

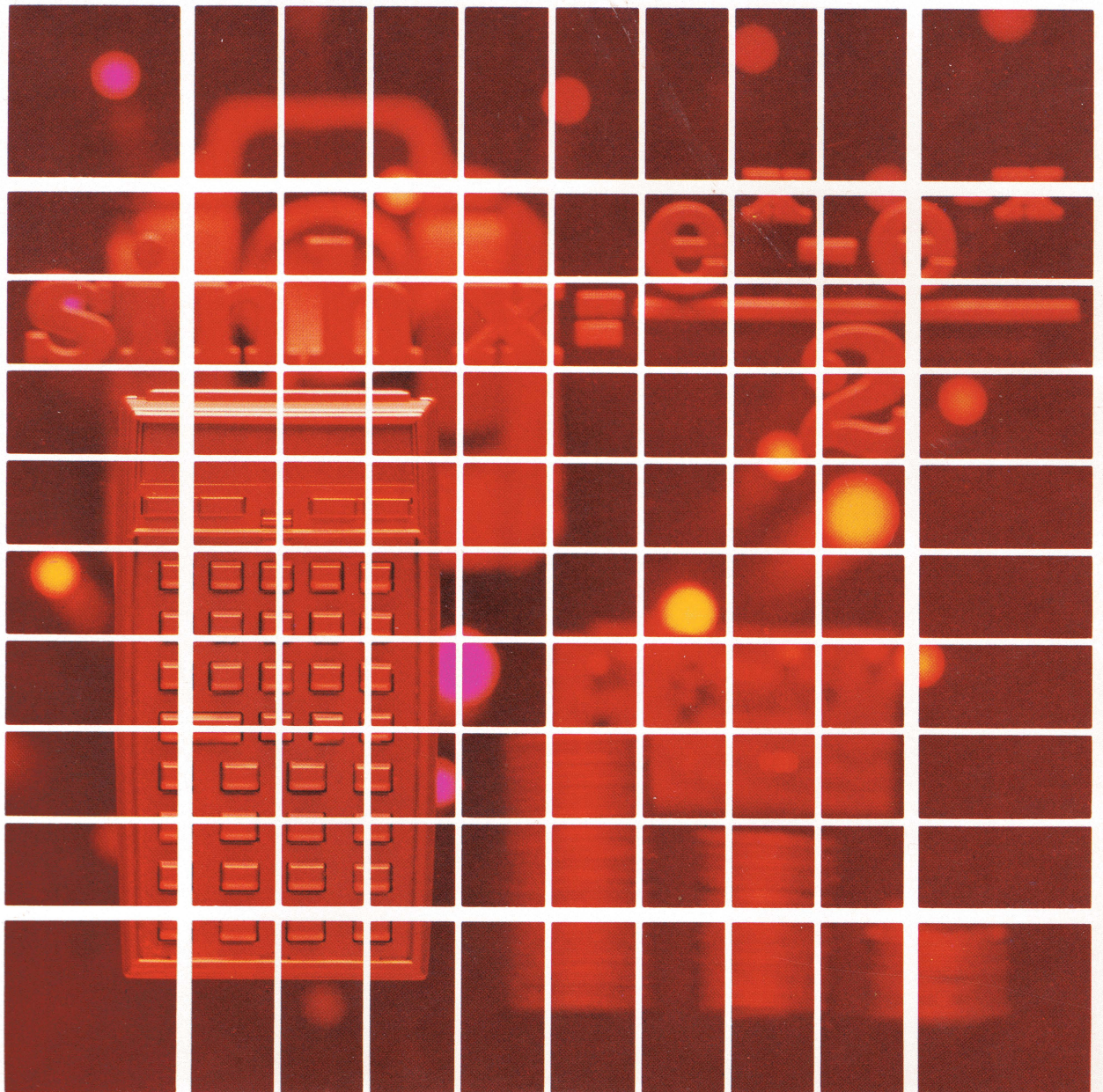
HEWLETT-PACKARD

HP-41

USERS' LIBRARY SOLUTIONS

Solar Engineering

Includes barcode for easy software entry.



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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:

- 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.

- Set the HP-41C to PRGM mode (press the **[PRGM]** key) and press **[GTO] [0] [.] [0]** to prepare the calculator for the new program.
- 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.
 - 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]**.
 - 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.
 - The printer indication of divide sign is /. When you see / in the program listing, press **[÷]**.
 - The printer indication of the multiply sign is ×. When you see × in the program listing, press **[×]**.
 - The ⌈ character in the program listing is an indication of the **[APPEND]** function. When you see ⌈, press **[APPEND]** in ALPHA mode (press **[ALPHA]** and the K key).
 - All operations requiring register addresses accept those addresses in these forms:

nn (a two-digit number)

IND nn (INDIRECT: **[IND]**, followed by a two-digit number)

X, Y, Z, T, or L (a STACK address: **[R/S]** followed by X, Y, Z, T, or L)

IND X, Y, Z, T or L (INDIRECT stack: **[IND]** followed by X, Y, Z, T, or L)

Indirect addresses are specified by pressing **[IND]** and then the indirect address. Stack addresses are specified by pressing **[R/S]** followed by X, Y, Z, T, or L. Indirect stack addresses are specified by pressing **[IND]** and X, Y, Z, T, or L.

Printer Listing

```

01 ♦ LBL "SAM
PLE"
02 "THIS IS
A "
03 "⌈SAMPLE
"
04 AVIEW
05 6
06 ENTER↑
07 -2
08 /
09 ABS
10 STO IND
L
11 "R3="
12 ARCL 03
13 AVIEW
14 RTN

```

Keystrokes

```

[♦] [LBL] [ALPHA] SAMPLE [ALPHA]
[ALPHA] THIS IS A [ALPHA]
[ALPHA] [APPEND] SAMPLE
[♦] AVIEW [ALPHA]
6
[ENTER↑]
2 [CHS]
[÷]
[XEQ] [ALPHA] ABS [ALPHA]
[STO] [R/S] L
[ALPHA] R3= [ARCL] 03
[♦] AVIEW
[ALPHA]
[RTN]

```

Display

```

01 LBLT SAMPLE
02T THIS IS A
03T ⌈SAMPLE
04 AVIEW
05 6
06 ENTER ↗
07 -2
08 /
09 ABS
10 STO IND L
11T R3=
12 ARCL 03
13 AVIEW
14 RTN

```

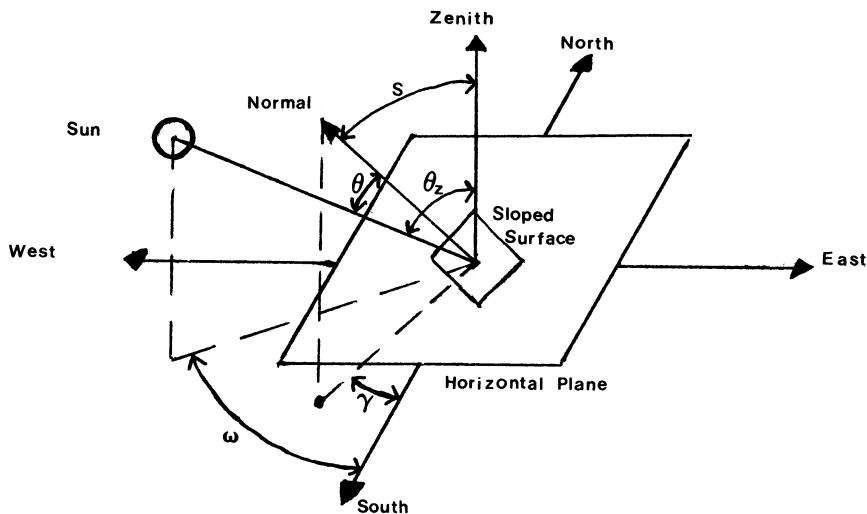
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	This program computes the exact position of the sun at any time of day on any date as well as the percent of radiation that will enter a solar pond of a given index of refraction.	
3.	ENERGY EQUIVALENTS-FUELS AND PRICES	22
	This program converts amounts and prices between 8 different fuel and energy units. Efficiencies may be included.	
*4.	HEAT EXCHANGERS	29
	Correlates heat transfer for counterflow, parallel flow, parallel-counterflow and crossflow heat exchangers.	
5.	VIEW FACTOR	51
	Calculates the amount of energy leaving one surface that gets to another surface.	
6.	HEAT TRANSFER THROUGH COMPOSITE CYLINDERS AND WALLS	58
	Calculates the heat transfer coefficient.	
7.	BLACK BODY THERMAL RADIATION	64
	Calculates thermal radiation as a function of temperature and wavelength for black bodies.]	
8.	ECONOMIC BREAK EVEN FOR SOLAR EQUIPMENT	73
	Calculates the number of years necessary for solar equipment to pay for itself.	
9.	SOLAR PANEL ARRAY	79
	This program calculates the distance between tilted solar panels so that no shading will occur.	
10.	CONDUIT FLOW	88
	Solves a variety of problems involving viscous conduit flow.	
**11.	ENERGY CASH FLOW	97
	creates a model of cost and return on an energy related investment.	
*	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.

$$\begin{aligned} \cos \theta = & \sin \delta \sin \phi \cos S - \sin \delta \cos \phi \sin S \cos \gamma \\ & + \cos \delta \cos \phi \cos S \cos \omega + \cos \delta \sin \phi \sin S \cos \gamma \cos \omega \\ & + \cos \delta \sin S \sin \gamma \sin \omega \end{aligned}$$

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)

$$\delta = 23.45 \sin [.9863 (284 + \eta)]$$

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

Calculation of solar angle (ω)

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

Where: E = Equation of Time

$$E = 8 \sin (1.06 \eta - 48) + 10 \sin [1.9 (1.1 \eta - 30)]$$

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

$$\omega = (12 - \text{solar time}) \times 15$$

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

Zenith Angle θ_z

$$\cos \theta_z = \sin \delta \sin \phi + \cos \delta \cos \phi \cos \omega$$

Radiant Energy (G) received at surface

$$G = G_0 \times t^m \cos \theta$$

Where: G_0 = Solar constant 428 BTU HR °F FT²

t = Transmission coefficient for unit air mass
(cloudy, 0.62; mean value, 0.70; clear day, 0.81)

m = Secant of zenith angle; $\sec \theta_z$

Time of sunrise and sunset

$$\cos \omega_s = -\tan \phi \tan \delta$$

WHERE: ω_s = Sunrise hour angle

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

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

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

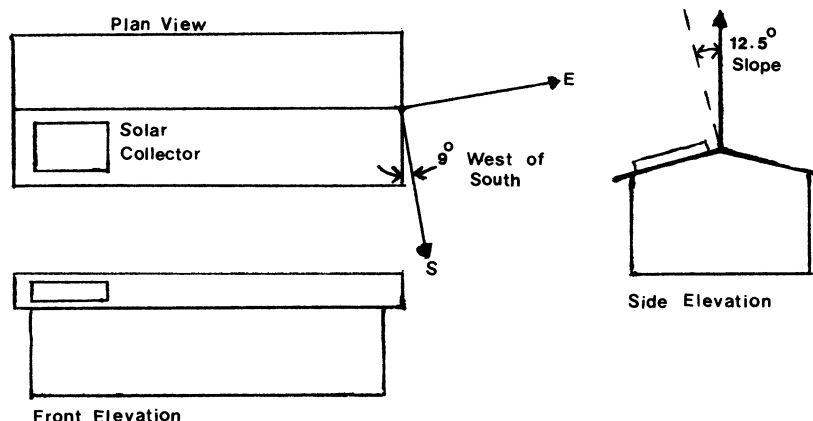
$$\text{Sunset standard time} = \text{Sunset solar time} - E - 4 (L_{st} - L_{loc})$$

The total irradiation during a time period

$$G_0 \int_{\omega_2}^{\omega_1} t \sec \theta_z \cos \theta d\omega = \Sigma G(\omega_1 - \omega_2)$$

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 $34^\circ 10'$ north latitude and $118^\circ 21'$ west longitude. The standard time meridian for Pacific Standard Time is 120° W.

Keystrokes:

Display:

[XEQ] [ALPHA] SIZE [ALPHA] 026

[XEQ] [ALPHA] IRRAD [ALPHA]

9.021981 [R/S]

34.1 [R/S]

118.21 [R/S]

120 [R/S]

12.5 [R/S]

9 [CHS] [R/S]

.7 [R/S]

10.45 [A]

14.20 [A]

10.30 [ENTER↑]

15.20 [ENTER↑]

.5 [B]

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

150 [X]

[C]

[R/S]

MM.DDYYYY ?

LAT. ?

LONG.?

TIME MER. ?

SLOPE ?

AZIMUTH ?

TRAN. COEF. ?

A, B OR C ?

$G = 258 \text{ (BTU/HR FT}^2\text{)}$

$G = 213 \text{ (BTU/HR FT}^2\text{)}$

$\Sigma G = 1,173 \text{ (BTU/FT}^2\text{)}$

175921 (BTU)

SUN R = 5:34 (AM)

SUN S = 18:14 (6:14 PM)

User Instructions

				SIZE: 026
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Load the program.			
2	Initialize.		[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?

[illegible]

Program Listings

01*LBL "IRR AD"		50 PROMPT	Latitude
02 SF 21	Input	51 FS?C 22	
03 CF 01		52 HR	
04 FIX 0		53 STO 00	
05 DEG		54 1	
06 CF 29		55 P-R	
07 SF 27		56 STO 11	
08 "MM.DDYY YY ?"		57 RDN	
09 CF 22		58 STO 10	
10 RCL 06		59 "LONG. ?	
11 PROMPT	Date	"	
12 FC?C 22		60 RCL 02	Longitude
13 GTO 00		61 PROMPT	
14 INT	Calculate	62 FS?C 22	
15 STO 01	DDY	63 HR	
16 LASTX		64 STO 02	
17 FRC		65 "TIME ME	
18 100		R. ?"	
19 *		66 RCL 01	Time Meridian
20 INT		67 PROMPT	
21 STO 06		68 STO 01	
22 LASTX		69 "SLOPE ?	
23 FRC		"	
24 2500		70 RCL 03	Slope
25 *		71 PROMPT	
26 FRC		72 STO 03	
27 STO 02		73 1	
28 RCL 01		74 P-R	
29 30.56		75 STO 13	
30 *		76 RDN	
31 INT		77 STO 12	
32 30		78 "AZIMUTH	Azimuth
33 -		?"	
34 ST+ 06		79 RCL 04	
35 RCL 02		80 CF 22	
36 ENTER↑		81 PROMPT	
37 X*0?		82 FS?C 22	
38 /		83 HR	
39 1		84 STO 04	
40 +		85 1	
41 2		86 P-R	
42 RCL 01		87 STO 15	
43 X<=Y?		88 RDN	
44 GTO 00		89 STO 14	
45 RCL Z		90 "TRAN. C	
46 ST- 06		DEF. ?"	
47*LBL 00		91 RCL 07	Transmission
48 "LAT. ?"		92 PROMPT	coefficient
49 RCL 00		93 STO 07	
		94 RCL 06	
		95 284	Set up

Program Listings

96 +		146 SF 00	
97 .986		147 XEQ 20	
98 *		148 RCL 19	
99 SIN		149 *	
100 23.45		150 +	
101 *		151 1/X	
102 STO 05	δ	152 6	
103 1		153 X<=Y?	
104 P-R		154 GT0 03	
105 STO 17		155 RDN	
106 RDN		156 RCL 07	
107 STO 16		157 X<>Y	
108 RCL 06		158 Y↑X	
109 81		159 428	Solar Constant
110 -		160 *	
111 .989		161 RCL 22	
112 *		162 *	
113 ENTER↑		163 X>0?	
114 SIN		164 GT0 04	
115 1.5		165♦LBL 03	
116 *		166 0	
117 CHS		167♦LBL 04	
118 X<>Y		168 "G="	Output of G
119 ENTER↑		169 ARCL X	
120 COS		170 RVIEW	
121 7.53		171 RTN	
122 *		172♦LBL B	
123 CHS		173 15	
124 X<>Y		174 *	$\int_{T_1}^{T_2} G$
125 2		175 STO 25	
126 *		176 RDN	
127 SIN		177 HR	
128 9.87		178 X<>Y	
129 *		179 HR	
130 +		180 X<>Y	
131 +		181 CF 00	
132 CHS		182 XEQ 20	
133 60		183 STO 19	
134 /		184♦LBL 01	
135 RCL 01		185 RCL 23	
136 RCL 02		186 RCL 24	
137 -		187 -	
138 15		188 RCL 25	
139 /		189 X<=Y?	
140 +		190 GT0 02	
141 STO 09		191 RDN	
142 "A, B OR		192 STO 25	
C?"		193 SF 01	
143 PROMPT	Set up done	194♦LBL 02	
144♦LBL A		195 RCL 23	
145 HR	Time	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
241 *
242 "ΣG="
243 ARCL X
244 AVIEW
245 RTN
246♦LBL 20
247 RCL 09

```

Solar Constant

Output ΣG

Common sub-
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 GT0 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
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

```

Sunrise/Sunset

```

350 -
351 "SUN R="
352 XEQ 00
353 RCL 25
354 RCL 24
355 +
356 "SUN S="
357♦LBL 00
358 HMS
359 INT
360 ARCL X
361 "H:"
362 9
363 LASTX
364 FRC
365 100
366 *
367 INT
368 X<=Y?
369 "H0"
370 ARCL X
371 AVIEW
372 .END.

```

Sunrise output

Sunset

Time output

DATA REGISTERS				STATUS			
00	ϕ	50		SIZE	026	TOT. REG.	113
	L _{st}			ENG		FIX	
	L _{loc}			DEG	X	RAD	
	S			SCI		GRAD	
	γ						
05	δ	55		FLAGS			
	η			#	INIT S/C	SET INDICATES	CLEAR INDICATES
	t			00		one pt	integral
	USED			01	C	done	not done
	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		ASSIGNMENTS			
				FUNCTION	KEY	FUNCTION	KEY
45		95					

Solar Beam Irradiation

Registers: 89

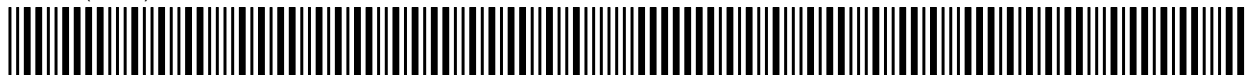
ROW 1 (1 : 3)



ROW 2 (4 : 8)



ROW 3 (8 : 13)



ROW 4 (13 : 23)



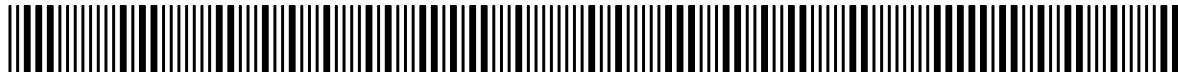
ROW 5 (24 : 29)



ROW 6 (30 : 40)



ROW 7 (41 : 48)



ROW 8 (48 : 56)



ROW 9 (57 : 62)



ROW 10 (62 : 65)



ROW 11 (65 : 69)



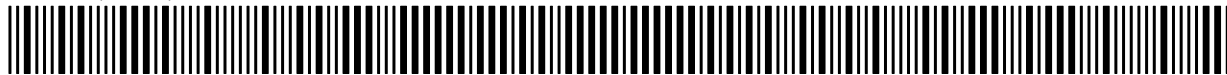
ROW 12 (70 : 78)



ROW 13 (78 : 84)



ROW 14 (85 : 90)



ROW 15 (90 : 95)



ROW 16 (96 : 101)



ROW 17 (102 : 111)

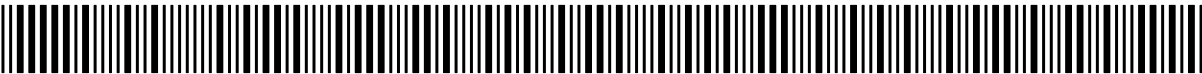


ROW 18 (111 : 119)



Solar Beam Irradiation

ROW 19 (120 : 128)



ROW 20 (128 : 138)



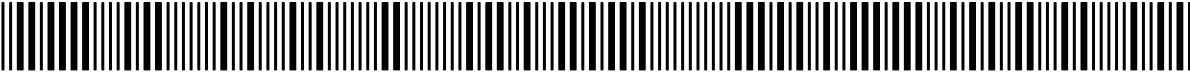
ROW 21 (138 : 142)



ROW 22 (142 : 148)



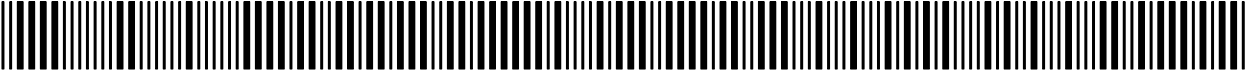
ROW 23 (149 : 159)



ROW 24 (159 : 168)



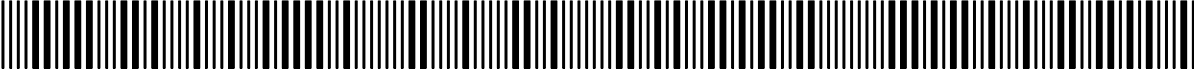
ROW 25 (168 : 176)



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)



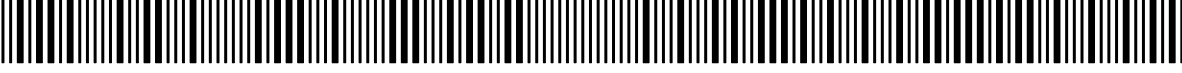
ROW 34 (247 : 255)



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 azimuth, 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:

```
[XEQ] [ALPHA] SIZE [ALPHA] 009
[XEQ] [ALPHA] ALMANAC [ALPHA]
9.011979 [R/S]
44.34 [R/S]
123.17 [R/S]
20 [R/S]
[R/S]
[B]
1.33 [R/S]
```

Display:

```
MM.DDYYYY ?
LAT ?
LONG ?
GMT ?
ZN=174.5022
HC=53.5985
N ?
%E=97.7355
```

Find the same information for 5 hours later.

Keystrokes:

[A]

[R/S]

[R/S]

[R/S]

25 [R/S]

[R/S]

[B]

[R/S]

Display:

MM.DDYYYY ?

LAT ?

LONG ?

GMT ?

ZN=262.9527

HC=18.7391

N ?

%E=85.1269

[illegible]

Program Listings

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

Program Listings

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

DATA REGISTERS				STATUS									
00	Long	50		SIZE	009	TOT. REG.	56	USER MODE					
	Lat			ENG		FIX		SCI		ON		OFF	
	15 (GMT)			DEG	X	RAD		GRAD					
	Days												
	Ω												
05	GHA	55		FLAGS									
	δ			#	INIT S/C	SET INDICATES			CLEAR INDICATES				
	r1c												
	n												
10		60											
15		65											
20		70											
25		75											
30		80											
35		85											
40		90		ASSIGNMENTS									
				FUNCTION		KEY		FUNCTION		KEY			
45		95											

Sun Altitude, Azimuth

Registers: 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

ROW 19 (137 : 146)



ROW 20 (147 : 153)



ROW 21 (154 : 160)



ROW 22 (160 : 169)



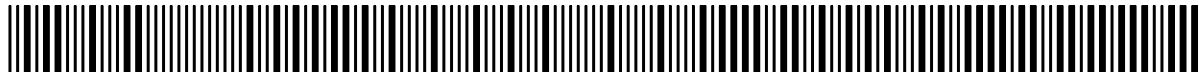
ROW 23 (170 : 182)



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_{38}^{235}	= 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

01♦LBL "ENE RGY"	Initialize	48 ARCL X	
02 SF 27		49 "F "	
03 1		50 ARCL 01	
04 STO 02		51 PROMPT	
05♦LBL A		52♦LBL D	-----
06 AON	Input	53 RCL 03	\$
07 CF 23		54 /	Forward
08 "UNITS 1		55 XEQ 01	
?"		56 RCL 04	
09 PROMPT		57 *	
10 FS?C 23		58 "\$"	
11 ASTO 01		59 GTO 03	-----
12 RCL 03		60♦LBL E	\$
13 "\$?"		61 RCL 04	Backward
14 AOFF		62 /	
15 PROMPT		63 XEQ 02	
16 STO 03		64 RCL 03	
17 "UNITS 2		65 *	
?"		66 "\$"	-----
18 AON		67 GTO 04	
19 PROMPT		68♦LBL 01	
20 FS?C 23		69 CF 00	
21 ASTO 00		70 XEQ IND	
22 AOFF		01	
23 "\$?"		71 SF 00	Conversion
24 RCL 04		72 XEQ IND	
25 PROMPT		00	
26 STO 04		73 RCL 02	
27 "% FOR 1		74 *	
TO 2"		75 RTN	
28 CF 22		76♦LBL 02	
29 PROMPT		77 CF 00	
30 100		78 XEQ IND	
31 /		00	
32 FS?C 22		79 SF 00	
33 STO 02		80 XEQ IND	
34 "READY"		01	
35 PROMPT		81 RCL 02	
36♦LBL B	Forward	82 /	
37 XEQ 01		83 RTN	
38 CLA		84♦LBL "BBL	-----
39♦LBL 03		"	Conversion
40 ARCL X		85 5.8	constants
41 "F "		86 GTO 05	
42 ARCL 00		87♦LBL "TCF	
43 PROMPT		"	
44♦LBL C		88 1.03	
45 XEQ 02	Backward	89 GTO 05	
46 CLA		90♦LBL "GJ"	
47♦LBL 04		91 1.055	
		92 GTO 05	

Program Listings

93♦LBL "STE		51	
"			
94 26			
95 GTO 05			
96♦LBL "STW			
"			
97 18			
98 GTO 05			
99♦LBL "MWH			
"			
100 3.412		60	
101 GTO 05			
102♦LBL "U30			
8"			
103 220			
104 GTO 05			
105♦LBL "MBT			
U"			
106 1			
107♦LBL 05			
108 FS? 00		70	
109 1/X			
110 *			
111 RTN			
112 .END.			
30		80	
40		90	
50		00	

DATA REGISTERS				STATUS			
00	To Units	50		SIZE 005	TOT. REG. 44	USER MODE	
	From Units			ENG	FIX	SCI	ON X OFF
	%			DEG	RAD	GRAD	
	\$ from			FLAGS			
	\$ to						
05		55		#	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
10		60					
15		65					
20		70					
25		75					
30		80					
35		85					
40		90		ASSIGNMENTS			
				FUNCTION	KEY	FUNCTION	KEY
45		95					

Energy Equivalents - Fuels and Prices

Registers: 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)



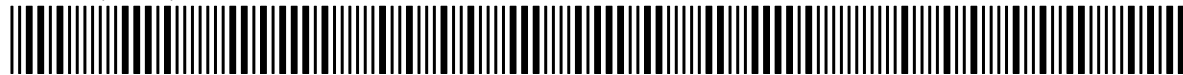
ROW 12 (63 : 71)



ROW 13 (71 : 79)



ROW 14 (80 : 85)



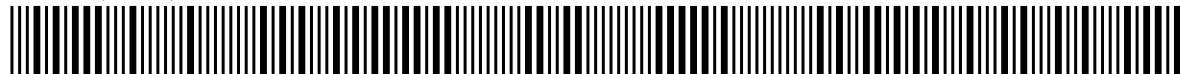
ROW 15 (85 : 88)



ROW 16 (88 : 91)



ROW 17 (91 : 94)



ROW 18 (95 : 98)

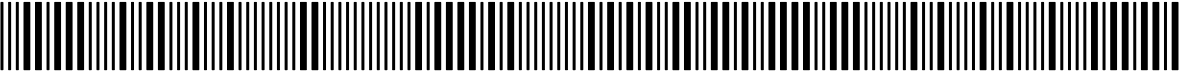


Energy Equivalents - Fuels and Prices

ROW 19 (99 : 101)



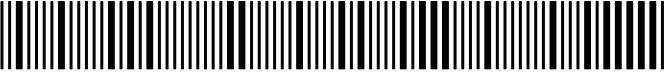
ROW 20 (101 : 104)



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:

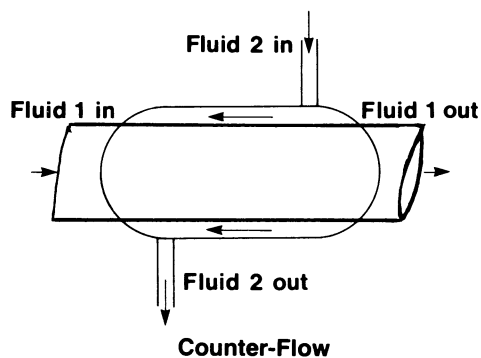


Figure 2:

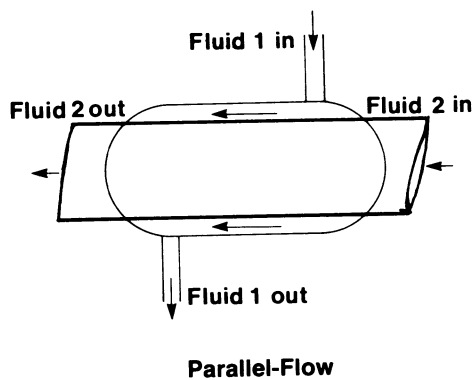


Figure 3:

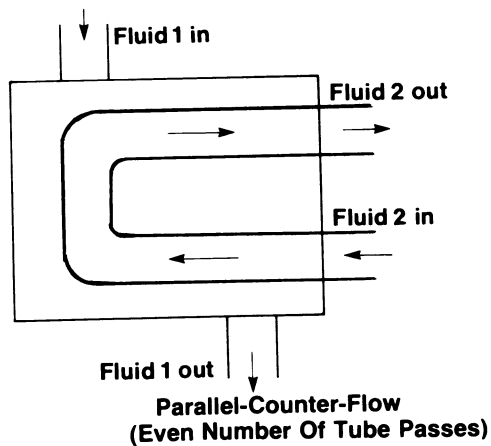
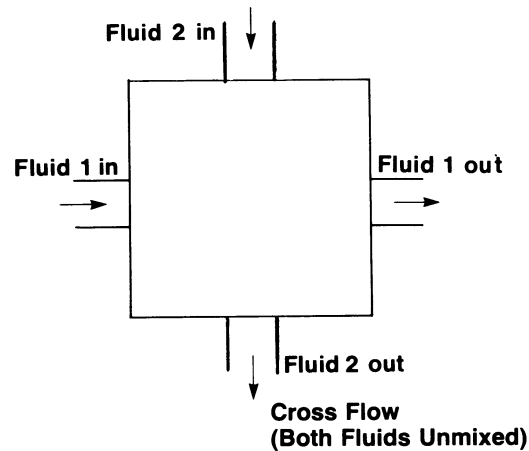


Figure 4:



Equations:

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

$$E = \frac{Q}{C_{\min} (T_{h\text{in}} - T_{c\text{in}})} = \frac{C_h (T_{h\text{in}} - T_{h\text{out}})}{C_{\min} (T_{h\text{in}} - T_{c\text{in}})} = \frac{C_c (T_{c\text{out}} - T_{c\text{in}})}{C_{\min} (T_{h\text{in}} - T_{c\text{in}})}$$

where:

Q is the actual heat transfer.

$T_{h\text{in}}$ and $T_{c\text{in}}$ are the inlet temperatures of the hot and cold fluids respectively.

$T_{h\text{out}}$ and $T_{c\text{out}}$ 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., $C_h = \dot{m}_h \times c_{ph}$, where $\dot{m}_h$ 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 geometries considered in this pac have the following correlations:

Counterflow (see figure 1)

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

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:

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

Crossflow (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-ft²-°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:

Since $A = AU/U$, calculate A.

2198.7662 [ENTER] 55 [$\div$]

Load crossflow subroutine.

[XEQ] [ALPHA] HEATX [ALPHA]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[E]

[R/S]

[R/S]*

[R/S]*

[R/S]*

[R/S]

2353.6675 [ENTER] 55 [$\div$]

Display:

39.9776

TC IN=?

TH IN=?

MC=?

MH=?

CPC=?

CPH=?

SELECT KEY: E AU Q TC TH

THO=?

E=0.4322

AU=2,353.6675

Q=164,934.0000

TCO=84.3613

SELECT KEY: E AU Q TC TH

42.7940

An analogous 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

[illegible]

Program Listings

Heat Exchanger - Main Routine

01♦LBL "HEA TX"	Input values.	49 XEQ "IN"	
02 2		50 ADV	
03 STO 00		51 GTO 16	
04 "TC IN"		52♦LBL B	
05 XEQ "IN"		53 SF 03	
06 "TH IN"		54 10	
07 XEQ "IN"		55 STO 00	Input AU.
08 14		56 "AU"	
09 STO 00		57 XEQ "IN"	
10 "MC"		58 ADV	
11 XEQ "IN"		59 GTO 01	
12 "MH"		60♦LBL C	
13 XEQ "IN"		61 SF 04	Input Q.
14 "CPC"		62 11	
15 XEQ "IN"		63 STO 00	
16 RCL 15		64 "Q"	
17 *		65 XEQ "IN"	
18 STO 05		66 ADV	
19 "CPH"		67 GTO 05	
20 XEQ "IN"		68♦LBL D	Input TCO.
21 RCL 16		69 SF 05	
22 *		70 12	
23 STO 06		71 STO 00	
24 "CON"		72 "TCO"	
25 ASTO 22		73 XEQ "IN"	
26♦LBL 06	Select last input.	74 ADV	Input THO.
27 CF 02		75 GTO 14	
28 CF 03		76♦LBL E	
29 CF 04		77 SF 06	
30 CF 05		78 13	
31 CF 06		79 STO 00	
32 CF 21		80 "THO"	Calculate AU.
33 SF 27		81 XEQ "IN"	
34 "SELECT KEY:"		82 ADV	
35 AVIEW		83 GTO 04	
36 SF 21		84♦LBL 16	
37 PSE		85 FS?C 03	Calculate Q.
38♦LBL 00	Input E.	86 GTO 06	
39 ADV		87 RCL 10	
40 "E AU Q TC TH"		88 "A"	
41 PROMPT		89 XEQ 08	
42 GTO 00		90 STO 11	
43♦LBL A		91 "AU"	
44 SF 02		92 XEQ "Q"	
45 9		93♦LBL 01	
46 STO 00		94 FS?C 04	
47 SF 01		95 GTO 06	
48 "E"		96 RCL 11	
		97 "E"	
		98 XEQ 08	
		99 RCL 07	

Program Listings

Heat Exchanger - Main Routine

100 *		151 X<>Y	
101 RCL 04		152 RCL 04	
102 RCL 03		153 RCL 03	
103 -		154 -	
104 *		155 /	
105 STO 12		156 RCL 05	
106 "Q"		157 RCL 06	
107 XEQ "O"		158 X<=Y?	
108♦LBL 05		159 X<>Y	
109 FS?C 05		160 RDN	
110 GTO 06	Calculate TCO.	161 X=0?	
111 RCL 12		162 X<> T	
112 RCL 05		163 /	
113 X≠0?		164 STO 10	
114 /		165 SF 01	
115 RCL 03		166 "E"	
116 +		167 XEQ "O"	
117 STO 13		168 GTO 16	
118 "TCO"		169♦LBL "A0"	
119 XEQ "O"		170 1	
120♦LBL 14		171 RCL 10	
121 FS?C 06		172 -	
122 GTO 06	Calculate THO.	173 LN	
123 RCL 13		174 CHS	A0 for $C_{\min}=0.00$.
124 RCL 03		175 RTN	
125 -		176♦LBL "E0"	
126 RCL 05		177 1	
127 *		178 RCL 11	
128 RCL 06		179 CHS	
129 X≠0?		180 E↑X	E0 for $C_{\min}=0.00$.
130 /		181 -	
131 RCL 04		182 RTN	
132 -		183♦LBL 08	
133 CHS		184 RCL 05	
134 STO 14		185 RCL 06	
135 "THO"		186 X>Y?	
136 XEQ "O"		187 X<>Y	
137♦LBL 04		188 X<>Y	
138 FS?C 02		189 STO 07	
139 GTO 06		190 X<>Y	
140 RCL 13	Calculate E.	191 X≠0?	
141 RCL 03		192 STO 07	
142 -		193 X<>Y	
143 RCL 05		194 X≠0?	
144 *		195 /	
145 RCL 04		196 STO 09	
146 RCL 14		197 SF 25	
147 -		198 X=0?	
148 RCL 06		199 "F0"	
149 *		200 X≠0?	
150 X=0?		201 ARCL 22	Find $C_{\min}$ and execute configuration subroutine.

Program Listings

202 ASTO T		51	
203 XEQ IND			
T			
204 FS?C 25			
205 RTN			
206 "2ND LAW			
ERR"	Trap errors from		
207 PROMPT	subroutines		
208 GTO 06			
209♦LBL "IN"			
210 CF 22	Input subroutine	60	
211 1			
212 ST+ 00			
213 RCL IND			
00			
214 "F="			
215 ASTO Y			
216 "F?"			
217 CF 21			
218 AVIEW			
219 SF 21		70	
220 CLA			
221 ARCL Y			
222 STOP			
223 STO IND			
00			
224 FS? 22			
225 FC? 55			
226 RTN			
227 ARCL X			
228 PRA		80	
229 RTN	Print if printer		
230♦LBL "O"	is attached		
231 "F="			
232 ARCL X	Output subroutine		
233 AVIEW			
234 .END.			
40		90	
50		00	

Program Listings

Parallel Flow Subroutine

01♦LBL "ACO N"	Calculate AU.	51	
02 RCL 09			
03 1			
04 +			
05 RCL 10			
06 *			
07 CHS			
08 1			
09 +		60	
10 LN			
11 CHS			
12 1			
13 RCL 09			
14 +			
15 /			
16 RCL 07			
17 *			
18 RTN			
19♦LBL "ECO N"	Calculate E.	70	
20 1			
21 +			
22 RCL 11			
23 RCL 07			
24 /			
25 *			
26 CHS			
27 E↑X			
28 CHS			
29 1		80	
30 +			
31 1			
32 RCL 09			
33 +			
34 /			
35 RTN			
40		90	
50		00	

Program Listings

Counter Flow Subroutine

01♦LBL "ACO N"	Calculate AU.	50 RCL 11 51 RCL 07 52 / 53 ENTER↑ 54 ENTER↑ 55 1 56 + 57 / 58 RTN	60	
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	Calculate E.		70	
20 RCL 10				
21 1				
22 RCL 10				
23 -				
24 /				
25 RCL 07				
26 *				
27 RTN				
28♦LBL "ECO N"				
29 1			80	
30 -				
31 RCL 11				
32 RCL 07				
33 /				
34 *				
35 E↑X				
36 1				
37 X<>Y				
38 -				
39 LASTX			90	
40 RCL 09				
41 *				
42 1				
43 X<>Y				
44 -				
45 X=0?				
46 GTO 11				
47 /				
48 RTN				
49♦LBL 11			00	

Program Listings

Parallel-Counter Flow Subroutine

01♦LBL "ACO N"	Calculate AU.	50♦LBL 12	
02 XEQ 12		51 RCL 09	
03 2		52 1	
04 *		53 +	
05 RCL 12		54 STO 08	
06 2		55 RCL 09	
07 RCL 10		56 X↑2	
08 /		57 1	
09 +		58 +	
10 RCL 08		59 SQRT	
11 -		60 STO 12	
12 /		61 RTN	
13 CHS			
14 1			
15 +			
16 LN			
17 RCL 12			
18 /			
19 CHS			
20 RCL 07		70	
21 /			
22 LASTX			
23 X↑2			
24 *			
25 RTN			
26♦LBL "ECO N"	Calculate E.		
27 XEQ 12			
28 RCL 11			
29 RCL 07		80	
30 /			
31 RCL 12			
32 *			
33 CHS			
34 E↑X			
35 1			
36 X<>Y			
37 +			
38 1			
39 LASTX		90	
40 -			
41 /			
42 RCL 12			
43 *			
44 RCL 08			
45 +			
46 2			
47 X<>Y			
48 /			
49 RTN		00	

01♦LBL "ACO N"	Calculate AU.	48 E↑X-1	
02 0		49 *	
03 STO 19		50 E↑X	
04 1		51 CHS	
05 RCL 10		52 1	
06 CHS		53 +	
07 STO 21		54 END	
08 +			
09 LN		60	
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		70	
19 RCL 11			
20 STO 19			
21 -			
22 RCL 21			
23 RCL 20			
24 STO 21			
25 -			
26 /			
27 *			
28 ST- 11		80	
29 ABS			
30 1 E-4			
31 X<=Y?			
32 GTO 13			
33 RCL 11			
34 RTN			
35♦LBL "ECO N"			
36 RCL 11			
37 RCL 07	90		
38 /			
39 STO Y			
40 .22			
41 Y↑X			
42 RCL 09			
43 /			
44 /			
45 LASTX			
46 X<>Y			
47 CHS	00		

DATA REGISTERS				STATUS			
00	Storage Index	50		SIZE	23	TOT. REG.	102
				ENG		FIX	SCI
				DEG		RAD	GRAD
	TC IN						
	TH IN						
05	CC	55		FLAGS			
	CH			#	INIT S/C	SET INDICATES	CLEAR INDICATES
	Cmin						
	Cmax						
	Cmin/Cmax			2	C	E was input	Calculate E
10	E	60		3	C	Au " "	" Au
	AU			4	C	Q was input	Calculate Q
	Q			5	C	TCO " "	" TCO
	Tco			6	C	THO " "	" THO
	Tho			21		Printer enable	Printer disable
15	MC	65		22		Numeric input	No input
	MH			25		Ignore l error	Display error
	cpc			27		User mode on	User mode off
	cph			55		Printer connected	No printer
	(AU _{i-1})						
20	F(AU _i)	70					
	F(AU _{i-1})						
	"CON"						
25		75					
30		80					
35		85					
				ASSIGNMENTS			
				FUNCTION KEY		FUNCTION KEY	
40		90					
45		95					

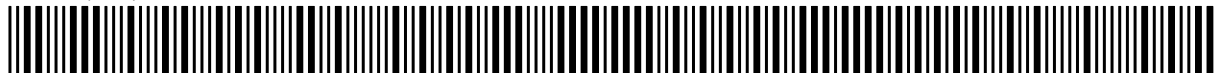
Heat Exchangers (Main Program)

Registers: 67

ROW 1 (1 : 4)



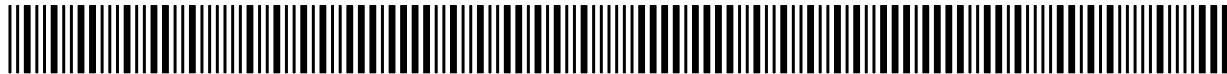
ROW 2 (4 : 6)



ROW 3 (6 : 11)



ROW 4 (11 : 14)



ROW 5 (15 : 20)



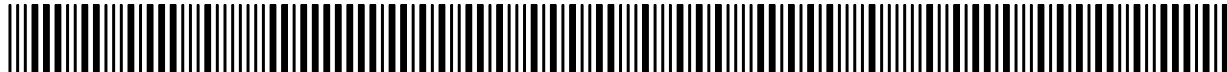
ROW 6 (20 : 26)



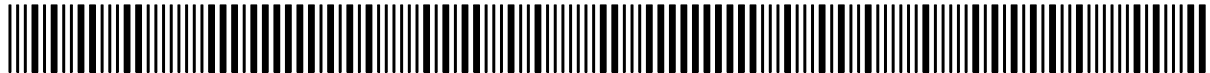
ROW 7 (27 : 33)



ROW 8 (33 : 34)



ROW 9 (35 : 40)



ROW 10 (40 : 44)



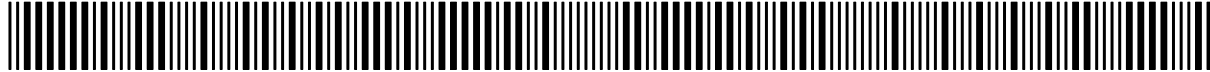
ROW 11 (45 : 51)



ROW 12 (51 : 57)



ROW 13 (57 : 64)



ROW 14 (64 : 70)



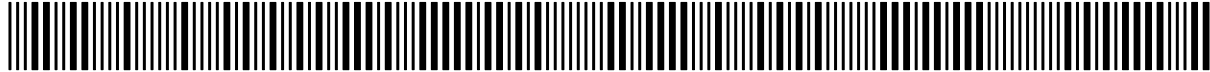
ROW 15 (70 : 75)



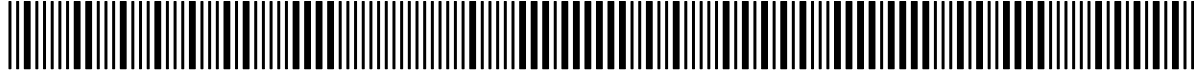
ROW 16 (76 : 81)



ROW 17 (81 : 88)



ROW 18 (88 : 94)



Heat Exchangers (Main Program)

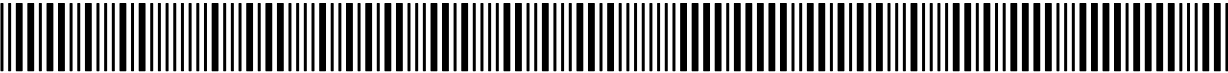
ROW 19 (94 : 102)



ROW 20 (103 : 110)



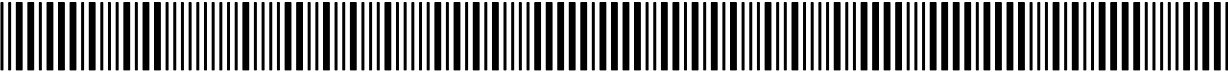
ROW 21 (111 : 119)



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 Subroutine Registers: 11

ROW 1 (1 : 6)



ROW 2 (7 : 18)



ROW 3 (19 : 28)



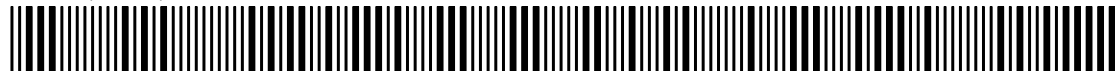
ROW 4 (28 : 37)



ROW 5 (38 : 49)



ROW 6 (50 - 59)



Heat Exchangers Cross Flow Subroutine

Registers: 14

ROW 1 (1 : 5)



ROW 2 (6 : 14)



ROW 3 (14 : 22)



ROW 4 (22 : 30)



ROW 5 (30 : 35)



ROW 6 (35 : 43)



ROW 7 (44 : 54)



Heat Exch. Parallel Counter Flow Subr.

Registers: 12

ROW 1 (1 : 4)



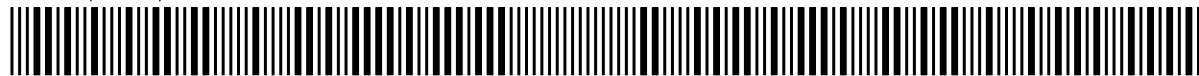
ROW 2 (5 : 17)



ROW 3 (18 : 26)



ROW 4 (26 : 34)



ROW 5 (35 : 47)



ROW 6 (48 : 60)

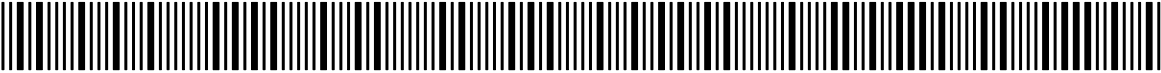
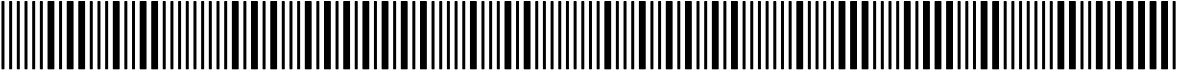


ROW 7 (61 - 62)



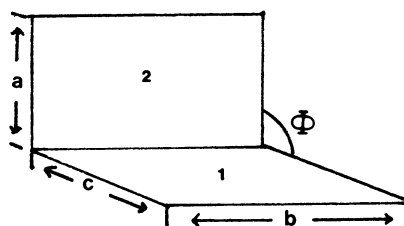
Heat Exchangers Parallel Flow Subroutine

Registers: 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.



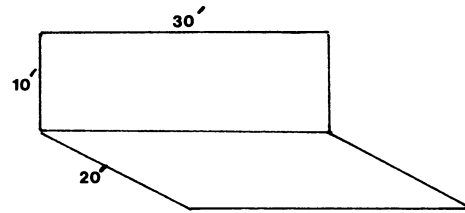
The fraction of radiation that gets from 1 to 2 is the same as that which gets from 2 to 1.

Equations:

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

Example:

Find the view factor for the arrangement below:



Keystrokes:

[XEQ] [ALPHA] SIZE [ALPHA] 006

[XEQ] [ALPHA] VIEW [ALPHA]

30 [R/S]

10 [R/S]

20 [R/S]

Display:

WIDTH ?

HEIGHT ?

DEPTH ?

F=0.1595

(what if the height were only 8'?)

[A]

[R/S]

8 [R/S]

[R/S]

WIDTH ?

HEIGHT ?

DEPTH ?

F=0.1379

Program Listings

01♦LBL "VIE W"	Initialize	48 *	
02 SF 27	-----	49 RCL 04	
03♦LBL A	Input	50 X↑2	
04 CF 22		51 1	
05 "WIDTH ?		52 +	
"		53 /	
06 PROMPT		54 RCL 05	
07 FS?C 22		55 /	
08 STO 00		56 LN	
09 "HEIGHT		57 RCL 04	
?"		58 X↑2	
10 PROMPT		59 *	
11 FS?C 22		60 +	
12 STO 01		61 RCL 03	
13 "DEPTH ?		62 X↑2	
"		63 RCL 05	
14 PROMPT		64 1	
15 FS?C 22		65 +	
16 STO 02		66 *	
17 RCL 01	Calculate	67 RCL 03	
18 RCL 00	X, Y and Z	68 X↑2	
19 /	-----	69 1	
20 STO 03		70 +	
21 X↑2		71 /	
22 RCL 02		72 RCL 05	
23 RCL 00		73 /	
24 /		74 LN	
25 STO 04		75 RCL 03	
26 X↑2		76 X↑2	
27 +		77 *	
28 STO 05		78 +	
29 RCL 03	Calculate	79 4	
30 X↑2	F	80 /	
31 1		81 1	
32 +		82 ASIN	
33 RCL 04		83 2	
34 X↑2		84 *	
35 1		85 PI	
36 +		86 /	
37 *		87 *	
38 RCL 05		88 RCL 03	
39 1		89 1/X	
40 +		90 ATAN	
41 /		91 RCL 03	
42 LN		92 *	
43 RCL 04		93 +	
44 X↑2		94 RCL 04	
45 RCL 05		95 1/X	
46 1		96 ATAN	
47 +		97 RCL 04	
		98 *	

Program Listings

99 +		51	
100 RCL 05			
101 SQRT			
102 1/X			
103 ATAN			
104 RCL 05			
105 SQRT			
106 *			
107 -			
108 RCL 04		60	
109 /			
110 1			
111 ASIN			
112 2			
113 *			
114 /			
115 "F="	Output F		
116 ARCL X			
117 AVIEW			
118 RTN		70	
119 .END.			
30		80	
40		90	
50		00	

[illegible]

View Factor

Registers: 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)

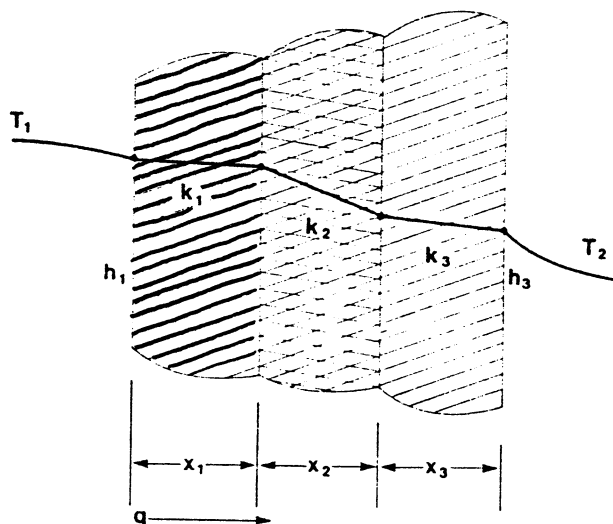
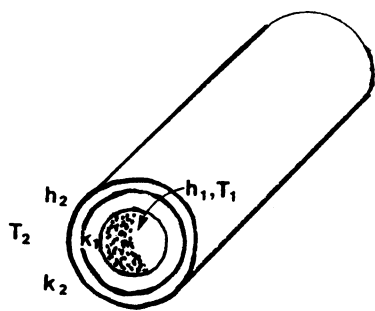


ROW 13 (119 - 119)



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.



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

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

For walls

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

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-ft²-°F and the outside coefficient is 5 Btu/hr-ft²-°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

[illegible]

[illegible]

Heat Transfer

Registers: 26

ROW 1 (1 : 4)



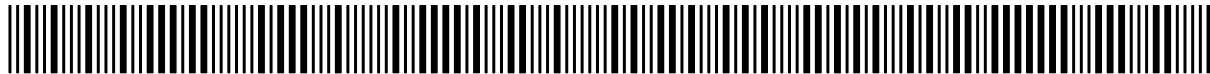
ROW 2 (4 : 8)



ROW 3 (9 : 16)



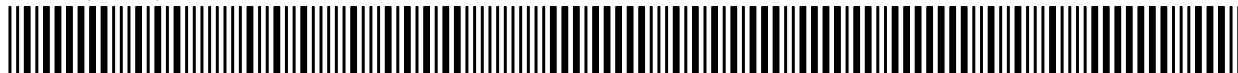
ROW 4 (16 : 18)



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)



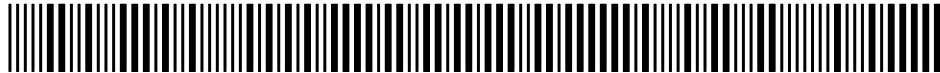
ROW 12 (66 : 72)



ROW 13 (72 : 79)



ROW 14 (79 : 83)



BLACK BODY THERMAL RADIATION

(Requires one memory module)

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.

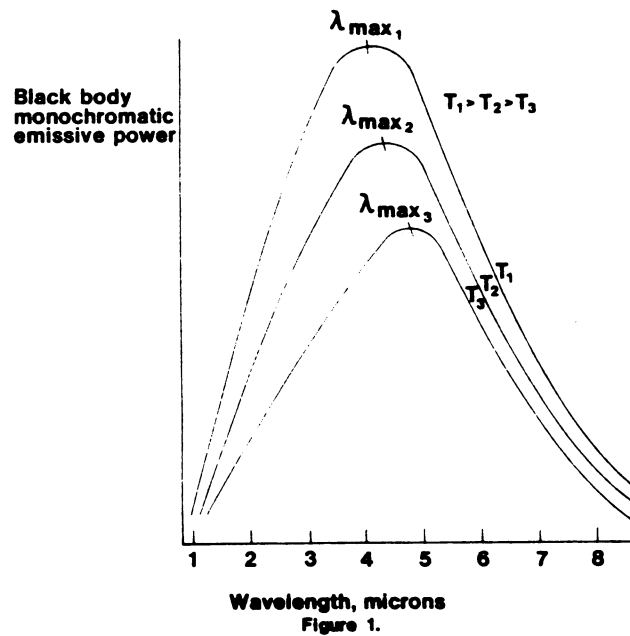


Figure 1.

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:

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

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

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

$$\begin{aligned} E_{b(0-\lambda)} &= \int_0^\lambda E_{b\lambda} d\lambda \\ &= 2\pi c_1 \sum_{k=1}^{\infty} -T/kc_2 e^{-\frac{kc_2}{T\lambda}} \left[\left(\frac{1}{\lambda} \right)^3 + \frac{3T}{\lambda^2 kc_2} \right. \\ &\quad \left. + \frac{6}{\lambda} \left(\frac{T}{kc_2} \right)^2 + 6 \left(\frac{T}{kc_2} \right)^3 \right] \end{aligned}$$

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

where:

$\lambda_{\max}$ 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-ft² or Watts/cm²;

$E_{b\lambda}$ is the emissive power at λ in Btu/hr-ft²-μm or Watts/cm²-μm;

$E_{b(0-\lambda)}$ is the emissive power for wavelengths less than λ in Btu/hr-ft² or Watts/cm²;

$E_{b(\lambda_1 - \lambda_2)}$ is the emissive power for wavelengths between λ_1 and λ_2 in Btu/hr-ft² or Watts/cm².

$$\begin{aligned} c_1 &= 1.8887982 \times 10^7 \text{ Btu-}\mu\text{m}^4/\text{hr-ft}^2 \\ &= 5.9544 \times 10^3 \text{ W}\mu\text{m}^4/\text{cm}^2 \end{aligned}$$

$$c_2 = 2.58984 \times 10^4 \mu\text{m-}^\circ\text{R} = 1.4388 \times 10^4 \mu\text{m-K}$$

$$c_3 = 5.216 \times 10^3 \mu\text{m-}^\circ\text{R} = 2.8978 \times 10^3 \mu\text{m-K}$$

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

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

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 $\geq$ 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=188.0938

[÷]

0.0264

100 [x]

2.6412

User Instructions

[illegible]

Program Listings

01♦LBL "BB"	Initialize and prompt for units	47 RCL 06	Calculate $T(\lambda_{\max})$
02 CLRG		48 /	
03 CF 22		49 "TEMP="	
04 "UNITS?"		50 ARCL X	
05 AON		51 PROMPT	
06 PROMPT		52♦LBL C	Calculate E_b total
07 AOFF		53 RCL 05	
08 ASTO X		54 X↑2	
09 GTO IND		55 X↑2	
X		56 RCL 04	
10♦LBL "SI"	Store units	57 *	
11 5954.4		58 "EbTOT="	
12 STO 01		59 ARCL X	
13 14388		60 PROMPT	
14 STO 02		61♦LBL D	Calculate $E_{b\lambda}$
15 2897.8		62 RCL 01	
16 STO 03		63 ENTER↑	
17 5.6693 E		64 +	
-12		65 PI	
18 STO 04		66 *	
19 GTO 00		67 RCL 06	
20♦LBL "EN"		68 5	
21 18887982		69 Y↑X	
22 STO 01		70 /	
23 25998.4		71 RCL 02	
24 STO 02		72 RCL 06	
25 5216		73 /	
26 STO 03		74 RCL 05	
27 .171312		75 /	
E-08		76 E↑X	
28 STO 04		77 1	
29♦LBL 00	Input prompting	78 -	
30 "TEMP?"		79 /	
31 PROMPT		80 "EbL="	
32 STO 05		81 ARCL X	
33 "WAVELEN		82 PROMPT	
GTH?"		83♦LBL E	Calculate $E_b(0-\lambda)$
34 PROMPT		84 0	
35 STO 06		85 STO 08	
36 "SOLVE"		86 STO 07	
37 PROMPT		87♦LBL 01	
38♦LBL A	Calculate $\lambda_{\max}$	88 RDN	
39 RCL 03		89 CLX	
40 RCL 05		90 RCL 08	
41 /		91 RCL 02	
42 "WL MAX="		92 RCL 05	
"		93 /	
43 ARCL X		94 -	
44 PROMPT		95 STO 08	
45♦LBL B		96 3	
46 RCL 03		97 X<>Y	

Program Listings

98 /		149 "WV LNTH	
99 RCL 06		2?"	
100 X↑2		150 PROMPT	
101 /		151 ENTER↑	
102 LASTX		152 ENTER↑	
103 1/X		153 SF 00	
104 RCL 06		154 XEQ E	
105 /		155 X<>Y	
106 -		156 RCL 06	
107 6		157 STO 00	
108 RCL 06		158 RDN	
109 /		159 STO 06	
110 RCL 08		160 SF 00	
111 X↑2		161 XEQ E	
112 /		162 -	
113 -		163 ABS	
114 6		164 RCL 00	
115 RCL 08		165 STO 06	
116 X↑2		166 RDN	
117 /		167 "EbL-L="	
118 RCL 08		168 ARCL X	
119 /		169 PROMPT	
120 +		170 .END.	
121 RCL 08			
122 RCL 06			
123 /			
124 E↑X			
125 *			
126 RCL 08			
127 /			
128 ST+ 07	80		
129 RCL 07			
130 /			
131 1 E-05			
132 X<=Y?			
133 GTO 01			
134 RDN			
135 CLX			
136 RCL 07			
137 ENTER↑			
138 +	90		
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		
	$E_b(\lambda_1 - \lambda_2)$	00	

DATA REGISTERS				STATUS			
00	λ	50		SIZE <u>009</u> TOT. REG. <u>57</u> USER MODE			
	C ₁			ENG _____ FIX <u>4</u> SCI _____ ON <u>X</u> OFF _____			
	C ₂			DEG _____ RAD _____ GRAD _____			
	C ₃						
	σ						
05	T	55		FLAGS			
	λ, λ'			#	INIT S/C	SET INDICATES	CLEAR INDICATES
	sum			00		Used	
	kc ₂ /T			22		Used	
10		60					
15		65					
20		70					
25		75					
30		80					
35		85					
				ASSIGNMENTS			
				FUNCTION		KEY	FUNCTION
40		90					KEY
45		95					

Black Body Thermal Radiation

Registers: 50

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

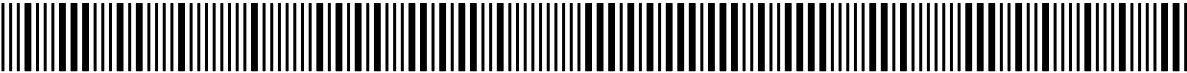
ROW 19 (109 : 121)



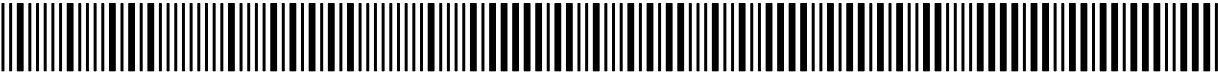
ROW 20 (122 : 131)



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:

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

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 $\$3.66 \times 10^{-6}$ \$/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

[illegible]

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
61 ARCL X          Output # of years
62 "F YEARS
"
63 AVIEW
64 END

```

DATA REGISTERS				STATUS			
00	\$ SPENT	50		SIZE 005	TOT. REG. 25	USER MODE	
	\$/BTU			ENG	FIX 2	SCI	ON OFF
	BTU/DAY			DEG	RAD	GRAD	
	%INT						
	%INF						
05		55		FLAGS			
				#	INIT S/C	SET INDICATES	CLEAR INDICATES
10		60					
15		65					
20		70					
25		75					
30		80					
35		85					
40		90		ASSIGNMENTS			
				FUNCTION	KEY	FUNCTION	KEY
45		95					

Economic Break-Even

Registers: 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 south-most 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 judgment 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 acceptable 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:

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

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 $MM > 2$

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

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

$$S = \tan^{-1} \frac{\sin \delta \sin \phi + \cos \delta \cos \phi \cos w}{\cos \delta \sin \phi \cos w - \sin \delta \cos \phi}$$

Where:

S = sun angle in a plane perpendicular to the earth and parallel to the longitude

ϕ = latitude (north positive)

w = hour angle, solar noon being zero, and each hour equaling 15° of longitude with morning positive and afternoon negative

$$V = L \sin T$$

$$D_1 = \frac{V}{\tan S} + L \cos T$$

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

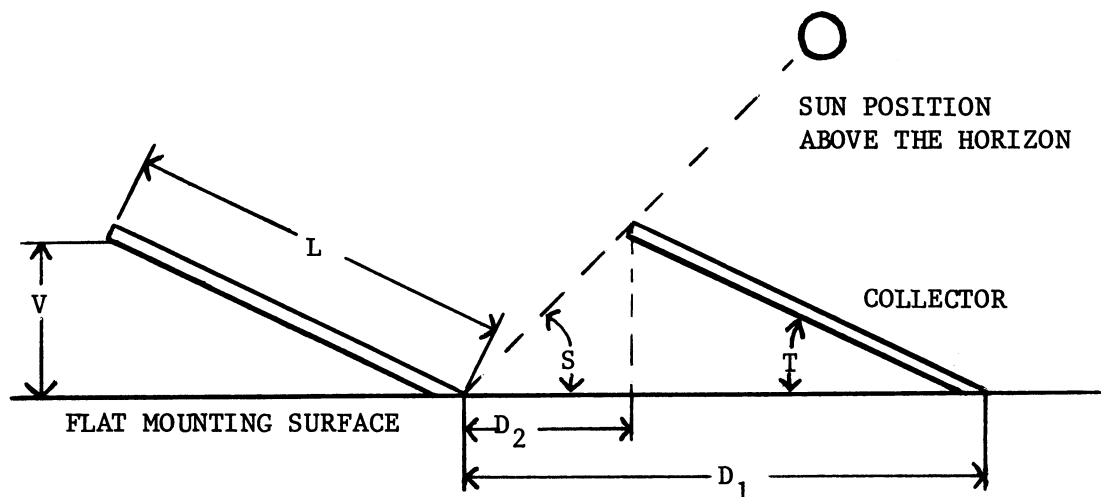
Where:

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]

12.211979 [R/S]

36.25 [R/S]

97.3 [R/S]

12 [R/S]

90 [R/S]

46 [R/S]

7 [R/S]

[R/S]

[R/S]

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

[A]

6.011979 [R/S]

[R/S]

[R/S]

13 [R/S]

[R/S]

[R/S]

[R/S]

[R/S]

[R/S]

MM.DDYYYY?

LAT ?

LONG ?

TIME ?

TIME MER ?

TILT $\angle$?

LENGTH ?

$V=5.0354$

$D_1=13.6006$

$D_2=8.7380$

MM.DDYYYY?

LAT ?

LONG ?

TIME ?

TIME MER ?

TILT $\angle$?

LENGTH ?

$V = 5.0354$

$D_1 = 6.1373$

$D_2 = 1.2747$

				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 east. Key in the local time from a 24 hour clock.	D.MS) t (H.MS)	[R/S]	TIME ? 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. Skip unchanging values with [R/S].		[A]	MM.DDYYYY ?

Program Listings

01♦LBL "PAN EL"	Initialization	50 *	Day # Get Day # for Jan. 1
02 SF 27	Input	51 INT	
03♦LBL A		52 +	
04 CF 22		53 RCL 08	
05 "MM.DDYY YY?"	Calculate DOY and declination	54 +	DOY
06 PROMPT		55 1720982	
07 FC?C 22		56 +	
08 GTO 04		57 FS? 02	
09 STO 00		58 GTO 02	Declination
10 ENTER↑		59 STO 01	
11 INT		60 1	
12 STO 07		61 STO 07	
13 -		62 STO 08	
14 1 E2		63 SF 02	
15 *		64 GTO 01	
16 ENTER↑		65♦LBL 02	
17 INT		66 RCL 01	
18 STO 08		67 1	
19 -		68 +	
20 1 E4		69 X<>Y	
21 *		70 -	
22 STO 09		71 STO 09	
23 CF 02		72 RCL 00	
24♦LBL 01		73 CF 02	
25 2		74 360	
26 RCL 07		75 ENTER↑	
27 X>Y?		76 284	
28 GTO 00		77 RCL 09	
29 RCL 09		78 +	
30 1		79 365	
31 -		80 /	
32 STO 09		81 *	
33 RCL 07		82 SIN	
34 13		83 23.45	
35 +		84 *	
36 STO 07		85 STO 08	
37 GTO 03		86♦LBL 04	
38♦LBL 00		87 "LAT ?"	
39 RCL 07		88 PROMPT	
40 1		89 HR	
41 +		90 FS?C 22	
42 STO 07		91 STO 05	
43♦LBL 03		92 "LONG ?"	
44 365.25		93 PROMPT	
45 RCL 09		94 HR	
46 *		95 FS?C 22	
47 INT		96 STO 02	
48 30.6001		97 "TIME ?"	
49 RCL 07		98 PROMPT	
		99 HR	
		100 FS?C 22	

Program Listings

101 STO 03		149 RCL 05	
102 "TIME ME		150 SIN	
R ?"		151 *	
103 PROMPT		152 RCL 06	
104 HR		153 COS	
105 FS?C 22		154 *	
106 STO 11		155 RCL 08	
107 RCL 11		156 SIN	
108 RCL 02		157 RCL 05	
109 X<>Y		158 COS	
110 -		159 *	
111 .0667		160 -	
112 *		161 /	
113 RCL 03		162 ATAN	δ
114 X<>Y		163 STO 00	
115 -		164 RCL 10	
116 12		165 RCL 04	
117 X<>Y		166 SIN	
118 -		167 *	
119 15		168 STO 07	
120 *		169 "V="	V
121 STO 06	hour angle	170 ARCL X	
122 "TILT $\angle$?		171 PROMPT	
"		172 RCL 00	
123 PROMPT		173 TAN	
124 HR		174 /	
125 FS?C 22		175 RCL 10	
126 STO 04		176 RCL 04	
127 *LBL B		177 COS	
128 "LENGTH	Given length	178 *	
?"	calculate V	179 +	
129 CF 22	D1 and D2	180 "D1="	D1
130 PROMPT		181 ARCL X	
131 FS?C 22		182 PROMPT	
132 STO 10		183 RCL 07	
133 RCL 08		184 RCL 00	
134 SIN		185 TAN	
135 RCL 05		186 /	
136 SIN		187 "D2="	D2
137 *		188 ARCL X	
138 RCL 08		189 PROMPT	
139 COS		190 .END.	
140 RCL 05			
141 COS			
142 *			
143 RCL 06			
144 COS			
145 *			
146 +			
147 RCL 08			
148 COS			
		00	

[illegible]

Solar Panel Array

Registers: 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

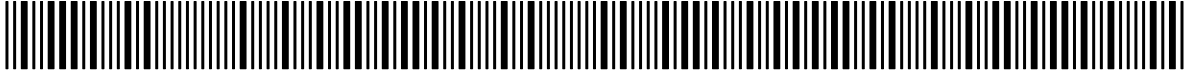
ROW 19 (127 : 129)



ROW 20 (130 : 141)



ROW 21 (142 : 154)



ROW 22 (155 : 167)



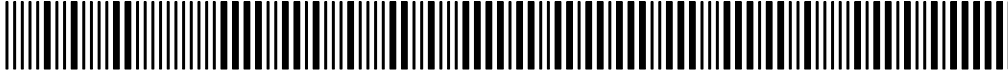
ROW 23 (168 : 177)



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 ($Re > 2300$)

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

is solved by Newton's method.

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

is used as an initial guess in the iteration.

where: Re is the Reynolds number, defined as $\rho D v / \mu$;

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

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 of 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 ($\nu = 9.3 \times 10^{-7} \text{ m}^2/\text{s}$, $\rho = 10^3 \text{ kg/m}^3$). The surface roughness is $3 \times 10^{-4} \text{ m}$ and the diameter is $2.54 \times 10^{-2} \text{ m}$. 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:

```
[XEQ] [ALPHA] SIZE [ALPHA] 015
[////] [ENG] 3
[XEQ] [ALPHA] CONDUIT [ALPHA]
9.3 [EEX] [CHS] 7 [ENTER↑]
[EEX] 3 [X] [R/S]
[EEX] 3 [R/S]
3 [EEX] [CHS] 4 [R/S]
60 [R/S]
2.54 [EEX] [CHS] 2 [R/S]
16 [R/S]
3.05 [R/S]
[R/S]
[R/S]
[R/S]
```

Display:

```
U=?
RHO=?
E=?
L=?
D=?
KT=?
V=?
DP=?
DP=521.9E3
Re=83.30E3
F=10.18E-3
```


Program Listings

<pre> 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 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=" 46 GTO 10 47♦LBL 03 48 RND 49 STO 00 </pre>	Input 1st V Calculate ΔP Iterate to find V using 1st V as guess	<pre> 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 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 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 92♦LBL 02 93 RCL 12 94 RCL 05 95 - 96 4.67 97 RCL 06 98 * 99 RCL 01 </pre>	Calculate constants Is flow turbulent? Iterate to find $\frac{1}{\sqrt{f}}$
---	---	---	---

Program Listings

<pre> 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 GT0 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 GT0 00 147 RTN 148♦LBL 00 149 / </pre>		<pre> 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 </pre>	Output
--	--	---	--------------

DATA REGISTERS				STATUS			
00	V	50		SIZE	015	TOT. REG.	52
	Re			ENG	3	FIX	____ SCI ____
	V			DEG	____	RAD	____ GRAD ____
	L						
	ΔP						
05	$1/\sqrt{f}$	55		FLAGS			
	ρ/ϵ			#	INIT S/C	SET INDICATES	CLEAR INDICATES
	1.737			00		calculate V	calculate ΔP
	$K_T/4$			22		calculate ΔP	calculate V
	μ			21		printer enable	printer disable
10	ρ	60		27		user mode on	user mode off
	used						
	$1/\sqrt{f_0}$						
	D						
	ϵ						
15		65					
20		70					
25		75					
30		80					
35		85					
40		90		ASSIGNMENTS			
				FUNCTION	KEY	FUNCTION	KEY
45		95					

Conduit Flow

Registers: 38

ROW 1 (1 : 2)



ROW 2 (3 : 7)



ROW 3 (7 : 14)



ROW 4 (14 : 20)



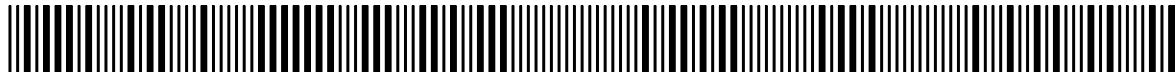
ROW 5 (20 : 27)



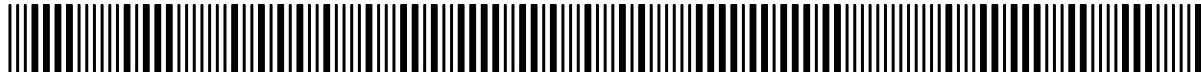
ROW 6 (27 : 33)



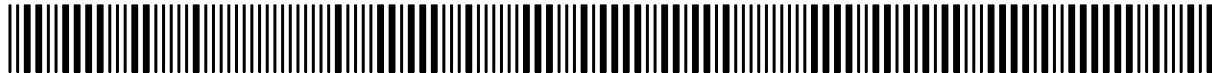
ROW 7 (33 : 41)



ROW 8 (42 : 50)



ROW 9 (50 : 57)



ROW 10 (58 : 66)



ROW 11 (66 : 74)



ROW 12 (74 : 83)



ROW 13 (83 : 93)



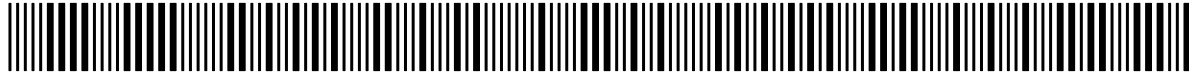
ROW 14 (94 : 103)



ROW 15 (104 : 116)



ROW 16 (117 : 126)



ROW 17 (126 : 137)

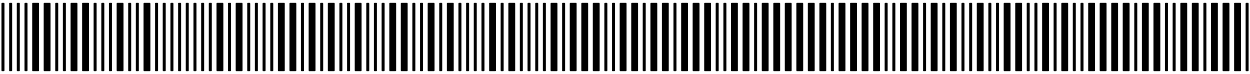


ROW 18 (138 : 148)



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

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

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:

<u>Input</u>	<u>Function</u>	<u>Display</u>	<u>Comments</u>
	[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

<u>Input</u>	<u>Function</u>	<u>Display</u>	<u>Comments</u>
	[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:

<u>Input</u>	<u>Function</u>	<u>Display</u>	<u>Comments</u>
	[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.	

<u>Input</u>	<u>Function</u>	<u>Display</u>	<u>Comments</u>
	[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?

[illegible]

Program Listings

```

01*LBL "ECF
"
02 CLRG
03 CF 06
04 XEQ I
05 SF 05
06 CF 08
07*LBL 13
08 1.011
09 FS? 06
10 1.008
11 STO 00
12*LBL 14
13 CF 22
14 XEQ IND
00
15 FS? 08
16 PRA
17 ISG 00
18 GTO 14
19 FS?C 05
20 GTO J
21 RTN
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
"

```

Initialize and enter the prompted sequence

Establish loop parameters for case with or without maintenance

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

If finished prompting go to J else return 124

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

```

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
"
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 "F: "
88 RCL IND
00

```

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

Program Listings

89 ARCL X		137 RCL 08	
90 FC? 08		138 %	$1 + \frac{\%M}{100}$
91 PROMPT		139 +	
92 RTN		140 STO 18	
93♦LBL 00		141 RCL 04	
94 CLX		142 RCL 05	
95 "F?"		143 %CH	Calculate and
96 PROMPT		144 SF 21	output % E change
97 STO IND		145 ADV	
00		146 "E % CH=	
98 RTN		"	
99♦LBL I		147 ARCL X	
100 "NO. YEA	Prompt for number	148 AVIEW	
RS?"	of years and put	149 RCL 01	
101 PROMPT	in loop control	150 12	Calculate monthly
102 INT	form	151 *	and annual loan
103 1 E3		152 1	payment
104 /		153 RCL 02	
105 STO 12		154 X=0?	
106 CLX		155 GTO 28	If loan interest
107 "START Y	Prompt for and	156 LASTX	= 0 branch to
EAR?"	store start year	157 /	label 28
108 PROMPT		158 %	
109 STO 13		159 +	
110 RTN		160 STO 14	
111♦LBL J		161 X<>Y	
112 CF 12		162 Y↑X	
113 FIX 2		163 STO Y	
114 CF 05	Clear prompted	164 1	
115 CF 06	sequence, clear	165 -	
116 RCL 10	"no maintenance",	166 /	
117 RCL 11	test for mainten-	167 RCL 03	
118 +	ance	168 *	
119 X=0?		169 RCL 14	
120 SF 06		170 1	
121 FS? 55	If printer is	171 -	
122 SF 08	attached list	172 *	
123 FS? 08	variable para-	173♦LBL 29	Re-entry point
124 XEQ 13	meters	174 RND	for 0%
125 CF 08		175 STO 14	
126 1	Calculate and	176 "MO PMT=	
127 RCL 07	store:	"	
128 %		177 ARCL X	Display or print
129 +	$1 + \frac{\%E}{100}$	178 AVIEW	monthly and annual
130 STO 16		179 12	payments
131 1		180 ST* 14	
132 RCL 09		181 RCL 14	
133 %	$1 + \frac{\%G}{100}$	182 "AN PMT=	
134 +		"	
135 STO 17		183 ARCL X	
136 1		184 AVIEW	

Program Listings

185 FC? 55			236 RCL 22	
186 CF 21	Reset flag 21		237 CHS	
187 1 E3			238 X<>Y	
188 RCL 13	Set up for column		239 STO 22	
189 X<Y?	#1, # of years to		240 STO 29	
190 +	be examined		241 +	
191 STO 13			242 STO 23	If there is main-
192 RCL 12			243 FC? 06	tenance calculate
193 FRC			244 XEQ 17	it
194 1			245 FIX 0	
195 +			246 CF 29	Accumulate cur-
196 STO 12			247 "AAAA"	rent year digits
197 ADV			248 RCL 13	in row #1
198 ADV			249 RCL 12	
199 FC? 55			250 INT	
200 GTO 23			251 +	
201 7			252 1	
202 SKPCHR	Format and print		253 -	
203 "YEARLY"	header		254 ARCL X	
204 ACA			255 SF 29	
205 5			256 ASHF	If no printer is
206 SKPCHR			257 FC? 55	present go to
207 "ACCUM"			258 GTO 24	separate output
208 ACA			259 ACA	
209 PRBUF			260 RCL 23	Format output for
210 "YR"			261 XEQ 15	printer
211 ACA			262 RCL 29	
212 5			263 XEQ 15	
213 SKPCHR			264 PRBUF	Print row #1
214 "COSTS"			265 LBL 26	
215 ACA			266 RCL 05	Re-entry for non-
216 6			267 RCL 06	print
217 SKPCHR			268 *	Load working regi-
218 ACA			269 RCL 21	sters with data
219 PRBUF			270 *	for "after" cal-
220 ADV			271 STO 30	culation
221 LBL 23			272 ENTER↑	
222 ΣREG 20	Clear working		273 X<> 25	
223 CLΣ	registers		274 -	
224 ΣREG 25			275 STO 26	
225 CLΣ	Reset discounting		276 RCL 20	
226 CF 10	flag		277 RCL 11	
227 LBL 19			278 *	
228 7	Set pointer for		279 ST+ 30	
229 STO 19	energy calc.		280 ENTER↑	
230 XEQ 16	Calculate energy		281 X<> 27	
231 STO 21	multiplier		282 -	
232 RCL 04	Load working regi-		283 ST+ 26	
233 RCL 06	sters with data		284 RCL 01	
234 *	for "before"		285 RCL 12	
235 *	calculation		286 INT	

Program Listings

287 X<=Y?	If loan is not	338 X<>Y	
288 GTO 12	paid off deal	339 RND	
289 RCL 28	with loan payment	340 RCL Y	
290 ST+ 30		341 RCL Y	
291 GTO 00		342 ABS	
292♦LBL 12	Discount loan	343 X≠0?	
293 SF 10	payment by infla-	344 LOG	
294 XEQ 16	tion rate	345 INT	
295 RCL 14	(general)	346 X<0?	
296 *		347 CLX	
297 ST+ 30		348 SF 29	
298 ENTER↑		349 .75	
299 X<> 28		350 /	
300 -		351 INT	
301 ST+ 26		352 -	
302♦LBL 00		353 SKPCHR	
303 " "	Load a space, Y,	354 RDN	Discount energy
304 RCL 23	or sigma into	355 ACX	or maintenance as
305 RCL 26	print row #2	356 RTN	pointed to be
306 X<=Y?		357♦LBL 16	register 19 using
307 "Y"		358 1	the uniform pre-
308 RCL 29		359 RCL IND	sent worth formula
309 RCL 30		19	
310 X<=Y?		360 FS? 10	Flag 10 causes
311 "Σ"		361 CLX	the rate of esca-
312 SF 12		362 %	lation to be ze-
313 FC? 55	Output for case	363 +	roed for the loan
314 GTO 25	where no printer	364 STO 15	payment which is
315 ACA	is attached	365 1	constant
316 CF 12		366 RCL 08	
317 X<> 2		367 %	
318 XEQ 15	Format and print	368 +	
319 RCL 30	row #2	369 /	
320 XEQ 15		370 RCL 12	
321 PRBUF		371 INT	
322 ADV		372 Y↑X	
323♦LBL 99	Re-entry for	373 CHS	
324 ISG 12	non-print	374 1	
325 GTO 19		375 +	
326 ADV		376 RCL 15	
327 ADV	Loop for next	377 RCL 08	
328 ADV	year or advance	378 RCL IND	
329 ADV	paper if done	19	
330 ADV		379 FS?C 10	
331 ADV		380 CLX	
332♦LBL 22		381 -	
333 FIX 2	"Stopper" to pre-	382 1 E2	
334 RTN	vent accidental	383 /	Test for case
335 GTO 22	R/S damage	384 X=0?	where %E = %G or
336♦LBL 15	Print formatting	385 GTO 12	%M = %G
337 8	routine	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 "F "	put for row #1
395 ARCL 23	
396 "F "	
397 ARCL 29	
398 PROMPT	
399 GTO 26	
400♦LBL 25	Non-printer out-
401 "F "	put for row #2
402 ARCL 26	
403 "F "	
404 ARCL 30	
405 PROMPT	
406 GTO 99	
407♦LBL 28	Deal with case
408 RCL 03	where loan in-
409 R↑	terest = 0
410 /	
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.	

[illegible]

Energy Cash Flow

Registers: 117

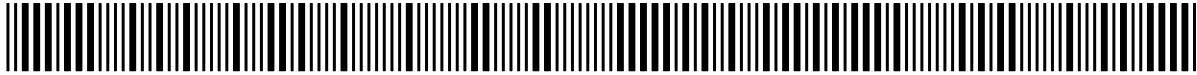
ROW 1 (1 : 4)



ROW 2 (5 : 10)



ROW 3 (10 : 16)



ROW 4 (16 : 22)



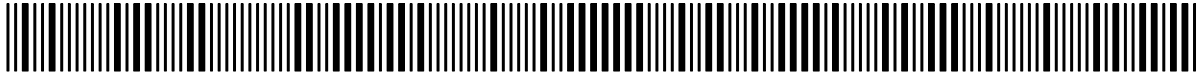
ROW 5 (23 : 26)



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)



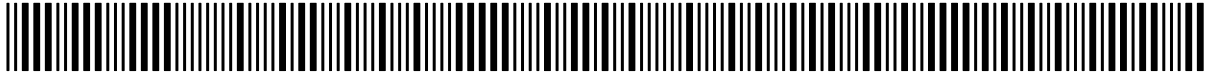
ROW 13 (60 : 63)



ROW 14 (64 : 67)



ROW 15 (68 : 71)



ROW 16 (71 : 75)



ROW 17 (75 : 82)



ROW 18 (82 : 88)

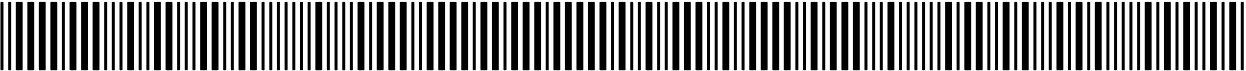


Energy Cash Flow

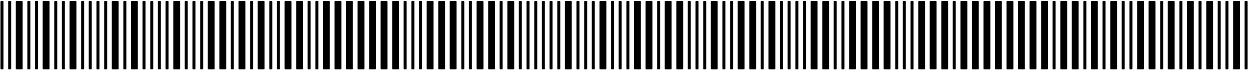
ROW 19 (89 : 97)



ROW 20 (97 : 100)



ROW 21 (100 : 107)



ROW 22 (107 : 111)



ROW 23 (111 : 119)



ROW 24 (120 : 125)



ROW 25 (126 : 136)



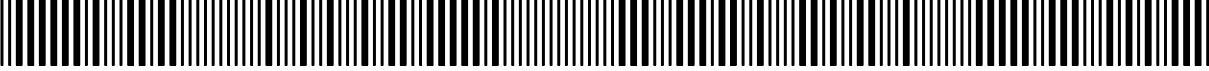
ROW 26 (137 : 146)



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)



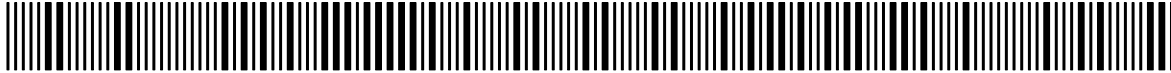
ROW 39 (230 : 239)



ROW 40 (239 : 245)



ROW 41 (246 : 253)



ROW 42 (254 : 260)



ROW 43 (260 : 265)



ROW 44 (266 : 275)



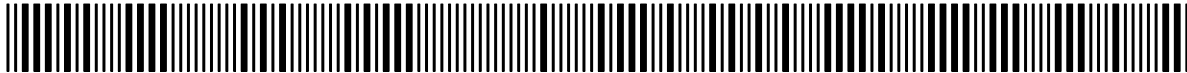
ROW 45 (275 : 283)



ROW 46 (284 : 292)



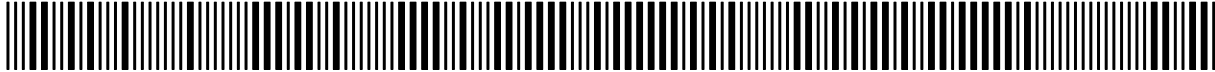
ROW 47 (293 : 300)



ROW 48 (301 : 308)



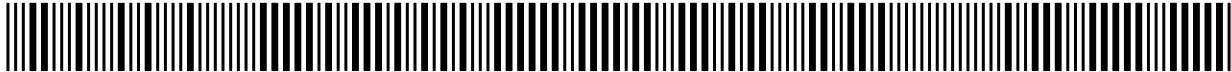
ROW 49 (308 : 314)



ROW 50 (315 : 320)



ROW 51 (320 : 327)



ROW 52 (328 : 336)



ROW 53 (336 : 346)

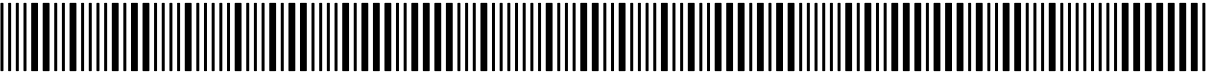


ROW 54 (347 : 355)

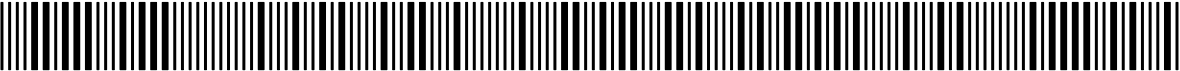


Energy Cash Flow

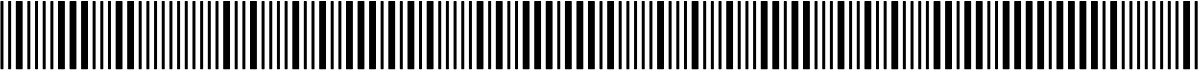
ROW 55 (355 : 364)



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)



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Machine Design 00041-15020
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