 03	
025	GTO4	22 04	
026	*LBLA	21 11	P_2/W
027	STO5	35 05	
028	GSB3	23 03	
029	CHS	-22	
030	STO5	35 05	
031	GTO4	22 04	
032	*LBLB	21 12	Z_2
033	STO6	35 06	
034	GSB3	23 03	
035	CHS	-22	
036	STO6	35 06	
037	GTO4	22 04	
038	*LBLC	21 13	V_2^2/sg
039	STO7	35 07	
040	GSB3	23 03	
041	CHS	-22	
042	STO7	35 07	
043	GTO4	22 04	
044	*LBLD	21 14	H_T
045	STO8	35 08	
046	GSB3	23 03	
047	CHS	-22	
048	STO8	35 08	
049	GTO4	22 04	
050	*LBLE	21 15	H_L
051	STO9	35 09	
052	GSB3	23 03	
053	CHS	-22	
054	STO9	35 09	
055	GTO4	22 04	
056	*LBL1	21 01	left side of equation
057	RCL1	36 01	
058	RCL2	36 02	
059	+	-55	
060	RCL3	36 03	
061	+	-55	
062	RCL4	36 04	
063	+	-55	
064	STOA	35 11	
065	RTN	24	
066	*LBL2	21 02	right side of equation
067	RCL5	36 05	
068	RCL6	36 06	
069	+	-55	
070	RCL7	36 07	
071	+	-55	
072	RCL8	36 08	
073	+	-55	
074	RCL9	36 09	
075	+	-55	
076	STOB	35 12	
077	RTN	24	
078	*LBL3	21 03	calculate unknown
079	GSB9	23 09	
080	GSB1	23 01	
081	GSB2	23 02	
082	RCLA	36 11	
083	-	-45	
084	RTN	24	
085	*LBL4	21 04	print
086	PRTX	-14	
087	SPC	16-11	
088	RTN	24	
089	*LBL9	21 09	check for unknown
090	F0?	16 23 00	
091	R/S	51	
092	RTN	24	
100			

FLAGS	
0	Input
1	
2	
3	

SET STATUS

FLAGS	ON	OFF
0	☐	■
1	☐	■
2	☐	■
3	☐	■

TRIG	
DEG	■
GRAD	☐
RAD	☐

DISP	
FIX	■
SCI	☐
ENG	☐
n	2

LABELS

A P_2/W	B Z_2	C $V_2^2/2g$	D H_T	E H_L
a START	b P_1/W	c Z_1	d $V_1^2/2g$	e H_p
0	1 Left	2 Right	3 Unknown	4 Print
5	6	7	8	9 Check

REGISTERS

0	1	2	3	4	5	6	7	8	9
	P_1/W	Z_1	$V_1^2/2g$	H_p	P_2/W	Z_2	$V_2^2/2g$	H_T	H_L

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title FLOW WITH A FREE SURFACE

Contributor's Name Hewlett-Packard

Address 19310 Pruneridge Avenue

City Cupertino **State** CA **Zip Code** 95014

Program Description, Equations, Variables

Manning flow formula:

$$S = \frac{(nQ)^2}{2.2082\, r^{4/3} \times a^2}, \text{ and}$$

$$Q = \frac{K}{n} D^{8/3} \times s^{1/3}$$

Where S= slope of the bottom, dimensionless

n= roughness coefficient

r= hydraulic radius ft.

Q= discharge rate ft^3/sec

a= crosssection area ft^2/sec

K= discharge factor dimensionless

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.

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Program Description II

Sketch(es)

Sample Problem(s) (1) Find Q for s=0.001, n=0.013. r= 5/12, a=5

(2) Find K for s=0.001, n=0.014, D=4, Q=200

Solution(s) Load side 1 and 2

(1) 0.001 [A], 0.013 [B], 5 [↑] 12 [÷] [C], 5 [D], [E] → 10.1 (Q=10.1 ft^3/sec)

(2) 0.001 [f] [A], 0.014 [f] [B], 4 [f] [C], 200 [f] [E], [f] [D] 2.2 (K=2.2)

Reference(s) Civil Engineering Handbook, Leonard Church Urquhart (Editor-in-chief). McGraw-Hill Book Company 4th edition.

User Instructions

1	S	N	D	K	Q	2
	s	n	r	a	Q	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and 2			
2	For discharge factor formula, go to step 6			
3	For Manning flow formula, input any 4 of the following 5 variables			
	s	s	A	s
	n	n	B	n
	r	r	C	r
	a	a	D	a
	Q	Q	E	Q
4	Calculate the remaining unkown by pressing the corresponding key			
5	For a new case go to step 2			
6	For discharge factor formula, input any 4 of the following 5 variables			
	s	s	f A	s
	n	n	f B	n
	D	D	f C	D
	K	K	f D	K
	Q	Q	f E	Q
7	Calculate the remaining unknown by pressing the corresponding key			
8	For a new case go to step 2			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	1	01	
003	GSB6	23 06	
004	RCL2	36 02	
005	RCL5	36 05	
006	x	-35	
007	X^2	53	
008	GSB7	23 07	
009	÷	-24	
010	RCL3	36 03	
011	4	04	s
012	ENT↑	-21	
013	3	03	
014	÷	-24	
015	Y^x	31	
016	÷	-24	
017	RCL4	36 04	
018	X^2	53	
019	÷	-24	
020	GTO9	22 09	
021	*LBLB	21 12	
022	2	02	
023	GSB6	23 06	
024	GSB1	23 01	n
025	RCL5	36 05	
026	X^2	53	
027	÷	-24	
028	$\sqrt{X}$	54	
029	GTO9	22 09	
030	*LBLC	21 13	
031	3	03	
032	GSB6	23 06	
033	RCL2	36 02	
034	RCL5	36 05	
035	x	-35	
036	X^2	53	
037	GSB7	23 07	
038	÷	-24	r
039	RCL4	36 04	
040	X^2	53	
041	÷	-24	
042	RCL1	36 01	
043	÷	-24	
044	3	03	
045	ENT↑	-21	
046	4	04	
047	÷	-24	
048	Y^x	31	
049	GTO9	22 09	
050	*LBLD	21 14	
051	4	04	
052	GSB6	23 06	
053	RCL2	36 02	
054	RCL5	36 05	
055	x	-35	
056	X^2	53	
057	GSB7	23 07	a
058	÷	-24	
059	RCL3	36 03	
060	4	04	
061	ENT↑	-21	
062	3	03	
063	÷	-24	
064	Y^x	31	
065	÷	-24	
066	RCL1	36 01	
067	÷	-24	
068	$\sqrt{X}$	54	
069	GTO9	22 09	
070	*LBLE	21 15	
071	5	05	
072	GSB6	23 06	
073	GSB1	23 01	
074	RCL2	36 02	Q
075	X^2	53	
076	÷	-24	
077	$\sqrt{X}$	54	
078	GTO9	22 09	
079	*LBLa	21 16 11	
080	1	01	
081	GSB6	23 06	
082	RCL5	36 05	
083	RCL2	36 02	
084	x	-35	
085	RCL4	36 04	
086	÷	-24	
087	RCL3	36 03	
088	ENT↑	-21	s
089	8	08	
090	ENT↑	-21	
091	3	03	
092	÷	-24	
093	Y^x	31	
094	÷	-24	
095	X^2	53	
096	GTO9	22 09	
097	*LBLb	21 16 12	
098	2	02	
099	GSB6	23 06	
100	GSB2	23 02	
101	RCL4	36 04	n
102	x	-35	
103	RCL5	36 05	
104	÷	-24	
105	GTO9	22 09	
106	*LBLc	21 16 13	
107	3	03	
108	GSB6	23 06	
109	RCL5	36 05	
110	RCL2	36 02	D
111	x	-35	
112	RCL4	36 04	

REGISTERS

0	1	2	3	4	5	6	7	8	9
	s	n	r,d	a,K	Q				

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
113	÷	-24	
114	RCL1	36 01	
115	√X	54	
116	÷	-24	
117	3	03	
118	ENT↑	-21	
119	8	08	
120	÷	-24	
121	Y^x	31	
122	GTO9	22 09	
123	*LBLd	21 16 14	
124	4	04	
125	GSB6	23 06	
126	RCL5	36 05	
127	RCL2	36 02	K
128	×	-35	
129	GSB2	23 02	
130	÷	-24	
131	GTO9	22 09	
132	*LBLe	21 16 15	
133	5	05	
134	GSB6	23 06	
135	GSB2	23 02	Q
136	RCL4	36 04	
137	×	-35	
138	RCL2	36 02	
139	÷	-24	
140	GTO9	22 09	
141	*LBL1	21 01	
142	RCL3	36 03	
143	4	04	
144	ENT↑	-21	
145	3	03	
146	÷	-24	
147	Y^x	31	
148	RCL4	36 04	Subroutine
149	X^2	53	
150	×	-35	
151	GSB7	23 07	
152	×	-35	
153	RCL1	36 01	
154	×	-35	
155	RTN	24	
156	*LBL2	21 02	
157	RCL3	36 03	
158	8	08	
159	ENT↑	-21	
160	3	03	
161	÷	-24	Subroutine
162	Y^x	31	
163	RCL1	36 01	
164	√X	54	
165	×	-35	
166	RTN	24	
167	*LBL6	21 06	
168	STOI	35 46	
169	X⇄Y	-41	
170	GSB8	23 08	
171	RTN	24	
172	*LBL7	21 07	
173	2	02	2.2082
174	.	-62	
175	2	02	
176	0	00	
177	8	08	
178	2	02	
179	RTN	24	
180	*LBL8	21 08	
181	X≠0?	16-42	Input or output?
182	PRTX	-14	
183	STOi	35 45	
184	0	00	
185	X≠Y?	16-32	
186	R/S	51	
187	RTN	24	
188	*LBL9	21 09	
189	STOi	35 45	
190	SPC	16-11	Print
191	PRTX	-14	
192	SPC	16-11	
193	RTN	24	

LABELS

A	B	C	D	E
s	n	r	a	Q
a: s	b: n	c: D	d: K	e: Q
0:	1: Subr.	2: Subr.	3:	4:
5:	6: STO 1	7: 2.2082	8: input?	9: Print

FLAGS

Flag	
0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF
0	☐	■
1	☐	■
2	☐	■
3	☐	■

TRIG	
DEG	■
GRAD	☐
RAD	☐

DISP	
FIX	☐
SCI	■
ENG	☐
n	2

Program Description I

Program Title PIPE SLIDE-RULE

Contributor's Name C. B. Coleman, Jr. CCT, Inc.
Address 419 Shields Drive
City Anaheim, **State** Calif. **Zip Code** 92804

Program Description, Equations, Variables The program computes the unknown, when given the surface coefficient (n) and any three of the following: 1. Flow (Q); 2. Slope (S); 3. Pipe diameter (D); 4. Depth % ($^D/d$). Also computes Velocity (V). When solving for Pipe diameter, the program automatically rounds up to a standard size of 6", 8", 12", 15", 18", 21", 24", etc.--pipe. Depth percentage ($^D/d$) is found by Newton's method of iteration. In the case of depth percentages between approx. 82% and 100%, two roots or values are appropriate and are both displayed in merged form. ie: 100% and 82% is displayed as 100.82; 94% and 94% (approx. max. Q) is displayed as 94.94. Any subsequent calculation for Velocity (V) is based on the depth percentage value on the right of the decimal. The alternate (lower) Velocity value may be obtained after entering the alternate depth percentage.

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.

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Program Description II

Sketch(es)

Sample Problem(s)

n = .013

Q = 850.3(CFS)

S = .1 (1 ft/1000)

D = 144" (inches)

$^D/d$ = 100.82 (100% and/or 82%)

V = 8.57 (ft/sec) @ 82%

V = 7.52 (ft/sec) @ 100%

Solution(s)

A. Solve for "Q"

Input n,S,D,*$^D/d$

Press B button

= 850.30 @ *1 $^D/d$

= 850.64 @ *.82 $^D/d$

B. Solve for "S"

Input n,Q,D,$^D/d$

Press C button

= .1

C. Solve for "D"

Input n,Q,S,$^D/d$

Press D button

= 144

[redacted]

D. Solve for "$^D/d$"

Input n,Q,S,D

Press E button

= 100.82

E. Solve for "V"

Input Q,D,*$^D/d$

Press f E buttons

= 7.52 @ *1. $^D/d$

= 8.57 @ *.82 D/d

User Instructions

PIPE SLIDE-RULE

→ V

n	Q	S	D	D/d

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Load side 1 and side 2.				
2.	To solve for either Q, S, D or D/d,				
	input "n", surface coefficient	n	A		n
	AND				
	input any three of the following				
	in any order:				
	"Q" Flow (cu. ft./sec.)	Q	B		Q
	"S" Slope (ft./100)	S	C		S
	"D" Pipe diameter (inches)	D	D		D
	"D/d" Depth percentage	D/d	E		D/d
3.	Press key corresponding to the unknown.		*		
4.	For new case go to step 2.				
5.	To calculate "V" Velocity, (ft./sec.)				
	input the following:				
	"Q"	Q	B		Q
	"D"	D	D		D
	"D/d"	D/d	E		D/d
6.	Calculate "V"		f	E	V
7.	For new case go to step 5.				
	*Note: User keys B, C, D & E function as input keys if a number is first keyed into the X-register; otherwise they act as output keys. Solutions are automatically stored.				

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	LBL E	31 25 15	
	F3?	35 71 03	
	GTO 1	22 01	
	3	03	
	5	05	
	CHS	42	
	ST I	35 33	
	π	35 73	
	STO 3	33 03	
010	4	04	
	STO 1	33 01	
	CHS	42	
	STO 2	33 02	
	LBL b	32 25 12	
	RCL D	34 14	
	8	08	
	↑	41	
	3	03	
	÷	81	
020	y^x	35 63	
	RCL C	34 13	
	$\sqrt{x}$	31 54	
	x	71	
	RCL A	34 11	
	÷	81	
	3	03	
	2	02	
	0	00	
	x^2	32 54	
030	÷	81	
	STO 5	33 05	
	RCL 3	34 03	
	↑	41	
	SIN	31 62	
	−	51	
	5	05	
	y^x	35 63	
	RCL 3	34 03	
	x^2	32 54	
040	÷	81	
	3	03	
	1/x	35 62	
	y^x	35 63	
	RCL 5	34 05	
	x	71	
	F2?	35 71 02	
	RTN	35 22	
	RCL B	34 12	
	−	51	
050	STO 0	33 00	
	RCL 1	34 01	
	RCL 3	34 03	
	STO 1	33 01	
	−	51	
	RCL 2	34 02	
	RCL 0	34 00	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	STO 2	33 02	
	−	51	
	÷	81	
060	x	71	
	CHS	42	
	STO + 3	33 61 03	
	RCL 3	34 03	
	÷	81	
	RND	31 24	
	x≠0	31 61	
	GTO (i)	22 24	
	7	07	
	RCL 3	34 03	
070	x>y	32 81	
	GTO c	22 31 13	
	2	02	
	÷	81	
	cos	31 63	
	1	01	
	−	51	
	2	02	
	÷	81	
	CHS	42	
080	F1?	35 71 01	
	GTO 6	22 06	
	STO 6	33 06	
	.	83	
	8	08	
	1	01	
	9	09	
	6	06	
	x≤y	32 71	
	GTO 5	22 05	
090	RCL 6	34 06	
	RTN	35 22	
	LBL 5	31 25 05	
	SF1	35 51 01	
	RCL 3	34 03	
	STO 7	33 07	
	π	35 73	
	2	02	
	x	71	
	STO 1	33 01	
100	CHS	42	
	STO 2	33 02	
	6	06	
	STO 3	33 03	
	GTO b	22 31 12	
	LBL 6	31 25 06	
	CF1	35 61 01	
	RND	31 24	
	EEX	43	
	2	02	
110	x	71	
	STO + 6	33 61 06	
	RCL 7	34 07	

REGISTERS

0	1	2	3	4	5	6	7	8	9
√	√	√	D/d		√	√	√		

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
n	Q	S	D		√

67 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
	STO 3	33 03			F3?	35 71 03	
	RCL 6	34 06		170	GTO 4	22 04	
	RTN	35 22			1	01	
	LBL 1	31 25 01			STO D	33 14	
	↑	41			GSB 5	31 22 05	
	↑	41			•	83	
	2	02			3	03	
120	x	71			7	07	
	1	01			5	05	
	−	51			y^x	35 63	
	CHS	42			3	03	
	COS^{-1}	32 63		180	÷	81	
	2	02			2	02	
	x	71			x⇄y	35 52	
	STO 3	33 03			x≤y	32 71	
	R↓	35 53			GTO 7	22 07	
	RTN	35 22			2	02	
130	LBL A	31 25 11			•	83	
	STO A	33 11			6	06	
	RTN	35 22			7	07	
	LBL B	31 25 12			x⇄y	35 52	
	F3?	35 71 03		190	x≤y	32 71	
	GTO 2	22 02			GTO 8	22 08	
	SF 2	35 51 02			4	04	
	GSB b	32 22 12			x⇄y	35 52	
	LBL 2	31 25 02			x≤y	32 71	
	STO B	33 12			GTO 9	22 09	
140	RTN	35 22			•	83	
	LBL C	31 25 13			9	09	
	F3?	35 71 03			9	09	
	GTO 3	22 03			9	09	
	1	01		200	+	61	
	STO C	33 13			INT	31 83	
	GSB 5	31 22 05			3	03	
	x^2	32 54			x	71	
	LBL 3	31 25 03			LBL 4	31 25 04	
	STO C	33 13			STO D	33 14	
150	RTN	35 22			RTN	35 22	
	LBL e	32 25 15			LBL 7	31 25 07	
	RCL 3	34 03			6	06	
	↑	41			GTO 4	22 04	
	SIN	31 62		210	LBL 8	31 25 08	
	−	51			8	08	
	1/x	35 62			GTO 4	22 04	
	RCL B	34 12			LBL 9	31 25 09	
	x	71			1	01	
	RCL D	34 14			2	02	
160	x^2	32 54			GTO 4	22 04	
	÷	81			LBL 5	31 25 05	
	1	01			SF2	35 51 02	
	1	01			GSB b	32 22 12	
	5	05		220	RCL B	34 12	
	2	02			÷	81	
	x	71			1/x	35 62	
	RTN	35 22			RTN	35 22	
	LBL D	31 25 14					

LABELS

A n	B Q	C S	D D	E D/d
a	b √	c Dummy	d	e V
0	1 √	2 √	3 √	4 √
5 √	6 √	7 √	8 √	9 √

FLAGS

0	
1	√
2	√
3	√

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☐	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☒	ENG	☐
3	☐	☒			n 2	

Program Description I

Program Title FORCE AT BENDS AND FITTINGS

Contributor's Name Hewlett-Packard

Address 19310 Pruneridge

City Cupertino **State** CA **Zip Code** 95014

Program Description, Equations, Variables

When the velocity of a flowing fluid is changed in magnitude or direction, such as at a bend or fitting, a force must act upon the fluid to cause the change. This program considers only the systems where the pipe itself is pressure-tight, but where accelerating forces must be resisted by external means to prevent movement of the piping, increased stress in the pipe walls, or both. The equations are:

$$F_x = \frac{QW}{g}(V_{2x} - V_{1x}), \qquad F_y = \frac{QW}{g}(V_{2y} - V_{1y})$$

$$\overline{F} = \vec{F_x} + \vec{F_y}, \qquad \overline{R} = -\overline{F}, \quad \text{where}$$

$\overline{F}$ = accelerating force on water, lbs.

Q = rate of flow, ft.^{3}/sec.

W = specific weight, lbs./ft.^{3}

g = acceleration of gravity, ft./sec.^{2}

V_2 = velocity leaving fittings, ft./sec.

V_1 = velocity entering fitting, ft./sec.

$\overline{R}$ = reaction of water on fitting, lbs.

Subscripts: x for x direction and y for y direction

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.

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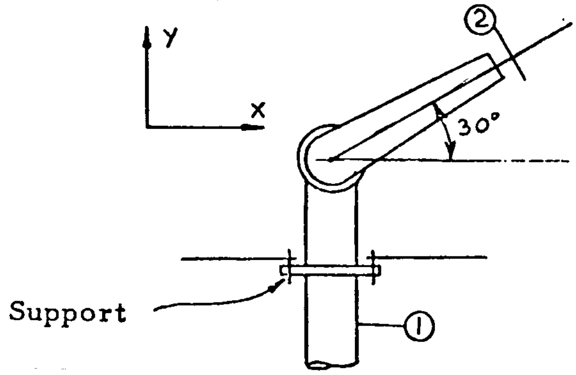
Program Description II

Sketch(es)



$Q = 2\ ft.^3/sec.$

$A_1 = 0.2\ ft.^2$

$A_2 = 0.016\ ft.^2$

Sample Problem(s)

Find the forces of the water deck gun due to the change of velocity and direction.

Solution(s) Load side 1 of program, switch to [NORM] ,

2 [ENT] 62.4 [A] 0 [ENT] 2 [ENT] .016 [÷] 30 [COS] [x] [B] →419.91 (F_x=419.91 lbs.)

10 [ENT] 2 [ENT] .016 [÷] 30 [SIN] [x] [C] →203.64 (F_y=203.64 lbs.),

[D] →466.68, 25.87 (F = 466.68 lbs., θ_F = 25.87°)

[E] →466.68, -154.13 (R = 466.68 lbs., θ_R = -154.13°)

Reference(s) <u>Fluid Mechanics and Hydraulics</u>, by Ronald V. Giles, Schaums Outline Series, McGraw-Hill Book Company, New York, 1962.

User Instructions

1 | 2

Q ↑ W	$V_{1x}\uparrow V_{2x}\rightarrow F_x$	$V_{1y}\uparrow V_{2y}\rightarrow F_y$	$\rightarrow \overline{F}$	$\rightarrow \overline{R}$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Load side 1 of program				
2	Switch to NORM				
3	Input rate of flow Q,	Q	↑		
	and specific weight of fluid, W	W	A		
4	Input x component of velocities				
	velocity entering V_{1x}	V_{1x}	↑		
	velocity leaving V_{2x}	V_{2x}	B		F_x
5	Input y component of velocities				
	velocity entering V_{1y}	V_{1y}	↑		
	velocity leaving V_{2y}	V_{2y}	C		F_y
6	To calculate $\overline{F}$		D		$\overline{F}$
7	To calculate $\overline{R}$		E		$\overline{R}$
8	For a new case, go to step 3.				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STOB	35 12	
003	X⇄Y	-41	
004	STOA	35 11	Input Q, W
005	x	-35	
006	3	03	Calculate $\frac{QW}{g}$
007	2	02	
008	.	-62	
009	1	01	
010	7	07	
011	3	03	
012	9	09	
013	÷	-24	
014	STOC	35 13	
015	RTN	24	
016	*LBLB	21 12	
017	STO2	35 02	
018	X⇄Y	-41	Input V_{1x}, V_{2x}
019	STO1	35 01	
020	-	-45	Calculate F_x
021	RCLC	36 13	
022	x	-35	
023	STO3	35 03	
024	GTO9	22 09	
025	*LBLC	21 13	
026	STO5	35 05	
027	X⇄Y	-41	Input V_{1y}, V_{2y}
028	STO4	35 04	
029	-	-45	Calculate F_y
030	RCLC	36 13	
031	x	-35	
032	STO6	35 06	
033	GTO9	22 09	
034	*LBLD	21 14	
035	RCL6	36 06	
036	RCL3	36 03	
037	→P	34	
038	STO7	35 07	
039	PRTX	-14	$\overline{F}$
040	X⇄Y	-41	
041	GSB9	23 09	
042	X⇄Y	-41	
043	RTN	24	
044	*LBLE	21 15	
045	RCL6	36 06	
046	CHS	-22	
047	RCL3	36 03	
048	CHS	-22	
049	→P	34	
050	STO8	35 08	$\overline{R}$
051	PRTX	-14	
052	X⇄Y	-41	
053	GSB9	23 09	
054	X⇄Y	-41	
055	RTN	24	
056	*LBL9	21 09	
057	PRTX	-14	Print, space
058	SPC	16-11	
059	RTN	24	

FLAGS	
0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	■	DEG	■	FIX	■
1	☐	■	GRAD	☐	SCI	☐
2	☐	■	RAD	☐	ENG	☐
3	☐	■			n	2

LABELS

A	B	C	D	E
Q↑W	$V_{1x}, V_{2x} \rightarrow F_x$	$V_{1y}, V_{2y} \rightarrow F_y$	$\overline{F}$	$\overline{R}$
a	b	c	d	e
0	1	2	3	4
5	6	7	8	9 print

REGISTERS

0	1	2	3	4	5	6	7	8	9
	V_{1x}	V_{2x}	F_x	V_{1y}	V_{2y}	F_y	$\lvert F \rvert$	$\lvert R \rvert$	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
Q	W	QW/g			

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