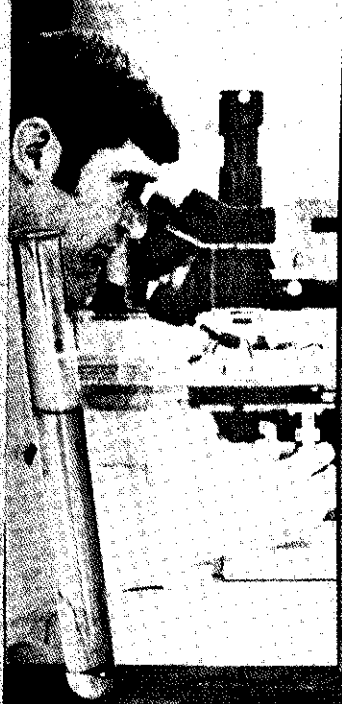
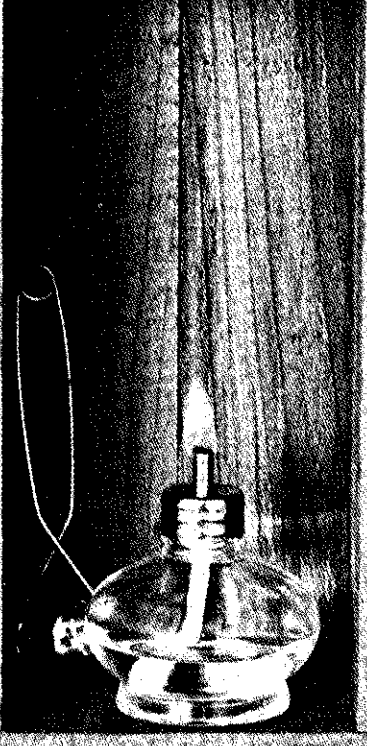


Hewlett-Packard HP-19C/HP-29C SOLUTIONS

SURVEYING



INTRODUCTION

This HP-19C/HP-29C 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 an expert on your HP calculator.

You will find general information on how to key in and run programs under "A Word about Program Usage" in the Applications book you received with your calculator.

We hope that this Solutions book will be a valuable tool in your work and would appreciate your comments about it.

The program material contained herein is supplied without representation or warranty of any kind. Hewlett-Packard Company therefore assumes no responsibility and shall have no liability, consequential or otherwise, of any kind arising from the use of this program material or any part thereof.

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* This program also appears in the HP-19C/29C Applications book, but is included here for the sake of completeness.

[illegible]

User Instructions

[illegible]

01 *LBL1	Bearing to Azimuth				
02 FIX4					
03 X \leftrightarrow Y	Bearing				
04 \leftrightarrow H					
05 X \leftrightarrow Y	Quadrant				
06 ENT \uparrow					
07 ENT \uparrow					
08 2					
09 \div					
10 INT					
11 1					
12 0					
13 0					
14 ST09					
15 \times					
16 X \leftrightarrow Y					
17 RCL9					
18 \times					
19 COS					
20 R \downarrow					
21 R \downarrow					
22 R \downarrow					
23 \times					
24 -					
25 \leftrightarrow HMS	***Azimuth				
26 R \downarrow S					
27 *LPL3	Azimuth to Bearing				
28 FIX4					
29 \leftrightarrow H					
30 ENT \uparrow					
31 SIN					
32 SIN $^{-1}$					
33 X \leftrightarrow 0?					
34 CHS					
35 \leftrightarrow HMS					
36 R \downarrow S	***Bearing				
37 R \downarrow					
38 9					
39 0					
40 \div					
41 1					
42 +					
43 INT					
44 FIX0	***Quadrant				
45 R \downarrow S					
REGISTERS					
0	1	2	3	4	5
6	7	8	9 180	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

***Print x may be used with or to replace R/S

FIELD ANGLE OR BEARING TRAVERSE

This program uses angles and/or deflections turned from a reference azimuth and horizontal distances, to compute the coordinates of successive points in a traverse. For a closed traverse, the area enclosed and closure distance and azimuth are computed.

Equations:

$$N_{i+1} = N_1 + \text{HDist} \cos \text{AZ}$$

$$E_{i+1} = E_1 + \text{HDist} \sin \text{AZ}$$

$$\text{Area} = \sum_{k=1}^n \text{LAT}_k \left(\frac{1}{2} \text{DEP}_k + \sum_{j=1}^{k-1} \text{DEP}_j \right)$$

where:

$$\text{DEP}_k = E_{k+1} - E_k \text{ and } \text{LAT}_k = N_{k+1} - N_k$$

Remarks:

If the user does not desire to do Field Angle Traverse, steps 012 through 026 may be eliminated; if he does not desire to do Bearing Traverse, steps 064 through 080 may be eliminated.

Angles left and deflections left must be entered as negative numbers.

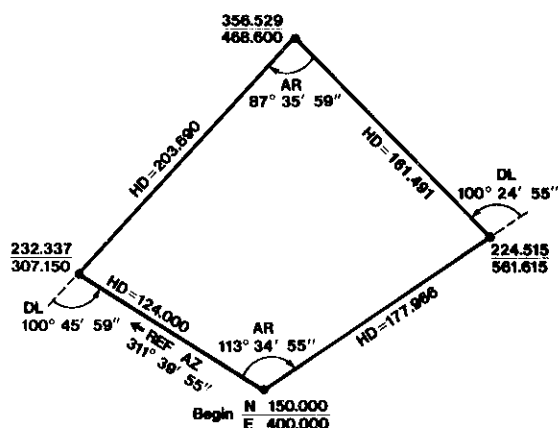
This program assumes the calculator is set in DEG mode.

Example 1:

Field Angle Traverse

Traverse the figure below starting at

$$\begin{array}{l} \text{N } 150 \\ \text{E } 400 \end{array}$$



Solution:

```

150.0000 ENT↑
400.0000 GSB1
180.0000 ***
311.3955 R/S
131.3955 ***
113.3455 GSB2
65.1450 ***
177.9660 R/S
224.5150 ***
224.5150 R/S (N)
561.6150 ***
-180.2455 GSB3 (E)
324.4955 ***
161.4910 R/S
356.5285 *** (N)
356.5285 R/S
468.6000 *** (E)
87.3559 GSB2
232.2554 ***
283.6900 R/S

```

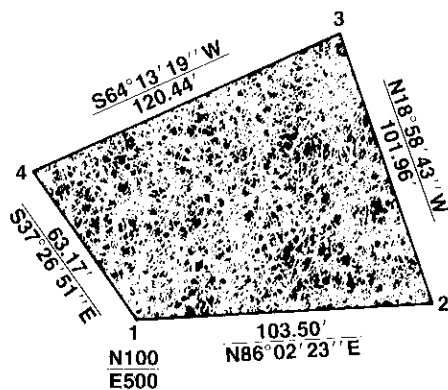

232.3372 ***
 R/S (N)
 307.1498 ***
 -100.4559 GSB3 (E)
 131.3955 ***
 124.0000 R/S
 149.9048 *** (N)
 R/S
 399.7829 *** (E)
 GSB5
 26558.8204 *** (Area)
 R/S
 0.2371 *** (Error Dist.)
 R/S (Error AZ)
 246.1844 ***

Example 2:

Bearing Traverse

Traverse the figure below starting at

N 100
 E 500



Solution:

100.0000 ENT↑
 500.0000 GSB1
 180.0000 ***
 86.0223 ENT↑
 1.0000 GSB4
 86.0223 ***
 103.5000 R/S
 107.1482 *** (N)
 R/S
 603.2529 *** (E)
 18.5843 ENT↑
 4.0000 GSB4
 341.0117 ***
 101.9600 R/S
 203.5657 *** (N)
 R/S
 570.0939 *** (E)
 64.1319 ENT↑
 3.0000 GSB4
 244.1319 ***
 120.4400 R/S
 151.1800 *** (N)
 R/S
 461.6395 *** (E)
 37.2651 ENT↑
 2.0000 GSB4
 142.3309 ***
 63.1700 R/S
 101.0366 *** (N)
 R/S
 500.0490 *** (E)
 GSB5
 8855.4922 *** (Area)
 R/S
 1.0378 *** (Error Dist.)
 R/S
 2.4219 *** (Error AZ)

User Instructions

[illegible]

01 *LBL1	Store starting	50 2	
02 FIX4	point coordinates	51 =	
03 CLRG	and 180°	52 RCL7	
04 ST01		53 -	
05 X↔Y		54 ×	
06 ST02		55 ST+8	
07 1		56 RCL6	
08 8		57 RCL2	
09 0		58 +	
10 ST03		59 R/S	***
11 R/S		60 RCL7	
12 +H		61 RCL1	
13 RCL3	Reference azimuth	62 +	
14 +H		63 R/S	***
15 +		64 *LBL4	
16 GT00		65 X↔Y	
17 *LBL2	Angle input	66 ST09	Convert bearing and
18 +H		67 X↔Y	quadrant code to
19 RCL3		68 ENT↑	azimuth.
20 +H		69 ENT↑	
21 +		70 2	
22 +HMS		71 ÷	
23 *LBL3	Deflection angle	72 INT	
24 +H	input	73 RCL3	
25 RCL4		74 ×	
26 +		75 X↔Y	
27 *LBL0		76 RCL3	
28 1		77 ×	
29 +R		78 COS	
30 +P	Compute azimuth	79 RCL9	
31 *LBL9		80 +H	
32 X↔Y		81 ×	
33 X>0?		82 -	
34 GT00		83 GT00	Area
35 3		84 *LBL5	
36 6		85 RCL8	
37 0		86 ABS	
38 +		87 R/S	***
39 *LBL8		88 RCL7	
40 ST04		89 RCL6	
41 +HMS		90 +P	Setup for closure
42 R/S	***	91 R/S	***
43 ST+5		92 ST09	
44 RCL4	Input horizontal	93 R/S	
45 X↔Y	distance		
46 +P			
47 ST+6			
48 X↔Y	Compute next coord.		
49 ST+7	and accumulate area.		

REGISTERS					
0	1 Beg.	2 Beg. N	3 180	4 ΔZ	5 EHD
6 Lat.	7 Dep.	8 Area	9 Bearing	10	11
12	13	14	15	16	17
18	19	20	21	22	23
24	25	26	27	28	29

*** indicates that "Print X" may be inserted or used to replace "R/S".

INVERSE WITH CLOSURE

This program calculates the distance and azimuth of the line joining two points. For a closed inverse, the area enclosed and closure distance and azimuth are computed.

Solution:

Equations:

$$HD = \sqrt{(N_i - N_{i-1})^2 + (E_i - E_{i-1})^2}$$

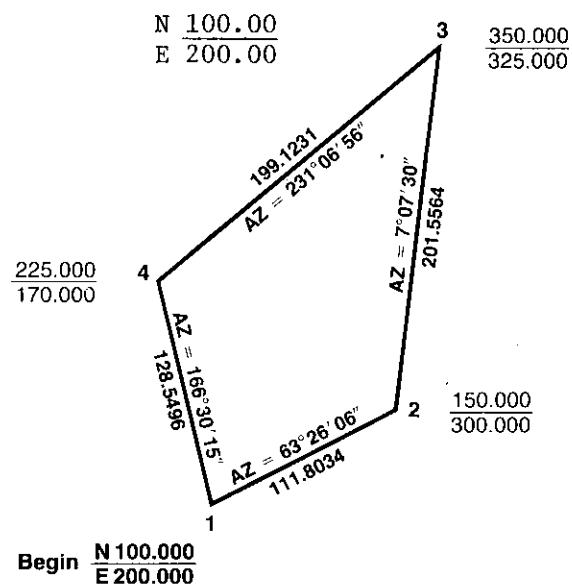
$$AZ = \tan^{-1} \frac{E_i - E_{i-1}}{N_i - N_{i-1}}$$

$$\text{Area} = \sum_{k=1}^n \text{LAT}_k \left(\frac{1}{2} \text{DEP}_k + \sum_{j=1}^{k-1} \text{DEP}_j \right)$$

where $\text{DEP}_k = E_{k+1} - E_k$ and

$$\text{LAT}_k = N_{k+1} - N_k$$

Example: Inverse the figure below starting at



```

100.0000 ENT+
200.0000 GSE1
150.0000 ENT+
300.0000 GSE2
111.8034 *** H Dist
R/S
63.2606 *** AZ
350.0000 ENT+
325.0000 GSE2
201.5564 *** H Dist
R/S
7.0730 *** AZ
225.0000 ENT+
170.0000 GSE2
-199.1231 *** H Dist
R/S
231.0656 *** AZ
100.0000 ENT+
200.0000 GSE2
128.5496 *** H Dist
R/S
166.3015 *** AZ
GSE7
20937.5000 *** Area
R/S
0.0000 *** Error, Dist
R/S
360.0000 *** Error, AZ
  
```

[illegible]

01 *LBL1		50 GT00	
02 FIX4		51 R/S	
03 CLRG			
04 ST01			
05 XZY			
06 ST02			
07 R/S			
08 *LBL2			
09 RCL7			
10 -			
11 RCL1			
12 -			
13 ST+7			
14 ST09			
15 XZY			
16 RCL6			
17 -			
18 RCL2			
19 -			
20 ST+6			
21 ST.0			
22 XZY			
23 2			
24 ÷			
25 RCL7			
26 -			
27 x			
28 ST+8			
29 RCL9			
30 RC.0			
31 *LBL0			
32 +P			
33 R/S	*** HD/Error Dist.		
34 XZY			
35 X>0?			
36 GT09			
37 3			
38 6			
39 0			
40 +			
41 *LBL9			
42 +HMS			
43 R/S	*** AZ/Error AZ		
44 *LBL3			
45 RCL8			
46 ABS			
47 R/S	***Area		
48 RCL7			
49 RCL6			

REGISTERS					
0	1 BEG E	2 BEG N	3	4	5
6 LAT	7 DEP	8 Area	9 Δ E	10 ΔN	11
12	13	14	15	16	17
18	19	20	21	22	23
24	25	26	27	28	29

*** "Print X" may replace or be used with "R/S"

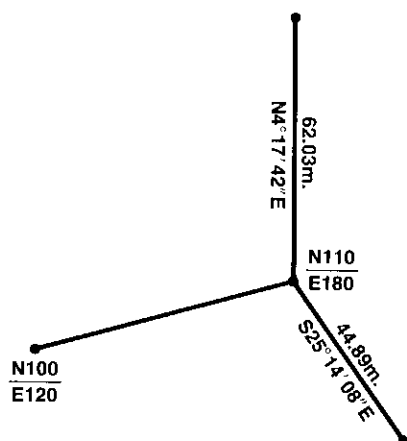
SIDESHOTS

This program is used to make sideshots or radials from a point. Two methods may be used for a sideshot, 1) input a bearing and distance and calculate the point coordinates, or 2) input the point coordinates and calculate the azimuth and distance to the point.

Equations:

$$N = N_0 + H \text{ Dist} \cos AZ$$

$$E = N_0 + H \text{ Dist} \sin AZ$$

Example:Solutions:

```

110.0000 ENT↑
180.0000 GSB1
  4.1742 ENT↑
  1.0000 GSB2
  4.1742 ***   AZ
62.0300 R/S
171.8558 ***   N
      R/S
184.6455 ***   E
25.1400 ENT↑
  2.0000 GSB2
154.4552 ***   AZ
  44.8900 R/S
  69.3942 ***   N
      R/S
199.1384 ***   E
100.0000 ENT↑
120.0000 GSB3
  60.8276 ***   H Dist
      R/S
260.3216 ***   AZ

```

User Instructions

[illegible]

01 *LBL1		50 +	***N
02 FIX4		51 R/S	
03 CLRG		52 X \div Y	
04 ST01		53 RCL1	
05 X \div Y		54 +	***E
06 ST02		55 R/S	
07 1		56 *LBL3	
08 8		57 RCL1	ΔE
09 0		58 -	
10 ST03		59 X \div Y	
11 R/S		60 RCL2	AN AE
12 *LBL2	Bearing to Azimuth conversion routine	61 -	Dist AZ
13 X \div Y		62 \div P	*** Dist
14 \div H		63 R/S	
15 X \div Y		64 GT09	
16 ENT \uparrow		65 R/S	
17 ENT \uparrow			
18 2			
19 =			
20 INT			
21 RCL3			
22 X			
23 R \downarrow			
24 X \div Y			
25 R \downarrow			
26 RCL3			
27 X			
28 COS			
29 X	AZ		
30 -	make		
31 1	$ AZ \leq 360^\circ$		
32 \div R			
33 \div P			
34 *LBL9	AZ		
35 X \div Y			
36 X \div 0?			
37 GT08			
38 3			
39 6			
40 0			
41 +			
42 *LBL8			
43 ST04			
44 \div HMS	***AZ		
45 R/S			
46 RCL4			
47 X \div Y			
48 \div R			
49 RCL2			

REGISTERS					
0	1 E_0	2 N_0	3 180	4	5
6	7	8	9	10	11
12	13	14	15	16	17
18	19	20	21	22	23
24	25	26	27	28	29

*** "Print X" may replace or be used with "R/S"

COMPASS RULE ADJUSTMENT

This program adjusts a traverse by the compass rule. It is intended to follow the program "Field Angle or Bearing Traverse" (with closure). However, if the correct coordinates of the last point and the total distance traversed are known, these parameters can be used in lieu of executing the closure program.

If this program is not used immediately after "Field Angle or Bearing Traverse" (with closure) or the storage registers have been altered since the closure program was run, enter the following data into the specified storage registers:

Register Parameter:

1. Correct closing easting.
2. Correct closing northing.
5. Total distance traversed.
6. Calculated ending northing.
7. Calculated ending easting.

The Inverse program may be used to obtain adjusted bearings, distances and area.

Equations:

$$C_L = \frac{(\Delta N) (Dist)}{\Sigma Dist}$$

$$C_D = \frac{(\Delta E) (Dist)}{\Sigma Dist}$$

Where: C_L = Correction to latitude of a course.
 C_D = Correction to departure of a course.
 ΔN = Closing latitude.
 ΔE = Closing departure.
 $Dist$ = Length of course to be corrected.
 $\Sigma Dist$ = Total length of traverse

Example:

667.147 Total distance traversed
 400.000 Correct closing easting
 150.000 Correct closing northing
 399.783 Calculated ending easting
 149.905 Calculated ending northing

POINT UNADJUSTED
 NO. COORDINATES

2 $\frac{N = 224.515}{E = 561.615}$

3 $\frac{N = 356.529}{E = 468.600}$

4 $\frac{N = 232.337}{E = 307.150}$

Ending & } $N = 149.905$
 Beginning } $E = 399.783$

Solution:

150.0000	ST02	
400.0000	ST01	
667.1470	ST05	
149.9050	ST06	
399.7830	ST07	
6981		
224.5150	ENT1	
561.6150	GSE2	
224.5403	***	Adj. N
	R/S	
561.6729	***	Adj. E
356.5290	ENT1	
468.6000	GSE2	
356.5773	***	Adj. N
	R/S	
468.7104	***	Adj. E
232.3370	ENT1	
307.1500	GSE2	
232.4143	***	Adj. N
	R/S	
307.3267	***	Adj. E
149.9050	ENT1	
399.7830	GSE2	
150.0000	***	Adj. N
	R/S	
400.0000	***	Adj. E

01 *LBL1	initialize				
02 RCL1					
03 ST08					
04 RCL7					
05 -					
06 RCL5	$\frac{\Delta E}{\Sigma Dist}$				
07 =					
08 ST03					
09 RCL2					
10 RCL6					
11 -					
12 RCL5	$\frac{\Delta N}{\Sigma Dist}$				
13 =					
14 ST04					
15 RCL2					
16 ST05					
17 RTN					
18 *LBL2	(x > y)				
19 X<Y					
20 ST06					
21 RCL2					
22 -					
23 ST+5					
24 X<Y					
25 ST07					
26 RCL1					
27 -	$\sqrt{x^2 + y^2} = Dist$				
28 ST+9					
29 +P					
30 ST09	C_D				
31 RCL3					
32 x					
33 ST+8					
34 RCL9	C_L				
35 RCL4					
36 x					
37 ST+5					
38 RCL6					
39 ST02					
40 RCL7					
41 ST01					
42 RCL5	***Adj N				
43 R/S					
44 RCL8	*** Adj E				
45 R/S					
REGISTERS					
0	1 Beg E	2 Beg N	3 AE/ $\Sigma Dist$	4 $\Delta E/\Sigma Dist$	5 ΣHD
6 Closing LAT	7 Closing DEP	8 Adj E	9 Dist	10	11
12	13	14	15	16	17
18	19	20	21	22	23
24	25	26	27	28	29

***"Print X" may be used to replace "R/S"

CURVE SOLUTIONS

Given values for any of the following pairs, this program computes the remaining parameters plus the sector, segment, and fillet areas: Δ and C; Δ and R; Δ and T; R and T; R and L; R and C.

Equations

$$\frac{1}{2}\Delta = \tan^{-1} (T/R) = \sin^{-1} (\frac{1}{2}C/R) = 90L/\pi R$$

$$T = R \tan (\frac{1}{2}\Delta)$$

$$C = 2T \cos (\frac{1}{2}\Delta)$$

$$R = T/\tan (\frac{1}{2}\Delta) = C/(2 \sin (\frac{1}{2}\Delta))$$

$$L = \Delta \pi R/180$$

$$\text{Sector area} = LR/2$$

$$\text{Segment area} = \text{Sector area} - \frac{1}{2}CR \cos(\frac{1}{2}\Delta)$$

$$\text{Fillet area} = T R - \text{Sector area}$$

Where: T = Tangent distance

C = Chord length

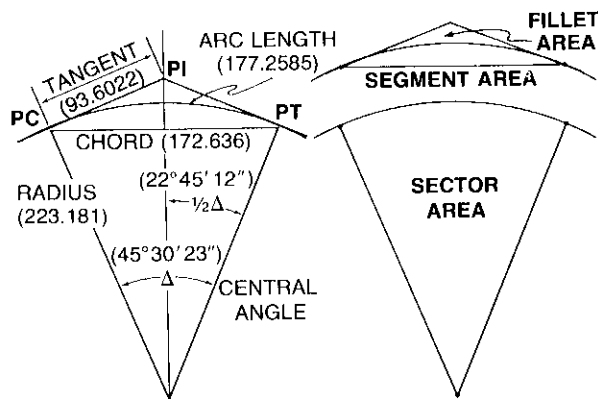
L = Arc length

R = Radius

Δ = Central angle

Solution:

	CLPC	
223.1810	ST02	R
172.6360	ST03	C
	G9B1	
223.1810	***	R
	R/S	
22.7532	***	$\Delta/2$
	R/S	
93.6022	***	T
	R/S	
172.6360	***	C
	R/S	
177.2584	***	L
	R/S	
19780.3563	***	Sector Area
	R/S	
2014.9959	***	Segment Area
	R/S	
1109.8705	***	Fillet Area



$$R = 223.181$$

$$\Delta = 45^{\circ} 30' 23''$$

$$\frac{1}{2}\Delta = 22^{\circ} 45' 11''$$

$$C = 172.636$$

$$T = 93.602$$

$$L = 177.258$$

$$\text{Sector area} = 19780.36$$

$$\text{Segment area} = 2015.00$$

$$\text{Fillet area} = 1109.87$$

User Instructions

[illegible]

01 *LBL1		50 X	
02 RCL1		51 RCL2	
03 +H		52 X	
04 2		53 R/S	***L
05 ÷		54 RCL2	
06 STO1		55 STX4	
07 X=0?		56 X	
08 GT09		57 2	
09 RCL3	have Δ , calculate R	58 ÷	
10 RCL1		59 R/S	***Sector area
11 SIN		60 -	
12 2		61 CHS	
13 X		62 R/S	***Segment area
14 ÷	$R = f(C, \Delta)$	63 RCL4	
15 X=0?		64 LSTX	
16 STO2		65 -	
17 RCL4		66 R/S	***Fillet area
18 RCL1		67 *LBL9	have R, calculate Δ
19 TAN		68 RCL5	
20 ÷		69 RCL2	
21 X=0?	$R = f(T, \Delta)$	70 ÷	
22 STO2		71 9	
23 *LBL5		72 0	
24 RCL2		73 X	
25 R/S	*** R	74 Pi	
26 RCL1		75 ÷	$\Delta = f(L, R)$
27 R/S	*** $\Delta/2$	76 X=0?	
28 TAN		77 STO1	
29 X		78 RCL3	
30 STO4		79 RCL2	
31 R/S	*** T	80 2	
32 2		81 X	
33 X		82 ÷	
34 RCL1		83 SIN ⁻¹	$\Delta = f(C, R)$
35 COS		84 X=0?	
36 X		85 STO1	
37 R/S	*** C	86 RCL4	
38 RCL2		87 RCL2	
39 X		88 ÷	
40 RCL1		89 TAN ⁻¹	$\Delta = f(T, R)$
41 COS		90 X=0?	
42 X		91 STO1	
43 2		92 GT05	
44 ÷		93 R/S	
45 Pi			
46 9			
47 0			
48 ÷			
49 RCL1			

REGISTERS					
0	1 $\Delta/2$	2 R	3 C	4 T	5 L
6	7	8	9	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

***"PrintX" may be inserted or used to replace "R/S"

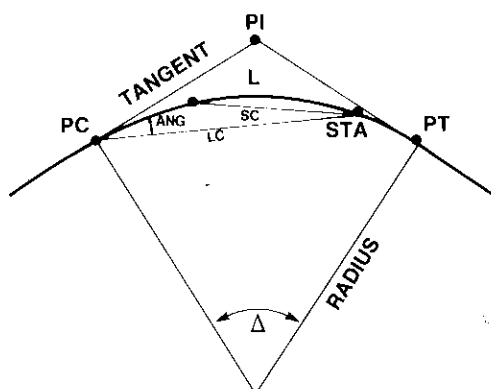
HORIZONTAL CURVE LAYOUT

This program calculates various field data for layout of an horizontal circular curve. The required information on the curve is the PC station and the radius or degree of curve. With this data one computes successively the arc length, deflection angle from tangent to chord, the long chord from PC to current station, and the short chord from previous station to current station. In addition, the tangent offset and tangent distance are available if desired.

If the central angle is known the program also will compute the total arc length from PC to PT, the station PT and the length of the tangent from PC to PI.

In the program, stations are entered in the form XXXX.XX for station XX+XX.XX. For example: 20 + 10.00 is entered as 2010.00. The degree of curve D, (or central angle subtending an arc of 100 ft.) is entered in degrees with a negative sign, always.

PC Deflections



Field data output for PC deflections consist of:

STA-current station

ANG-deflection angle from tangent to long chord.

LC-long chord from PC to current station

SC-Short chord from previous station to current station

Δ A-central angle

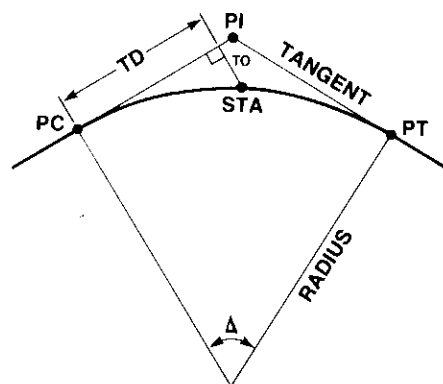
PI-point of intersection of tangents

PC,PT-ends of curve

L-Arc length

R-radius

Tangent Offsets and Distances



Field data output for tangent offsets consist of:

STA-current station

TD-tangent distance

TO-tangent offset

T-distance from PC to PI

(HORIZONTAL CURVE LAYOUT)

Example:

Compute field data for a curve with a central angle of $35^{\circ}30'$ and degree of curve of $12^{\circ}30'$. The PC station is $7+85.40$.

Solution:

785.4000	ENT				
-12.3000	GSB1				
785.4000	***	(PC)			
	RCL1				
458.3662	***	(R)			
800.0000	GSB2	(For STA. 8)			
14.6000	***	(L)			
	R/S				
0.5445	***	(ANG)			
	R/S				
14.5994	***	(LC)			
	R/S				
14.5994	***	(SC)			
	RCL8				
0.2325	***	(TO)			
	RCL9				
14.5975	***	(TD)			
900.0000	GSB2	(For STA. 9)			
114.6000	***	(L)			
	R/S				
7.0945	***	(ANG)			
	R/S				
114.3018	***	(LC)			
	R/S				
99.8018	***	(SC)			
	RCL8				
14.2516	***	(TO)			
	RCL9				
113.4098	***	(TD)			
1000.0000	GSB2	(For STA. 10)			
214.6000	***	(L)			
	R/S				
13.2445	***	(ANG)			
	R/S				
212.6454	***	(LC)			
	R/S				
99.8018	***	(SC)			
	RCL8				
49.3252	***	(TO)			
	RCL9				
206.8455	***	(TD)			
35.3000	GSB3				
284.0000	***	(L)			
	R/S				
1069.4000	***	(PT)			
	R/S				
146.7242	***	(T)			
1069.4000	GSB2	(Field data: PT)			
284.0000	***	(L)			
	R/S				
17.4500	***	(ANG)			
	R/S				
279.4790	***	(LC)			
	R/S				
69.3337	***	(SC)			

User Instructions

[illegible]

01 *LBL1		50 SIN	Calculate TO
02 CLRG		51 X	
03 FIX4	Store R&D	52 ST08	
04 X<0?		53 RCL5	Calculate TD
05 GSB0		54 RCL7	
06 ST01		55 COS	
07 Pi		56 X	
08 X		57 ST09	dsp LC
09 9		58 RCL5	***
10 0		59 R/S	
11 ÷		60 RCL4	
12 ST02	Input PC	61 RC.2	
13 R4		62 -	
14 ST03		63 GSB9	
15 ST04		64 X	
16 RTN		65 SIN	
17 *LBL0		66 RCL1	
18 CHS		67 2	
19 →H	Calculate R from D	68 X	
20 Pi		69 X	***Calculate SC
21 X		70 RTN	
22 1/X		71 *LBL9	
23 1		72 9	
24 8		73 0	90
25 EEX		74 Pi	πR
26 3		75 ÷	
27 X		76 RCL1	Input Δ
28 RTN		77 ÷	
29 *LBL2	Input station	78 RTN	
30 RCL4		79 *LBL3.	
31 ST.2		80 →H	
32 R4		81 2	
33 ST04		82 ÷	
34 RCL3		83 ST06	
35 -		84 GSB9	
36 R/S	*** Calculate L	85 ÷	Calculate L
37 GSB9		86 R/S	***
38 X		87 RCL3	
39 ST07		88 +	Calculate PT
40 +HMS		89 R/S	***
41 R/S	*** Calculate ANG	90 RCL6	
42 RCL7		91 TAN	
43 SIN		92 RCL1	
44 RCL1		93 X	***
45 X		94 R/S	Calculate T
46 2			
47 X	Calculate LC		
48 ST05			
49 RCL7			

REGISTERS					
0	1 R	2 Ft/Deflect	3 PC	4 STA Current	5 LC
6 Δ/2	7 ANG	8 TO	9 TD	10	11
12 Prev. Sta.	13	14	15	16	17
18	19	20	21	22	23
24	25	26	27	28	29

*** indicates that "Print X" may be inserted or used to replace "R/S".

BEARING-DISTANCE AND BEARING-BEARING INTERSECTION

This program computes the coordinates of the point of intersection of two lines:
1) one of known bearing through known coordinates and the other of known length from a point of known coordinates; or 2) when the bearing of each line is known and the coordinates of a point on each line are known. For the first case, both solutions may be computed.

Equations:

Bearing-Distance

$$AZ_{12} = \tan^{-1} \frac{E_2 - E_1}{N_2 - N_1}$$

$$h = \text{Dist}_{12} \sin \phi$$

$$b = \sqrt{\text{Dist}_2^2 - h^2}$$

$$N = N_1 + ((\text{Dist}_{12} \cos \phi) + b) \cos (AZ_1)$$

$$E = E_1 + ((\text{Dist}_{12} \cos \phi) + b) \sin (AZ_1)$$

where: AZ_{12} = Azimuth of line from point 1 to point 2

AZ_1 = Azimuth of line 1

ϕ = Angle between line 1 and line from point 1 to point 2

h = Perpendicular distance from point 2 to line 1

b = Distance from point of intersection to the point where the perpendicular (h) intersects line 1

Dist_2 = Length of line 2 (the known distance)

$N_1 E_1$ = Northing, easting of point 1

$N_2 E_2$ = Northing, easting of point 2

Dist_{12} = Distance from point 1 to point 2

Bearing-Bearing

$$N = N_1 + \text{Dist} (\cos AZ_1)$$

$$E = E_1 + \text{Dist} (\sin AZ_1)$$

$$\text{Dist} = \frac{\text{Dist}_{12} \sin (AZ_2 - AZ_{12})}{\sin (AZ_2 - AZ_1)}$$

where:

AZ_{12} = Azimuth of line from point 1 to point 2

AZ_1 = Azimuth of line 1

AZ_2 = Azimuth of line 2

$N_1 E_1$ = Northing, easting of point 1

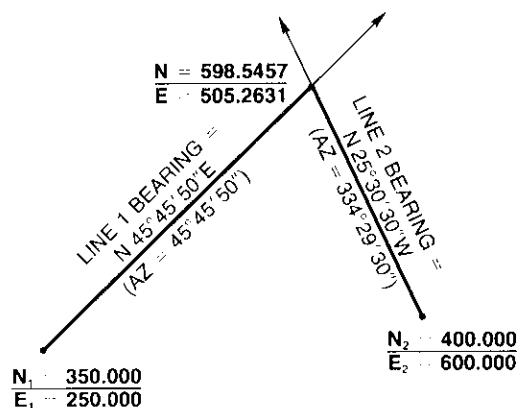
$N_2 E_2$ = Northing, easting of point 2

N, E = Northing, easting of intersect point

Dist = Distance from point 1 to intersection

Dist_{12} = Distance from point 1 to point 2

Example 1:



Solution:

```

750.0000 ENT↑
250.0000 GSB1
400.0000 ENT↑
500.0000 R/S
45.4550 ENT↑
1.0000 GSB2
25.3020 ENT↑
4.0000 GSB3
      GSB4
598.5457 *** N
      R/S
505.2631 *** E

```

Example 2:

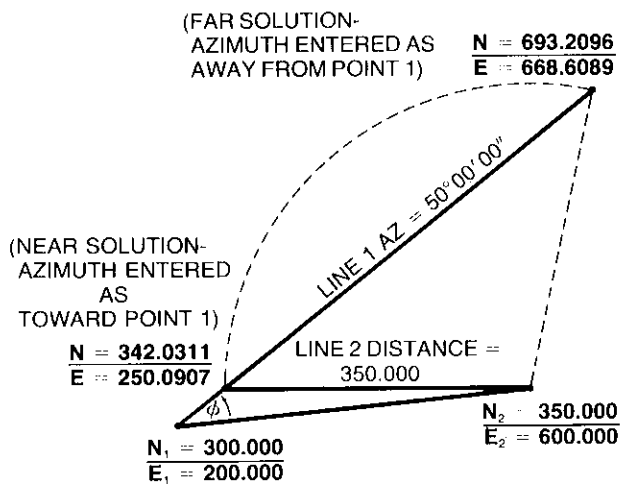
Solution:

```

300.0000 ENT↑
200.0000 GSB1
350.0000 ENT↑
600.0000 R/S
50.0000 ENT↑
1.0000 GSB2
350.0000 ST07
      GSB5
693.2096 *** N1
      R/S
668.6089 *** E1

300.0000 ENT↑
200.0000 GSB1
350.0000 ENT↑
600.0000 R/S
50.0000 ENT↑
3.0000 GSB2
350.0000 ST07
      GSB5
342.0311 *** N2
      R/S
250.0907 *** E2

```



User Instructions

[illegible]

01 *LBL1	Store Coordinates	50 X*Y	
02 ST02		51 X>0?	
03 R↓		52 RTN	
04 ST01		53 3	
05 1		54 6	
06 8		55 0	
07 0		56 +	
08 ST00		57 RTN	
09 R/S		58 *LBL4	
10 ST04		59 GSB6	
11 R↓		60 RCL6	
12 ST03		61 -	AZ ₁₂ - AZ ₁₂
13 RTN		62 CHS	
14 *LBL2		63 SIN	
15 GSB0		64 X	
16 ST05		65 RCL6	
17 RTN		66 RCL5	
18 *LBL3		67 -	
19 GSB0		68 SIN	Dist
20 ST06		69 ÷	
21 RTN		70 ST08	
22 *LBL0	Bearing→Azimuth Conversion	71 *LBL9	
23 X*Y		72 RCL5	
24 →H		73 RCL8	
25 X*Y		74 →R	X cos AZ ₁ , X sin AZ ₁
26 ENT↑		75 RCL1	
27 ENT↑		76 +	
28 2		77 R/S	***N
29 ÷		78 X*Y	
30 INT		79 RCL2	***E
31 RCL0		80 +	
32 X		81 R/S	
33 R↓		82 *LBL5	
34 X*Y		83 GSB6	
35 R↓		84 RCL5	
36 RCL0		85 -	
37 X		86 CHS	AZ ₁ - AZ ₁₂ = 0
38 COS		87 X*Y	
39 X	AZ	88 →R	
40 -		89 X*Y	
41 RTN		90 X²	h²
42 *LBL6		91 RCL7	
43 RCL4		92 X²	
44 RCL2		93 -	
45 -		94 CHS	
46 RCL3		95 JX	b
47 RCL1		96 +	
48 -		97 ST08	
49 →P	-Dist ₁₂ AZ ₁₂	98 GT09	

REGISTERS					
0 180	1 N ₁	2 E ₁	3 N ₂	4 E ₂	5 AZ ₁
6 AZ ₂	7 Dist 2	8 used	9	.0	.1
.2	.3	.4	.5	16	17
18	19	20	21	22	23
24	25	26	27	28	29

***"Print X" may replace or be used with "R/S"

DISTANCE-DISTANCE INTERSECTION

Given two lines, each of known length and originating from two known points, this program computes the intersection coordinates. There are two possible solutions; this program calculates the one found by proceeding in a clockwise direction from the first known point to the second known point. The other solution is found by reversing the entry of the known point coordinates.

Equations:

$$\phi = \cos^{-1} \frac{\text{Dist}_{12}^2 + \text{Dist}_1^2 - \text{Dist}_2^2}{2(\text{Dist}_1)(\text{Dist}_{12})}$$

$$AZ = \tan^{-1} \frac{E_2 - E_1}{N_2 - N_1}$$

$$N = N_1 + \text{Dist}_1 \cos (AZ - \phi)$$

$$E = E_1 + \text{Dist}_1 \sin (AZ - \phi)$$

where: ϕ = Angle between line 1 and line 1-2

Dist_{12} = Distance from point 1 to point 2

Dist_1 = Known distance along line 1

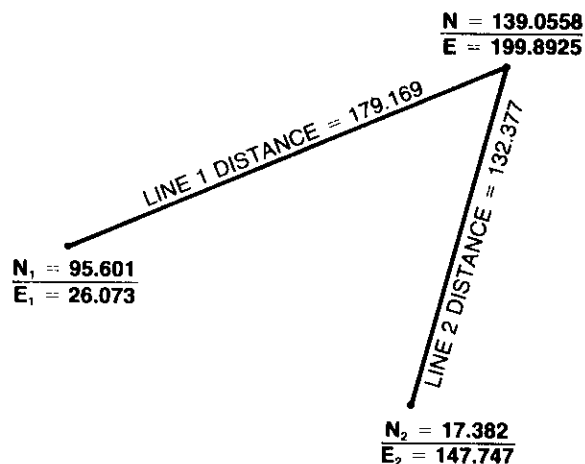
Dist_2 = Known distance along line 2

N_1, E_1 = Northing, easting of point 1

N, E = Northing, easting of intersection point

AZ = Azimuth of line from point 1 to point 2

Example:



Solution:

```

CLRS
179.1690 ENT1
132.3770 GSB1
95.6010 ENT1
26.0730 GSB2
17.3820 ENT1
147.7470 GSB2
139.0558 *** N
199.8925 *** E

```


01 *LBL1					
02 ST06					
03 R4					
04 ST05					
05 RTN					
06 *LBL2					
07 ST02					
08 X*Y					
09 ST01					
10 RTN					
11 *LBL3					
12 ST04					
13 R4					
14 ST03					
15 RCL4					
16 RCL2					
17 -					
18 RCL3					
19 RCL1					
20 -					
21 +P	Dist ₁₂ AZ				
22 ST07					
23 X ²					
24 RCL5					
25 X ²					
26 +					
27 RCL6					
28 X ²					
29 -					
30 2					
31 ÷					
32 RCL7					
33 RCL5					
34 X					
35 ÷					
36 COS ⁻¹	φ AZ				
37 -					
38 RCL5					
39 +R					
40 RCL1					
41 +					
42 R/S	*** N				
43 X*Y					
44 RCL2					
45 +					
46 R/S	*** E				
REGISTERS					
0	1 N ₁	2 E ₁	3 N ₂	4 E ₂	5 Dist 1
6 Dist 2	7 Dist 12	8	9	10	11
12	13	14	15	16	17
18	19	20	21	22	23
24	25	26	27	28	29

*** "Print X" may be used to replace "R/S"

OFFSET FROM A POINT TO A LINE

Given the point of known coordinates with a line of known bearing passing through it and a second point of known coordinates, this program calculates the offset distance from the second point to the line, the distance from the intersection to the first known point, the coordinates of the intersection, and the azimuth from the point of intersection to the second point.

Equations:

$$\text{Dist}_{BO} = \sqrt{(N_O - N_B)^2 + (E_O - E_B)^2}$$

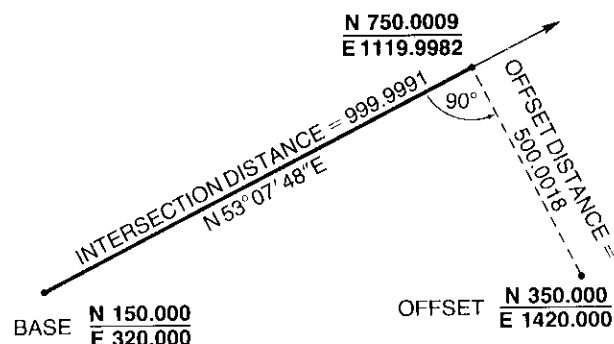
$$\text{Dist}_{BI} = \sqrt{(N_O - N_I)^2 + (E_O - E_I)^2}$$

$$N_I = \frac{E_O - E_B + N_O \cot(\text{Az}_{BI}) + N_B \tan(\text{Az}_{BI})}{\cot(\text{Az}_{BI}) + \tan(\text{Az}_{BI})}$$

$$E_I = E_B + (N_I - N_B) \tan(\text{Az}_{BI})$$

Where: Dist_{BO} = Distance from point to offset point
 Dist_{BI} = Distance from base point to intersection point
 Dist_{IO} = Distance from intersection point to offset point
 N_O, E_O = Northing, easting of offset point
 N_B, E_B = Northing, easting of base point
 N_I, E_I = Northing, easting of intersection point
 Az_{BI} = Known AZ from base point to intersection point

Example:



Solution:

150.0000	ST01	
320.0000	ST02	
350.0000	ST03	
1420.0000	ST04	
53.0748	ST05	AZ
1.0000	ST06	
180.0000	ST07	
	GSB1	N _I
750.0009	***	
	R/S	
1119.9982	***	E _I
	R/S	
500.0018	***	O.D.
	R/S	
999.9991	***	I.D.
	R/S	
143.3748	***	O. AZ

User Instructions

[illegible]

01 *LBL9	bearing to azimuth	50 +			
02 RCL7	conversion routine	51 CHS			
03 RCL6		52 ÷			
04 2		53 ST.0			
05 ÷		54 R/S	***N ₁		
06 INT		55 RCL8			
07 x		56 x			
08 RCL6		57 RCL9			
09 RCL7		58 +			
10 x		59 ST.1			
11 COS		60 R/S	***E ₁		
12 RCL5		61 RCL3			
13 +H		62 RC.0			
14 x		63 -			
15 -	AZ	64 RCL4			
16 *LBL8		65 RC.1			
17 1		66 -			
18 +R	make AZ ≤ 360°	67 +P			
19 +P		68 R/S	***offset distance		
20 X*Y		69 RCL1			
21 X>0?		70 RC.0			
22 GT0?		71 -			
23 3		72 RCL2			
24 6		73 RC.1			
25 0		74 -			
26 +		75 +P			
27 *LBL7		76 R/S	***intersect distance		
28 ST05		77 X*Y	0 I.D. O.D.		
29 +HMS		78 R↓			
30 RTN		79 +P			
31 *LBL1	***azimuth	80 X*Y			
32 GSB9		81 RCL5			
33 RCL2		82 +			
34 RCL1		83 X*Y			
35 RCL5		84 +R	N E		
36 TAN		85 X*Y			
37 ST08		86 RCL2	E _B		
38 x		87 +			
39 -		88 RCL4	E _O E calculated		
40 ST09		89 X=Y?			
41 RCL4		90 GT00			
42 RCL3		91 RCL7	180		
43 RCL8		92 ST-5	AZ-180 results		
44 ÷		93 *LBL0			
45 +		94 RCL5			
46 -		95 0			
47 RCL8		96 0			
48 ENT↑		97 +			
49 1/X		98 GT08	AZ ± 90		

REGISTERS					
0	1 N _B	2 E _B	3 N _O	4 E _O	5 BRG/AZ
6 QD	7 180	8 tan AZ	9 used	10 N _I	11 E _I
12	13	14	15	16	17
18	19	20	21	22	23
24	25	26	27	28	29

*** "Printx" may be inserted or used to replace "R/S".

EARTHWORK

VOLUME BY AVERAGE END AREA

Routines labeled 1 and 2 calculate the end area for any station, volume from previous station, and accumulated volume to the present station. Inputs are the elevations and distances from the centerline for all points of a cross section and the interval from the previous station.

Equations:

$$V_{avg} = \left(|Area_i| + |Area_{i-1}| \right) \frac{I}{2}$$

$$Area = \frac{1}{2} [Elev_1 (H Dist_2 - H Dist_n) + Elev_2 (H Dist_3 - H Dist_1) + \dots + Elev_n (H Dist_1 - H Dist_{n-1})]$$

Where: V_{avg} = Average volume between two stations
 Area = Cross sectional area at a station
 H Dist = Horizontal distance from centerline at cross section
 Elev = Elevation at a point on the cross section
 I = Interval between stations
 Subscript i refers to current point
 Subscript n refers to last point
 Numeric subscript refers to point number

VOLUME OF BORROW PIT

Routines labeled 3-6 calculate the volume of fill which can be taken from a borrow pit given grid dimensions and elevations at the grid intersections. Volume is available for each grid section and also as an accumulative volume for all previous sections.

If several grid blocks have the same horizontal dimensions, the sum of the volumes of all these blocks can be calculated at once. For example, if three rectangular blocks have the same dimensions, the 12 elevations are entered before pressing GSB 6.

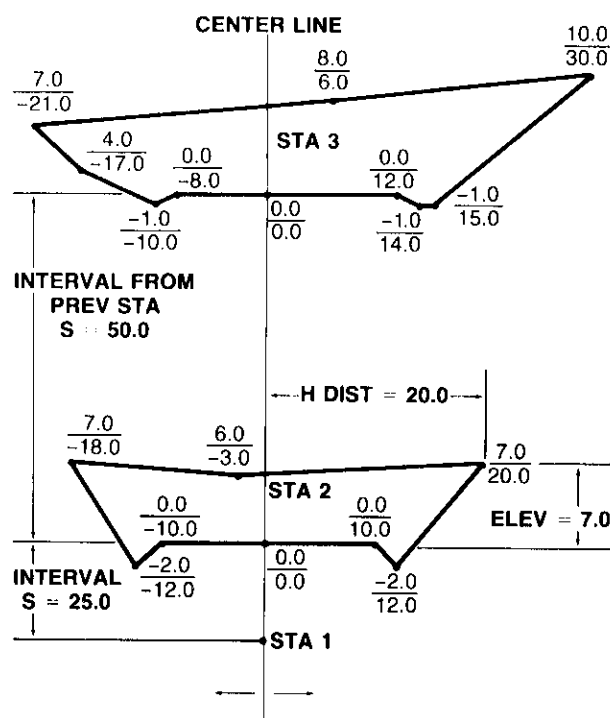
Equations:

$$Vol_{\Delta} = \frac{1}{2} (Base)(Ht)(Elev)$$

$$Vol = (Width)(Length)(Elev)$$

Where: Vol_{Δ} = Volume of triangular grid section
 Base = Base of triangle
 Ht = Height of triangle
 Elev = Elevation of grid section (depth of cut)
 Vol = Volume of rectangular grid section
 Width = Width of rectangle
 Length = Length of rectangle

Example 1:



Solution:

```

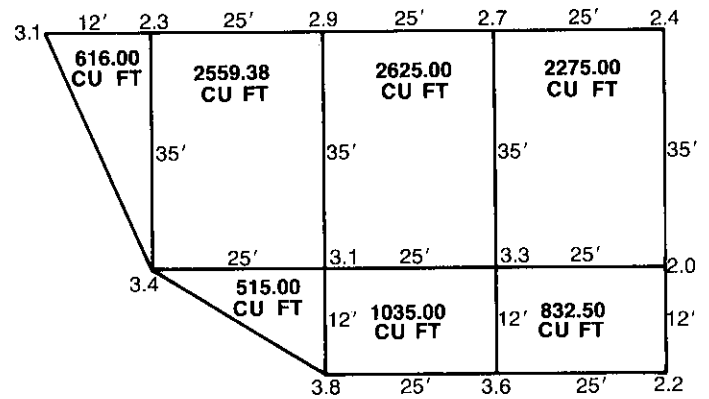
      CLRG
0.0000 GSB2 1st Sta.
0.0000 ENT↑ Starting at 0/0 &
0.0000 GSB1 Going CCW.
0.0000 ENT↑
10.0000 GSB1
-2.0000 ENT↑
12.0000 GSB1
7.0000 ENT↑
20.0000 GSB1
6.0000 ENT↑
-3.0000 GSB1
7.0000 ENT↑
-10.0000 GSB1
-2.0000 ENT↑
-12.0000 GSB1
0.0000 ENT↑
-10.0000 GSB1
0.0000 ENT↑ Reinput 1st Elev &
0.0000 GSB1 Dist.
25.0000 GSB2 1st INT.
100.0000 *** Vol. (total)
      RCL5
100.0000 *** Vol. (internal)
      RCL4
216.0000 *** Area

```

```

0.0000 ENT↑
0.0000 GSB1
0.0000 ENT↑
12.0000 GSB1
-1.0000 ENT↑
14.0000 GSB1
-1.0000 ENT↑
15.0000 GSB1
10.0000 ENT↑
30.0000 GSB1
8.0000 ENT↑
6.0000 GSB1
7.0000 ENT↑
-21.0000 GSB1
4.0000 ENT↑
-17.0000 GSB1
-1.0000 ENT↑
-10.0000 GSB1
0.0000 ENT↑
-8.0000 GSB1
0.0000 ENT↑
0.0000 GSB1
50.0000 GSB2 2nd INT.
597.6852 *** Vol. (total)
      RCL5
497.6852 *** Vol. (internal)
      RCL4
321.5000 *** Area

```

Example 2:

```

      CLX
12.0000 ENT↑
35.0000 GSB3
2.3000 GSB5
3.1000 GSB5
3.4000 GSB5
      GSB6
616.0000 *** G. Vol.

25.0000 ENT↑
35.0000 GSB4
2.3000 GSB5
3.4000 GSB5
3.1000 GSB5
2.9000 GSB5
2.9000 GSB5
3.1000 GSB5
3.3000 GSB5
3.3000 GSB5
2.7000 GSB5
2.7000 GSB5
2.4000 GSB5
2.0000 GSB5
      GSB6
1867.5000 *** G. Vol.
      R/S
10457.8750 *** A. Vol.

7459.3750 *** G. Vol.

25.0000 ENT↑
12.0000 GSB3
3.1000 GSB5
3.4000 GSB5
3.8000 GSB5
      GSB6
515.0000 *** G. Vol.

```

User Instructions

[illegible]

01 *LBL1	Avg. End Area routines <
----------	--

***"PrintX" may be used in place of "R/S"

COORDINATE TRANSFORMATION

This program translates, rotates, and rescales coordinates. Traverse rotation angle is entered as a negative value for counterclockwise rotation and positive for clockwise rotation. The translation factors are calculated by entering old and new grid system coordinates for the same point; rotation is also about this point.

Equations:

$$AZ_R = \phi + \tan^{-1} \frac{E_i - E_p}{N_i - N_p}$$

$$H \text{ Dist}_s = S \sqrt{(N_i - N_p)^2 + (E_i - E_p)^2}$$

$$N = H \text{ Dist}_s \cos (AZ_R) + N_{T_1}$$

$$E = H \text{ Dist}_s \sin (AZ_R) + E_{T_1}$$

Where: AZ_R = Rotated azimuth

ϕ = Rotation angle

N_i, E_i = Northing, easting of current point before transformation

N_p, E_p = Original northing, easting of pivot point

$H \text{ Dist}_s$ = Scaled horizontal distance

S = Scale factor

N, E = Northing, easting after transformation

N_{T_1}, E_{T_1} = Northing, easting of pivot point after transformation

Note: The scale factor is taken as one, unless the new grid system is to a different scale.

Example:

Coordinates before transformation are those computed by Compass Rule

Adjustment.

COORDINATES IN OLD SYSTEM	COORDINATES IN NEW SYSTEM
------------------------------	------------------------------

N 150.000*	N 100.00*
E 400.000	E 350.00

N 224.540	
E 561.673	

N 356.577	
E 468.710	

N 232.414	
E 307.327	

* Rotated about this point

Rotation Angle = $-3^\circ 00' 00''$

Scale Factor = 1.00

Solution:

-3.0000 ST05	
1.0000 ST05	
150.0000 ENT1	
400.0000 GSB1	
100.0000 ENT1	
350.0000 GSB2	
224.5400 ENT1	
561.6730 GSB7	
165.9765 ***	N
R/C	
515.3526 ***	E
356.5570 ENT1	
468.7100 GSB7	
302.6779 ***	N
R/C	
429.4262 ***	E
232.4140 ENT1	
307.3270 GSB7	
187.1512 ***	N
R/C	
261.7672 ***	E

01 *LBL1					
02 ST02					
03 X*Y					
04 ST01					
05 RTN					
06 *LBL2					
07 ST04					
08 X*Y					
09 ST03					
10 RTN					
11 *LBL3					
12 RCL2					
13 -					
14 X*Y					
15 RCL1					
16 -					
17 +P					
18 RCL6					
19 x	H Dist _s				
20 X*Y					
21 RCL5					
22 +H	AZ _R Note sign				
23 -	convention				
24 X*Y					
25 +R					
26 RCL3					
27 +	*** N				
28 R/S					
29 X*Y					
30 RCL4					
31 +	*** E				
32 R/S					
REGISTERS					
0	1 N _P	2 E _P	3 N _{T1}	4 E _{T1}	5 \emptyset
6 S	7	8	9	10	11
12	13	14	15	16	17
18	19	20	21	22	23
24	25	26	27	28	29

NOTES

In the Hewlett-Packard tradition of supporting HP programmable calculators with quality software, the following titles have been carefully selected to offer useful solutions to many of the most often encountered problems in your field of interest. These ready-made programs are provided with convenient instructions that will allow flexibility of use and efficient operation. We hope that these Solutions books will save your valuable time. They provide you with a tool that will multiply the power of your HP-19C or HP-29C many times over in the months or years ahead.

Mathematics Solutions
Statistics Solutions
Financial Solutions
Electrical Engineering Solutions
Surveying Solutions
Games
Navigational Solutions
Civil Engineering Solutions
Mechanical Engineering Solutions
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