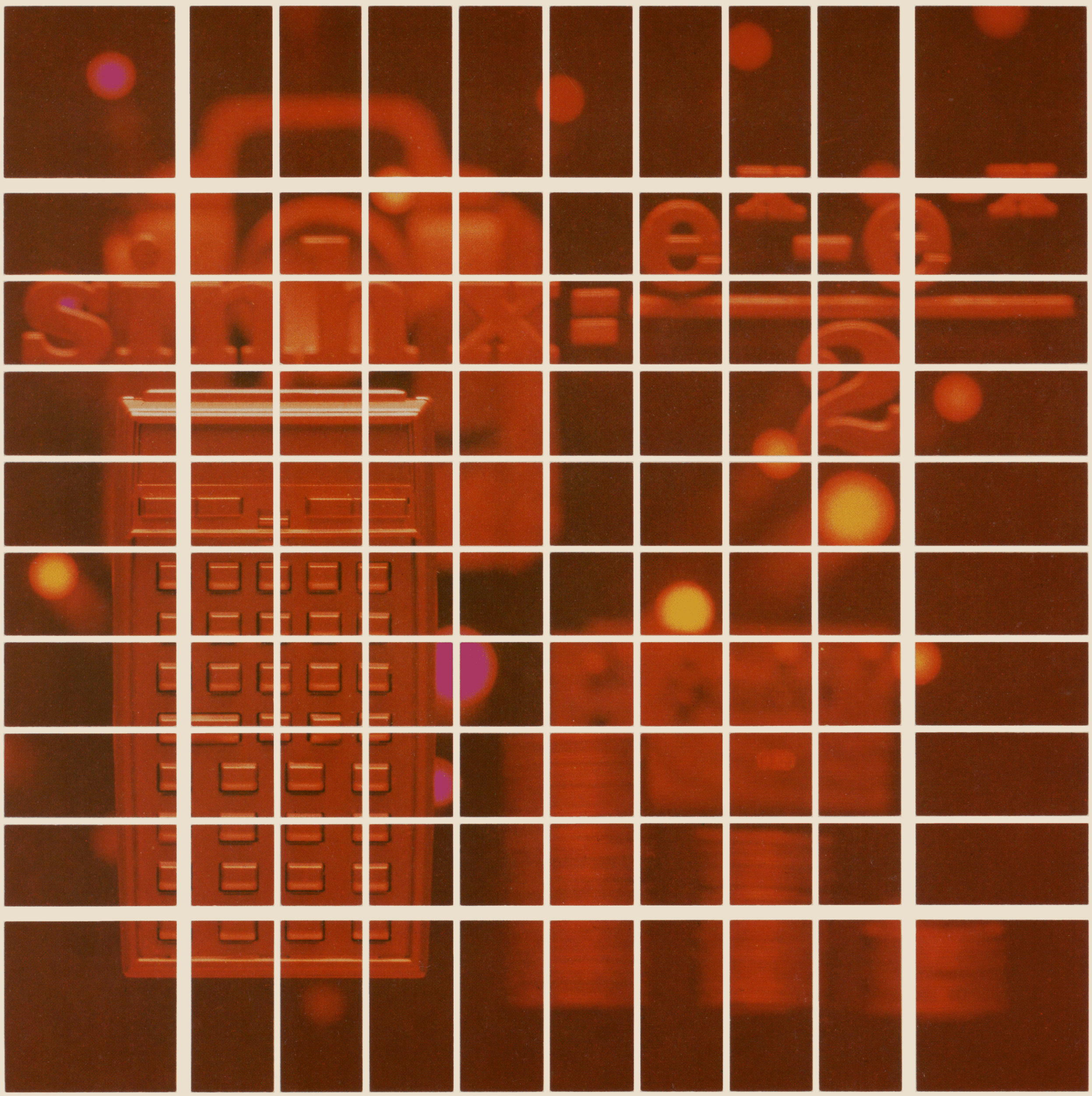
Includes barcode for easy software entry.

HEWLETT-PACKARD

HP-41

USERS' LIBRARY SOLUTIONS

Solar Engineering



INTRODUCTION

This HP-41C Solutions book was written to help you get the most from your calculator. The programs were chosen to provide useful calculations for many of the common problems encountered.

They will provide you with immediate capabilities in your everyday calculations and you will find them useful as guides to programming techniques for writing your own customized software. The comments on each program listing describe the approach used to reach the solution and help you follow the programmer's logic as you become and expert on your HP calculator.

KEYING A PROGRAM INTO THE HP-41C

There are several things that you should keep in mind while you are keying in programs from the program listings provided in this book. The output from the HP 82143A printer provides a convenient way of listing and an easily understood method of keying in programs without showing every keystroke. This type of output is what appears in this handbook. Once you understand the procedure for keying programs in from the printed listings, you will find this method simple and fast. Here is the procedure:

1. At the end of each program listing is a listing of status information required to properly execute that program. Included is the SIZE allocation required. Before you begin keying in the program, press [XEQ] [ALPHA] SIZE [ALPHA] and specify the allocation (three digits; e.g., 10 should be specified as 010).

   Also included in the status information is the display format and status of flags important to the program. To ensure proper execution, check to see that the display status of the HP-41C is set as specified and check to see that all applicable flags are set or clear as specified.

2. Set the HP-41C to PRGM mode (press the [PRGM] key) and press ■ [GTO] [•] [•] to prepare the calculator for the new program.

3. Begin keying in the program. Following is a list of hints that will help you when you key in your programs from the program listings in this handbook.

   a. When you see " (quote marks) around a character or group of characters in the program listing, those characters are ALPHA. To key them in, simply press [ALPHA], key in the characters, then press [ALPHA] again. So "SAMPLE" would be keyed in as [ALPHA] "SAMPLE" [ALPHA].

   b. The diamond in front of each LBL instruction is only a visual aid to help you locate labels in the program listings. When you key in a program, ignore the diamond.

   c. The printer indication of divide sign is /. When you see / in the program listing, press [÷].

   d. The printer indication of the multiply sign is ⁑. When you see ⁑ in the program listing, press [×].

   e. The ⊢ character in the program listing is an indication of the [APPEND] function. When you see ⊢, press ■ [APPEND] in ALPHA mode (press ■ and the K key).

   f. All operations requiring register addresses accept those addresses in these forms:

      nn (a two-digit number)
      IND nn (INDIRECT: ■ , followed fy a two-digit number)
      X, Y, Z, T, or L (a STACK address: [•] followed by X, Y, Z, T, or L)
      IND X, Y, Z, T or L (INDIRECT stack: ■ [•] followed by X, Y, Z, T, or L)

      Indirect addresses are specified by pressing ■ and then the indirect address. Stack addresses are specified by pressing [•] followed by X, Y, Z, T, or L. Indirect stack addresses are specified by pressing ■ [•] and X, Y, Z, T, or L.

Printer Listing	Keystrokes	Display
01♦LBL "SAMPLE"	■ [LBL] [ALPHA] SAMPLE [ALPHA]	***01 LBL^{T}SAMPLE***
02 "THIS IS A "	[ALPHA] ***THIS IS A*** [ALPHA]	***02^{T}THIS IS A***
03 "⊢SAMPLE"	[ALPHA] ■ [APPEND] SAMPLE	***03^T ⊢ SAMPLE***
04 AVIEW	■ AVIEW [ALPHA]	***04 AVIEW***
05 6	6	***05 6***
06 ENTER↑	[ENTER↑]	***06 ENTER ↗***
07 -2	2 [CHS]	***07 -2***
08 /	[÷]	***08 /***
09 ABS	[XEQ] [ALPHA] ABS [ALPHA]	***09 ABS***
10 STO IND L	[STO] ■ [•] L	***10 STO IND L***
11 "R3="	[ALPHA] R3= ■ [ARCL] 03	***11^{T}R3=***
12 ARCL 03	■ [AVIEW]	***12 ARCL 03***
13 AVIEW	[ALPHA]	***13 AVIEW***
14 RTN	■ [RTN]	***14 RTN***

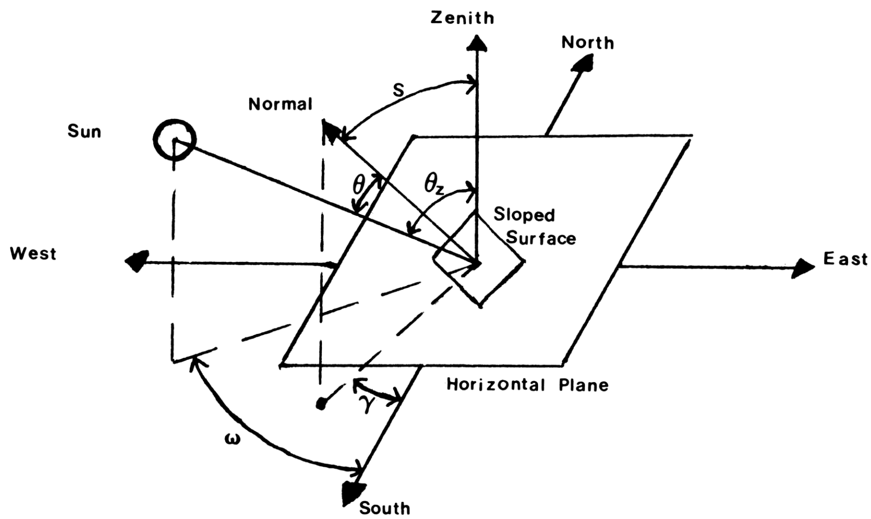
TABLE OF CONTENTS

* Requires an additional memory module.
** Requires two additional memory modules.

SOLAR-BEAM IRRADIATION

(Requires an additional memory module.)

This program enables the user to estimate solar-beam radiation impingement on a surface of any orientation and location on the earth for any day of the year. No prior knowledge of solar orbital mechanics is necessary. Solar-beam radiation rates may be estimated for any hour of the day. The program allows the user to integrate the total beam radiation over a given span of time during the day. Approximations of sunrise and sunset times may be calculated for any day of the year at any location on the earth.



Angle of incidence (θ) of beam radiation.

COS θ= SIN δ SIN ϕ COS S − SIN δ COS ϕ SIN S COS γ
+ COS δ COS ϕ COS S COS ω + COS δ SIN ϕ SIN S COS γ COS ω
+ COS δ SIN S SIN γ SIN ω

$$\cos\theta = \sin\delta\sin\phi\cos S - \sin\delta\cos\phi\sin S\cos\gamma + \cos\delta\cos\phi\cos S\cos\omega + \cos\delta\sin\phi\sin S\cos\gamma\cos\omega + \cos\delta\sin S\sin\gamma\sin\omega$$

WHERE: δ = Declination (i.e., angular position of sun at solar noon with respect to plane of equator; north is positive (see below)

ϕ = Latitude; North is positive

ω = Surface azimuth angle, the deviation of the normal to the surface from local meridian. The zero point is due south, east is positive and west is negative.

θ = Angle of incidence of beam radiation, measured between beam and normal to the plane.

Declination (δ) (Approximate)

$$\delta = 23.45 \text{ SIN } [.9863\ (284 + \eta)]$$

Where: η = Numbered day of year (i.e., February 15 is 46th day of year.)

Calculation of solar angle (ω)

Solar time = Standard Time + E + 4 $(L_{st} - L_{loc})$

Where: E = Equation of Time

$E = 8 \text{ SIN } (1.06\,\eta - 48) + 10 \text{ SIN } [1.9\,(1.1\,\eta - 30)]$

L_{st} = Standard Meridian for local time zone
(Standard meridians for Continental U.S. time zones are: Atlantic, 60° W; Eastern, 75° W; Central, 90° W; Mountain, 105° W; and Pacific, 120° W.)

L_{loc} = Longitude of location in question

ω = (12-solartime) x 15

Where: ω = hour angle in degrees (positive for morning and negative for afternoon.)

Zenith Angle θ_z

$$\text{COS } \theta_z = \text{SIN } \delta \text{ SIN } \phi + \text{COS } \delta \text{ COS } \phi \text{ COS } \omega$$

Radiant Energy (G) received at surface

$$G = G_0 \times t^m \text{ COS } \theta$$

Where: G_0 = Solar constant 428 BTU HR °F FT^2
t = Transmission coefficient for unit air mass (cloudy, 0.62; mean value, 0.70; clear day, 0.81)
m = Secant of zenith angle; SEC θ_z

Time of sunrise and sunset

$$\text{COS } \omega_s = -\text{TAN } \Phi \text{ TAN } \delta$$

WHERE: ω_s = Sunrise hour angle

Sunrise solar time = $12 - \frac{\omega_s}{15}$

Sunrise standard time = Sunrise solar time - E - 4 $(L_{st} - L_{loc})$

Sunset solar time = $12 + \frac{\omega_s}{15}$

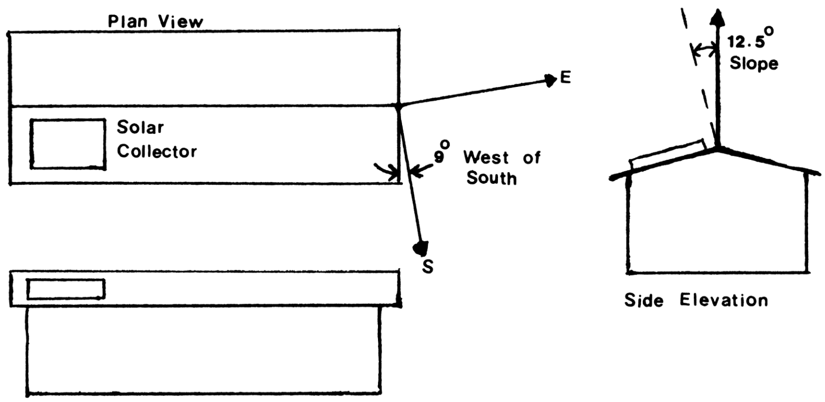
Sunset standard time = Sunset solar time - E - 4 $(L_{st} - L_{loc})$

The total irradiation during a time period

$$G_0 \int_{\omega_2}^{\omega_1} t^{\text{SEC } \theta_z} \text{ COS } \theta \, d\omega = \Sigma G(\omega_1 - \omega_2)$$

The time of rise and set as computed by "IRRAD" is generally accurate to within 30 minutes. Since 90% of the solar energy arriving at the earth's surface occurs during the middle two thirds of the day, this accuracy is adequate for the computation of solar beam irradiation.

EXAMPLE:



Find solar-beam radiation rate impinging on a solar collector at 10:45 a.m. and 2:20 p.m., and the total energy from 10:30 a.m. to 3:20 p.m. Also, what is the time of sunrise and sunset? The solar collector is mounted on a roof sloped 12.5° from horizontal and pointed 9° west of south. The date is September 2, 1981 and is an average clear day in Los Angeles, California. The approximate coordinates are 34° 10' north latitude and 118° 21' west longitude. The standard time meridian for Pacific Standard Time is 120° W.

Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 026	
[XEQ] [ALPHA] IRRAD [ALPHA]	MM.DDYYY ?
9.021981 [R/S]	LAT. ?
34.1 [R/S]	LONG.?
118.21 [R/S]	TIME MER. ?
120 [R/S]	SLOPE ?
12.5 [R/S]	AZIMUTH ?
9 [CHS] [R/S]	TRAN. COEF. ?
.7 [R/S]	A, B OR C ?
10.45 [A]	G = 258 (BTU/HR FT^2)
14.20 [A]	G = 213 (BTU/HR FT^2)
10.30 [ENTER↑]	
15.20 [ENTER↑]	
.5 [B]	ΣG = 1,173 (BTU/FT^2)

If a collector of 150 ft^2 is used, how many BTU is this.

150 [X]	175921 (BTU)
[C]	SUN R = 5:34 (AM)
[R/S]	SUN S = 18:14 (6:14 PM)

User Instructions

SIZE: 026

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program.			
2	Initalize.		[XEQ] IRRAD	MM.DDYYYY ?
3	Key in the date.	date	[R/S]	LAT
4	Key in the latitude (neg. for south)			
	in degrees, minutes and seconds.	ϕ	[R/S]	LONG. ?
5.	Key in the longitude (neg. for east)			
	in degrees, minutes and seconds.	L_{loc}	[R/S]	TIME MER. ?
6	Key in the time meridian for			
	local standard time:			
	Atlantic = 60° W			
	Eastern = 75° W			
	Central = 90° W			
	Mountain = 105° W			
	Pacific = 120° W	L_{st}	[R/S]	SLOPE ?
7	Key in the slope of the plane in decimal			
	degrees.	S	[R/S]	AZIMUTH ?
8	Key in the surface azimuth in degrees,			
	minutes, seconds:			
	East is positive			
	South is zero			
	West is negative	γ	[R/S]	TRAN. COEF.?
9	Key the solar transmission coefficient:			
	Cloudy = .62			
	Mean = .70			
	Clear = .81	t	[R/S]	A, B OR C?

User Instructions

				SIZE:
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
10	To find solar beam rate:			
a	Key in time of interest in hours, minutes			
	and seconds using a 24 hour clock	time	[A]	G=(BTU/FT^2)
11	To find total solar radiation over a			
	period of time:			
a	Key in starting time in hours, minutes			
	and seconds	T beg	[ENTER]	
b	Key in ending time in hours, minutes			
	and seconds	T end	[ENTER]	
c	Key in step time in decimal hours (.5			
	is good)	Δ T	[B]	ΣG=(BTU/FT^2)
12	To find sunrise and sunset:		[C]	SUN R=
	(to within ~30 minutes)		[R/S]	SUN S=

Program Listings

```
 01♦LBL "IRR
AD"
 02 SF 21            Input
 03 CF 01
 04 FIX 0
 05 DEG
 06 CF 29
 07 SF 27
 08 "MM.DDYY
YY ?"
 09 CF 22
 10 RCL 06
 11 PROMPT           Date
 12 FC?C 22
 13 GTO 00
 14 INT              Calculate
 15 STO 01           DDY
 16 LASTX
 17 FRC
 18 100
 19 *
 20 INT
 21 STO 06
 22 LASTX
 23 FRC
 24 2500
 25 *
 26 FRC
 27 STO 02
 28 RCL 01
 29 30.56
 30 *
 31 INT
 32 30
 33 -
 34 ST+ 06
 35 RCL 02
 36 ENTER↑
 37 X≠0?
 38 /
 39 1
 40 +
 41 2
 42 RCL 01
 43 X<=Y?
 44 GTO 00
 45 RCL Z
 46 ST- 06
 47♦LBL 00
 48 "LAT. ?"
 49 RCL 00
```

```
 50 PROMPT           Latitude
 51 FS?C 22
 52 HR
 53 STO 00
 54 1
 55 P-R
 56 STO 11
 57 RDN
 58 STO 10
 59 "LONG. ?
"
 60 RCL 02
 61 PROMPT           Longitude
 62 FS?C 22
 63 HR
 64 STO 02
 65 "TIME ME
R. ?"
 66 RCL 01
 67 PROMPT           Time Meridian
 68 STO 01
 69 "SLOPE ?
"
 70 RCL 03
 71 PROMPT           Slope
 72 STO 03
 73 1
 74 P-R
 75 STO 13
 76 RDN
 77 STO 12
 78 "AZIMUTH         Azimuth
?"
 79 RCL 04
 80 CF 22
 81 PROMPT
 82 FS?C 22
 83 HR
 84 STO 04
 85 1
 86 P-R
 87 STO 15
 88 RDN
 89 STO 14
 90 "TRAN. C
OEF. ?"
 91 RCL 07
 92 PROMPT           Transmission
 93 STO 07           coefficient
 94 RCL 06
 95 284              Set up
```

Program Listings

```
 96 +
 97 .986
 98 *
 99 SIN
100 23.45
101 *
102 STO 05                δ
103 1
104 P-R
105 STO 17
106 RDN
107 STO 16
108 RCL 06
109 81
110 -
111 .989
112 *
113 ENTER↑
114 SIN
115 1.5
116 *
117 CHS
118 X<>Y
119 ENTER↑
120 COS
121 7.53
122 *
123 CHS
124 X<>Y
125 2
126 *
127 SIN
128 9.87
129 *
130 +
131 +
132 CHS
133 60
134 /
135 RCL 01
136 RCL 02
137 -
138 15
139 /
140 +
141 STO 09
142 "A, B OR
 C?"
143 PROMPT                Set up done
144♦LBL A
145 HR                    Time
146 SF 00
147 XEQ 20
148 RCL 19
149 *
150 +
151 1/X
152 6
153 X<=Y?
154 GTO 03
155 RDN
156 RCL 07
157 X<>Y
158 Y↑X
159 428                   Solar Constant
160 *
161 RCL 22
162 *
163 X>0?
164 GTO 04
165♦LBL 03
166 0
167♦LBL 04
168 "G="                 Output of G
169 ARCL X
170 AVIEW
171 RTN
```

$\int_{T_1}^{T_2} G$

```
172♦LBL B
173 15
174 *
175 STO 25
176 RDN
177 HR
178 X<>Y
179 HR
180 X<>Y
181 CF 00
182 XEQ 20
183 STO 19
184♦LBL 01
185 RCL 23
186 RCL 24
187 -
188 RCL 25
189 X<=Y?
190 GTO 02
191 RDN
192 STO 25
193 SF 01
194♦LBL 02
195 RCL 23
196 RCL 25
```

Program Listings

```
197 2
198 /
199 -
200 ENTER↑
201 COS
202 RCL 21
203 *
204 X<>Y
205 1/X
206 RCL 22
207 *
208 +
209 RCL 20
210 +
211 RCL 23
212 RCL 25
213 2
214 /
215 -
216 COS
217 RCL 19
218 *
219 RCL 18
220 +
221 1/X
222 RCL 07
223 X<>Y
224 Y↑X
225 *
226 RCL 25
227 *
228 15
229 /
230 X<0?
231 0
232 ST+ 08
233 RCL 23
234 RCL 25
235 -
236 STO 23
237 FC?C 01
238 GTO 01
239 RCL 08
240 428              Solar Constant
241 *
242 "ΣG="            Output ΣG
243 ARCL X
244 AVIEW
245 RTN
246♦LBL 20          Common sub-
247 RCL 09           routine
248 +
249 12
250 X<>Y
251 -
252 15
253 *
254 STO 24
255 FS? 00
256 GTO 00
257 RDN
258 RCL 09
259 +
260 12
261 X<>Y
262 -
263 15
264 *
265 STO 23
266 0
267 STO 08
268 GTO 02
269♦LBL 00
270 1
271 P-R
272 STO 19
273 RDN
274 STO 18
275♦LBL 02
276 RCL 16
277 RCL 10
278 *
279 RCL 13
280 *
281 RCL 16
282 RCL 11
283 *
284 RCL 12
285 *
286 RCL 15
287 *
288 -
289 STO 20
290 RCL 17
291 RCL 11
292 *
293 RCL 13
294 *
295 FC? 00
296 GTO 00
297 RCL 19
298 *
```

Program Listings

```
299 +
300◆LBL 00
301 RCL 17
302 RCL 10
303 *
304 RCL 12
305 *
306 RCL 15
307 *
308 FS? 00
309 RCL 19
310 FS? 00
311 *
312 +
313 STO 21
314 RCL 17
315 RCL 12
316 *
317 RCL 14
318 *
319 FC? 00
320 GTO 00
321 RCL 18
322 *
323 +
324◆LBL 00
325 STO 22
326 RCL 16
327 RCL 10
328 *
329 STO 18
330 RCL 17
331 RCL 11
332 *
333 RTN
334◆LBL C              Sunrise/Sunset
335 RCL 00
336 TAN
337 RCL 05
338 TAN
339 *
340 CHS
341 ACOS
342 15
343 /
344 STO 24
345 12
346 RCL 09
347 -
348 STO 25
349 X<>Y
350 -
351 "SUN R="           Sunrise output
352 XEQ 00
353 RCL 25
354 RCL 24
355 +
356 "SUN S="           Sunset
357◆LBL 00
358 HMS                Time output
359 INT
360 ARCL X
361 "⊢:"
362 9
363 LASTX
364 FRC
365 100
366 *
367 INT
368 X<=Y?
369 "⊢0"
370 ARCL X
371 AVIEW
372 .END.
```

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	ϕ	50	
	L_{st}		
	L_{loc}		
	S		
	γ		
05	δ	55	
	η		
	t		
	USED		
	USED		
10	SIN ϕ	60	
	COS ϕ		
	SIN S		
	COS S		
	SIN γ		
15	COS γ	65	
	SIN δ		
	COS δ		
	SIN ω		
	COS ω		
20	USED	70	
	USED		
	USED		
	USED		
	USED		
25	USED	75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 026 TOT. REG. 113 USER MODE

ENG ____ FIX ____ SCI ____ ON X OFF ____

DEG X RAD ____ GRAD ____

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES
00		one pt	integral
01	C	done	not done

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

SOLAR BEAM IRRADIATION

PROGRAM REGISTERS NEEDED: 89

ROW 1 (1 : 3)

ROW 2 (4 : 8)

ROW 3 (8 : 13)

ROW 4 (13 : 23)

ROW 5 (24 : 29)

ROW 6 (30 : 40)

ROW 7 (41 : 48)

ROW 8 (48 : 56)

ROW 9 (57 : 62)

ROW 10 (62 : 65)

ROW 11 (65 : 69)

ROW 12 (70 : 78)

ROW 13 (78 : 84)

ROW 14 (85 : 90)

ROW 15 (90 : 95)

ROW 16 (96 : 101)

ROW 17 (102 : 111)

ROW 18 (111 : 119)

SOLAR BEAM IRRADIATION

ROW 19 (120 : 128)

ROW 20 (128 : 138)

ROW 21 (138 : 142)

ROW 22 (142 : 148)

ROW 23 (149 : 159)

ROW 24 (159 : 168)

ROW 25 (168 : 176)

ROW 26 (177 : 185)

ROW 27 (185 : 193)

ROW 28 (193 : 202)

ROW 29 (203 : 212)

ROW 30 (212 : 222)

ROW 31 (223 : 232)

ROW 32 (233 : 240)

ROW 33 (240 : 246)

ROW 34 (247 : 255)

ROW 35 (256 : 265)

ROW 36 (265 : 274)

SOLAR BEAM IRRADIATION

ROW 37 (275 : 285)

ROW 38 (286 : 295)

ROW 39 (296 : 305)

ROW 40 (306 : 314)

ROW 41 (314 : 323)

ROW 42 (324 : 332)

ROW 43 (333 : 343)

ROW 44 (344 : 351)

ROW 45 (351 : 356)

ROW 46 (356 : 361)

ROW 47 (361 : 369)

ROW 48 (370 : 372)

SUN ALTITUDE, AZIMUTH, SOLAR POND ABSORPTION

This program computes the Sun's azimuth and altitude (Z_n and H_c) in decimal degrees given any latitude, longitude, date and time. Then, if you wish, you can input an index of refraction for any fluid and calculate the percent of radiation which would penetrate the surface of the fluid.

The almanac equations used in this program have been checked to the end of the century for accuracy and found to be accurate to within a .2' arc.

Example:

Find the Sun's asimuth, altitude, and the fraction of the Sun's radiation which will penetrate the surface of a solar pond under the following circumstances:

Date	9/1/79
Latitude	44°34'
Longitude	123°17'
GMT	20:00:00 (Noon PST)
Index of refraction	1.33

Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 009	
[XEQ] [ALPHA] ALMANAC [ALPHA]	MM.DDYYYY ?
9.011979 [R/S]	LAT ?
44.34 [R/S]	LONG ?
123.17 [R/S]	GMT ?
20 [R/S]	ZN=174.5022
[R/S]	HC=53.5985
[B]	N ?
1.33 [R/S]	%E=97.7355

Find the same information for 5 hours later.

Keystrokes:	Display:
[A]	MM.DDYYYY ?
[R/S]	LAT ?
[R/S]	LONG ?
[R/S]	GMT ?
25 [R/S]	ZN=262.9527
[R/S]	HC=18.7391
[B]	N ?
[R/S]	%E=85.1269

User Instructions

SIZE: 009

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1.	Load the program.			
2.	Initialize.		[XEQ] ALMANAC	MM.DDYYYY ?
3.	Key in the date.	date	[R/S]	LAT ?
4.	Key in the latitude.			
	([CHS] for south.)	L(D.MS)	[R/S]	LONG ?
5.	Key in the longitude.			
	([CHS] for east.)	λ(D.MS)	[R/S]	GMT ?
6.	Key in the Greenwich Meridian time.	GMT(H.MS)	[R/S]	ZN=
			[R/S]	HC=
7.	Press [A] and go to step 3 for another sun			
	position problem.		[A]	MM.DDYYYY ?
	OR			
8.	Press [B] for pond absorption.		[B]	N ?
9.	Key in the index of refraction n. If it			
	has been previously input, and is unchang-			
	ing, just press [R/S].	n	[R/S]	%E=
10.	For another index, go to step 8.			
	For another sun position, go to step 7.			
	Inputs that don't change can be skipped			
	by just pressing [R/S].			

Program Listings

01♦LBL "ALMANAC"	Initialize	50 20	
02 SF 27		51 *	
03♦LBL A	----------------	52 STO 04	
04 SF 21		53 SIN	
05 CF 22		54 4	
06 "MM.DDYYYY ?"		55 *	
		56 50941	
07 PROMPT	Input date	57 +	
08 FC?C 22		58 RCL 06	
09 GTO 00	----------------	59 7	
10 INT	Calculate DOY	60 *	
11 STO 06	and	61 +	
12 LASTX	longitude of	62 896	
13 FRC	Moon's ascending	63 /	
14 100	node	64 -	
15 *		65 ST- 03	
16 INT		66 360	
17 STO 03		67 ST* 03	----------------
18 LASTX		68♦LBL 00	Input other
19 FRC		69 "LAT ?"	quantities
20 1 E4		70 PROMPT	
21 *		71 HR	
22 X<> Z		72 FS?C 22	
23 3056		73 STO 01	
24 %		74 "LONG ?"	
25 INT		75 PROMPT	
26 ST+ 03		76 HR	
27 R↑		77 FS?C 22	
28 STO 04		78 STO 00	
29 RCL 06		79 "GMT ?"	
30 3		80 PROMPT	
31 X>Y?		81 HR	
32 1		82 15	
33 RCL 04		83 *	
34 4		84 FS?C 22	
35 /		85 STO 02	----------------
36 FRC		86 RCL 02	Calculate Z_n
37 +		87 STO 05	and H_c
38 1		88 RCL 03	
39 X<>Y		89 +	
40 X=Y?		90 365.25	
41 2		91 /	
42 RCL 04		92 118.1	
43 7		93 RCL 04	
44 -		94 968	
45 RCL 03		95 /	
46 365.25		96 -	
47 /		97 +	
48 +		98 .2	
49 STO 06		99 P-R	
		100 9.58	

Program Listings

101 -	Semidiameter
102 *	
103 +	
104 RCL 04	
105 427	
106 /	
107 RCL 04	
108 COS	
109 -	
110 8531.5	
111 -	
112 360	
113 /	
114 CHS	
115 X<>Y	
116 -1	
117 P-R	
118 RDN	
119 P-R	
120 R↑	
121 R-P	
122 RDN	
123 X<>Y	
124 STO 07	
125 ASIN	
126 STO 06	Declination
127 RDN	
128 -	
129 ST+ 05	
130 RCL 05	GHA
131 RCL 00	
132 -	LHA
133 RCL 06	
134 COS	
135 P-R	
136 RCL 01	
137 STO 06	
138 X<>Y	
139 P-R	
140 X<> 06	
141 RCL 07	
142 P-R	
143 X<> 06	
144 +	
145 ASIN	
146 X<> 06	
147 -	
148 R-P	
149 RDN	
150 180	
151 +	
152 "ZN="	
153 ARCL X	
154 AVIEW	
155 "HC="	
156 ARCL 06	
157 AVIEW	
158 RTN	----------------
159♦LBL B	
160 "N ?"	Input n
161 PROMPT	
162 FS?C 22	----------------
163 STO 08	
164 90	Calculate %E
165 RCL 06	
166 -	
167 STO 05	
168 SIN	
169 RCL 08	
170 /	
171 ASIN	
172 COS	
173 STO 07	
174 RCL 08	
175 *	
176 RCL 05	
177 COS	
178 +	
179 1/X	
180 X↑2	
181 RCL 05	
182 COS	
183 RCL 08	
184 *	
185 RCL 07	
186 +	
187 1/X	
188 X↑2	
189 +	
190 2	
191 *	
192 RCL 08	
193 *	
194 RCL 07	
195 *	
196 RCL 05	
197 COS	
198 *	
199 100	
200 *	
201 "%E="	
202 ARCL X	
203 AVIEW	
204 RTN	
205 .END.	

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	Long	50	
	Lat		
	15(GMT)		
	Days		
	Ω		
05	GHA	55	
	δ		
	r1c		
	n		
10		60	
15		65	
20		70	
25		75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 009 TOT. REG. 56 USER MODE
ENG ___ FIX ___ SCI ___ ON ___ OFF ___
DEG X RAD ___ GRAD ___

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

SUN ALTITUDE AZIMUTH
SOLAR POND ABSORPTION
PROGRAM REGISTERS NEEDED: 48

ROW 1 (1 - 2)

ROW 2 (3 - 6)

ROW 3 (6 - 12)

ROW 4 (13 - 21)

ROW 5 (22 - 29)

ROW 6 (30 - 42)

ROW 7 (43 - 50)

ROW 8 (50 - 58)

ROW 9 (59 - 66)

ROW 10 (67 - 72)

ROW 11 (73 - 78)

ROW 12 (79 - 84)

ROW 13 (85 - 92)

ROW 14 (92 - 98)

ROW 15 (99 - 106)

ROW 16 (107 - 112)

ROW 17 (113 - 124)

ROW 18 (125 - 136)

SUN ALTITUDE AZIMUTH
SOLAR POND ABSORPTION

ROW 19 (137 - 146)

ROW 20 (147 - 153)

ROW 21 (154 - 160)

ROW 22 (160 - 169)

ROW 23 (170 - 182)

ROW 24 (183 - 195)

ROW 25 (196 - 202)

ROW 26 (203 - 205)

ENERGY EQUIVALENTS - FUELS AND PRICES

Given an amount of fuel or energy expressed in one of the units in Table I, this program converts to an equivalent amount of another of the fuels or energy units in Table I. Also, given the price per unit of two fuels or energy units the program will convert an amount spent on one into an amount spent on the other. You may also include efficiencies between conversions. For example coal to electricity is not 100% efficient.

TABLE I

1 Barrel of Oil	= 1 BBL	= 5.8 MBTU
1000 Cubic Feet of Gas	= 1 TCF	= 1.03 MBTU
1 Gigajoule	= 1 GJ	= 1.055 MBTU
1 Short Ton of Eastern Bituminous Coal	= 1 STE	= 26 MBTU
1 Short Ton of Western Coal	= 1 STW	= 18 MBTU
1 Megawatt-hour	= 1 MWH	= 3.412 MBTU
1 Pound U_3O_8	= 1 U308	= 220 MBTU*
1 Million British Thermal Units	= 1 MBTU	

* All U^{235} atoms fissioned

Example:

How many Gigajoules can you get from 20,000 cubic feet of gas if the overall efficiency is 30%.

Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 005	
[XEQ] [ALPHA] ENERGY [ALPHA]	UNITS 1 ?
TCF [R/S]	$?
[R/S]	UNITS 2 ?
GJ [R/S]	$?
[R/S]	% FOR 1 TO 2
30 [R/S]	READY
20 [B]	5.86 GJ

If you wanted 10 GJ how many thousand cubic feet of gas are required?

10 [C]	31.14 TCF

User Instructions

				SIZE: 005
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program.			
2	Initialize.		[XEQ]ENERGY	UNITS 1 ?
3	Key in the units for units 1.	Units*	[R/S]	$?
4	Key in the price per unit of unit 1.			
	Just press [R/S] if not needed.	$	[R/S]	UNITS 2 ?
5	Key in the units for units 2.	Units*	[R/S]	$?
6	Key in the price per unit of unit 2. Just			
	press [R/S] if not needed.	$	[R/S]	% FOR 1 TO 2
7	Key in the conversion efficiency to con-			
	vert from unit 1 to unit 2 if different			
	from %100, otherwise just press [R/S].	%	[R/S]	READY
8	To convert an amount from 1 to 2			
9	Key in amount of 1.	A_1	[B]	( )(UNITS 2)
10	To convert an amount from 2 to 1			
11	Key in amount of 2.	A_2	[C]	( )(UNITS 1)
12	To convert price 1 to 2			
13	Key in price 1.	P_1	[D]	$( )(UNITS 2)
14	To convert price 2 to 1			
15	Key in price 2.	P_2	[E]	$( )(UNITS 1)
16	Repeat steps 8-15 as desired.			
17	To change any or all of steps 3-6 press [A]			
	and go to step 3. For inputs that do not			
	change just press [R/S].		[A]	UNITS 1 ?
	*Key in an abbreviation from Table I.			

Program Listings

Initialize

```
 01◆LBL "ENE
RGY"
 02 SF 27
 03 1
 04 STO 02
```

Input

```
 05◆LBL A
 06 AON
 07 CF 23
 08 "UNITS 1
?"
 09 PROMPT
 10 FS?C 23
 11 ASTO 01
 12 RCL 03
 13 "$ ?"
 14 AOFF
 15 PROMPT
 16 STO 03
 17 "UNITS 2
?"
 18 AON
 19 PROMPT
 20 FS?C 23
 21 ASTO 00
 22 AOFF
 23 "$ ?"
 24 RCL 04
 25 PROMPT
 26 STO 04
 27 "% FOR 1
TO 2"
 28 CF 22
 29 PROMPT
 30 100
 31 /
 32 FS?C 22
 33 STO 02
 34 "READY"
 35 PROMPT
```

Forward

```
 36◆LBL B
 37 XEQ 01
 38 CLA
 39◆LBL 03
 40 ARCL X
 41 "⊢ "
 42 ARCL 00
 43 PROMPT
```

Backward

```
 44◆LBL C
 45 XEQ 02
 46 CLA
 47◆LBL 04
 48 ARCL X
 49 "⊢ "
 50 ARCL 01
 51 PROMPT
```

$
Forward

```
 52◆LBL D
 53 RCL 03
 54 /
 55 XEQ 01
 56 RCL 04
 57 *
 58 "$"
 59 GTO 03
```

$
Backward

```
 60◆LBL E
 61 RCL 04
 62 /
 63 XEQ 02
 64 RCL 03
 65 *
 66 "$"
 67 GTO 04
```

Conversion

```
 68◆LBL 01
 69 CF 00
 70 XEQ IND
01
 71 SF 00
 72 XEQ IND
00
 73 RCL 02
 74 *
 75 RTN
 76◆LBL 02
 77 CF 00
 78 XEQ IND
00
 79 SF 00
 80 XEQ IND
01
 81 RCL 02
 82 /
 83 RTN
```

Conversion
constants

```
 84◆LBL "BBL
"
 85 5.8
 86 GTO 05
 87◆LBL "TCF
"
 88 1.03
 89 GTO 05
 90◆LBL "GJ"
 91 1.055
 92 GTO 05
```

Program Listings

```
 93♦LBL "STE
"
 94 26
 95 GTO 05
 96♦LBL "STW
"
 97 18
 98 GTO 05
 99♦LBL "MWH
"
100 3.412
101 GTO 05
102♦LBL "U3O
8"
103 220
104 GTO 05
105♦LBL "MBT
U"
106 1
107♦LBL 05
108 FS? 00
109 1/X
110 *
111 RTN
112 .END.
```

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	To Units	50	
	From Units		
	%		
	$ from		
	$ to		
05		55	
10		60	
15		65	
20		70	
25		75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 005 TOT. REG. 44 USER MODE
ENG ____ FIX ____ SCI ____ ON X OFF ____
DEG ____ RAD ____ GRAD ____

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES
00		Multiply by 1/X	Multiply by x
22		Numeric input	No input
27		User mode on	User mode off

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

ENERGY EQUIVALENTS
FUELS AND PRICES
PROGRAM REGISTERS NEEDED: 40

ROW 1 (1 - 3)

ROW 2 (4 - 8)

ROW 3 (8 - 14)

ROW 4 (15 - 19)

ROW 5 (20 - 27)

ROW 6 (27 - 28)

ROW 7 (28 - 34)

ROW 8 (34 - 41)

ROW 9 (41 - 48)

ROW 10 (48 - 55)

ROW 11 (55 - 63)

ROW 12 (63 - 71)

ROW 13 (71 - 79)

ROW 14 (80 - 85)

ROW 15 (85 - 88)

ROW 16 (88 - 91)

ROW 17 (91 - 94)

ROW 18 (95 - 98)

ENERGY EQUIVALENTS
FUELS AND PRICES

ROW 19 (99 - 101)

ROW 20 (101 - 104)

ROW 21 (104 - 108)

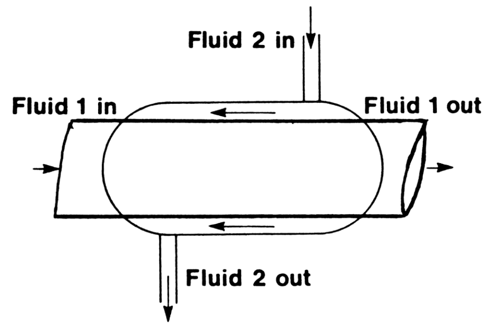
ROW 22 (109 - 112)

HEAT EXCHANGERS

(Requires one memory module)

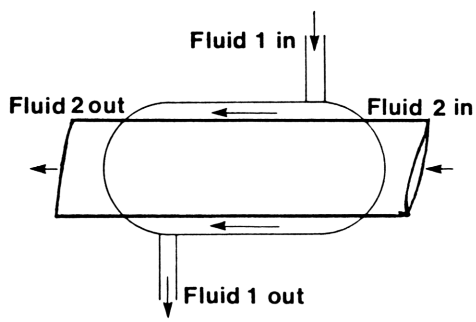
This program allows analysis of counterflow, parallel flow, parallel-counterflow, and crossflow heat exchangers.

Figure 1:



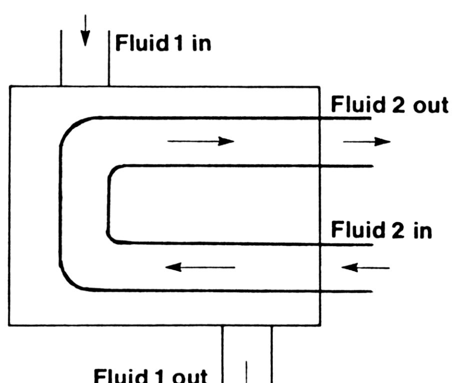
Counter-Flow

Figure 2:



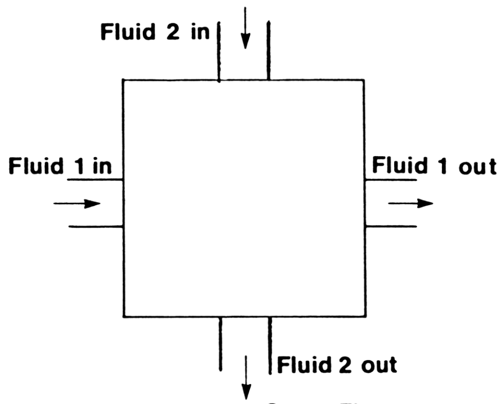
Parallel-Flow

Figure 3:



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

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.

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

Counterflow (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-Counterflow (well 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:

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

<u>Crossflow</u> (both fluids unmixed; see figure 4)

No exact expression exists for this case, but the following is a very good approximation. Note that an iterative solution is required for AU.

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

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:

For cases where the inlet and outlet temperatures of one of the fluids are equal(change of phase), use zero for the heat capacity of that fluid.

The solution for AU in the crossflow configuration takes significantly longer than other solutions because of the iterative technique required.

The program must be allowed to solve for all values (AU, Q, T_{co}, T_{ho}, and E). It is quite possible for the heat balance equations to yield physically meaningless solutions for a particular configuration. However, the message "2ND LAW ERR" will be displayed if the 2nd law of thermodynamics has been violated during the calculation of AU or Q.

This program is organized into five routines. The first routine performs heat balance calculations and acts as a controller for the four configuration subroutines. Each configuration subroutine has two sections that calculate AU and E for that heat exchanger. You should first load the controller, then load the configuration of interest as a separate program.

You may wish to write your own configuration routines. A routine for a configuration must be in the following format:

LBL ACON
•
•
•
(calculates AU for this configuration)
•
•
•
RTN
•
•
•
LBL ECON
•
•
•
(calculates E for this configuration)
•
•
•
END

Example:

A liquid at 168°F is to be cooled to 117°F. The liquid has a heat capacity of 0.42 Btu/LBM-°F and flows at 7700 LBM/hr. Cooling water (heat capacity = 1.00) is available at 4800 lbm/hr at 50°F. For counterflow, crossflow, parallel-counterflow, and parallel flow heat exchangers with overall coefficients of 55 Btu/hr-ft^2-°F what areas are required?

Keystrokes: (SIZE ⩾ 023)	Display:
[///] [FIX] 4	
Load main routine and counterflow subroutine.	
[XEQ] [ALPHA] HEATX [ALPHA]	TC IN=?
50 [R/S]	TH IN=?
168 [R/S]	MC=?
4800 [R/S]	MH=?
7700 [R/S]	CPC=?
1 [R/S]	CPH=?
.42 [R/S]	SELECT KEY: E AU Q TC TH
Since the temperature of the outgoing fluid is known, press the [E] key.	
[E]	THO=?
117 [R/S]	E=0.4322
[R/S]*	AU=2,198.7662
[R/S]*	Q=164,933.9999
[R/S]*	TCO=84.3612
[R/S]*	SELECT KEY: E AU Q TC TH

Keystrokes:	Display:
Since A = AU/U, calculate A.	
2198.7662 [ENTER] 55 [÷]	39.9776
Load crossflow subroutine.	
[XEQ] [ALPHA] HEATX [ALPHA]	TC IN=?
[R/S]	TH IN=?
[R/S]	MC=?
[R/S]	MH=?
[R/S]	CPC=?
[R/S]	CPH=?
[R/S]	SELECT KEY: E AU Q TC TH
[E]	THO=?
[R/S]	E=0.4322
[R/S]*	AU=2,353.6675
[R/S]*	Q=164,934.0000
[R/S]*	TCO=84.3613
[R/S]	SELECT KEY: E AU Q TC TH
2353.6675 [ENTER] 55 [÷]	42.7940

An analogus procedure will yield areas of 42.2776 ft^2 and 45.1494 ft^2 for parallel-counterflow and parallel exchanges respectively.

User Instructions

				SIZE: 023
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1.	Load program and then:		[GTO] ..	
2.	Load configuration subroutine corresponding			
	to your heat exchanger geometry		[XEQ] HEATX	TC IN=?
3.	Input inlet temperature of cold fluid	T_{cin}	[R/S]	TH IN=?
4.	Input inlet temperature of hot fluid	T_{hin}	[R/S]	MC=?
5.	Input mass flow rate of cold fluid	m_c	[R/S]	MH=?
6.	Input mass flow rate of hot fluid	m_h	[R/S]	CPC=?
7.	Input specific heat of cold fluid	C_{pc}	[R/S]	CPH=?
8.	Input specific heat of hot fluid	C_{ph}	[R/S]	SELECT KEY
				E AU Q TC TH
9.	Select the known value:			
	heat exchanger effectiveness		[A]	E=?
	area-heat transfer coefficient product		[B]	AU=?
	heat transfer		[C]	Q=?
	outlet temperature of cold fluid		[D]	TCO=?
	outlet temperature of hot fluid		[E]	THO=?
	input the known value.	E	[R/S]	
		AU	[R/S]	
		Q	[R/S]	
		TCO	[R/S]	
		THO	[R/S]	
	The four variables other than the one you			E=
	input will be output. The output order		[R/S]*	AU=
	will vary depending on which value was		[R/S]*	Q=
	input. If the 2nd law of thermodynamics		[R/S]*	TCO=
	is violated, the message "2ND LAW ERR"		[R/S]*	THO=
	will be displayed.		[R/S]*	SELECT KEY

User Instructions

SIZE: 023

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
10.	For a new problem, go to step 2 or step 9.			E AU Q TC TH
	It is not necessary to key in any values			
	which do not change. Ignore the prompts			
	and press [R/S].			
*	Press [R/S] if you do not have a printer.			

Program Listings

Heat Exchanger - Main Routine

Input values.

```
01♦LBL "HEA
TX"
 02 2
 03 STO 00
 04 "TC IN"
 05 XEQ "IN"
 06 "TH IN"
 07 XEQ "IN"
 08 14
 09 STO 00
 10 "MC"
 11 XEQ "IN"
 12 "MH"
 13 XEQ "IN"
 14 "CPC"
 15 XEQ "IN"
 16 RCL 15
 17 *
 18 STO 05
 19 "CPH"
 20 XEQ "IN"
 21 RCL 16
 22 *
 23 STO 06
 24 "CON"
 25 ASTO 22
```

Select last input.

```
 26♦LBL 06
 27 CF 02
 28 CF 03
 29 CF 04
 30 CF 05
 31 CF 06
 32 CF 21
 33 SF 27
 34 "SELECT
KEY:"
 35 AVIEW
 36 SF 21
 37 PSE
 38♦LBL 00
 39 ADV
 40 "E AU Q
TC TH"
 41 PROMPT
 42 GTO 00
```

Input E.

```
 43♦LBL A
 44 SF 02
 45 9
 46 STO 00
 47 SF 01
 48 "E"
 49 XEQ "IN"
 50 ADV
 51 GTO 16
```

Input AU.

```
 52♦LBL B
 53 SF 03
 54 10
 55 STO 00
 56 "AU"
 57 XEQ "IN"
 58 ADV
 59 GTO 01
```

Input Q.

```
 60♦LBL C
 61 SF 04
 62 11
 63 STO 00
 64 "Q"
 65 XEQ "IN"
 66 ADV
 67 GTO 05
```

Input TCO.

```
 68♦LBL D
 69 SF 05
 70 12
 71 STO 00
 72 "TCO"
 73 XEQ "IN"
 74 ADV
 75 GTO 14
```

Input THO.

```
 76♦LBL E
 77 SF 06
 78 13
 79 STO 00
 80 "THO"
 81 XEQ "IN"
 82 ADV
 83 GTO 04
```

Calculate AU.

```
 84♦LBL 16
 85 FS?C 03
 86 GTO 06
 87 RCL 10
 88 "A"
 89 XEQ 08
 90 STO 11
 91 "AU"
 92 XEQ "O"
```

Calculate Q.

```
 93♦LBL 01
 94 FS?C 04
 95 GTO 06
 96 RCL 11
 97 "E"
 98 XEQ 08
 99 RCL 07
```

Program Listings

Heat Exchanger - Main Routine

```
*
RCL 04
RCL 03
-
*
STO 12
"Q"
XEQ "O"
```

Calculate TCO.

```
◆LBL 05
FS?C 05
GTO 06
RCL 12
RCL 05
X≠0?
/
RCL 03
+
STO 13
"TCO"
XEQ "O"
```

Calculate THO.

```
◆LBL 14
FS?C 06
GTO 06
RCL 13
RCL 03
-
RCL 05
*
RCL 06
X≠0?
/
RCL 04
-
CHS
STO 14
"THO"
XEQ "O"
```

Calculate E.

```
◆LBL 04
FS?C 02
GTO 06
RCL 13
RCL 03
-
RCL 05
*
RCL 04
RCL 14
-
RCL 06
*
X=0?
X<>Y
RCL 04
RCL 03
-
/
RCL 05
RCL 06
X<=Y?
X<>Y
RDN
X=0?
X<> T
/
STO 10
SF 01
"E"
XEQ "O"
GTO 16
```

A0 for C_{min}=0.00.

```
◆LBL "A0"
1
RCL 10
-
LN
CHS
RTN
```

E0 for C_{min}=0.00.

```
◆LBL "E0"
1
RCL 11
CHS
E↑X
-
RTN
```

Find C_{min} and execute configuration subroutine.

```
◆LBL 08
RCL 05
RCL 06
X>Y?
X<>Y
X<>Y
STO 07
X<>Y
X≠0?
STO 07
X<>Y
X≠0?
/
STO 09
SF 25
X=0?
"⊢0"
X≠0?
ARCL 22
```

Program Listings

Program	Comments
202 ASTO T	
203 XEQ IND T	
204 FS?C 25	
205 RTN	
206 "2ND LAW ERR"	Trap errors from subroutines
207 PROMPT	
208 GTO 06	
209♦LBL "IN"	Input subroutine
210 CF 22	
211 1	
212 ST+ 00	
213 RCL IND 00	
214 "⊢="	
215 ASTO Y	
216 "⊢?"	
217 CF 21	
218 AVIEW	
219 SF 21	
220 CLA	
221 ARCL Y	
222 STOP	
223 STO IND 00	
224 FS? 22	
225 FC? 55	
226 RTN	
227 ARCL X	Print if printer is attached
228 PRA	
229 RTN	
230♦LBL "O"	Output subroutine
231 "⊢="	
232 ARCL X	
233 AVIEW	
234 .END.	

Program Listings

Parallel Flow Subroutine

Calculate AU.

```
 01◆LBL "ACO
N"
 02 RCL 09
 03 1
 04 +
 05 RCL 10
 06 *
 07 CHS
 08 1
 09 +
 10 LN
 11 CHS
 12 1
 13 RCL 09
 14 +
 15 /
 16 RCL 07
 17 *
 18 RTN
```

Calculate E.

```
 19◆LBL "ECO
N"
 20 1
 21 +
 22 RCL 11
 23 RCL 07
 24 /
 25 *
 26 CHS
 27 E↑X
 28 CHS
 29 1
 30 +
 31 1
 32 RCL 09
 33 +
 34 /
 35 RTN
```

Program Listings

Counter Flow Subroutine

Calculate AU.

```
01♦LBL "ACO
N"
02 RCL 10
03 1/X
04 -
05 1
06 LASTX
07 -
08 /
09 LN
10 1
11 RCL 09
12 -
13 X=0?
14 GTO 10
15 /
16 RCL 07
17 *
18 RTN
19♦LBL 10
20 RCL 10
21 1
22 RCL 10
23 -
24 /
25 RCL 07
26 *
27 RTN
```

Calculate E.

```
28♦LBL "ECO
N"
29 1
30 -
31 RCL 11
32 RCL 07
33 /
34 *
35 E↑X
36 1
37 X<>Y
38 -
39 LASTX
40 RCL 09
41 *
42 1
43 X<>Y
44 -
45 X=0?
46 GTO 11
47 /
48 RTN
49♦LBL 11
50 RCL 11
51 RCL 07
52 /
53 ENTER↑
54 ENTER↑
55 1
56 +
57 /
58 RTN
```

Program Listings

Parallel-Counter Flow Subroutine

Calculate AU.

```
01♦LBL "ACO
N"
02 XEQ 12
03 2
04 *
05 RCL 12
06 2
07 RCL 10
08 /
09 +
10 RCL 08
11 -
12 /
13 CHS
14 1
15 +
16 LN
17 RCL 12
18 /
19 CHS
20 RCL 07
21 /
22 LASTX
23 X↑2
24 *
25 RTN
```

Calculate E.

```
26♦LBL "ECO
N"
27 XEQ 12
28 RCL 11
29 RCL 07
30 /
31 RCL 12
32 *
33 CHS
34 E↑X
35 1
36 X<>Y
37 +
38 1
39 LASTX
40 -
41 /
42 RCL 12
43 *
44 RCL 08
45 +
46 2
47 X<>Y
48 /
49 RTN
```

```
50♦LBL 12
51 RCL 09
52 1
53 +
54 STO 08
55 RCL 09
56 X↑2
57 1
58 +
59 SQRT
60 STO 12
61 RTN
```

Program Listings

Cross Flow Subroutine

Calculate AU.

```
 01♦LBL "ACO
N"
 02 0
 03 STO 19
 04 1
 05 RCL 10
 06 CHS
 07 STO 21
 08 +
 09 LN
 10 CHS
 11 STO 11
 12♦LBL 13
 13 RCL 11
 14 XEQ "ECO
N"
 15 RCL 10
 16 -
 17 STO 20
 18 RCL 19
 19 RCL 11
 20 STO 19
 21 -
 22 RCL 21
 23 RCL 20
 24 STO 21
 25 -
 26 /
 27 *
 28 ST- 11
 29 ABS
 30 1 E-4
 31 X<=Y?
 32 GTO 13
 33 RCL 11
 34 RTN
```

Calculate E.

```
 35♦LBL "ECO
N"
 36 RCL 11
 37 RCL 07
 38 /
 39 STO Y
 40 .22
 41 Y↑X
 42 RCL 09
 43 /
 44 /
 45 LASTX
 46 X<>Y
 47 CHS
 48 E↑X-1
 49 *
 50 E↑X
 51 CHS
 52 1
 53 +
 54 END
```

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	Storage Index	50	
	TC IN		
	TH IN		
05	CC	55	
	CH		
	Cmin		
	Cmax		
	Cmin/Cmax		
10	E	60	
	AU		
	Q		
	Tco		
	Tho		
15	MC	65	
	MH		
	cpc		
	cph		
	(AU_{i-1})		
20	$F(AU_i)$	70	
	$F(AU_{i-1})$		
	"CON"		
25		75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 23 TOT. REG. 102 USER MODE

ENG ____ FIX ____ SCI ____ ON X OFF ____

DEG ____ RAD ____ GRAD ____

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES
2	C	E was input	Calculate E
3	C	Au " "	" Au
4	C	Q was input	Calculate Q
5	C	TCO " "	" TCO
6	C	THO " "	" THO
21		Printer enable	Printer disable
22		Numeric input	No input
25		Ignore 1 error	Display error
27		User mode on	User mode off
55		Printer connected	No printer

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

HEAT EXCHANGERS

PROGRAM REGISTERS NEEDED: 67

ROW 1 (1 - 4)

ROW 2 (4 - 6)

ROW 3 (6 - 11)

ROW 4 (11 - 14)

ROW 5 (15 - 20)

ROW 6 (20 - 26)

ROW 7 (27 - 33)

ROW 8 (33 - 34)

ROW 9 (35 - 40)

ROW 10 (40 - 44)

ROW 11 (45 - 51)

ROW 12 (51 - 57)

ROW 13 (57 - 64)

ROW 14 (64 - 70)

ROW 15 (70 - 75)

ROW 16 (76 - 81)

ROW 17 (81 - 88)

ROW 18 (88 - 94)

HEAT EXCHANGERS

ROW 19 (94 - 102)

ROW 20 (103 - 110)

ROW 21 (111 - 119)

ROW 22 (119 - 129)

ROW 23 (130 - 137)

ROW 24 (138 - 148)

ROW 25 (149 - 161)

ROW 26 (162 - 168)

ROW 27 (168 - 175)

ROW 28 (176 - 183)

ROW 29 (184 - 196)

ROW 30 (197 - 203)

ROW 31 (204 - 206)

ROW 32 (206 - 210)

ROW 33 (211 - 216)

ROW 34 (217 - 224)

ROW 35 (225 - 230)

ROW 36 (231 - 234)

HEAT EXCHANGERS
COUNTER FLOW
PROGRAM REGISTERS NEEDED: 8

ROW 1 (1 - 6)

ROW 2 (7 - 19)

ROW 3 (19 - 25)

ROW 4 (26 - 36)

HEAT EXCHANGERS
CROSS FLOW
PROGRAM REGISTERS NEEDED: 14

ROW 1 (1 - 5)

ROW 2 (6 - 14)

ROW 3 (14 - 22)

ROW 4 (22 - 30)

ROW 5 (30 - 35)

ROW 6 (35 - 44)

ROW 7 (45 - 57)

ROW 8 (57 - 57)

HEAT EXCHANGERS
PAR–COUNTER FLOW
PROGRAM REGISTERS NEEDED: 12

ROW 1 (1 - 4)

ROW 2 (5 - 17)

ROW 3 (18 - 26)

ROW 4 (26 - 34)

ROW 5 (35 - 47)

ROW 6 (48 - 60)

ROW 7 (61 - 62)

HEAT EXCHANGERS
PARALLEL FLOW
PROGRAM REGISTERS NEEDED: 8

ROW 1 (1 – 6)

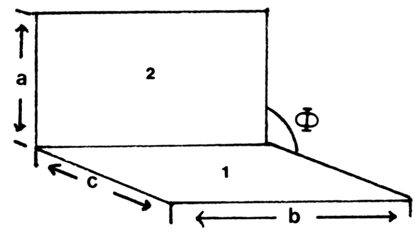
ROW 2 (7 – 19)

ROW 3 (19 – 25)

ROW 4 (26 – 36)

VIEW FACTOR

Given two surfaces, oriented as shown below, this program calculates the fraction of radiation leaving one surface that gets to the other, assuming a 90° angle.



The fraction of radiation that gets from 1 to 2 is the same as that which gets from 2 to 1.

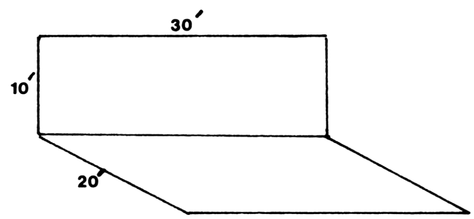
Equations:

$$X = a/b, \quad Y = c/b, \quad Z = X^2 + Y^2 - 2XY\cos\Phi$$

$$\begin{aligned}
F_{A_1-A_2}(\pi Y) = & -\frac{\sin 2\Phi}{4}\left[XY\sin\Phi + \left(\frac{\pi}{2} - \Phi\right)(X^2 + Y^2)\right. \\
& + Y^2\tan^{-1}\left(\frac{X - Y\cos\Phi}{Y\sin\Phi}\right) \\
& \left. + X^2\tan^{-1}\left(\frac{Y - X\cos\Phi}{X\sin\Phi}\right)\right] \\
& + \frac{\sin^2\Phi}{4}\left\{\left(\frac{2}{\sin^2\Phi} - 1\right)\ln\left[\frac{(1 + X^2)(1 + Y^2)}{1 + Z}\right]\right. \\
& \left. + Y^2\ln\left[\frac{Y^2(1 + Z)}{(1 + Y^2)Z}\right] + X^2\ln\left[\frac{X^2(1 + X^2)^{\cos 2\Phi}}{Z(1 + Z)^{\cos 2\Phi}}\right]\right\} \\
& + Y\tan^{-1}\left(\frac{1}{Y}\right) + X\tan^{-1}\left(\frac{1}{X}\right) - \sqrt{Z}\tan^{-1}\left(\frac{1}{\sqrt{Z}}\right) \\
& + \frac{\sin\Phi\sin 2\Phi}{2}X\sqrt{1 + X^2\sin^2\Phi} \\
& \times\left[\tan^{-1}\left(\frac{X\cos\Phi}{\sqrt{1 + X^2\sin^2\Phi}}\right)\right. \\
& \left. + \tan^{-1}\left(\frac{Y - X\cos\Phi}{\sqrt{1 + X^2\sin^2\Phi}}\right)\right] \\
& + \cos\Phi\int_0^Y \sqrt{1 + \xi^2\sin^2\Phi}\left[\tan^{-1}\left(\frac{X - \xi\cos\Phi}{\sqrt{1 + \xi^2\sin^2\Phi}}\right)\right. \\
& \left. + \tan^{-1}\left(\frac{\xi\cos\Phi}{\sqrt{1 + \xi^2\sin^2\Phi}}\right)\right] d\xi
\end{aligned}$$

Example:

Find the view factor for the arrangement below:



Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 006	
[XEQ] [ALPHA] VIEW [ALPHA]	WIDTH ?
30 [R/S]	HEIGHT ?
10 [R/S]	DEPTH ?
20 [R/S]	F=0.1595

(what if the height were only 8'?)

[A]	WIDTH ?
[R/S]	HEIGHT ?
8 [R/S]	DEPTH ?
[R/S]	F=0.1379

User Instructions

SIZE: 006

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program			
2	Initialize		[XEQ] VIEW	WIDTH ?
3	Key in width	b	[R/S]	HEIGHT ?
4	Key in height	a	[R/S]	DEPTH ?
5	Key in depth	c	[R/S]	F=
6	For a new problem press [A] and go to step			
	3. Inputs that don't change can be skipped			
	by just pressing [R/S].		[A]	WIDTH ?

Program Listings

Initialize

```
01♦LBL "VIEW"
02 SF 27
```

Input

```
03♦LBL A
04 CF 22
05 "WIDTH ?"
06 PROMPT
07 FS?C 22
08 STO 00
09 "HEIGHT ?"
10 PROMPT
11 FS?C 22
12 STO 01
13 "DEPTH ?"
14 PROMPT
15 FS?C 22
16 STO 02
```

Calculate X, Y and Z

```
17 RCL 01
18 RCL 00
19 /
20 STO 03
21 X↑2
22 RCL 02
23 RCL 00
24 /
25 STO 04
26 X↑2
27 +
28 STO 05
```

Calculate F

```
29 RCL 03
30 X↑2
31 1
32 +
33 RCL 04
34 X↑2
35 1
36 +
37 *
38 RCL 05
39 1
40 +
41 /
42 LN
43 RCL 04
44 X↑2
45 RCL 05
46 1
47 +
48 *
49 RCL 04
50 X↑2
51 1
52 +
53 /
54 RCL 05
55 /
56 LN
57 RCL 04
58 X↑2
59 *
60 +
61 RCL 03
62 X↑2
63 RCL 05
64 1
65 +
66 *
67 RCL 03
68 X↑2
69 1
70 +
71 /
72 RCL 05
73 /
74 LN
75 RCL 03
76 X↑2
77 *
78 +
79 4
80 /
81 1
82 ASIN
83 2
84 *
85 PI
86 /
87 *
88 RCL 03
89 1/X
90 ATAN
91 RCL 03
92 *
93 +
94 RCL 04
95 1/X
96 ATAN
97 RCL 04
98 *
```

Program Listings

```
 99 +
100 RCL 05
101 SQRT
102 1/X
103 ATAN
104 RCL 05
105 SQRT
106 *
107 -
108 RCL 04
109 /
110 1
111 ASIN
112 2
113 *
114 /
115 "F="          Output F
116 ARCL X
117 AVIEW
118 RTN
119 .END.
```

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	b	50	
	a		
	c		
	X		
	Y		
05	Z	55	
10		60	
15		65	
20		70	
25		75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 006 TOT. REG. 28 USER MODE
ENG ____ FIX ____ SCI ____ ON X OFF ____
DEG ____ RAD ____ GRAD ____

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES
22	C	Numeric input	No input
27	S	User mode on	User mode off

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

VIEW FACTOR

PROGRAM REGISTERS NEEDED: 23

ROW 1 (1 - 4)

ROW 2 (4 - 8)

ROW 3 (9 - 12)

ROW 4 (13 - 17)

ROW 5 (18 - 30)

ROW 6 (31 - 43)

ROW 7 (44 - 56)

ROW 8 (57 - 69)

ROW 9 (70 - 82)

ROW 10 (83 - 95)

ROW 11 (96 - 108)

ROW 12 (109 - 118)

ROW 13 (119 - 119)

HEAT TRANSFER THROUGH COMPOSITE CYLINDERS AND WALLS

This program can be used to calculate the overall heat transfer coefficient for composite tubes and walls from individual section conductances and surface coefficients.

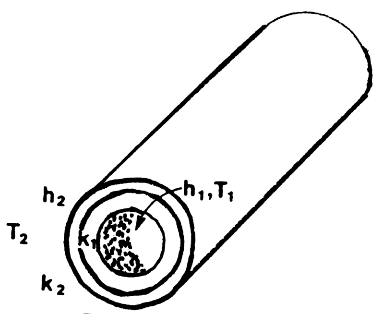


Figure 1.—Composite tube

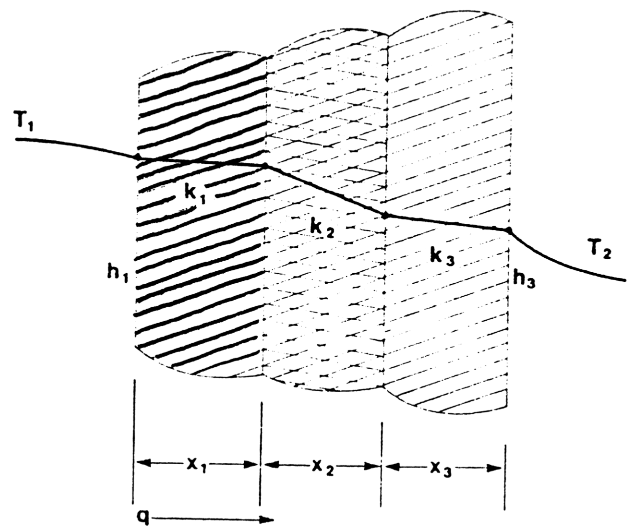


Figure 2. —Composite wall

Equations:

The overall heat transfer coefficient U is defined by:

$$q/L = U \, \Delta T$$

or

$$q/A = U \, \Delta T$$

where ΔT is the total temperature difference $(T_2 - T_1)$, q/L is the heat transfer per unit length of pipe, and q/A is the heat transfer per unit area of wall.

For cylinders

$$U = \frac{2\pi}{\frac{2}{h_1 D_1} + \frac{\ln(D_2/D_1)}{k_1} + \frac{\ln(D_3/D_2)}{k_2} + \ldots + \frac{\ln(D_n/D_{n-1})}{k_{n-1}} + \frac{2}{h_n D_n}}$$

For walls

$$U = \frac{1}{\frac{1}{h_1} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \ldots + \frac{x_n}{k_n} + \frac{1}{h_n}}$$

where

- h is the convective surface coefficient;
- D_n is the outside diameter of the annulus;
- k is the conductive coefficient;
- x is the thickness of a wall section.

Remarks:

These equations are for steady state heat transfer through materials with constant properties in all directions.

For composite cylinders, inputs must start with the inside convective coefficient and work out.

Zero is an invalid input for D, k, and h.

Dimensional consistency must be maintained.

Example:

A steel pipe with an inside diameter of 4 inches and a thickness of 0.5 inches has a conductivity of 25 Btu/ft-hr-°F. Two inches of asbestos (k = 0.1 Btu/hr-ft-°F) enclose the pipe bringing the total diameter to 9 inches. If the inside convective coefficient is 1000 Btu/hr-ft^2-°F and the outside coefficient is 5 Btu/hr-ft^2-°F, what is the overall heat transfer coefficient? What is the heat loss for 100 feet of pipe if ΔT is 115°F?

Keystrokes:	Display:	
[XEQ] [ALPHA] SIZE [ALPHA] 009		
[XEQ] [ALPHA] CYL [ALPHA]	NO. OF SECTS?	
2 [R/S]	D?	
4 [ENTER↑] 12 [÷] [R/S]	H?	
1000 [R/S]	D?	
5 [ENTER↑] 12 [÷] [R/S]	K?	
25 [R/S]	D?	
9 [ENTER↑] 12 [÷] [R/S]	K?	
0.1 [R/S]	H?	
5 [R/S]	U=0.98	Btu/hr-ft-°F
115 [X]	112.44	Btu/hr-ft
100 [X]	11,244.20	Btu/hr

User Instructions

				SIZE: 009
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load program			
2	For walls go to step 3, and for cylinders			
	go to step 9.			
3	Initialize for walls		[XEQ] WALLS	NO. OF SECTS?
4	Key in number of sections	N	[R/S]	H?
5	Key in the first section's			
	convective coefficient	h_1	[R/S]	X?
6	Key in thickness of the current section	x_i	[R/S]	k?
7	Key in the conductive coefficient for the			
	section of step 6	k_i	[R/S]	X? or H?
	(Repeat steps 6 and 7 for each section.			
	The prompt after the last section will be			
	"H?")			
8	Key in the last section's			
	convective coefficient	h_n	[R/S]	U=
9	Initialize for cylinders		[XEQ] CYL	NO. OF SECTS?
10	Key in number of sections	N	[R/S]	D?
11	Key in the inside section's inner			
	diameter	D_1	[R/S]	H?
12	Key in the inside convective coefficient	h_1	[R/S]	D?
13	Key in the outside diameter of the current			
	section	D_i	[R/S]	K?
14	Key in the conductive coefficient for the			
	section of step 13	k_i	[R/S]	D? or H?
	(Repeat steps 13 and 14 for each section)			
15	Key in the outside convective coefficient	h_n	[R/S]	U=

Program Listings

Initialization

```
01◆LBL "CYL"
02 SF 00
03 GTO 00
04◆LBL "WALLS"
05 CF 00
06◆LBL 00
07 FIX 2
08 1
09 FS? 00
10 PI
11 STO 06
12 CLX
13 STO 08
14 FC? 00
15 GTO 01
```

Cylinders

```
16 "NO. OF SECTS?"
17 PROMPT
18 STO 00
19 "D?"
20 PROMPT
21◆LBL A
22 STO 07
23 "H?"
24 PROMPT
25 *
26 1/X
27 ST+ 08
28 FC?C 00
29 GTO "U"
30◆LBL B
31 "D?"
32 PROMPT
33 STO 01
34 "K?"
35 PROMPT
36 1/X
37 X<>Y
38 RCL 07
39 X<>Y
40 STO 07
41 /
42 LN
43 *
44 2
45 /
46 ST- 08
47 DSE 00
48 GTO B
49 RCL 01
50 GTO A
```

Walls

```
51◆LBL 01
52 SF 00
53 "NO. OF SECTS?"
54 PROMPT
55 STO 00
56◆LBL C
57 "H?"
58 PROMPT
59 1/X
60 ST+ 08
61 FC?C 00
62 GTO "U"
63◆LBL D
64 "X?"
65 PROMPT
66 "K?"
67 PROMPT
68 /
69 ST+ 08
70 DSE 00
71 GTO D
72 GTO C
```

Calculate U and display

```
73◆LBL "U"
74 RCL 08
75 1/X
76 RCL 06
77 *
78 STO 04
79 "U="
80 ARCL X
81 AVIEW
82 STOP
83 .END.
```

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	No. of surfaces	50	
	outside diameter		
	U		
05		55	
	1 or π		
	temp. storage		
	ΣR		
10		60	
15		65	
20		70	
25		75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 009 TOT. REG. 034 USER MODE
ENG ____ FIX 2 SCI ____ ON ____ OFF X
DEG ____ RAD ____ GRAD ____

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES
00		Cyl	Walls

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

HEAT TRANSFER THROUGH COMPOSITE CYLINDERS AND WALLS

PROGRAM REGISTERS NEEDED: 26

ROW 1 (1 - 4)

ROW 2 (4 - 8)

ROW 3 (9 - 16)

ROW 4 (16 - 18)

ROW 5 (19 - 26)

ROW 6 (27 - 32)

ROW 7 (33 - 43)

ROW 8 (44 - 50)

ROW 9 (51 - 53)

ROW 10 (53 - 59)

ROW 11 (60 - 65)

ROW 12 (66 - 72)

ROW 13 (72 - 79)

RCW 14 (79 - 83)

BLACK BODY THERMAL RADIATION

Bodies with finite temperatures emit thermal radiation. The higher the absolute temperature, the more thermal radiation emitted. Bodies which emit the maximum possible amount of energy at every wavelength for a specified temperature are said to be black bodies. While black bodies do not actually exist in nature, many surfaces may be assumed to be black for engineering considerations.

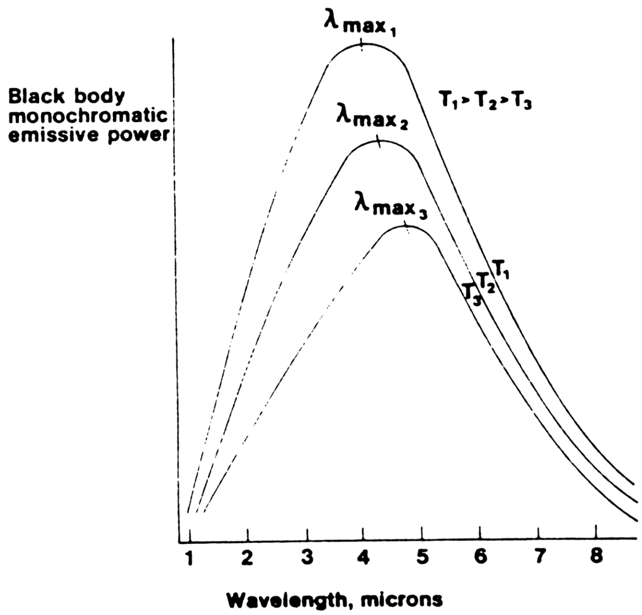


Figure 1.

Notes:

A half minute or more may be required to obtain $E_{b(0-\lambda)}$ or $E_{b(\lambda_1-\lambda_2)}$ since the integration is numerical.

Sources differ on values for constants. This could yield small discrepancies between published tables and program outputs.

Figure 1 is a representation of black body thermal emission as a function of wavelength. Note that as temperature increases, the area under the curves (total emissive power $E_{b(0-\infty)}$) increases. Also note that the wavelength of maximum emissive power λ_{max} shifts to the left as temperature increases.

This program calculates the wavelength of maximum emissive power for a given temperature, the temperature for which a given wavelength would be the wavelength of maximum emissive power, the total emissive power over all wavelengths, the emissive power at a particular wavelength, the emissive power from zero to a specified wavelength, and the emissive power between specified wavelengths.

Equations:

$$\lambda_{max} T_{\lambda_{max}} = c_3$$

$$E_{b(0-\infty)} = \sigma T^4$$

$$E_{b\lambda} = \frac{2\pi c_1}{\lambda^5 (e^{c_2/\lambda T} - 1)}$$

$$E_{b(0-\lambda)} = \int_0^\lambda E_{b\lambda}\, d\lambda$$

$$= 2\pi c_1 \sum_{k=1}^{\infty} -T/kc_2\, e^{-\frac{kc_2}{T\lambda}} \left[\left(\frac{1}{\lambda}\right)^3 + \frac{3T}{\lambda^2 kc_2} + \frac{6}{\lambda}\left(\frac{T}{kc_2}\right)^2 + 6\left(\frac{T}{kc_2}\right)^3 \right]$$

$$E_{b(\lambda_1-\lambda_2)} = E_{b(0-\lambda_2)} - E_{b(0-\lambda_1)}$$

where:

λ_{max} is the wavelength of maximum emissivity in microns;

T is the absolute temperature in °R or K;

$E_{b(0-\infty)}$ is the total emissive power in Btu/hr-ft^2 or Watts/cm^2;

$E_{b\lambda}$ is the emissive power at λ in Btu/hr-ft^2-μm or Watts/cm^2-μm;

$E_{b(0-\lambda)}$ is the emissive power for wavelengths less than λ in Btu/hr-ft^2 or Watts/cm^2;

$E_{b(\lambda_1-\lambda_2)}$ is the emissive power for wavelengths between λ_1 and λ_2 in Btu/hr-ft^2 or Watts/cm^2.

$c_1 = 1.8887982 \times 10^7$ Btu-μm^4/hr-ft^2
$= 5.9544 \times 10^3$ Wμm^4/cm^2

$c_2 = 2.58984 \times 10^4$ μm-°R $= 1.4388 \times 10^4$ μm-K

$c_3 = 5.216 \times 10^3$ μm-°R $= 2.8978 \times 10^3$ μm-K

$\sigma = 1.713 \times 10^{-9}$ Btu/hr-ft^2-°R^4 $= 5.6693 \times 10^{-12}$ W/cm^2-K^4

$\sigma_{exp} = 1.731 \times 10^{-9}$ Btu/hr-ft^2-°R^4 $= 5.729 \times 10^{-12}$ W/cm^2-K^4

References: HP-67/97 Users' Library Program.

Example:

What percentage of the radiant output of a lamp is in the visible range (0.4 to 0.7 microns) if the filament of the lamp is assumed to be a black body at 2400K?

Keystrokes: (SIZE ⩾ 009)	Display:
[USER]	(set USER mode)
[XEQ] [ALPHA] BB [ALPHA]	UNITS?
SI [R/S]	TEMP?
2400 [R/S]	WAVELENGTH?
.4 [R/S]	SOLVE
[F]	WV LNTH 2?
.7 [R/S]	EbL-L=4.9679
[C]	EbTOT=188.094
[÷]	0.0264
100 [x]	2.6412

User Instructions

SIZE: 009

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load program and set USER mode.		[USER]	
2.	Initialize program		[XEQ] BB	UNITS?
3.	Input code for desired units SI, or EN	SI	[R/S]	
	or EN	EN	[R/S]	TEMP?
4.	Input temperature, if temperature is	Temp	[R/S]	WAVELENGTH?
	unknown, press [R/S].			
5.	Input first wavelength, if wavelength is	λ	[R/S]	SOLVE
	unknown, press [R/S].			
6.	Calculate any or all of the following:			
	λmax for a given temperature		[A]	WLMAX=
	T such that λ is λmax for T		[B]	TEMP=
	total emissive power at T		[C]	EbTOT=
	emissive power at T and λ		[D]	EbL=
	emissive power between zero and λ		[E]	Eb0-L=
	emissive power between λ_1 and λ_2		[F]	WV LNTH 2?
		λ_2	[R/S]	EbL-L=
7.	For a new case, go to step 2.			

Program Listings

Initialize and prompt for units

```
01♦LBL "BB"
02 CLRG
03 CF 22
04 "UNITS?"
05 AON
06 PROMPT
07 AOFF
08 ASTO X
09 GTO IND
X
10♦LBL "SI"
```

Store units

```
11 5954.4
12 STO 01
13 14388
14 STO 02
15 2897.8
16 STO 03
17 5.6693 E
-12
18 STO 04
19 GTO 00
20♦LBL "EN"
21 18887982
22 STO 01
23 25998.4
24 STO 02
25 5216
26 STO 03
27 .171312
E-08
28 STO 04
```

Input prompting

```
29♦LBL 00
30 "TEMP?"
31 PROMPT
32 STO 05
33 "WAVELEN
GTH?"
34 PROMPT
35 STO 06
36 "SOLVE"
```

Calculate λmax

```
37 PROMPT
38♦LBL A
39 RCL 03
40 RCL 05
41 /
42 "WL MAX=
"
43 ARCL X
44 PROMPT
45♦LBL B
46 RCL 03
47 RCL 06
```

Calculate T(λmax)

```
48 /
49 "TEMP="
50 ARCL X
51 PROMPT
```

Calculate E_b total

```
52♦LBL C
53 RCL 05
54 X↑2
55 X↑2
56 RCL 04
57 *
58 "EbTOT="
59 ARCL X
60 PROMPT
```

Calculate $E_{b\lambda}$

```
61♦LBL D
62 RCL 01
63 ENTER↑
64 +
65 PI
66 *
67 RCL 06
68 5
69 Y↑X
70 /
71 RCL 02
72 RCL 06
73 /
74 RCL 05
75 /
76 E↑X
77 1
78 -
79 /
80 "EbL="
81 ARCL X
82 PROMPT
```

Calculate $E_b(0-\lambda)$

```
83♦LBL E
84 0
85 STO 08
86 STO 07
87♦LBL 01
88 RDN
89 CLX
90 RCL 08
91 RCL 02
92 RCL 05
93 /
94 -
95 STO 08
96 3
97 X<>Y
```

Program Listings

```
 98 /
 99 RCL 06
100 X↑2
101 /
102 LASTX
103 1/X
104 RCL 06
105 /
106 -
107 6
108 RCL 06
109 /
110 RCL 08
111 X↑2
112 /
113 -
114 6
115 RCL 08
116 X↑2
117 /
118 RCL 08
119 /
120 +
121 RCL 08
122 RCL 06
123 /
124 E↑X
125 *
126 RCL 08
127 /
128 ST+ 07
129 RCL 07
130 /
131 1 E-05
132 X<=Y?
133 GTO 01
134 RDN
135 CLX
136 RCL 07
137 ENTER↑
138 +
139 PI
140 *
141 RCL 01
142 *
143 FS?C 00
144 RTN
145 "Eb0-L="
146 ARCL X
147 PROMPT
148♦LBL F          Calculate Eb(λ1-λ2)
149 "WV LNTH
 2?"
150 PROMPT
151 ENTER↑
152 ENTER↑
153 SF 00
154 XEQ E
155 X<>Y
156 RCL 06
157 STO 00
158 RDN
159 STO 06
160 SF 00
161 XEQ E
162 -
163 ABS
164 RCL 00
165 STO 06
166 RDN
167 "EbL-L="
168 ARCL X
169 PROMPT
170 .END.
```

80

90

00

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	λ	50	
	C_1		
	C_2		
	C_3		
	σ		
05	T	55	
	λ,λ'		
	sum		
	kc_2/T		
10		60	
15		65	
20		70	
25		75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 009 TOT. REG. 57 USER MODE
ENG ___ FIX 4 SCI ___ ON X OFF ___
DEG ___ RAD ___ GRAD ___

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES
00		Used	
22		Used	

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

BLACK BODY THERMAL RADIATION

PROGRAM REGISTERS NEEDED: 48

ROW 1 (1 – 4)

ROW 2 (4 – 10)

ROW 3 (10 – 13)

ROW 4 (13 – 17)

ROW 5 (17 – 20)

ROW 6 (20 – 23)

ROW 7 (23 – 27)

ROW 8 (27 – 30)

ROW 9 (30 – 33)

ROW 10 (33 – 36)

ROW 11 (36 – 42)

ROW 12 (42 – 49)

ROW 13 (49 – 57)

ROW 14 (58 – 62)

ROW 15 (63 – 75)

ROW 16 (76 – 83)

ROW 17 (83 – 95)

ROW 18 (96 – 108)

BLACK BODY THERMAL RADIATION

ROW 19 (109 - 121)

ROW 20 (122 - 131)

ROW 21 (131 - 141)

ROW 22 (142 - 146)

ROW 23 (147 - 149)

ROW 24 (149 - 158)

ROW 25 (159 - 167)

ROW 26 (167 - 170)

ECONOMIC BREAK EVEN FOR SOLAR EQUIPMENT

This program calculates the number of years necessary for solar equipment to pay for itself.

Equation:

$$\text{YEARS} = \frac{-\ln\left\{1 - \dfrac{\$\ \text{SPENT}\ (\%\text{INT}-\%\text{INF})}{365\,(\text{BTU/DAY})\,(\$/\text{BTU})\,(1+\%\text{INF})}\right\}}{\ln\left\{1 + \dfrac{\%\text{INT}-\%\text{INF}}{1+\%\text{INF}}\right\}}$$

where:

- \$ SPENT = the cost of the solar equipment.
- \$/BTU = the cost of purchased energy per BTU.
- BTU/DAY = the amount of energy drawn from your solar equipment per day.
- %INT = the current lending rate to buy equipment
- %INF = the expected inflation rate for the cost of energy.
- YEARS = the number of years before the solar equipment pays for itself.

Example:

Aaron B. Waters wants to buy \$2000 worth of solar equipment with which he hopes to bring in 75,000 BTU per day. The cost per BTU for the energy source he is replacing is $\$3.66\times10^{-6}$ \$/BTU. The lending rate is 14.5% and the inflation rate is 15%. How long will it take the equipment to pay for itself?

Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 005	
[XEQ] [ALPHA] EBE [ALPHA]	\$ SPENT ?
2000 [R/S]	\$/BTU ?
3.66 [EEX] 6 [CHS] [R/S]	BTU/DAY ?
75000 [R/S]	%INT ?
14.5 [R/S]	%INF ?
15 [R/S]	19.10 YEARS

What if he spent $1500 and got 65,000 BTU/DAY?

[R/S]	$ SPENT ?
1500 [R/S]	$/BTU ?
[R/S]	BTU/DAY ?
65000 [R/S]	%INT ?
[R/S]	%INF ?
[R/S]	16.62 YEARS

User Instructions

SIZE: 005

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program.			
2	Initialize.		[XEQ] EBE	$ SPENT ?
3	Key in amount spent on solar equipment.	$ SPENT	[R/S]	$/BTU ?
4	Key in amount per BTU for the energy source			
	being replaced.	$/BTU	[R/S]	BTU/DAY ?
5	Key in the number of BTU per day to be			
	drawn from the solar equipment.	BTU/DAY	[R/S]	%INT ?
6	Key in the current lending rate.	%INT	[R/S]	%INF ?
7	Key in the expected fuel inflation rate.	%INF	[R/S]	( ) YEARS
8	For a new problem press [A] and go to step			
	3.		[R/S]	$ SPENT ?
	For any value which does not change just			
	press [R/S].			

Program Listings

```
 01♦LBL "EBE
"
 02 "$ SPENT      Input
?"
 03 RCL 00
 04 PROMPT
 05 STO 00
 06 RCL 01
 07 "$/BTU?"
 08 PROMPT
 09 STO 01
 10 RCL 02
 11 "BTU/DAY
?"
 12 PROMPT
 13 STO 02
 14 RCL 03
 15 "%INT?"
 16 PROMPT
 17 STO 03
 18 RCL 04
 19 "%INF?"
 20 PROMPT
 21 STO 04
 22 RCL 03
 23 X<>Y          Calculate break-
 24 -             even
 25 1
 26 %
 27 RCL 04
 28 1 E2
 29 /
 30 1
 31 +
 32 /
 33 RCL 00
 34 365
 35 RCL 01
 36 *
 37 RCL 02
 38 *
 39 /
 40 X<>Y
 41 X=0?
 42 GTO 01
 43 *
 44 CHS
 45 LN1+X
 46 CHS
 47 X<>Y
 48 LN1+X
 49 /
 50 GTO 02
 51♦LBL 01
 52 LASTX         Special case
 53 RCL 00        where %INT=%INF
 54 RCL 04
 55 %
 56 +
 57 X<>Y
 58 /
 59♦LBL 02
 60 CLA           Output # of years
 61 ARCL X
 62 "├ YEARS
"
 63 AVIEW
 64 END
```

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	$ SPENT	50	
	$/BTU		
	BTU/DAY		
	%INT		
	%INF		
05		55	
10		60	
15		65	
20		70	
25		75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 005 TOT. REG. 25 USER MODE

ENG ____ FIX 2 SCI ____ ON ____ OFF ____

DEG ____ RAD ____ GRAD ____

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

ECONOMIC BREAK EVEN FOR SOLAR EQUIPMENT

PROGRAM REGISTERS NEEDED: 17

ROW 1 (1 : 2)

ROW 2 (2 : 7)

ROW 3 (7 : 11)

ROW 4 (12 : 19)

ROW 5 (19 : 27)

ROW 6 (28 : 36)

ROW 7 (37 : 48)

ROW 8 (49 : 60)

ROW 9 (61 : 64)

ROW 10 (64 : 64)

SOLAR PANEL ARRAY

When solar panels are installed on flat roofs or on the ground it often is necessary or desirable to arrange the collectors in several rows, one in back of another. In such an array the arrangement to prevent the southmost rows from shading the others becomes important. This program calculates the appropriate distance between the collector arrays. Input is the Date, Latitude, Longitude, Time of Day, Local Standard Time Meridian, and the length of the solar collector panel.

Actual distance between rows, will, in final analysis, be a matter of judgement based on available space and economic conditions. For example, partial shading during the early morning and late afternoon hours in late December may be an accpetable compromise based on limited space available for panel mounting.

A most important factor in establishing the array is to establish the sun angle, S, and shade length, D_2, on an hourly and daily basis. Assuming that the array is facing south, and that you know the latitude of the location, this can be accomplished for any day of the year and time of day.

Equations:

$$N = [INT(365.25y') + INT(30.6001m') + DD + 1,720,983] - [INT(365.25(YYYY-1)) + INT(30.6001(MM+13)) + 1,720,983]$$

Where:

N=Numbered day of the year counting from Jan. 1 as day 1
MM=Month
DD=Day of the month
YYYY=Year
y'= Year-1, if MM=1 or 2
Year, if MM > 2
m'= Month+13, if MM=1 or 2
Month +1, if MM > 2

$$\delta = 23.45SIN\left[\frac{360(284+N)}{365}\right]$$

Where:

δ = Sun's declination, degrees

AST = LST + 4(LSM - LON)

Where: LON = Local Longitude

AST = Apparent Solar Time

LST = Local Standard Time

LSM = Local Standard Meridian

$$S = TAN^{-1} \frac{SIN\ \delta\ SIN\ \emptyset + COS\ \delta\ COS\ \emptyset\ COS\ w}{COS\ \delta\ SIN\ \emptyset\ COS\ w - SIN\ \delta\ COS\ \emptyset}$$

Where:

S = sun angle in a plane perpendicular to the earth and parallel to the longitude
Ø = latitude (north positive)
w = hour angle, solar noon being zero, and each hour equaling 15° of longitude with morning positive and afternoon negative

$$V = L\ SIN\ T$$

$$D_1 = \frac{V}{TAN\ S} + L\ COS\ T$$

$$D_2 = \frac{V}{TAN\ S}$$

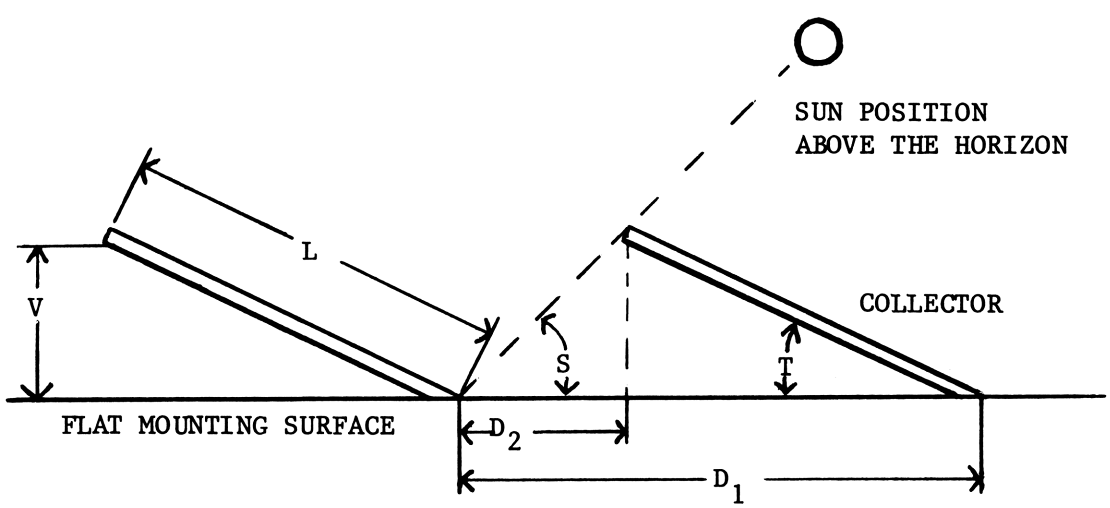
Where:

V = height from the horizontal to the top of solar panel, FT.

D_1 = distance from front of first row of collectors to the front of the row behind, FT.

D_2 = shade length, FT.

L = solar collector panel length, FT.



Establishing Distance Between Rows on a Flat Mounting Surface

Example:

In an array of 7' panels located at 36°25' north latitude and 97°30' west longitude with a panel tilt of 46° find V, D_1 and D_2 at 12 noon Central Standard Time on 12/21/1979.

Keystrokes:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 012	
[XEQ] [ALPHA] PANEL [ALPHA]	MM.DDYYYY?
12.211979 [R/S]	LAT ?
36.25 [R/S]	LONG ?
97.3 [R/S]	TIME ?
12 [R/S]	TIME MER ?
90 [R/S]	TILT $\angle$?
46 [R/S]	LENGTH ?
7 [R/S]	V=5.0354
[R/S]	D_1=13.6006
[R/S]	D_2=8.7380

What about at 1 PM on 6/1/1979?

[A]	MM.DDYYYY?
6.011979 [R/S]	LAT ?
[R/S]	LONG ?
[R/S]	TIME ?
13 [R/S]	TIME MER ?
[R/S]	TILT $\angle$?
[R/S]	LENGTH ?
[R/S]	V = 5.0354
[R/S]	D_1= 6.1373
[R/S]	D_2= 1.2747

User Instructions

SIZE: 012

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program.			
2	Initialize.		[XEQ]PANEL	MM.DDYYYY ?
3	Key in the date.	Date	[R/S]	LAT ?
4	Key in the latitude in Degrees, Minutes			
	and Seconds (D.MS). [CHS] for south.	(D.MS)	[R/S]	LONG ?
5	Key in the longitude in D.MS. [CHS] for	D.MS)	[R/S]	TIME ?
	east. Key in the local time from a 24			
	hour clock.	t(H.MS)	[R/S]	TIME MER ?
6	Key in the time meridian:			
	60°=Atlantic Standard Time			
	75°=Eastern Standard Time			
	90°=Central Standard Time			
	105°=Mountain Standard Time			
	120°=Pacific Standard Time	(D.MS)	[R/S]	TILT∠ ?
7	Key in the angle of panel tilt.	T(D.MS)	[R/S]	LENGTH?
8	Key in the length of the panel.	L	[R/S]	V=
			[R/S]	D1=
			[R/S]	D2=
9	For a new length press [B] and go to step 8.		[B]	LENGTH?
10	To change any or all of the other variables,			
	press [A] and go to step 3.		[A]	MM.DDYYYY ?
	Skip unchanging values with [R/S].			

Program Listings

Initialization

```
 01♦LBL "PAN
EL"
 02 SF 27
```

Input

```
 03♦LBL A
 04 CF 22
 05 "MM.DDYY
YY?"
 06 PROMPT
 07 FC?C 22
 08 GTO 04
```

Calculate DOY and declination

```
 09 STO 00
 10 ENTER↑
 11 INT
 12 STO 07
 13 -
 14 1 E2
 15 *
 16 ENTER↑
 17 INT
 18 STO 08
 19 -
 20 1 E4
 21 *
 22 STO 09
 23 CF 02
 24♦LBL 01
 25 2
 26 RCL 07
 27 X>Y?
 28 GTO 00
 29 RCL 09
 30 1
 31 -
 32 STO 09
 33 RCL 07
 34 13
 35 +
 36 STO 07
 37 GTO 03
 38♦LBL 00
 39 RCL 07
 40 1
 41 +
 42 STO 07
 43♦LBL 03
 44 365.25
 45 RCL 09
 46 *
 47 INT
 48 30.6001
 49 RCL 07
 50 *
 51 INT
 52 +
 53 RCL 08
 54 +
 55 1720982
 56 +
 57 FS? 02
 58 GTO 02
 59 STO 01
```

Day #

Get Day # for Jan. 1

```
 60 1
 61 STO 07
 62 STO 08
 63 SF 02
 64 GTO 01
 65♦LBL 02
 66 RCL 01
 67 1
 68 +
 69 X<>Y
 70 -
 71 STO 09
```

DOY

```
 72 RCL 00
 73 CF 02
 74 360
 75 ENTER↑
 76 284
 77 RCL 09
 78 +
 79 365
 80 /
 81 *
 82 SIN
 83 23.45
 84 *
 85 STO 08
```

Declination

```
 86♦LBL 04
 87 "LAT ?"
 88 PROMPT
 89 HR
 90 FS?C 22
 91 STO 05
 92 "LONG ?"
 93 PROMPT
 94 HR
 95 FS?C 22
 96 STO 02
 97 "TIME ?"
 98 PROMPT
 99 HR
100 FS?C 22
```

Program Listings

```
101 STO 03
102 "TIME ME
R ?"
103 PROMPT
104 HR
105 FS?C 22
106 STO 11
107 RCL 11
108 RCL 02
109 X<>Y
110 -
111 .0667
112 *
113 RCL 03
114 X<>Y
115 -
116 12
117 X<>Y
118 -
119 15
120 *
121 STO 06
```

hour angle

```
122 "TILT∡ ?
"
123 PROMPT
124 HR
125 FS?C 22
126 STO 04
```

Given length calculate V D1 and D2

```
127♦LBL B
128 "LENGTH
?"
129 CF 22
130 PROMPT
131 FS?C 22
132 STO 10
133 RCL 08
134 SIN
135 RCL 05
136 SIN
137 *
138 RCL 08
139 COS
140 RCL 05
141 COS
142 *
143 RCL 06
144 COS
145 *
146 +
147 RCL 08
148 COS
149 RCL 05
150 SIN
151 *
152 RCL 06
153 COS
154 *
155 RCL 08
156 SIN
157 RCL 05
158 COS
159 *
160 -
161 /
162 ATAN
163 STO 00
```

δ

```
164 RCL 10
165 RCL 04
166 SIN
167 *
168 STO 07
169 "V="
170 ARCL X
171 PROMPT
```

V

```
172 RCL 00
173 TAN
174 /
175 RCL 10
176 RCL 04
177 COS
178 *
179 +
180 "D1="
181 ARCL X
182 PROMPT
```

D1

```
183 RCL 07
184 RCL 00
185 TAN
186 /
187 "D2="
188 ARCL X
189 PROMPT
```

D2

```
190 .END.
```

00	

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	Used	50	
	Used		
	Long.		
	Time		
	Tilt δ		
05	Lat.	55	
	δ		
	Used		
	AST		
	Used		
10	Length	60	
	Time Mer.		
15		65	
20		70	
25		75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 012 TOT. REG. 57 USER MODE
ENG ___ FIX 4 SCI ___ ON ___ OFF ___
DEG X RAD ___ GRAD ___

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES
02		Jan 1	Date

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

SOLAR PANEL ARRAY

PROGRAM REGISTERS NEEDED: 46

ROW 1 (1 - 3)

ROW 2 (4 - 5)

ROW 3 (6 - 14)

ROW 4 (15 - 24)

ROW 5 (25 - 35)

ROW 6 (36 - 44)

ROW 7 (44 - 49)

ROW 8 (50 - 56)

ROW 9 (57 - 65)

ROW 10 (66 - 75)

ROW 11 (76 - 83)

ROW 12 (83 - 88)

ROW 13 (89 - 94)

ROW 14 (95 - 100)

ROW 15 (100 - 102)

ROW 16 (103 - 111)

ROW 17 (111 - 121)

ROW 18 (122 - 126)

SOLAR PANEL ARRAY

ROW 19 (127 - 129)

ROW 20 (130 - 141)

ROW 21 (142 - 154)

ROW 22 (155 - 167)

ROW 23 (168 - 177)

ROW 24 (178 - 186)

ROW 25 (187 - 190)

CONDUIT FLOW

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)

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

is solved by Newton's method.

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

is used an 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 and $\mu = \rho\nu$;
- L is the conduit length;
- v is the average fluid velocity;
- K_T is the total of the applicable fitting coefficients in table 1.

Table 1

Fitting Coefficients

Fitting	K
Globe valve, wide open	7.5—10
Angle valve, wide open	3.8
Gate valve, wide open	0.15—0.19
Gate valve, 3/4 open	0.85
Gate valve, 1/2 open	4.4
Gate valve, 1/4 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	$5.0x10^{-6}$	$1.5x10^{-6}$
Commercial Steel or Wrought Iron	$1.5x10^{-4}$	$4.6x10^{-5}$
Asphalted Cast Iron	$4.0x10^{-4}$	$1.2x10^{-4}$
Galvanized Iron	$5.0x10^{-4}$	$1.5x10^{-4}$
Cast Iron	$8.3x10^{-4}$	$2.5x10^{-4}$
Wood Stave	$6.0x10^{-4}$ to $3.0x10^{-3}$	$1.8x10^{-4}$ to $9.1x10^{-4}$
Concrete	$1.0x10^{-3}$ to $1.0x10^{-2}$	$3.0x10^{-4}$ to $3.0x10^{-3}$
Riveted Steel	$3.0x10^{-3}$ to $3.0x10^{-2}$	$9.1x10^{-4}$ to $9.1x10^{-3}$

Reference:

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

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.

Example:

A heat exchanger has 20, 3 meter tube passes (60 m of pipe) with 180 degrees bends connecting each pair of tubes (from table 1, $K_T = 10 \times 1.6$). The fluid is water ($\nu = 9.3 \times 10^{-7} m^2/s$, $\rho = 10^3 kg/m^3$). 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:	Display:
[XEQ] [ALPHA] SIZE [ALPHA] 015	
[///] [ENG] 3	
[XEQ] [ALPHA] CONDUIT [ALPHA]	U=?
9.3 [EEX] [CHS] 7 [ENTER↑]	
[EEX] 3 [X] [R/S]	RHO=?
[EEX] 3 [R/S]	E=?
3 [EEX] [CHS] 4 [R/S]	L=?
60 [R/S]	D=?
2.54 [EEX] [CHS] 2 [R/S]	KT=?
16 [R/S]	V=?
3.05 [R/S]	DP=?
[R/S]	DP=521.9E3
[R/S]	Re=83.30E3
[R/S]	F=10.18E-3

User Instructions

				SIZE: 015
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load program			
2	Initialize		[XEQ] CONDUIT	U=?
3	Key in viscosity	μ	[R/S]	RHO=?
4	Key in density	ρ	[R/S]	E=?
5	Key in surface irregularity	ε	[R/S]	L=?
6	Key in length of conduit	L	[R/S]	D=?
7	Key in equivalent diameter	D	[R/S]	KT=?
8	Key in total fitting coefficient	K_T	[R/S]	V=?
9	Key in velocity if known, otherwise			
	press [R/S]	v	[R/S]	DP=?
10	Key in pressure drop if known, otherwise			
	press [R/S]. (either v or ΔP must be			
	known)	ΔP	[R/S]	(unknown)=
11	Optional: obtain Reynolds no.		[R/S]	Re=
	Optional: obtain Fanning friction factor		[R/S]	F=
12	To change just v or ΔP		[XEQ] C	V=?
13	Go to step 9			
14	To begin a whole new problem go to step 2			

Program Listings

Input

```
01◆LBL "CON
DUIT"
02 SF 21
03 SF 27
04 "U=?"
05 PROMPT
06 STO 09
07 "RHO=?"
08 PROMPT
09 STO 10
10 ST/ 09
11 "E=?"
12 PROMPT
13 STO 14
14 "L=?"
15 PROMPT
16 STO 03
17 "D=?"
18 PROMPT
19 STO 13
20 "KT=?"
21 PROMPT
22 4
23 /
24 STO 08
25◆LBL C
26 CF 22
27 "V=?"
28 PROMPT
29 SF 00
30 FS? 22
31 CF 00
32 STO 02
33 "DP=?"
34 PROMPT
```

1st V

Calculate ΔP

```
35 STO 04
36 XEQ 09
37 FS? 00
38 GTO 03
39 RCL 02
40 X↑2
41 *
42 RCL 10
43 *
44 STO 04
45 "DP="
```

Iterate to find V using 1st V as guess

```
46 GTO 10
47◆LBL 03
48 RND
49 STO 00
50 XEQ 08
51 RND
52 RCL 00
53 X<>Y
54 X≠Y?
55 GTO 03
56 "V=?"
57 RCL 02
58 GTO 10
```

Calculate constants

```
59◆LBL 09
60 RCL 10
61 RCL 13
62 RCL 14
63 /
64 STO 06
65 LN
66 1.737
67 STO 07
68 *
69 2.28
70 +
71 STO 12
72 STO 05
73 FS? 00
74 GTO 07
```

Is flow turbulent?

```
75◆LBL 08
76 16
77 RCL 02
78 RCL 13
79 *
80 RCL 09
81 /
82 STO 01
83 2300
84 X<=Y?
85 GTO 02
86 RDN
87 /
88 SQRT
89 1/X
90 STO 05
91 GTO 07
```

Iterate to find $\frac{1}{\sqrt{f}}$

```
92◆LBL 02
93 RCL 12
94 RCL 05
95 -
96 4.67
97 RCL 06
98 *
99 RCL 01
```

Program Listings

```
100 /
101 RCL 05
102 *
103 1
104 +
105 STO 11
106 LN
107 RCL 07
108 *
109 -
110 RCL 11
111 1/X
112 CHS
113 1
114 +
115 RCL 07
116 *
117 RCL 05
118 /
119 1
120 +
121 /
122 ST+ 05
123 RCL 05
124 /
125 ABS
126 1 E-3
127 X<=Y?
128 GTO 02
129◆LBL 07
130 RCL 05
131 1/X
132 X↑2
133 RCL 03
134 *
135 RCL 13
136 /
137 RCL 08
138 +
139 2
140 *
141 RCL 04
142 RCL 10
143 /
144 X<>Y
145 FS? 00
146 GTO 00
147 RTN
148◆LBL 00
149 /
```

```
150 SQRT
151 STO 02
152 RTN
153◆LBL 10
154 ARCL X
155 AVIEW
156 "Re="
157 ARCL 01
158 AVIEW
159 "F="
160 RCL 05
161 1/X
162 X↑2
163 ARCL X
164 AVIEW
165 END
```

Output

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00	V	50	
	Re		
	V		
	L		
	ΔP		
05	$1/\sqrt{f}$	55	
	ρ/ε		
	1.737		
	$K_T/4$		
	μ		
10	ρ	60	
	used		
	$1/\sqrt{f_0}$		
	D		
	ε		
15		65	
20		70	
25		75	
30		80	
35		85	
40		90	
45		95	

STATUS

SIZE 015 TOT. REG. 52 USER MODE
ENG 3 FIX ___ SCI ___ ON ___ OFF X
DEG ___ RAD ___ GRAD ___

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES
00		calculate V	calculate ΔP
22		calculate ΔP	calculate V
21		printer enable	printer disable
27		user mode on	user mode off

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

CONDUIT FLOW

PROGRAM REGISTERS NEEDED: 38

ROW 1 (1 : 2)

ROW 2 (3 : 7)

ROW 3 (7 : 14)

ROW 4 (14 : 20)

ROW 5 (20 : 27)

ROW 6 (27 : 33)

ROW 7 (33 : 41)

ROW 8 (42 : 50)

ROW 9 (50 : 57)

ROW 10 (58 : 66)

ROW 11 (66 : 74)

ROW 12 (74 : 83)

ROW 13 (83 : 93)

ROW 14 (94 : 103)

ROW 15 (104 : 116)

ROW 16 (117 : 126)

ROW 17 (126 : 137)

ROW 18 (138 : 148)

CONDUIT FLOW

ROW 19 (149 : 157)

ROW 20 (157 : 165)

ROW 21 (165 : 165)

ENERGY CASH FLOW

Energy cash flow gives information about the affordability of an energy related investment. This program uses many input variables (several are optional) to create a more accurate model of the cost and return on an energy investment than is possible with simple breakeven analysis. One of the major advantages of energy cash flow is that results appear in dollars on an annual basis so answers are meaningful to the typical investor. The program automatically uses the general inflation rate to adjust dollar amounts back to base year value.

The workhorses of this program are the local alpha labels and labels 00 and 16. The labels "A" through "F" and "a" through "e" pass alpha descriptors and pointers to label 00 which uses flag tests to determine whether to attach a "?" to the descriptor and then store the user's input, or to append ": " then ARCL the current parameter value. The bulk of the calculations are handled by label 19 which is initialized by label "J". Label 19 calls label 16 which is the subroutine that handles all the computation relating to inflation and discounting. Label 16 is derived from the uniform present worth modified formula:

$$P = A \frac{(1+e)}{(i-e)} \left[1 - \left(\frac{1+e}{1+i} \right)^N \right]$$

where: P = a present sum of money

A = an end of period payment in a uniform series of payments over N periods at i rate

i = an interest or discount rate

e = rate of escalation of A in each of N periods

N = number of interest or discounting periods

For clarity, let us divide the formula into four components

$$P \qquad A \qquad \frac{(1+e)}{(i-e)} \qquad \text{and} \qquad 1 - \left(\frac{1+e}{1+i} \right)^N$$

P = the accumulated present value in base year dollars after N years

A = at various times when label 16 is called, the base year's energy bills (before or after the proposed energy/conservation investment) the base year's maintenance costs (before or after . . .), or the annual loan payment

i = the general inflation rate

e = at various times when label 16 is called, the energy cost inflation rate, the maintenance cost inflation rate, or when figuring the discounted value of the loan payment (which is constant) 0

N = the number of years that have passed since the end of the base period

A bit of inspection reveals that the above formula is, for any given year with the same i and e, equivalent to P = A * C where C is a constant multiplier for various A's. Label 16 computes that constant for the year of concern since for both the before and after cases of energy costs and maintenance costs we are assuming the same rate of escalation (from before to after--not necessarily the same escalation rates for energy as for maintenance.) Thus we see that label 16 is computing the last two of the four sections of our formula.

Here is a typical output for one year with description:

		yearly cost- no investment	cumulative cost- no investment
year	83	1,970.	5,354.
	Y	1,916.	5,459.
after investment costs are lower for this year than if no investment were made		yearly cost- after investment	cumulative cost- after investment

Reference: "Simplified Energy Design Economics", by H. E. Marshall and Rosalie T. Ruegg, National Bureau of Standards Special Publication 544, U. S. Department of Commerce, January 1980.

SAMPLE PROBLEM:

Sven Junquist lives in Zumbrota, Minnesota. Due to the severe Minnesota winters, his fuel bill was $1400 in 1982, and he is interested in reducing it by installing solar equipment. His old natural gas furnace and water heater consumed 2800 CCF (hundred Cubic feet) of gas in 1982. The new equipment will reduce that to about 1800 CCF. The old system costs about $50 per year to maintain and the new system will add another $50 for a total maintenance cost of $100 per year. Natural gas costs about $0.50 per CCF, but that price is going up at 20% per year even though the general inflation rate is only 8%. The cost of maintenance is increasing at the 8% general inflation rate. If Sven takes out a 15-year loan for $3500 to buy the solar equipment, and the interest rate is 18%, will his investment save money?

SOLUTION:

Input	Function	Display	Comments
	[XEQ] "SIZE" 031		
	[XEQ] "ECF"	NO. YEARS?	Enter number of years for which calculations are to be made
5	[R/S]	START YEAR?	Enter 1st year
1983	[R/S]	LOAN TERM?	Enter loan term
15	[R/S]	LOAN %?	Enter interest rate on loan
18	[R/S]	LOAN AMT?	Enter amount of loan
3500	[R/S]	E BEFORE?	Enter energy costs before and after investment
2800	[R/S]	E AFTER?	
1800	[R/S]	E $/UNIT?	Enter cost per unit of energy source
.5	[R/S]	% E INF?	Enter rate of inflation for energy source
20	[R/S]	% G INF?	Enter general inflation rate
8	[R/S]	% M INF?	Enter rate of inflation for maintenance
8	[R/S]	M BEFORE?	Enter maintenance costs before investment
50	[R/S]	M AFTER?	Enter maintenance costs after investment
			The above values are echo printed if a printer is in the system
100	[R/S]	E % CH=-35.71	% change in energy costs with investment
	[R/S]*	MO PMT=56.36	Monthly payment required

Input	Function	Display	Comments
	[R/S]*	AN PMT=676.32	Annual payment required
	[R/S]*	83 1,606. 1,606.	(Rest of output as described in program description section)
	[R/S]*	1,726. 1,726.	
	[R/S]*	84 1,778. 3,384.	
	[R/S]*	1,791. 3,517.	
	[R/S]*	85 1,970. 5,354.	
	[R/S]*	Y 1,871. 5,389.	
	[R/S]*	86 2,184. 7,538.	
	[R/S]*	Σ 1,969. 7,357.	
	[R/S]*	87 2,421. 9,959.	
	[R/S]*	Σ 2,084. 9,442.	

*It is not necessary to press [R/S] if a printer is in the system.

SAMPLE PROBLEM (Part II):

Sven has found that he can get a low interest loan at 14% from the Department of Clever Conservation Techniques. In addition, he has increased his estimate of annual maintenance to $250. How much money would he save by the end of seven years.

SOLUTION:

Input	Function	Display	Comments
	[USER]		Set User mode. Enter new interest rate
14	[B]	LOAN %: 14.00	Enter new annual maintenance cost
250	[shift] [e]	M AFTER: 250.00	
	[I]	NO. YEARS?	Enter number of years to be calculated
10	[R/S]	START YEAR?	Start year remains the same. Push J to obtain new results
	[J]	E % CH=-35.71	
	[R/S]	MO PMT= 46.61	
	[R/S]	AN PMT=559.32	
	[R/S]*	83 1,606. 1,606.	
	[R/S]*	1,768. 1,768.	
	[R/S]*	84 1,778. 3,384.	
	[R/S]*	1,841. 3,609.	

Input	Function	Display	Comments
	[R/S]*	85 1,970. 5,354.	
	[R/S]*	Y 1,929. 5,537.	
	[R/S]*	86 2,184. 7,538.	
	[R/S]*	Y 2,033. 7,570.	
	[R/S]*	87 2,421. 9,959.	
	[R/S]*	Σ 2,155. 9,725.	
	[R/S]*	88 2,684. 12,643.	
	[R/S]*	Σ 2,296. 12,021.	
	[R/S]*	89 2,977. 15,621.	
	[R/S]*	Σ 2,458. 14,479.	
	.		
	.		
	.		
	.		
	.		
	.		
	.		Savings will continue to
	.		increase each year

*It is not necessary to press [R/S] if a printer is in the system.

User Instructions

SIZE: 031

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1.	Load the program.			
2.	Initialize.		[XEQ] "ECF"	NO. OF YRS?
3.	Key in number of years to be printed.	# years	[R/S]	START YEAR?
4.	Key in first year.	year	[R/S]	LOAN TERM?
5.	Key in the loan term.	# years	[R/S]	LOAN %?
6.	Key interest rate of the loan in percent.	%	[R/S]	LOAN AMT?
7.	Key in the amount of the loan in dollars.	$ amount	[R/S]	E BEFORE?
8.	Key in the amount of energy used per			
	season before the improvement.	# units	[R/S]	E AFTER?
9.	Key in the amount of energy (estimate)			
	used per season after the improvement.	# units	[R/S]	E $/UNIT?
10.	Key in energy cost per unit.	$/unit	[R/S]	% E INF?
*11.	Key in percent energy inflation.	%	[R/S]	% G INF?
*12.	Key in percent general inflation.	%	[R/S]	% M INF?
*13.	Key in percent maintenance inflation.	%	[R/S]	M BEFORE?
*14.	Key in cost of maintenance before the			
	improvement (per season).	$ amount	[R/S]	M AFTER?
*15.	Key in cost of maintenance after the			
	improvement (per season).	$ amount	[R/S]	E %CH=
			[R/S]^p	MO PMT=
			[R/S]^p	AN PMT=
			[R/S]^p	yr y$bef t$bef
	yr represents the year.		[R/S]^p	** y$aft t$aft
	y$bef represents the cost for the year if no modification had been made.	*	indicates an optional step.	
	t$bef represents the total cost to date if no modification had been made.	p	indicates a step that is necessary only if printer is absent.	
	y$aft represents the cost for the year after the modification.	**	a Y in this position indicates positive annual cashflow, a	
	t$aft represents the total cost to date after the modification.		Σ indicates positive total cashflow.	

User Instructions

				SIZE:
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
*16.	Set User Mode.		[USER]	LOAN TERM:
*17.	To examine any variable:			
	Loan term.		[A]	LOAN TERM:
	Loan interest rate.		[B]	LOAN %:
	Loan amount.		[C]	LOAN AMT:
	Energy before improvement.		[D]	E BEFORE:
	Energy after improvement.		[E]	E AFTER:
	Energy: dollars per unit.		[F]	E $/UNIT:
	% Energy inflation.		[shift] [a]	% E INF:
	% general inflation.		[shift] [b]	% G INF:
	% maintenance inflation.		[shift] [c]	% M INF:
	Maintenance before improvement.		[shift] [d]	M BEFORE:
	Maintenance after improvement.		[shift] [e]	M AFTER:
*18.	To change any variable:			
	Loan term.	# years	[A]	LOAN TERM:
	Loan interest rate.	%	[B]	LOAN %:
	Loan amount.	$ amount	[C]	LOAN AMT:
	Energy before improvement.	# units	[D]	E BEFORE:
	Energy after improvement.	# units	[E]	E AFTER:
	Energy: dollars per unit.	$/unit	[F]	E $/UNIT:
	% energy inflation.	%	[shift] [a]	% E INF:
	% general inflation.	%	[shift] [b]	% G INF:
	% maintenance inflation.	%	[shift] [c]	% M INF:
	Maintenance before improvement.	$ amount	[shift] [d]	M BEFORE:
	Maintenance after improvement.	$ amount	[shift] [e]	M AFTER:
	Number of years to be printed and			
	starting year.		[I]	NO. OF YRS?

User Instructions

				SIZE:
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
		# years	[R/S]	START YEAR?
		year	[R/S]	year
*19.	To reprint cashflow after changes.		[J]	yr y$bef t$bef
			[R/S]p	** y$aft t$aft
			⋮	⋮

Program Listings

```
 01♦LBL "ECF
"
```

Initialize and enter the prompted sequence

```
 02 CLRG
 03 CF 06
 04 XEQ I
 05 SF 05
 06 CF 08
```

Establish loop parameters for case with or without maintenance

```
 07♦LBL 13
 08 1.011
 09 FS? 06
 10 1.008
 11 STO 00
```

Loop to prompt for input or print output if printer is present

```
 12♦LBL 14
 13 CF 22
 14 XEQ IND
00
 15 FS? 08
 16 PRA
 17 ISG 00
 18 GTO 14
```

If finished prompting go to J else return 124

```
 19 FS?C 05
 20 GTO J
 21 RTN
```

Local labels also serve as source of register addresses and variable descriptors for prompted sequence and printed output

```
 22♦LBL A
 23♦LBL 01
 24 1
 25 "LOAN TE
RM"
 26 GTO 00
 27♦LBL B
 28♦LBL 02
 29 2
 30 "LOAN %"
 31 GTO 00
 32♦LBL C
 33♦LBL 03
 34 3
 35 "LOAN AM
T"
 36 GTO 00
 37♦LBL D
 38♦LBL 04
 39 4
 40 "E BEFOR
E"
 41 GTO 00
 42♦LBL E
 43♦LBL 05
 44 5
 45 "E AFTER
"
 46 GTO 00
 47♦LBL F
 48♦LBL 06
 49 6
 50 "E $/UNI
T"
 51 GTO 00
 52♦LBL a
 53♦LBL 07
 54 7
 55 "% E INF
"
 56 GTO 00
 57♦LBL b
 58♦LBL 08
 59 8
 60 "% G INF
"
 61 GTO 00
 62♦LBL c
 63♦LBL 09
 64 9
 65 "% M INF
"
 66 GTO 00
 67♦LBL d
 68♦LBL 10
 69 10
 70 "M BEFOR
E"
 71 GTO 00
 72♦LBL e
 73♦LBL 11
 74 11
 75 "M AFTER
"
```

Routine to prompt and store inputs, print or display output, and process local labels

```
 76♦LBL 00
 77 FIX 2
 78 FS? 22
 79 CF 05
 80 FS? 05
 81 GTO 00
 82 FC? 08
 83 STO 00
 84 RDN
 85 FS?C 22
 86 STO IND
00
 87 "⊢: "
 88 RCL IND
00
```

Program Listings

```
 89 ARCL X
 90 FC? 08
 91 PROMPT
 92 RTN
 93•LBL 00
 94 CLX
 95 "⊢?"
 96 PROMPT
 97 STO IND
00
 98 RTN
 99•LBL I
100 "NO. YEA          Prompt for number
RS?"                 of years and put
101 PROMPT           in loop control
102 INT              form
103 1 E3
104 /
105 STO 12
106 CLX
107 "START Y          Prompt for and
EAR?"                store start year
108 PROMPT
109 STO 13
110 RTN
111•LBL J
112 CF 12
113 FIX 2
114 CF 05            Clear prompted
115 CF 06            sequence, clear
116 RCL 10           "no maintenance",
117 RCL 11           test for mainten-
118 +                ance
119 X=0?
120 SF 06
121 FS? 55           If printer is
122 SF 08            attached list
123 FS? 08           variable para-
124 XEQ 13           meters
125 CF 08
126 1                Calculate and
127 RCL 07           store:
128 %
129 +                1 + %E/100
130 STO 16
131 1
132 RCL 09
133 %
134 +                1 + %G/100
135 STO 17
136 1
```

```
137 RCL 08
138 %                1 + %M/100
139 +
140 STO 18
141 RCL 04
142 RCL 05
143 %CH              Calculate and
144 SF 21            output % E change
145 ADV
146 "E % CH=
"
147 ARCL X
148 AVIEW
149 RCL 01
150 12               Calculate monthly
151 *                and annual loan
152 1                payment
153 RCL 02
154 X=0?
155 GTO 28           If loan interest
156 LASTX            = 0 branch to
157 /                label 28
158 %
159 +
160 STO 14
161 X<>Y
162 Y↑X
163 STO Y
164 1
165 -
166 /
167 RCL 03
168 *
169 RCL 14
170 1
171 -
172 *
173•LBL 29          Re-entry point
174 RND              for 0%
175 STO 14
176 "MO PMT=
"
177 ARCL X           Display or print
178 AVIEW            monthly and annual
179 12               payments
180 ST* 14
181 RCL 14
182 "AN PMT=
"
183 ARCL X
184 AVIEW
```

Program Listings

```
185 FC? 55
186 CF 21          Reset flag 21
187 1 E3
188 RCL 13         Set up for column
189 X<Y?           #1, # of years to
190 +              be examined
191 STO 13
192 RCL 12
193 FRC
194 1
195 +
196 STO 12
197 ADV
198 ADV
199 FC? 55
200 GTO 23
201 7
202 SKPCHR         Format and print
203 "YEARLY"       header
204 ACA
205 5
206 SKPCHR
207 "ACCUM"
208 ACA
209 PRBUF
210 "YR"
211 ACA
212 5
213 SKPCHR
214 "COSTS"
215 ACA
216 6
217 SKPCHR
218 ACA
219 PRBUF
220 ADV
221♦LBL 23         Clear working
222 ΣREG 20        registers
223 CLΣ
224 ΣREG 25
225 CLΣ            Reset discounting
226 CF 10          flag
227♦LBL 19
228 7              Set pointer for
229 STO 19         energy calc.
230 XEQ 16         Calculate energy
231 STO 21         multiplier
232 RCL 04         Load working regi-
233 RCL 06         sters with data
234 *              for "before"
235 *              calculation
```

```
236 RCL 22
237 CHS
238 X<>Y
239 STO 22
240 STO 29
241 +
242 STO 23         If there is main-
243 FC? 06         tenance calculate
244 XEQ 17         it
245 FIX 0
246 CF 29          Accumulate cur-
247 "AAAA"         rent year digits
248 RCL 13         in row #1
249 RCL 12
250 INT
251 +
252 1
253 -
254 ARCL X
255 SF 29
256 ASHF
257 FC? 55         If no printer is
258 GTO 24         present go to
259 ACA            separate output
260 RCL 23
261 XEQ 15         Format output for
262 RCL 29         printer
263 XEQ 15
264 PRBUF          Print row #1
265♦LBL 26
266 RCL 05         Re-entry for non-
267 RCL 06         print
268 *              Load working regi-
269 RCL 21         sters with data
270 *              for "after" cal-
271 STO 30         culation
272 ENTER↑
273 X<> 25
274 -
275 STO 26
276 RCL 20
277 RCL 11
278 *
279 ST+ 30
280 ENTER↑
281 X<> 27
282 -
283 ST+ 26
284 RCL 01
285 RCL 12
286 INT
```

Program Listings

```
287 X<=Y?          If loan is not
288 GTO 12         paid off deal
289 RCL 28         with loan payment
290 ST+ 30
291 GTO 00
292♦LBL 12
293 SF 10          Discount loan
294 XEQ 16         payment by infla-
295 RCL 14         tion rate
296 *              (general)
297 ST+ 30
298 ENTER↑
299 X<> 28
300 -
301 ST+ 26
302♦LBL 00
303 " "            Load a space, Y,
304 RCL 23         or sigma into
305 RCL 26         print row #2
306 X<=Y?
307 "Y"
308 RCL 29
309 RCL 30
310 X<=Y?
311 "Σ"
312 SF 12
313 FC? 55         Output for case
314 GTO 25         where no printer
315 ACA            is attached
316 CF 12
317 X<> Z          Format and print
318 XEQ 15         row #2
319 RCL 30
320 XEQ 15
321 PRBUF
322 ADV
323♦LBL 99         Re-entry for
324 ISG 12         non-print
325 GTO 19
326 ADV            Loop for next
327 ADV            year or advance
328 ADV            paper if done
329 ADV
330 ADV
331 ADV
332♦LBL 22
333 FIX 2          "Stopper" to pre-
334 RTN            vent accidental
335 GTO 22         R/S damage
336♦LBL 15         Print formatting
337 8              routine
```

```
338 X<>Y
339 RND
340 RCL Y
341 RCL Y
342 ABS
343 X≠0?
344 LOG
345 INT
346 X<0?
347 CLX
348 SF 29
349 .75
350 /
351 INT
352 -
353 SKPCHR
354 RDN
355 ACX            Discount energy
356 RTN            or maintenance as
357♦LBL 16         pointed to be
358 1              register 19 using
359 RCL IND        the uniform pre-
19                 sent worth formula
360 FS? 10
361 CLX            Flag 10 causes
362 %              the rate of esca-
363 +              lation to be ze-
364 STO 15         roed for the loan
365 1              payment which is
366 RCL 08         constant
367 %
368 +
369 /
370 RCL 12
371 INT
372 Y↑X
373 CHS
374 1
375 +
376 RCL 15
377 RCL 08
378 RCL IND
19
379 FS?C 10
380 CLX
381 -
382 1 E2
383 /              Test for case
384 X=0?           where %E = %G or
385 GTO 12         %M = %G
386 /
```

Program Listings

```
387 *
388 RTN
389♦LBL 12          Deal with case
390 RCL 12          where %E or %M
391 INT             = %G
392 RTN
393♦LBL 24          Non-printer out-
394 "⊦ "            put for row #1
395 ARCL 23
396 "⊦ "
397 ARCL 29
398 PROMPT
399 GTO 26
400♦LBL 25          Non-printer out-
401 "⊦ "            put for row #2
402 ARCL 26
403 "⊦ "
404 ARCL 30
405 PROMPT
406 GTO 99
407♦LBL 28
408 RCL 03          Deal with case
409 R↑              where loan in-
410 /               terest = 0
411 GTO 29
412♦LBL 17          Calculate
413 9               maintenance
414 STO 19
415 XEQ 16
416 STO 20
417 RCL 10
418 *
419 RCL 24
420 CHS
421 X<>Y
422 STO 24
423 ST+ 29
424 +
425 ST+ 23
426 .END.
```

REGISTERS, STATUS, FLAGS, ASSIGNMENTS

DATA REGISTERS

00 Pointer
01 Loan term (years)
02 Loan interest rate (%)
03 Loan amount ($)
04 Energy quantity before (gals, CCF,KWHR)
05 Energy quantity after (gals, CCF,KWHR)
06 Energy costs ($/gal, CCF, or KWHR)
07 Energy inflation (%)
08 General inflation (%)
09 Maintenance inflation (%)
10 Maintenance costs before ($)
11 Maintenance costs after ($)
12 Number of years to calculate/1000
13 Start year
14 Monthly then annual loan payment ($)
15 Used
16 1 + (R-07/100)
17 1 + (R-09/100)
18 1 + (R-08/100)
19 Pointer
20 Maintenance multiplier
21 Energy multiplier
22 Last calculated accumulated value of energy dollars before
23 Current year dollars before (E+M)
24 Last calculated accumulated value of maintenance dollars before
25 Last calculated accumulated value of energy dollars after
26 Current year dollars after (E+M+L)
27 Last calculated accumulated value of maintenance dollars after
28 Last calculated accumulated value of discounted loan payment
29 Accumulated dollars before (E+M) after discounting
30 Accumulated dollars after (E+M+L) after discounting

Note: before indicates before the proposed energy/conservation modification after indicates after the modification has been made.

STATUS

SIZE 31 TOT. REG. 147 USER MODE
ENG ____ FIX 0,2 SCI ____ ON ____ OFF ____
DEG ____ RAD ____ GRAD ____

FLAGS

#	INIT S/C	SET INDICATES	CLEAR INDICATES
05	S	In promted seq.	Out of promted seq.
06	C	No maintenance	Maintenance
08	C	Printer version	No printer
10	C	Discounting of loan	Discounting of energy or maint.
12	C	Print double wide	Print single width
21		Printer enabled	Printer disabled
22	C	Data entry	No data entry
29		Radix separator displayed	No separators
55		Printer exists	No printer

ASSIGNMENTS

FUNCTION	KEY	FUNCTION	KEY

ENERGY CASH FLOW

PROGRAM REGISTERS NEEDED: 117

ROW 1 (1 : 4)

ROW 2 (5 : 10)

ROW 3 (10 : 16)

ROW 4 (16 : 22)

ROW 5 (23 : 26)

ROW 6 (26 : 31)

ROW 7 (31 : 35)

ROW 8 (35 : 40)

ROW 9 (40 : 45)

ROW 10 (45 : 50)

ROW 11 (50 : 55)

ROW 12 (55 : 59)

ROW 13 (60 : 63)

ROW 14 (64 : 67)

ROW 15 (68 : 71)

ROW 16 (71 : 75)

ROW 17 (75 : 82)

ROW 18 (82 : 88)

ENERGY CASH FLOW

ROW 19 (89 : 97)

ROW 20 (97 : 100)

ROW 21 (100 : 107)

ROW 22 (107 : 111)

ROW 23 (111 : 119)

ROW 24 (120 : 125)

ROW 25 (126 : 136)

ROW 26 (137 : 146)

ROW 27 (146 : 151)

ROW 28 (152 : 162)

ROW 29 (163 : 173)

ROW 30 (174 : 178)

ROW 31 (179 : 182)

ROW 32 (183 : 190)

ROW 33 (191 : 200)

ROW 34 (201 : 205)

ROW 35 (206 : 210)

ROW 36 (210 : 214)

ENERGY CASH FLOW

ROW 37 (215 : 222)

ROW 38 (222 : 230)

ROW 39 (230 : 239)

ROW 40 (239 : 245)

ROW 41 (246 : 253)

ROW 42 (254 : 260)

ROW 43 (260 : 265)

ROW 44 (266 : 275)

ROW 45 (275 : 283)

ROW 46 (284 : 292)

ROW 47 (293 : 300)

ROW 48 (301 : 308)

ROW 49 (308 : 314)

ROW 50 (315 : 320)

ROW 51 (320 : 327)

ROW 52 (328 : 336)

ROW 53 (336 : 346)

ROW 54 (347 : 355)

ENERGY CASH FLOW

ROW 55 (355 : 364)

ROW 56 (365 : 377)

ROW 57 (378 : 385)

ROW 58 (386 : 395)

ROW 59 (395 : 401)

ROW 60 (401 : 406)

ROW 61 (407 : 414)

ROW 62 (415 : 422)

ROW 63 (423 : 426)

NOTES

NOTES

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