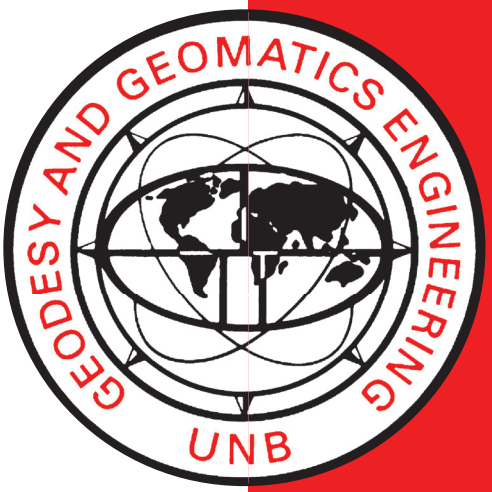
ORTHOGONAL MATRIX PACKAGE PROGRAM (ORTMATPAC) FOR THE WANG-700

EGON DORRER

April 1973



TECHNICAL REPORT
NO. 24

PREFACE

In order to make our extensive series of technical reports more readily available, we have scanned the old master copies and produced electronic versions in Portable Document Format. The quality of the images varies depending on the quality of the originals. The images have not been converted to searchable text.

ORTHOGONAL MATRIX PACKAGE PROGRAM

(O R T M A T P A C)

FOR THE WANG-700

By E. Dorrer

ORTMATPAC is a first attempt to make available to users of the WANG 700 desk calculator a few routines for fundamental analytical-geometric and analytical-photogrammetric problems.

Basically three different types of routines are contained:

(1) Trigonometric functions, such as , SIN, COS, ARCTAN, together with conversion functions from degrees, minutes, seconds or from gons to radians and vice versa. These functions were taken from SURVTRIGPACK, the idea behind them being to use only radians for angles during any type of computations. Degrees or gons are required only for I/O-operations.

(2) Storing and recalling elements of vectors and matrices. Presently, matrices are confined to size 3 x 3. It was considered as fundamentally important to keep these two routines as general as possible; i.e., to influence from outside the position of the arrays to be acted upon.

(3) For manipulating spatial rotations at the present stage two routines for determining an orthogonal 3 x 3 matrix from 3 independent orientation angles, and vice versa, are available. Although similar programs could have been incorporated relatively easy, it was felt to make use of the sequence (ω,ϕ,κ) of rotations only. Whereas for aerial photogrammetric purposes the sequence as such is mostly immaterial, terrestrial photogrammetric formulation require it that way. At a later time, similar routines for the sequence (ω,ϕ,κ) and for the Rodriguez parameters are intended to be included.

It is hoped that the program package will serve some needs of the photogrammetrist who wants quick results for his problems that are not worthwhile to be solved by larger computers.

Egon Dorrer
April 1972

WANG 700A PROGRAM DESCRIPTION

Programmer: E. Dorrer

Date: March 1972

Program Title

Verify Program: 6182

ORTHOGONAL MATRIX PACKAGE PROGRAM

Set P.C. 000

(O R T M A T P A C)

No. of Steps 608

Data Registers used 000, 001, 002, 003, 004, 120, 121.

Marks used External: 0000 - 0006, 0012 - 0015.

Internal: 0201 - 0213, 0300, 0315, 1402, 1403, 1606 - 1508, 1513, 1515.

Operating Procedure

1. Load the program tape;

   Depress REWIND

   Depress TAPE READY, RUN, PRIME, LOAD PROGRAM.

2. PRIME; VERIFY PROGRAM; Read x = 6182.

3. PRIME.

   Then load data according to instruction on the following pages.

Function Keys

0000	RADEGR	0001	RADGON
0002	SIN	0003	COS
0004	MATSTIN	0005	ORTMAT2
0006	ROTANG2		
0012	MATREIN	0013	ARCTAN
0014	GON	0015	DEGR

Function Key: 00 RADEGR

Purpose: To convert angles given in degrees, minutes, and seconds to radians.

Function: X = RADEGR (X)

Procedure: Key DMS-value in X; Depress 00; Read Radians in X.

Example: Given α =-35° 17' 03.''6

Key -351703.6 in X; Depress 00

Read -.615827791037

Function Key: 01 RADGON

Purpose: To convert angles given in Gon to Radians.

Function: X = RADGON (X)

Procedure: Key Gons in X; Depress 01.

Read Radians in X.

Example: Given α = 103.6782 gon

Key 103.6782 in X; Depress 01

Read +1.62857335728

Function Key: 02 SIN

Purpose: To compute the sine of an angle given in radians.

Function: X = SIN (X)

Procedure: Key radians in X; Depress 02.
Read SIN of X in X.

Example: Key 0.571 in X; Depress 02
Read +.540518039256

Function Key: 03 COS

Purpose: To compute the cosine of an angle given in radians.

Function: X = COS (X)

Procedure: Key radians in X; Depress 03.
Read cos of X in X.

Example: Key 0.571 in X; Depress 03.
Read +.841360922257

Function Key: 04 MATSTIN

Purpose: To store indirectly in core elements of a vector or of a 3 x 3 matrix (stored row-wise).

Function: ((000)+Y) = MATSTIN (000,X,Y)

Procedure: (1) Store starting address of array in register 000.

PRIME; Key starting address in X;

Depress STIN.

Note: Starting address must be larger than 004.

(2) For vector element V_i

Key i in Y; Key V_i in X

For matrix-element M_{ij}

Key i·j in Y; Key M_{ij} in X

Depress MATSTIN

(3) For other elements go to (2).

Example: The element $M_{2,3}$ = 216.1 of a 3 x 3 matrix is supposed to be stored in an array starting with address 015. Then,

PRIME; Key 015 in X; Depress STIN

Key 2.3 in X; Depress ↑; Key 216.1 in X.

Depress MATSTIN.

216.1 is now stored in address 020.

Function Key: 05

ORTMAT2

Purpose: To compute the elements of a 3 x 3 orthogonal matrix [r] from three rotation angles α_1, α_2, α_3, where α_2 is primary (ϕ) and α_1 is secondary (ω) rotation. The result is stored according to MATSTIN directly behind the stored 3 angles.

Procedure: (1) Store α_1, α_2, α_3 in consecutive addresses.

(2) Key starting address of α-array in X;

Depress ORTMAT2.

(3) Result can be displayed immediately with MATREIN (see function Key 12), since starting address of [r] is supplied in 000.

Note: The rotation angles must be given in radians.

Storage:

α_1	α_2	α_3	r_{11}	r_{12}	r_{13}	r_{21}	r_{22}	r_{23}	r_{31}	r_{32}	r_{33}
↑			↑								
)α(			)r(=)α(+ 3								

Example: (1) Assume (008) = 0, (009) = .5, (010) = -.7

(2) Key 008 in X; Depress 05;

(Read 3 in X; 19 in Y; both not significant)

(3) Result is stored in (011) - (019);

.671212166160	.565354208381	.479425538599
-.644217687233	.764842187280	0
-.3666848775582	-.308854411678	.877582561891

Function Key: 06

ROTANG2

Purpose: To compute the three independent rotation parameters χ_1, χ_2, χ_3 of a 3 x 3 orthogonal matrix [r], stored row-wise in a core array. The result is stored immediately prior to [r]. Primary rotation is χ_2 (φ), secondary is χ_1 (ω).

Procedure: (1) Store [r] row-wise in consecutive addresses.

(2) Key starting address of [r] −3 in X

Depress ROTANG2.

(3) Result in radians can be displayed immediately with MATREIN (see function Key 12).

Example: (1) Assume the result of the example of ORTMAT2 is input here.

(2) Key 008 in X; Depress 06;

(Read 0 in X; 8 in Y)

(3) Result stored in (008) - (010):

0, .499999999989, -.699999999997.

Function Key: 12 MATREIN

Purpose: To indirectly recall the elements of a vector or of a 3 x 3 matrix, stored row-wise.

Function: (X,Y) = MATREIN (000, X)

Operating Procedure:

(1) Store starting address of array in address 000, e.g. by:
PRIME; Key starting address in X; Depress STIN.

(2) For vector-element V_i Key i in X;
For matrix-element M_{ij} Key i·j in X;
Depress MATREIN
Read V_i (or M_{ij}) in X; i (or i·j) in Y.

(3) For other element goto (2).

Example: Assume that matrix [M] to be recalled is stored in locations 005-013.
PRIME; Key 005 in X; Depress STIN.
In order to recall element $M_{1,2}$,
Key 1.2 in X, Depress MATREIN.
Read $M_{1,2}$ in X and 1.2 in Y.

Storage:

α_1	α_2	α_3	r_{11}	r_{12}	r_{13}	r_{21}	r_{22}	r_{23}	r_{31}	r_{32}	r_{33}
↑			↑								
)α(			)r(=)α(+ 3								

Function Key: 13 ARCTAN

Purpose: To compute the arctan of a value.

Function: X = ARCTAN(X)

Procedure: Key argument in X; Depress 13.

Read arctan given in radians in X.

Example: Key 1.0073821 in X; Depress 13.

Read .789075623072

Note: If result is wanted in degrees, minutes, seconds, depress DEGR.

Function Key: 14 GON

Purpose: To convert an angle given in radians into gons.

Function: X = GON (X)

Procedure: Key Radians in X; Depress 14.

Example: Key 0.3781259; Depress 14. Read 24.0722424384

Function Key: 15 DEGR

Purpose: To convert an angle given in radians into a DMS-value (degrees, minutes, seconds)

Function: X = DEGR (X)

Procedure: Key radians in X; Depress 15

Read DMS-value in X.

Example: Key 0.3781259; Depress 15. Read 213954.065500.

(21° 39' 54".065500)

Storage Map

Routines

Register	0000	0001	0002	0003	0004	0005	0006	0012	0013	0014	0015
121	X	X	X	X		(X)	(X)		X	X	X
120	X		X	X	(X)	(X)	(X)	(X)	X		X
000					X	X	X	X			
001						X	X	X			
002						X	(X)		X		
003			X	X		(X)	(X)		X		
004			X	X		(X)	(X)		X		

Note: Subroutine 0300 = ADDR is a useful subprogram for computing indirectly addresses of array elements

```
000     MARK
001     RADEGR  0000    BEGIN RADEGR
002     ↑
003     WRITEA
004     STDX
005     INTX
006     STDX
007     120
008     6
009     0

010     *DX
011     120
012     ←
013     WRITEA
014     *DX
015     INTX
016     +DX
017     120
018     4
019     0

020     *DX
021     120
022     REDX
023     120
024     -
025     PI
026     *
027     6
028     4
029     8

030     SEXP
031     6
032     /
033     ←
034     SEARCH          END RADEGR
035     1515
036     MARK
037     RADGON  0001    BEGIN RADGON
038     ↑
039     PI

040     *
041     2
042     0
043     0
044     /
045     ←
046     SEARCH          END RADGON
047     1515
```

```
048     MARK
049     COS     0003    BEGIN COS

050     ↑
051     +
052     PI
053     +
054     2
055     /
056     ←
057     MARK
058     SIN     0002    BEGIN SIN
059     STDX

060     120
061     PI
062     ↑
063     +
064     REDX
065     120
066     EXY
067     /
068     EXY
069     INTX

070     *
071     REDX
072     120
073     EXY
074     -
075     PI
076     /
077     ←
078     INTX
079     WRITEA

080     LOGEX
081     -
082     CHSGN
083     1
084     *
085     .
086     5
087     SKIP Y<X
088     SEARCH
089     1508

090     CHSGN
091     SKIP Y>=X
092     SEARCH
093     1508
094     MARK
095     1507
```

```
096     PI
097     *
098     STDY    0414
099     120

100     -
101     X↑2
102     STDX
103     003
104     1
105     5
106     ↑
107     1
108     STDX
109     004

110     MARK
111     1506
112     REDX
113     003
114     CHSGN
115     *DX
116     004
117     -
118     /DX
119     004

120     1
121     -
122     -
123     /DX
124     004
125     1
126     +DX
127     004
128     RESID
129     +DX

130     004
131     1
132     -
133     SKIP Y=X
134     SEARCH
135     1506
136     REDX
137     004
138     REDY    0415
139     120

140     *
141     -
142     SEARCH
143     1515
144     MARK
```

```
145     1508
146     -
147     -
148     -
149     CHSGN

150     ↑
151     SEARCH
152     1507                    END COS AND SIN
153     MARK
154     ARCTAN  0013    BEGIN ARCTAN
155     WRITEA
156     CLX
157     ↑
158     .
159     5

160     SKIP Y>=X
161     WRITEA
162     X↑2
163     1
164     +
165     STDY    0414
166     003
167     2
168     -
169     REDX

170     003
171     /
172     -
173     STDY    0414
174     002
175     *
176     STDY    0414
177     003
178     1
179     STDX

180     120
181     1
182     5
183     ↑
184     8
185     STDX
186     004
187     MARK
188I    1513
189     REDX

190     003
191     *DX
192     120
```

```
193     REDX
194     004
195     *DX
196     004
197     EXDX
198     004
199     *DX

200     120
201     ←
202     +DX
203     120
204     2
205     -
206     1
207     -DX
208     004
209     EXDX

210     120
211     /DX
212     120
213     REDX
214     004
215     WRITEA
216     LOGEX
217     SEARCH
218     1513
219     REDY    0415

220     002
221     REDX
222     120
223     *
224     WRITEA
225     GO
226     *
227     4
228     5
229     WRITEA

230     10↑X
231     WRITEA
232     STOP
233     *
234     ←
235     WRITEA
236     ENDPRGM
237     SEARCH
238     1515            END ARCTAN
239     MARK
240     GON     0014    BEGIN GON
```

```
241     ↑
242     2
243     Ø
244     Ø
245     *
246     PI
247     /
248     ←
249     SEARCH

250     1515                    END GON
251     MARK
252     DEGR    ØØ15    BEGIN DEGR
253     ↑
254     WRITEA
255     GO
256     *
257     CLX
258     STDX
259     12Ø

260     SUB     Ø315
261     SUB     Ø315
262     REDX
263     12Ø
264     +
265     ←
266     SEARCH
267     1515                    END DEGR
268     MARK
269     SUB     Ø315

270     ←
271     INTX
272     -
273     +DX
274     12Ø
275     2
276     1Ø↑X
277     *DX
278     12Ø
279     6

280     Ø
281     *
282     RETURN
283     MARK
284     1515
285     REDY    Ø415
286     121
287     RETURN                  END TRIGPACK
288     MARK
289     MATSTIN ØØØ4    BEGIN MATSTIN
```

```
290     EXDX
291     000
292     ADDR    0300
293     EXDX
294     000
295     STIN
296     STOP            END MATSTIN
297     MARK
298     MATREIN 0012    BEGIN MATREIN
299     +

300     STDY    0414
301     001
302     REDX
303     000
304     ADDR    0300
305     REIN
306     REDY    0415
307     001
308     STOP            END MATREIN
309     MARK

310     ADDR    0300    BEGIN ADDR
311     STDX
312     120
313     -
314     INTX
315     SKIP Y=X
316     SEARCH
317     MATRIX  1402
318     1
319     SEARCH

320     END     1403
321     MARK
322     MATRIX
323     +
324     +
325     -
326     INTX
327     -
328     EXY
329     WRITEA

330     1
331     +
332     4
333     MARK
334     END
335     -
336     REDX
337     120
338     +
339     RETURN          END ADDR
```

```
340     MARK
341     ORTMAT2 0005    BEGIN ORTMAT2
342     STDX
343     000
344     1
345     SR1     0201
346     SIN     0002
347     CHSGN
348     SR3     0203
349     2

350     .
351     3
352     SR2     0202
353     3
354     SR1     0201
355     SIN     0002
356     SR3     0203
357     2
358     .
359     1

360     SR2     0202
361     3
362     SR1     0201
363     COS     0003
364     SR3     0203
365     2
366     .
367     2
368     SR2     0202
369     2

370     SR1     0201
371     SIN     0002
372     SR3     0203
373     1
374     .
375     3
376     SR2     0202
377     2
378     SR1     0201
379     COS     0003

380     SR3     0203
381     3
382     .
383     3
384     SR2     0202
385     4
386     -
387     SR4     0204
388     1
389     SR5     0205
```

```
390     2
391     SR6     0206
392     1
393     SR7     0207
394     2
395     -
396     SR8     0208
397     8
398     +
399     REIN

400     CHSGN
401     SR3     0203
402     5
403     -
404     SR4     0204
405     2
406     SR5     0205
407     1
408     SR6     0206
409     2

410     SR7     0207
411     1
412     -
413     SR8     0208
414     1
415     +
416     REIN
417     CHSGN
418     SR3     0203
419     2

420     +
421     SR4     0204
422     4
423     SR5     0205
424     3
425     SR6     0206
426     2
427     SR7     0207
428     3
429     +

430     SR8     0208
431     4
432     -
433     REIN
434     SR3     0203
435     1
436     +
437     SR4     0204
438     5
439     SR5     0205
```

```
440     3
441     SR6     0206
442     1
443     SR7     0207
444     3
445     +
446     SR8     0208
447     1
448     SR1     0201
449     COS     0003

450     SR3     0203
451     1
452     •
453     2
454     SR10    0210
455     ADDR    0300
456     SR9     0209
457     SR9     0209
458     SR9     0209
459     3

460     +
461     SR9     0209
462     3
463     +DX
464     000
465     STOP            END ORTMAT2
466     MARK
467     SR1     0201
468     ↑
469     REDX

470     000
471     ADDR    0300
472     REIN
473     RETURN
474     MARK
475     SR2     0202
476     SR10    0210
477     ADDR    0300
478     REDX
479     001

480     STIN
481     RETURN
482     MARK
483     SR3     0203
484     STDX
485     001
486     RETURN
487     MARK
488     SR4     0204
489     REIN
```

```
490     *DX
491     001
492     RETURN
493     MARK
494     SR5     0205
495     +
496     REIN
497     STDX
498     002
499     RETURN

500     MARK
501     SR6     0206
502     -
503     REIN
504     *DX
505     002
506     RETURN
507     MARK
508     SR7     0207
509     SR6     0206
510     REDX

511     002
512     -DX
513     001
514     RETURN
515     MARK
516     SR8     0208
517     REDX
518     001
519     STIN
520     RETURN

521     MARK
522     SR9     0209
523     1
524     +
525     REIN
526     EXDX
527     001
528     *DX
529     001
530     EXDX

531     001
532     STIN
533     RETURN
534     MARK
535     SR10    0210
536     -
537     3
538     EXDX
539     000
540     +DX
```

```
541     000
542     EXDX
543     000
544     RETURN
545     MARK
546     ROTANG2 0006    BEGIN ROTANG2
547     STDX
548     000
549     1
550     •

551     3
552     SR11    0211
553     6
554     SR12    0212
555     2
556     SR13    0213
557     2
558     •
559     1
560     SR11    0211

561     1
562     SR12    0212
563     3
564     SR13    0213
565     2
566     •
567     3
568     SR11    0211
569     X↑2
570     ↑

571     1
572     -
573     ←
574     CHSGN
575     SQRX
576     CHSGN
577     /DX
578     001
579     1
580     SR13    0213

581     STOP            END ROTANG2
582     MARK
583     SR11    0211
584     SR10    0210
585     ADDR    0300
586     REIN
587     SR3     0203
588     RETURN
589     MARK
590     SR12    0212
```

```
591     *
592     REIN
593     /DX
594     001
595     RETURN
596     MARK
597     SR13    0213
598     *
599     REDX
600     000

601     ADDR    0300
602     REDX
603     001
604     ARCTAN  0013
605     STIN
606     RETURN
607     ENDPRG          END ORTMATPACK.
```

SURVEY TRIGONOMETRIC PACKAGE PROGRAM

(S U R V T R I G P A K)

For the WANG-700

By E. Dorrer

Introduction 1

SURVTRIGPAK is an attempt to utilize the WANG-700 programmable desk calculator more efficiently for simple, plane-surveying problems such as conversion of angles from degrees, minutes, seconds in radians and vice versa, or from gons (=grads) in radians and vice versa, the essential trigonometric functions sin, cos, tan, arctan, etc. In addition frequently occurring problems such as conversion from polar to rectangular (in the plane), or from spherical to cartesian (in space) and vice versa, have been included for further convenience.

It has been the intention to use as arguments for the trigonometric functions angles given in radians only. This makes the program package general, quite flexible and independent of special conversion conventions. Angles given in degrees, minutes and seconds are supposed to be keyed in as one number (DMS). This arrangement is much more convenient than keying each of the three numbers independently. The routines ARCSIN, ARCCOS are found to be not necessary, as they can simply be expressed in terms of ARCTAN, e.g.

$$\text{ARCSIN } X = \text{ARCTAN } \frac{X}{\sqrt{1 - X^2}}$$

$$\text{ARCCOS } X = \pi/2 - \text{ARCSIN } X$$

SURVTRIGPAK has been hastily and quickly compiled. The form of this report may therefore be somewhat undesirable, although the program package has been thoroughly tested. Also, the documentation is principally in order. In a University environment, form per se is often not as

important as content and exactness are.

Particular thanks has to be given to Mr. O. Afolabi, who tested the program package and made it working properly. Without him, SURVTRIGPAK would have remained unfinished fragments (dated back to 1971).

It is hoped that this program package will serve some of the needs of practicing surveyors, particularly when the work involved is too small as to require a large electronic data processor.

Egon Dorrer
March 1973

Introduction 2

A Surveying Engineer is often involved in carrying out calculations in one form or the other. If the calculation is to be performed only once, it is simple enough to do it manually on the key board of any one of the calculating machines at his disposal. However, if the same calculations are to be done repeatedly, it is highly beneficial to record and save the steps of the calculation in the form of a program and let the calculator perform these repeated operations. The program is loaded into the core of the calculating machine and executed from the core. In WANG 700, such programs can be stored on magnetic tape for later use.

The routines contained in SURVEY-TRIGONOMETRIC PACKAGE (SURVTRIGPAK) are of four main types:

(1) Trigonometric functions, such as, SIN, COS, TAN, ARCTAN, together with conversion functions from degrees, minutes and seconds or from gons to radians (RAD) and vice versa. Degrees or grades are required only for I/O-operations.

(2) Routines to convert polar coordinates to rectangular coordinates and vice versa. This is extremely useful in calculations of traverse coordinates and conversely to obtain azimuths and distances from known coordinates.

(3) Routine ECCORR may be used to reduce bearings observed at eccentric stations to centre. The routine takes care of the two possible cases; that is: (a) when the distances from the eccentric station to targets are known and (b) when distances from centre to targets are known.

(4) Routine INSECT calculates the coordinates of the point of intersection of two observed azimuths from two given points.

Routine TRAVERS computes coordinates of traverse stations when traverse angles and distances are keyed in sequentially.

WANG 700A PROGRAM DESCRIPTION Programmer: E. DORRER

Date:

Program Title Verify Program: 7156

SURVEY TRIGONOMETRIC PACKAGE PROGRAM Set P.C. 000

(S U R V T R I G P A C)

No. of Steps 629

Data Registers used 000, 001, 002, 003, 004, 005.

Marks used External:

Internal:

(a) TO 'LEARN' PROGRAM (keyboard to core)

1. Set LEARN mode
2. SET PC to desired step
3. Index keys in program
4. Index END PROGRAM as last step in program.

(b) TO RECORD PROGRAM (core to tape)

1. Insert tape cartridge, REWIND if necessary
2. Set TAPE READY
3. SET PC to first step of program
4. Index RECORD PROGRAM

(c) TO LOAD PROGRAM (tape to core)

1. Set RUN mode
2. Insert tape cartridge, REWIND if necessary
3. Set TAPE READY
4. SET PC to desired step number
5. Index LOAD PROGRAM

Operating Procedure

1. Load the program tape;

   Depress REWIND

   Depress TAPE READY, RUN, PRIME, LOAD PROGRAM

2. PRIME; VERIFY PROGRAM; Read X = 7156

3. PRIME

   Then load data according to the instruction on the following pages.

Function Keys

C00	RADEGR	C01	RADGON
C02	SIN	C03	COS
C04	TAN	C05	RECT
C06	CART	C07	DCCORR
C08	INSECT	C09	TRAVRS
C11	SPHER	C12	POLAR
C13	ARCTAN	C14	GON
C15	DEG		

Function Key: 00C0 RADEGR

Purpose: To convert angles given in degrees, minutes and seconds to radians.

Function: X = RADEGR (X)

Procedure: Key DMS-value in X; Depress C0; Read Radians in X

Example: Given α = 65° 34' 29".16

Key 653429.16 in X; Depress C0

Read 1.14449558456

Function Key: 00 C1 RADGON

Purpose: To convert angles given in GON to Radians.

Function: X = RADGON (X)

Procedure: Key Gons in X; Depress C1

Read Radians in X

Example: Given α = 103.6782 gon

Key 103.6782 in X; Depress C1

Read 1.62857335728

Function Key: 00 C2 SIN

Purpose: To compute the sine of an angle given in radians.

Function: X = SIN (X)

Procedure: Key radians in X; Depress C2

Read SIN of X in X

Example: Key 0.971 in X; Depress C2

Read + .824473679750

Function Key: 0003 Purpose: To compute the cosine of an angle given in radians.

COS

Function: X = COS (X)

Procedure: Key radians in X; Depress 03

Read COS of X in X

Example: Key 0.571 in X; Depress 03

Read + .841360922257

Function Key: 0004 Purpose: To compute the tangent of an angle given in radians.

TAN

Function: X = TAN (X)

Procedure: Key radians in X; Depress 04

Read COS of X in X

Example: Key .462 in X; Depress 04

Read + .497942182120

Function Key:	0005 RECT	Purpose: To calculate rectangular coordinates X,Y from polar coordinates Q,R; Q in radians.

Function: (X,Y) = RECT (Q,R)

Procedure:

1. Key R in X; Depress , R is in Y register
2. Key Q in X, eventually convert into radians.
3. Depress 0005
4. Read Y = R sin(Q) in Y register
   Read X = R cos(Q) in X register.

Example:

1. Key 400.00 into Y register
2. Key 300000.0 (=30°0'0") into X register

Depress 0005

4. Read 199.999999999 in Y
   Read 346.410161515 in X

Function Key: 0006

CART
(inverse to SPHER)

Purpose: To calculate three-dimensional cartesian coordinates, X, Y, Z from spherical coordinates α, β, R. α, β in radians

Function: 1. (Z, R cos β) = CART (β, R)

2. (X, Y,) = GO (α, R cos β)

Procedure:

1. Key R in Y and β in X register. Eventually convert β to radians.
2. Depress 06
3. Read Z from X-register
4. Key α in X, eventually convert to radians.
5. Depress 60
6. Read X in X and Y in Y register.

Example:

1. Key 1000.000 in Y, 152934 in X (15° 29' 34").
   Depress 00 to convert to radians.
2. Depress 06
3. Read Z = 267.116834 from X register
4. Key 1271204 in X (127° 12' o4")
   Depress 00 to convert to radians
5. Depress GO
6. Read X = - 582.645366199
   Y = 767.576012734

Remark: R = Slope distance

β = Vertical angle

α = Horizontal angle

Function Key: 0007

ECCORR

Purpose: To convert eccentric bearings to centre given (a) distance from eccentric station to target or (b) distance from centre to target.

Function: Reference to Figure 2

(a) $P_{ci} = f(e, \phi_o, Se_i, P_i)$

(b) $P_{ci} = f(e, \phi_o, Sc_i, P_i)$

Procedure:

1. Key e in Y; ϕ_o in X
2. Depress CC
3. Depress C7
4. Key Sc_i in Y, ϕ_i in X
5. Depress CC
6. SEARCH 2; Read ϕ_{ci} in X (in radians)
7. Depress C15; Read ϕ_{ci} in X (in DMS)

Repeat steps 4-7 for different values of S_{ci} and ϕ_i

N.B. When distance from eccentric station to target is known, procedure 4 and 6 will be

4. Key Se_i in Y, ϕ_i in X
6. Key SEARCH 1, Read ϕ_{ci} in X (in radians)

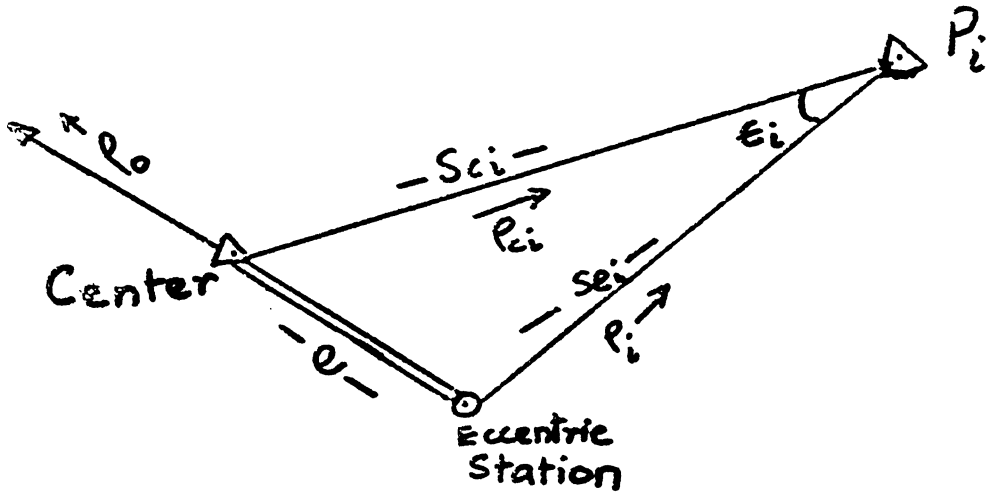
Example: Reference to Figure 2

1. Key 6.54 in Y; 000000 in X
   (0° 00' 00")
2. Depress C0
3. Depress 07
4. Key 7031.0 in Y, 391247.28 in X
   (39° 12' 47".28)
5. Depress C0
6. SEARCH 2; Read .684986344360 in X (in radians)
7. Depress C15; Read 391448.575601 in X (in DMS)
   (39° 14' 48.575601")

For new values of Sc_i and ϕ_i, repeat steps 4-7

Key 5556.0 in Y, 1692747.18 in X
(169° 27' 47".18)
Depress C0
SEARCH 2, Read 2.9579044C832 in X (in radians)
Depress C15, Read 1692831.57967 in X (in DMS)
(169° 28' 31.57967")

FIGURE 2



Given: (a) Fixed e; ρ_o

(b) Variable P_i; S_{ei} or S_{ci}

Wanted: ϵ_i or $\rho_{ci} = \rho_i + \epsilon_i$

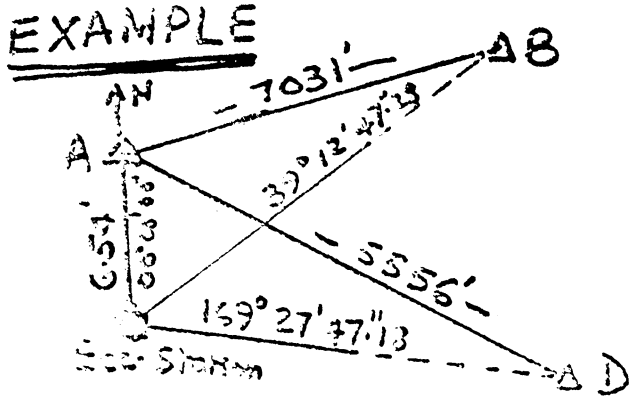
2 cases: Case 2: given S_{ci}; $\rho_{ci} = f(e, \rho_o, \rho_i, S_{ci})$

Case 1: given S_{ei}; $\rho_{ci} = f(e, \rho_o, \rho_i, S_{ei})$

Case 2: $$\rho_{ci} = \rho_i + \arctan\left[\frac{e\sin(\rho_i - \rho_o)}{\sqrt{(S_{ci} - e\sin(\rho_i - \rho_o)(S_{ci} + e\sin(\rho_i - \rho_o)}}\right]$$

Case 1: $$\rho_{ci} = \rho_i + \arctan\left[\frac{e\sin(\rho_i - \rho_o)}{S_{ei} - e\cos(\rho_i - \rho_o)}\right]$$

EXAMPLE



Function Key: 0008 INSTCT

Purpose: To compute the intersection to two straight lines. That is given coordinates of A (X_1,Y_1), B (X_2,Y_2) and azimuths AC (α_{AC}) and BC (α_{BC}); required to compute C (X_c,Y_c).

Function: $(X,Y) = f(X_1,Y_1,\alpha_1,X_2,Y_2,\alpha_2)$

(See Figure 3)

Procedure:

1. Depress 08
2. Read 1.0000000000 in Y; 1.0000000000 in X
3. Key Y_1 in Y; X_1 in X
4. Depress GO
5. Read 2.0000000000 in Y; 2.0000000000 in X
6. Key Y_2 in Y; X_2 in X
7. Depress GO
8. Read 1.0000000000 in Y; 2.0000000000 in X
9. Key α_1* in Y; α_2* in X
10. Depress GO
11. Read Y value of intersected point in Y and X value in X

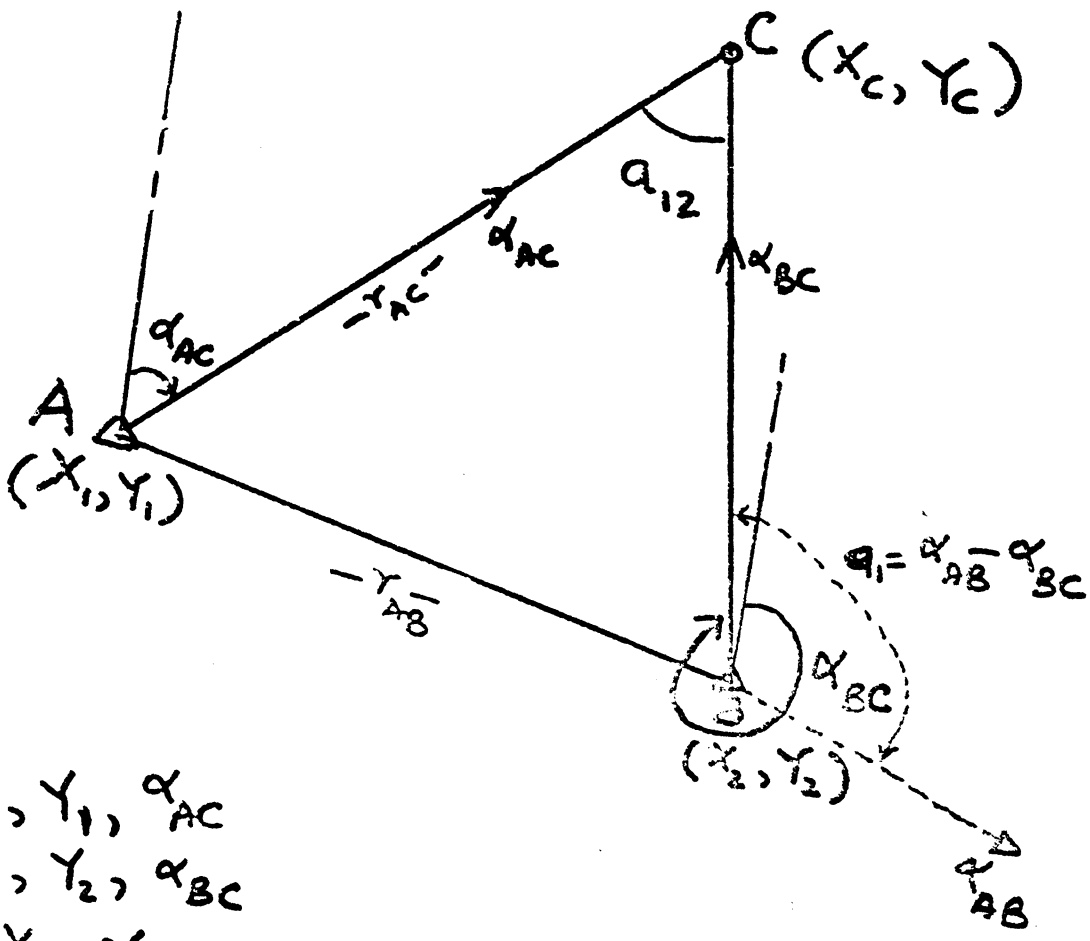
* α_1, α_2 should each be converted to radians; thus before transferring α_1 to Y register, depress CO and depress CO after α_2 has been entered into X register. If more than one point is intersected at both stations (X_1,Y_1), (X_2,Y_2) repeat steps 9-11 for other values of α_{1i} and α_{2i}.

Example: See Figure #3

1. Depress 08
2. Read 1.CCCCCCCCCC0 in Y; 1.CCCCCCCCCC0 in X
3. Key 4.0 in Y; 6.0 in X
4. Depress GO
5. Read 2.CCCCCCCCCC0 in Y; 2.CCCCCCCCCC0 in X
6. Key 13.0 in Y, 4.0 in X
7. Depress GO
8. Read 1.CCCCCCCCCC0 in Y; 2.CCCCCCCCCC0 in X
9. Key 600000, depress 00, depress ↑, read
   1.04719755119 (60°00'00") in Y

   Key 3300000, depress 00, read 5.75958653157
   in X (330°00'00")
10. Depress GO
11. Read 9.88397459600 in Y, 9.39711431700 in X

FIGURE 3



Given:- X_1, Y_1, α_{AC}
X_2, Y_2, α_{BC}

Required:- X_C, Y_C

$(\alpha_{AB}, r_{AB}) = \text{To Polar}(X_2 - X_1, Y_2 - Y_1)$

$q_1 = \alpha_{AB} - \alpha_{BC}$

$a_{12} = \alpha_{AC} - \alpha_{BC} = \alpha_{AC} - \alpha_{AB} + q_1$

$r_{AC} = r_{AB} \cdot \dfrac{\sin q_1}{\sin a_{12}}$

$(X_C, Y_C) = (X_1, Y_1) + \text{To RECT}(\alpha_{AC}, r_{AC})$

Function Key: 0009 **Purpose:** To compute coordinates of traverse stations

TRAVERS

Function: $(X_i, Y_i) = f(\alpha_{i-1}, \beta_o, X_o, Y_o, S_i)$; see figure 4

Procedure:

1. Key Y_o in Y; X_o in X
2. Depress C9
3. Key β_o* in X
4. Depress GO
5. Key S_i in Y; α_{i-1}* in X
6. Depress GO
7. Read Y_i in Y; X_i in X

Repeat steps 5-7 for other values of S and α.

Example: See figure 4

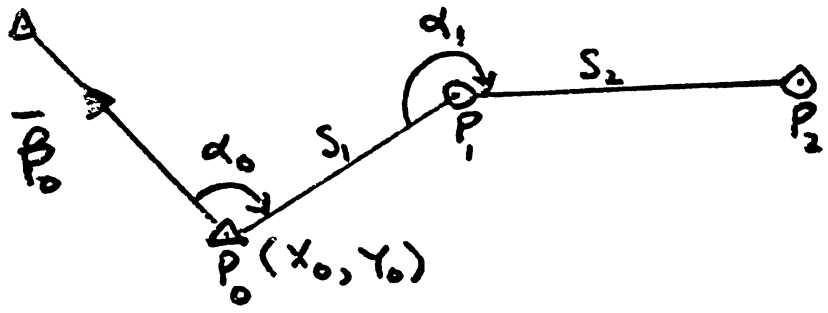
1. Key 10.0 in Y; 10.0 in X
2. Depress 09
3. Key 270000 in X (270° 00' 00")
4. Depress GO
5. Key 500.000 in Y; 120000 in X (120° 00' 00")
6. Depress GO
7. Read 259.999999991 in Y; 443.012701911 in X

Repeat steps 5-7 to obtain coordinates of next point (that is point C in the figure)

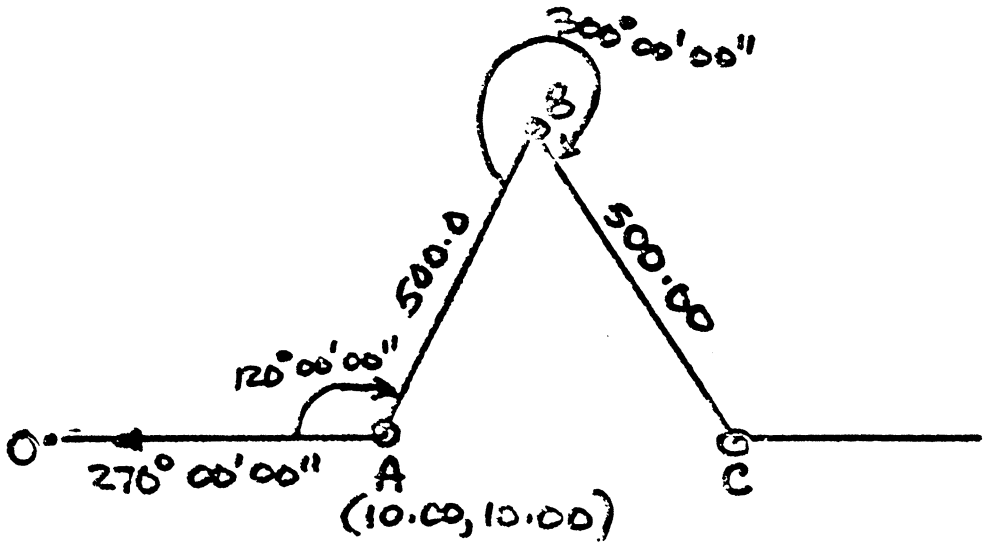
5. Key 750.00 in Y, 300000 in X (300° 00' 00")
6. Depress GO
7. Read 109.999999979 in Y; 10.000000000 in X

* Values should always be in DMS (degrees, minutes and seconds) for this routine (TRAVERS).

FIGURE 4



EXAMPLE



Function Key: 0011

SPHER

(inverse to CART)

Purpose: To calculate spherical coordinates (R,β,α) from cartesian coordinates X,Y,Z. β,α in radians.

Function: 1. $(\alpha, \sqrt{X^2 + y^2})$: = SPHER (X, Y)

2. (β, R): = GO(Z, $\sqrt{X^2 + Y^2}$)

Procedure:

1. Key Y in Y and X in X register
2. Depress 0011
3. Read α (in radians) from X register, eventually convert to degrees, minutes, seconds or grads.
4. Key Z in X register
5. Depress GO
6. Read R from Y and β (in radians) from X register

Example:

1. Key 767.576 in Y and -582.645 in X register.
2. Depress 0011
3. Depress DEG (0015) and read 127° 12' 13".93921 from X register
4. Key 267.117 in X register
5. Depress GO
6. Depress DEG (0015)and read 15° 29' 34". 031275 from X and 999.999801744 from Y register.

Remark:

R = slope distance

β = vertical angle

α = horizontal angle

Function Key: 0012 POLAR

Purpose: To calculate polar coordinates (R, θ) from rectangular coordinates (X,Y). θ in radians.

Function: (R, θ) = POLAR (X,Y)

Procedure: Key Y coordinate in X; Depress ↑

Key X coordinate in X; Depress C12

Read: Distance R in Y

Angle θ in X (in radians)

Depress C15; Read θ in DMS in X

Example: Key 3 in X; Depress ↑

Key 4 in X; Depress C12

Read: 5.000000000000 in Y

.643501108792 radians in X

Depress C15; Read 365211.631524 in X

(36° 52' 11.631524")

Function Key: 0013 ARCTAN

Purpose: To compute the arctan of a value.

Function: X = ARCTAN (X)

Procedure: Key argument in X; Depress C13

Read arctan given in radians in X

Example: Key 1.0073821 in X; Depress C13

Read .7490756230?2

Note: If result is wanted in degrees, minutes and seconds, depress DMS.

Function Key: 0014 GON

Purpose: To convert an angle given in radians to gons.

Function: X = GON (X)

Procedure: Key radians in X; Depress C14

Example: Key 3.14159265359; Depress C14

Read 200.000000000 in X

Function Key: 0015 DMG

Purpose: To convert an angle given in radians into a DMS-value (degrees, minutes, seconds)

Function: X = DMG (X)

Procedure: Key radians in X; Depress C15

Read DMS-value in X

Example: Key 0.3701259; Depress C15

Read 21.3954.065500

(21° 39' 54".065500)

```
000     MAIN
  1     RADEGR    0000      BEGIN RADEGR
  2       ↑
  3     WRITEA
  4     STDIR
  5     INTX
  6     STDIR
  7     120
  8     6
  9     0
 10     XDIR
 11     120
 12       ↓
 13     WRITEA
 14     XDIR
 15     INTX
 16     +DIR
 17     120
 18     4
 19     0
 20     XDIR
 21     120
 22     REDIR
 23     120
 24       -
 25       π
 26     X
 27     6
 28     4
 29     8
 30     SEXP
 31     6
 32       ÷
 33       ↓
 34     SEARCH              END RADEGR
 35     1515
 36     MAIN
 37     RADGON    0001      BEGIN RADGON
 38       ↑
 39       π
 40     X
 41     2
 42     C
 43     C
 44       ÷
 45       ↓
 46     SEARCH              END RADGON
 47     1515
000     MAIN
 81     COS       0003      BEGIN COS
 82       ↑
 83       +
 84       π
 85       +
 86     2
 87       ÷
 88       ↓
```

```
089         MARI
 90         SIN          ℓℓℓ2        BEGIN SIN
 91         STDIR
 92         120
 93         π
 94         ↑
 95         +
 96         RTDIR
 97         120
 98         EXY (↑↓ )
 99         ÷
100         EXY (↑↓ )
  1         INTX
  2         X
  3         RTDIR
  4         120
  5         EXY (↑↓ )
  6         -
  7         π
  8         ÷
  9         ↓
 10         INTX
 11         WRITBA
 12         LOG2X
 13         -
 14         CHSGN
 15         1
 16         X
 17         •
 18         5
 19         SKIPY < X
 20         SEARCH
 21         1508
 22         CHSGN
 23         SKIPY ≥ X
 24         SEARCH
 25         1508
 26         MARI
 27         1507
 28         π
 29         X
 30         STDY         ℓ414
 31         120
 32         ↓
 33         X2
 34         STDIR
 35         113
 36         1
 37         5
 38         ↑
 39         1
 40         STDIR
 41         112
 42         MARI
 43         1506
 44         RTDIR
 45         113
```

```
146         CHSGN
 47         XDIR
 48         112
 49         ↓
 50         ÷DIR
 51         112
 52         1
 53         -
 54         ↓
 55         ÷DIR
 56         112
 57         1
 58         +DIR
 59         112
 60         RESID
 61         +DIR
 62         112
 63         1
 64         -
 65         SKIPY=X
 66         SEARCH
 67         1506
 68         REDIR
 69         112
 70         RLDY        C415
 71         120
 72         X
 73         ↓
 74         SEARCH
 75         1515
 76         MARK
 77         1508
 78         -
 79         -
 80         ↓
 81         CHSGN
 82         ↑
 83         SEARCH
 84         1507                    END COS AND SIN
 85         MARK
 86         TAN         CCC4
 87         STDY        C414
 88         111
 89         ↑
 90         CCC2
 91         EXY
 92         CCC3
 93         ÷
 94         ↓
 95         RTDX        C415
 96         111
 97         RETURN
 98         MARK
 99         RECT        ØØØ5
200         STDIR
 01         111
 02         CCC3
 03         EXY (↑↓)
```

```
2C4       X
  C5      EXDIR(⇄)
  C6      111
  C7      CCC2
  C8      XDIR
  C9      111
  10      ↓
  11      RDDY        C415
  12      111
  13      RETURN
  14      MARI
  15      ARCTAN      ØØ13        BEGIN ARCTAN
  16      WRITEA
  17      CLX
  18      ↑
  19      •
  20      5
  21      SKIPY≥X
  22      WRITEA
  23      X2
  24      1
  25      +
  26      STDY        C414
  27      113
  28      2
  29      -
  30      RDDIR
  31      113
  32      •
  33      ↓
  34      STDY        C414
  35      112
  36      X
  37      STDY        C414
  38      113
  39      1
  40      STDIR
  41      12C
  42      1
  43      5
  44      ↑
  45      8
  46      STDIR
  47      111
  48      MARI
  49      1513
  50      RDDIR
  51      113
  52      XDIR
  53      12C
  54      RDDIR
  55      111
  56      XDIR
  57      111
  58      EXDIR
  59      111
  60      XDIR
```

```
261         120
 62         ↓
 63         +DIR
 64         120
 65         2
 66         -
 67         1
 68         -DIR
 69         111
 70         EXDIR
 71         120
 72         ÷DIR
 73         120
 74         REDIR
 75         111
 76         WRITEA
 77         LOGeX
 78         SEARCH
 79         1513
 80         REDY        0415
 81         112
 82         REDX
 83         120
 84         X
 85         WRITEA
 86         GO
 87         X
 88         4
 89         5
 90         WRITEA
 91              10^X
 92         WRITEA
 93         STOP
 94         X
 95         ↓
 96         WRITLA
 97         ENDPRG
 98         SEARCH
 99         1515                    END ARCTAN
300         MARK
  1         POLAR       0012        BEGIN POLAR
  2         WRITLA
  3         WRITE
  4         SEARCH
  5         1505
  6         WRITEA
  7         SETEXP
  8         IXY(↑↓)
  9         RETURN
 10         CHSGN
 11         ↑
 12         π
 13         RETURN
 14         MARK
 15         1505
 16         WRITLA
 17         LOGeX
```

```
318         SEARCH
19          1504
20          1
21          SLTEXP
22          CHSGN
23          9
24          5
25          MAN
26          1504
27          WRITLA
28          e^x
29          ÷
30          x^2
31          STLIR
32          11C
33          RLDIR
34          121
35          x^2
36          + DIR
37          11O
38          RIDIR
39          11C
40          EXY(↑↓)
41          WRITLA
42          LOG10X
43          1/X
44          CHSGN
45          C13
46          STDIR
47          11C
48          π
49          ↑
50          2
51          ÷
52          1
53          WRITLA
54          LOADPRG
55          X
56          RLDIR
57          11C
58          +
59          RLDIR
60          121
61          √X
62          EXY(↑↓)
63          RLTURN                  END POLAR
64          MAN
65          GON         C14         BEGIN GON
66          ↑
67          2
68          0
69          0
70          X
71          π
72          ÷
73          ↓
74          SEARCH
75          1515
```

```
376         MARI
 77         DEGR        ØØ15        BEGIN DEGR
 78         ↑
 79         WRITDA
 80         GO
 81         X
 82         CLX
 83         STDIR
 84         120
 85         0315
 86         0315
 87         RTDIR
 88         120
 89         +
 90         ↓
 91         SEARCH
 92         1515
 93         MARI
 94         0315
 95         ↓
 96         INTX
 97         -
 98         + DIR
 99         120
400         2
 01         10X
 02         XDIR
 03         120
 04         6
 05         0
 06         X
 07         RETURN                  END DEGR
 08         MARI
 09         ECCORR      0007        BEGIN ECCORR
410         STDY(0414)
 11         065
 12         STDIR
 13         064
 14         MARI
 15         GO
 16         STOP
 17         MARI
 18         1
 19         0314
 20         0005
 21         -DIR
 22         063
 23         RTDIR
 24         063
 25         0313
 26         MARI
 27         2
 28         0314
 29         0002
 30         SEARCH
 31         1500
 32         -447=064;065
440         -463=062;063
```

```
454         MAIN
 55         1500
 56         X
 57         REDIR
 58         C63
 59         ÷
 70         STDY(C414)
 71         C63
 72         1
 73         EXY(↑↓)
 74         X²
 75         -
 76         ↓
 77         √X
 78         REDY(C415)
 79         C63
 80         C313
 81         MARK
 82         C314
 83         STDY(C414)
 84         C63
 85         STDIR
 86         C62
 87         ↑
 88         REDIR
 89         C64
 90         -
 91         ↓
 92         REDY(C415)
 93         C65
 94         RETURN
 95         MAIN
 96         C313
 97         C12
 98         +DIR
 99         C62
500         Π
 01         ↑
 02         2
 03         X
 04         ↓
 05         REDY(C415)
 06         C62
 07         SKIPY< X
 08         -
 09         GO
 10         CLX
 11         EXY(↓↑)
 12         SEARCH
 13         GO
 14         MAIN
 15         1515
 16         REDY(C415)
 17         121
 18         RETURN                  END ECCORR
 19         MAIN
 20         CART        C06         BEGIN CART
```

```
0005
exy
STOP
0005
STOP                    END CART
MARK
SPHER       0011        BEGIN SPHER
012
STOP
EXY
012
STOP                    END SPHER
MARK
INSECT      0008        BEGIN INSECT
1
↑
STOP
STDX
062
STDY        0414
063
2
↑
STOP
EXDX
062
-DX
062
EXY
EXDX
063
-DX
063
EXDX
063
EXY
EXDX
062
POLAR       0012
STDX
064
STDY        0414
065
1
↑
2
|X|
STOP
-DX
064
EXY
-
EXDX
064
0002
EXY
```

```
577     CHSGN
578     0002
579     /
580     REDX
581     065
582     *
583     REDX
584     064
585     0005
586     +DX
587     062
588     REDX
589     063
590     +
591     REDX
592     062
593     STOP                    END INSECT
594     MARK
595     TRAVERS   0009          BEGIN TRAVERS
596     STDX
597     001
598     STDY      0414
599     002
600     STOP
601     RADEG     0000
602     STDX
603     000
604     PI
605     +DX
606     000
607     MARK
608     STOP
609     STOP
610     RADEG     0000
611     +DX
612     000
613     PI
614     -DX
615     000
616     REDX
617     000
618     RECT      0005
619     +DX
620     001
621     ↓
622     +DX
623     002
624     REDY      0415
625     002
626     REDX
627     001
628     SEARCH
629     STOP
630     ENDPRGM                 END TRAVERS;  END SURVTRIGPAK
```