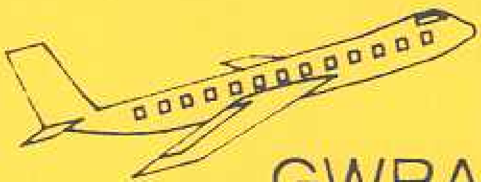
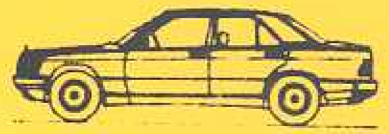
STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

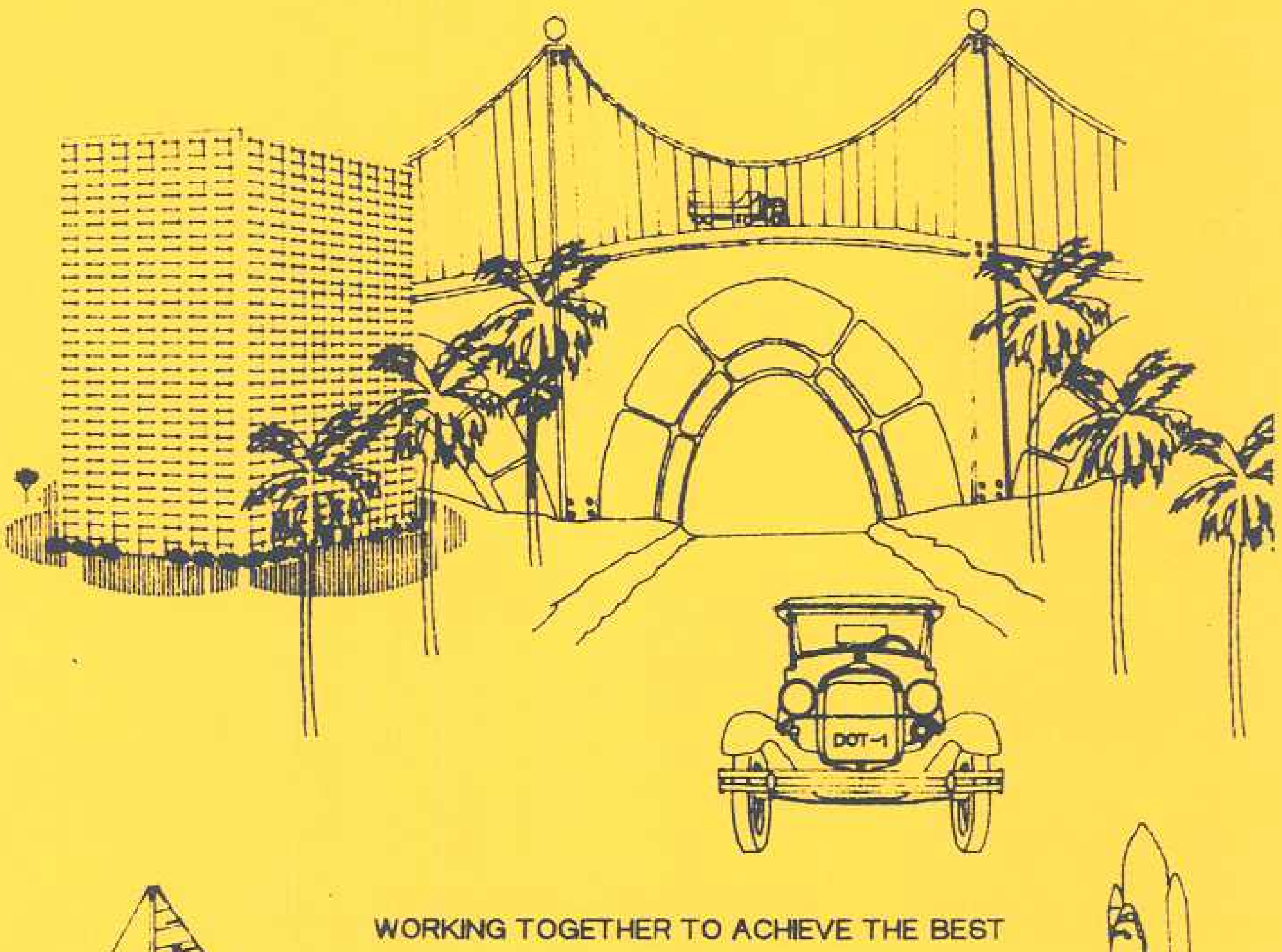
CARTER KEY



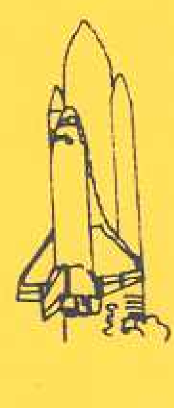
AND



GWBASIC ENGINEERING MANUAL



WORKING TOGETHER TO ACHIEVE THE BEST



1991 Edition

PURPOSE:

The purpose of the Carter Key/GWBASIC Engineering Programs Manual is to present one or more methods of calculating pay item quantities for transportation projects during design, construction and final payment. This manual should be used as a supplemental aid during the aforementioned procedures.

HISTORY:

This collection of engineering methods is the result of the efforts of several individuals in the Estimates Office over a period of years. The aim of this manual is to outline quicker, more efficient ways to check large volumes of calculations in the shortest possible time.

When this collection was started, there were only eight people to check all the estimates statewide, so quick methods had to be adopted to keep abreast of the workload. At that time, the main "modern tool" was the electric mechanical calculator, an immensely complex mass of keys, levers, cams, springs, dials and solenoids. A company repairman was constantly on duty, keeping those noisy wonders chattering!

With the gradual expansion of the Estimates Office, also came the "boon" of the central computer, followed by the first electronic calculators. These marvels were quickly adopted, and the original "Carter's Little Nuggets of Knowledge", (three pages), was expanded into a manual, dubbed "The Carter Key Manual".

Eventually, "keystroke programming" of electronic calculators was introduced, and the "GWBASIC Engineering Programs Manual" was merged with the original "Carter Key Manual", so that another "modern tool" could be added to the arsenal.

Continual update is required to keep the manual in line with current engineering practices. Yet the basic "hand" methods must also be retained for the benefit of newcomers unfamiliar with traditional DOT practices.

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PURPOSE AND HISTORY
SUGGESTIONS AND COMMENTS SHEET
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PART I - CARTER KEY MANUAL

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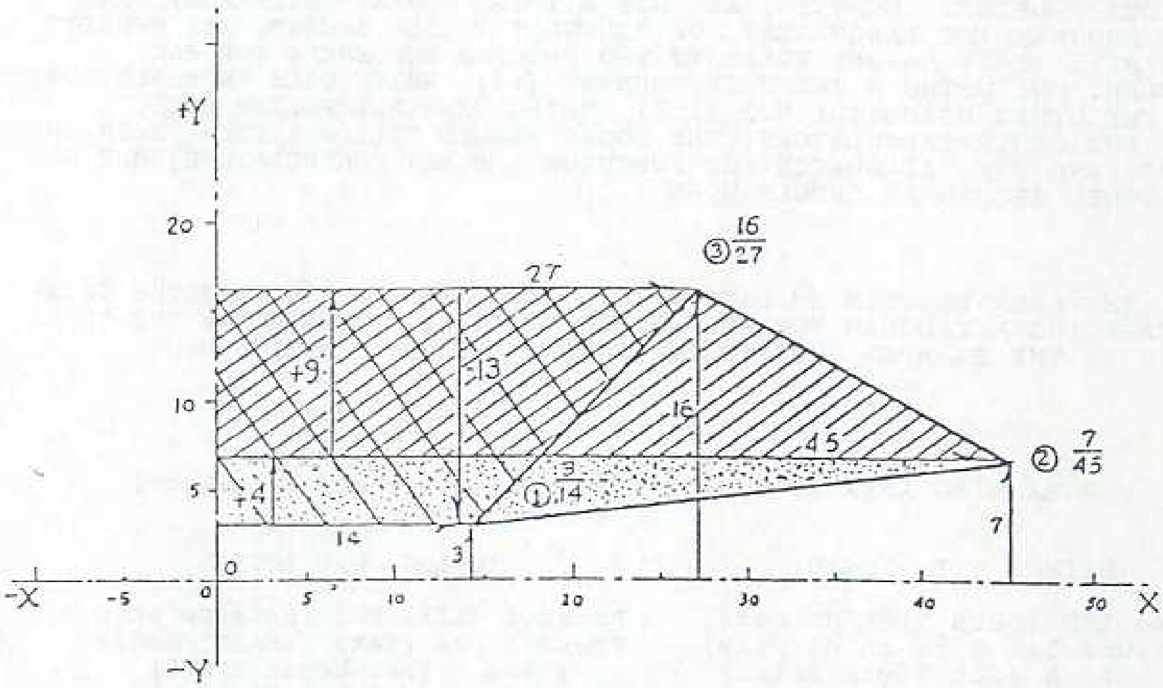
SECTION I

CIVIL ENGINEERING CALCULATIONS

AREA BY COORDINATES (THEORY)



IF THE FIGURE IS TRAVERSED COUNTERCLOCKWISE (1 TO 2 TO 3 TO 1) THE AREA MAY BE THOUGHT OF AS BEING THE SUMMATION OF THREE TRAPEZOIDS, AS FOLLOWS:

ADD THE DEPARTURE (X) OF POINT 1 WHICH IS 14, TO THE DEPARTURE OF POINT 2 WHICH IS 45. (THIS CORRESPONDS TO ADDING THE TWO BASES OF A TRAPEZOID.) THE SUM, 59 IS STORED TEMPORARILY; AND THE DIFFERENCE BETWEEN THE LATITUDES (Y) OF POINTS 1 AND 2 IS FOUND; CHANGING THE SIGN OF THE FIRST POINT. (3 CHANGE SIGN +7 = +4) THIS 4 IS MULTIPLIED BY THE PREVIOUSLY STORED 59 TO GIVE 236, (THE DOUBLED AREA OF A TRAPEZOID.) THIS AREA HAS A POSITIVE VALUE, SINCE THE "ALTITUDE" 4 IS PLUS (UPWARD). STORE THE AREA (+236) IN AN ACCUMULATIVE REGISTER. THIS COMPLETES THE CYCLE.

IN GOING FROM 2 TO 3, 45 IS ADDED TO 27 (=72 STORED); 7 CHSN + 16 = +9. (UPWARD) +9 x 72 = +648 (DOUBLED TRAPEZOID AREA) + 648 IS ADDED TO THE PREVIOUSLY STORED +236, BY STORING ACCUM IN THE SAME REGISTER. FINAL COURSE 3 TO 2; 27 + 14 (=41 STORED), 16 CHGSN +3 (= -13). -13 x 41 (= -533) ADD TO ACCUM. REGISTER. WHEN THE STORAGE IS RECALLED, THE DOUBLE AREA IS FOUND TO BE 351. DIVIDE BY 2 = 175.5 S.F.

THIS SYSTEM ABOVE MAY BE APPLIED TO ANY OF THE ELECTRONIC CALCULATORS WHICH HAVE A STORAGE REGISTER WHICH WILL ACCUMULATE. THE METHOD MAY BE APPLIED TO AREAS WITH ANY NUMBER OF POINTS, ALSO POINTS MAY BE IN ANY OR ALL OF THE 4 QUADRANTS, AS SHOWN ON THE FOLLOWING PAGES.

PROGRAMMABLE CALCULATORS

THERE ARE MANY MAKES OF PROGRAMMABLE CALCULATORS AVAILABLE NOW. TOO MANY TO USE EACH IN THE FOLLOWING EXAMPLES OF "HOW TO" PROGRAM VARIOUS PROBLEMS. HOWEVER, ALL USE EITHER "NORMAL" HIERARCHY, (AS MOST PROGRAMMING LANGUAGES), OR "INVERSE POLISH LOGIC", (AS HEWLETT PACKARD). THIS MANUAL PRESENTS TWO PROGRAM SEQUENCES FOR EACH PROBLEM. ONE USING A TEXAS INSTRUMENT (59), WHICH USES "NORMAL" LOGIC AND THE OTHER USING THE H.P (15C), USING "INVERSE POLISH LOGIC".

FOR OTHER CALCULATORS, THE LOGIC SHOULD FOLLOW EITHER "T.I" OR "H.P", AND WITH ALLOWANCE FOR FUNCTION AND KEY NOMENCLATURE, ONE OR THE OTHER SEQUENCES SHOULD WORK !

THE AREA PROBLEM ON PAGE I-1 IS PROGRAMMED BELOW WITH THE IDEA OF CREATING A PROGRAM FOR ANY NUMBER OF SIDES, RATHER THAN THE THREE SIDES IN THE EXAMPLE, BUT FOLLOWING THE METHOD AS OUTLINED .

PROGRAMMING AREA BY COORDINATES, (Latitude and Departure)

(USING T.I. LOGIC)

```
Press LRN (Sets "LEARN" mode)
 (Assume 1st x is on display)
2ND LBL, A (Set begin LABEL)
STO, 01  (Stores x in 01)
R/S     (Stop to enter 1st y)
STO, 02  (Stores y in 02)
0,STO,00 (Clears reg.00)
2ND LBL, B (Set loop LABEL)
RCL, 01  (Recall x)
+, R/S (Stop, enter new x)
STO, 01
=
X, (
RCL, 02  (Recall y)
+/-  (Chg.Sign of y)
+, R/S (Stop, enter new y)
STO, 02, )
÷, 2, =     (Increm. Area)
SUM, 00 (Sums Area in 00)
B     (Loops to LABEL B)
Press LRN (End Program
   sets RUN mode)
```

(USING H/P LOGIC)

```
Press f CLEAR PGM (Sets to step 0)
Press g P/R (Sets "LEARN" mode)
   f LBL A (Set begin LABEL)
 (Assume 1st x is on display)
   STO 1  (Stores x in REG 1)
   R/S    (Stop to enter 1st y)
   STO 2  (Stores 1st y in 2)
   0 STO 0  (Clears REG 0)
   f LBL 1 (Set loop LABEL 1)
   RCL 1    (Recalls x)
   R/S    (Stop, enter new x)
   STO 1 (Stores new x)
   +     (Adds old & new x's)
   ENTER  (Saves sum x in STACK)
   RCL 2    (Recalls y)
   CHS    (change sign of y)
   R/S     (Stop, enter new y)
   STO 2  (Stores new y)
   +      (Sums old & new y)
   X      (Mult. ysum by xsum)
   2      (Introduce divisor)
   ÷      (Divide product by 2)
   STO + 0  (Sums areas in 0)
   GTO 1  (Loops to LBL 1)
       End of Program
   Press g P/R (Sets RUN mode)
```

AREAS BY ELECTRONIC CALCULATOR (Using Lat & Dept method, page I-1)
AN AREA IN ALL FOUR QUADRANTS.(See figure below):

1. USING A MACHINE WITH T.I. LOGIC (Note: CHS & +/- are identical, and indicates "CHANGE SIGN")

```
0 STO 00: 21 - 7 = X (7 CHS + 14)= (READ 98), STO 00
7 CHS -20 = X (14 CHS - 23) = (READ 999), SUM 00
20 CHS + 13 = X (23 - 9 ) = (READ -98),   SUM 00
13 + 21 = X (9 + 7) = (READ 544)  ........SUM 00
      RCL 00, (READ 1543)  ÷ 2 = 771.5 S.F
```

2. USING THE H.P. CALCULATOR (Inverse Polish Logic)

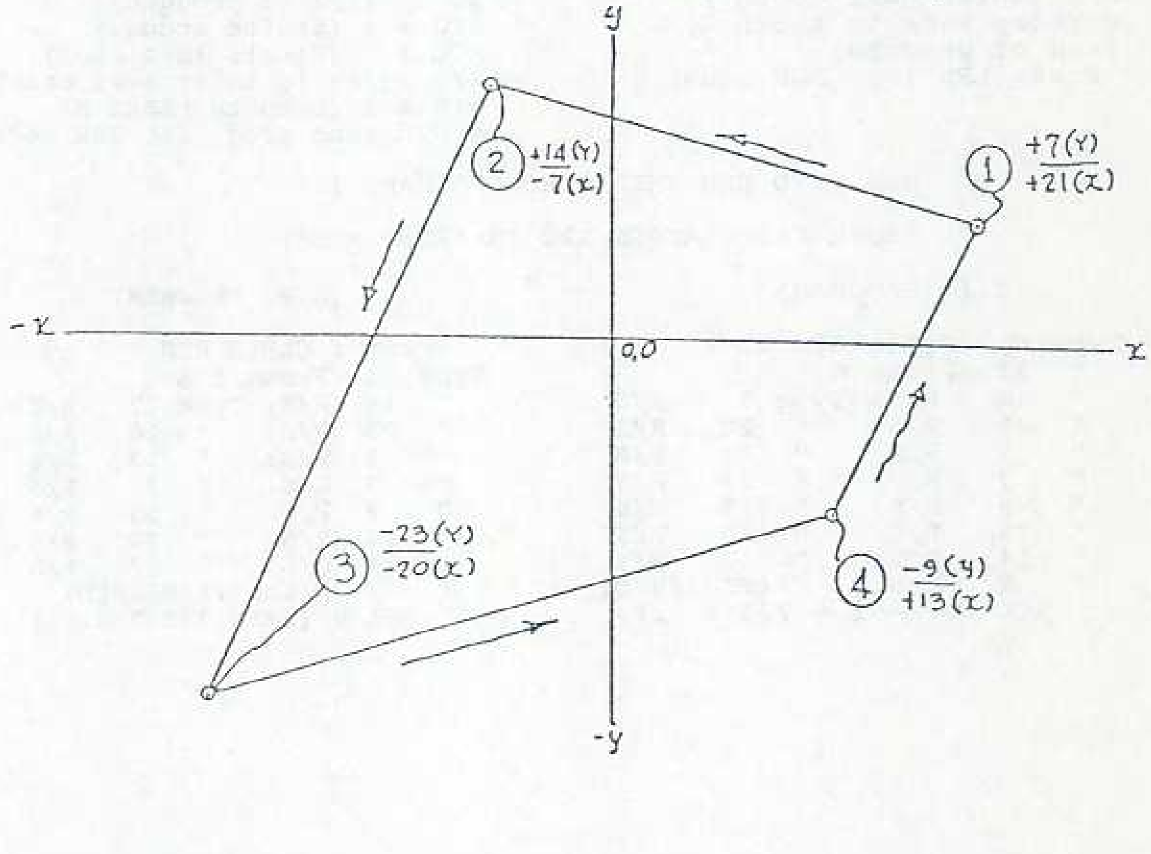
```
f REG: 21, ENTER, 7, -, 7 CHS, ENTER, 14, +, X, (READ 98)
7 CHS, ENTER, 20, -, 14 CHS, ENTER, 23, -, X, +, (READ 1097)
20 CHS, ENTER, 13, +, 23, ENTER, 9, -, X, +, ...(READ 999)
13, ENTER, 21, +, 9, ENTER, 7, +, X, +, (READ 1543), 2, ÷
                                          (READ 771.5 S.F.)
```

3. USING T.I. PROGRAM (See page I-2)

```
21, Press A, 7 R/S (Read Old x 21, Enter New x), 7  +/- R/S
(Read Old y, Enter New y), 14 R/S ..(Continue thus):
20 +/- R/S, 23 +/- R/S, 13 R/S, 9 +/- R/S, 21 R/S,
7 R/S, (Read 21, 1st x..FINISHED !)CLR, RCL 00 (Read 771.5 SF) !
```

4. USING H.P. PROGRAM (See page I-2)

```
f REG : 21 f A, 7 R/S, (Read Old X, 21, Type new x, 7 CHS R/S
(Read old y, -7, Type new y, 14 R/S..(Continue Thus):
20 CHS R/S, 23 CHS R/S, 13 R/S, 9 CHS R/S, 21 R/S 7 R/S
(Read 21..1st x..FINISHED ! RCL 0 (Read 771.5 SF !)
```



AREAS BY ELECTRONIC CALCULATOR (Continued)

ANOTHER APPROACH TO THE AREA PROBLEM IS THE "CROSS-MULTIPLICATION" METHOD. THE COORDINATES ARE COPIED DOWN IN ORDER: (See fig. page I-3)
(As shown on this page to the right)

THEN, FOLLOWING THE SOLID ARROWS: 21 TIMES 14 IS 294: STO IN REG 00. -7 TIMES -23 IS +161 STO (Accumulatively) in REG 00. IN LIKE MANNER, -20 X -9 = 180: SUM 00 AND 13 X 7 = 91: SUM 00. NOW STARTING AT BOTTOM, 21 X -9 IS NORMALLY -189, BUT THE JAGGED ARROW INDICATES A FINAL CHANGE OF SIGN (i.e. +189): SUM 00. 13 X -23 = -299 CHS (299): SUM 00: -20 X 14 = -280 CHS (280): SUM 00. AND FINALLY, -7 X 7 = -49 CHS (49) SUM 00. RCL 00 ÷ 2 = 771.5 S.F.

PT	X	Y
1	21	-7
2	-7	14
3	-20	23
4	13	-9
1	21	-7

NOTE: The final sign of each of these products should be done mentally, thus saving several keystrokes. AS: 21 x -9 would normally be -189, but with the CHS indicated by the jagged arrow, becomes +189 ACTUAL INPUT: 21 X 9 = 189 !

LET'S WRITE A SIMPLE PROGRAM TO DO THIS PROBLEM !

(USING T.I. LOGIC)

Press GTO 035

Press LRN: (Go to LEARN mode)
2ND LBL C (1st coor.on display)
X, R/S (Enter next coord.)
= (Product)
SUM 00 (Product sto. accum)
R/S (Enter next coord.)
C (Loop back to LABEL C)
(End of program)
Press LRN (Set RUN mode)

(USING H.P. LOGIC)

Press GTO CHS 022

Press g P/R (Go to LEARN mode)
f LBL B (1st coor.on display)
R/S (Enter next coord)
STO 1 (Store coord)
X (Product)
2, ÷ (1/2 of product)
STO + 0 (Stored accum.)
RCL 1 (Recall last coor)
R/S (See !, Enter next coor)
GTO f B (Loop to LABEL B)
g P/R (End prog, set RUN mode)

NOW...TO RUN THESE TWO PROGRAMS !!

(BOTH CALCULATORS ARE IN "RUN" MODE)

(T.I. PROGRAM)

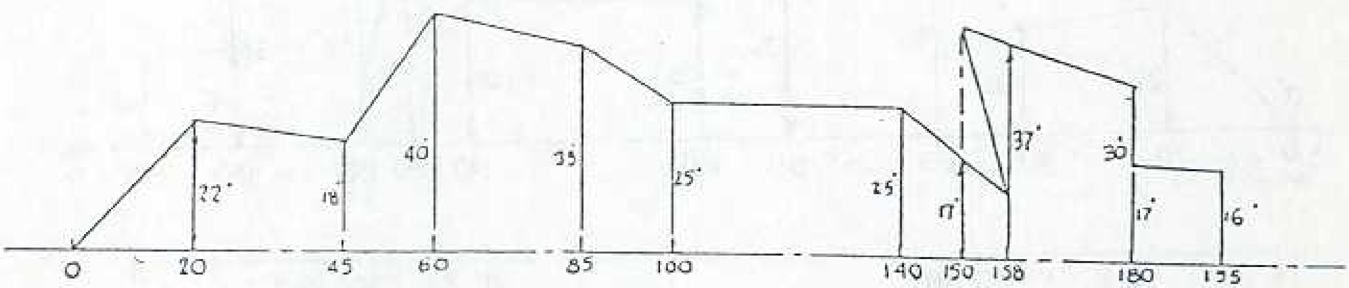
Type 0, Press STO 00
" 21 Press C
" 14 R/S: Type 7 R/S
" 23 R/S: " 20 R/S
" 9 R/S: " 13 R/S
" 7 R/S: " 21 R/S
" 9 R/S: " 13 R/S
" 23 R/S: " 20 R/S
" 14 R/S: " 7 R/S
" 7 R/S: (FINISHED)
RCL 00 ÷ 2 = 771.5 S.F.

(H.P. PROGRAM)

Press f CLEAR REG
Type 21 Press f B
" 14 R/S: Type 7 R/S
" 23 R/S: " 20 R/S
" 9 R/S: " 13 R/S
" 7 R/S: " 21 R/S
" 9 R/S: " 13 R/S
" 23 R/S: " 20 R/S
" 14 R/S: " 7 R/S
" 7 R/S: (FINISHED)
RCL 0 (Read 771.5 S.F.)

AREAS BY ELECTRONIC CALCULATOR (Continued)

LATITUDE AND DEPARTURE (or BASELINE STATIONS AND ORDINATES)



THIS IS AN OFTEN USED METHOD OF MEASURING IRREGUAR AREAS IN THE FIELD. THE BASE LINE MAY BE THE C/L OF A ROADWAY OR MAY BE AN ARBITRARY LINE SET STRICTLY FOR THE PURPOSE OF DESCRIBING THE AREA.

IN THIS METHOD, EACH ORDINATE (or Y value) IS MULTIPLIED BY THE DISTANCE BETWEEN THE STATION OF THE PRECEEDING ORDINATE AND THAT OF THE FOLLOWING ORDINATE, AND SUM THE PRODUCTS IN A COMMON REGISTER. OBVIOUS DISTANCES MAY BE DONE MENTALLY, THUS SAVING MANY KEYSTROKES.

1. MANUAL SOLUTION (T.I. CALCULATOR)

22 X 45 = STO 00, 18 X 40 = SUM 00, 40 X 40 = SUM 00, 35 X 40 = SUM 00, 140-85 = X 25 = SUM 00, 25 X 50 = SUM 00, 17 X 18 = SUM 00 37 X 30 = SUM 00, 180-158 = X 30 = SUM 00, 17 X 15 = SUM 00, 16 X 15 = SUM 00.. RCL 00 ÷ 2 = (Read 4953 S.F.)

2. MANUAL SOLUTION (H.P. CALCULATOR)

22 ENT, 45 X, 18 ENT, 40 X +, 40 ENT, 40 X +, 35 ENT, 40 X +, 25 ENT 140 ENT, 85 - X +, 25 ENT, 50 X +, 17 ENT, 18 X +, 37 ENT, 30 X +, 30 ENT, 180 ENT, 158 - X +, 17 ENT, 15 X +, 16 ENT, 15 X +, (Read 9906) 2 ÷, (Read 4953 S.F.)

SINCE THIS METHOD INVOLVES MULTIPLICATION OF TWO VALUES , SUMMING THE PRODUCTS, AND TAKING HALF THE TOTAL FOR THE ANSWER; THE PROGRAMS ON PAGE I-4 CAN BE USED HERE !

3. USING THE T.I. AREA PROGRAM ON PAGE I-4

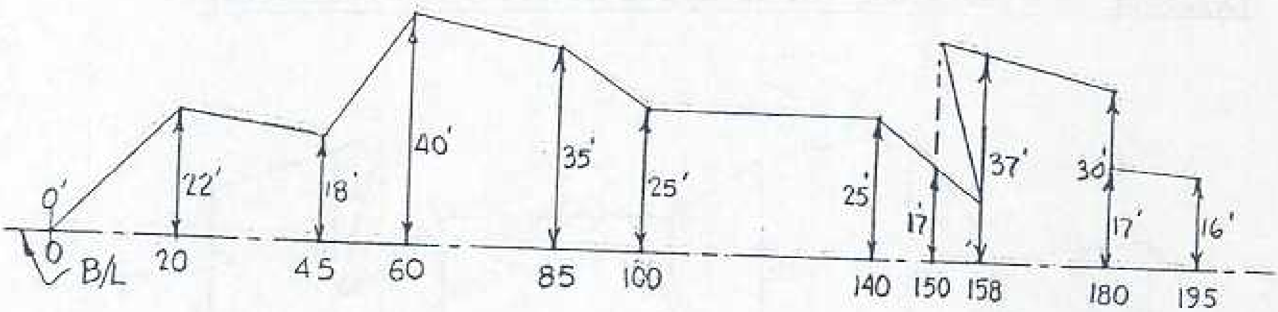
0 STO 00: 22 C, 45 R/S, 18 R/S, 40 R/S, 40 R/S, 40 R/S, 35 R/S, 40 R/S, 25 R/S, 55 R/S, 25 R/S, 50 R/S, 17 R/S, 18 R/S, 37 R/S, 30 R/S, 30 R/S, 22 R/S, 17 R/S, 15 R/S, 16 R/S, 15 R/S. RCL 00 ÷2 = 4953 S.F

4. USING THE H.P. AREA PROGRAM ON PAGE I-4

f CLEAR REG: 22 Press f B, 45 R/S,18 R/S, 40 R/S, 40 R/S, 40 R/S, 35 R/S, 40 R/S, 25 R/S, 55 R/S, 25 R/S, 50 R/S, 17 R/S, 18 R/S, 37 R/S, 30 R/S, 30 R/S, 22 R/S, 17 R/S, 15 R/S, 16 R/S, 15 R/S. RCL 0 (Read 4953 S.F.)

ELECTRONIC CALCULATOR (Continued)

Here's another program to run this irregular area problem, which is easier to use, since there is no need for calculating distances. It takes 23 program lines on the H.P., or 39 program lines on the T.I.



H.P. PROGRAM

```
131 f LBL .1 (Display 1st Sta)
132 STO 1
133 R/S        (Enter 1st Ord.)
134 STO 2
135  0
136 STO 0
137 f LBL .2
138 RCL 1
139 R/S      (Enter next Sta.)
140 STO 1
141 X⇄Y
142  —
143 ENTER
144 RCL 2
145 R/S     (Enter next Ord.)
146 STO 2
147  +
148 ENTER
149   2
150  ÷
151 X
152 STO + 0
153 GTO .2
```

T.I. PROGRAM

```
001 2ND LBL
002 2ND A (Display Sta)
003 STO
004  01
005  R/S
006 STO
007 02
008  0
009-10 STO, 00
011 2ND LBL
012 2ND B
013 RCL
014  01
015  +/-
016  +
017  R/S (Enter next Sta.)
018-20  STO, 01, =
021-22  STO, 03
023-24  RCL, 02
025    +
026  R/S (Enter next Ord.)
027-29  STO, 02, =
030-32  ÷, 2, =
033-35  X, RCL, 03
036-39  =, SUM, 00, 2ND B
```

U S A G E O F A B O V E P R O G R A M S

With Calculator in RUN mode, Type 1st STA ...(0)

FOR H.P.CALCULATOR — Press GSB .1

FOR T.I. CALCULATOR — Press 2nd A

(For Either) :Enter 1st ORD (0), Press R/S, Read (0)

Enter next STA (20), R/S, Enter ORD (22), Press R/S

Read (20) | Read (-20)

Enter next STA (45), R/S, Enter ORD (18), Press R/S

Continue in like manner and at STA 180, Enter ORD (30), for the BK, then STA 180 AGAIN, enter ORD (17),AHD.

After the final entry (ORD 16)

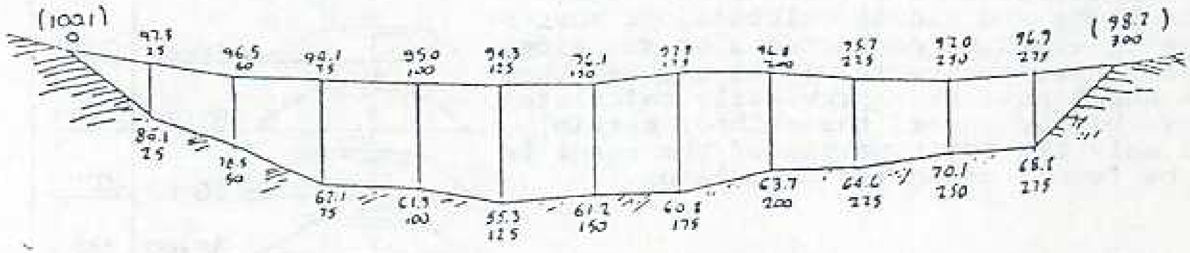
RCL 0 — Read 4953 S.F.

RCL 00 — Read 4953 S.F.

AREAS BY ELECTRONIC CALCULATOR (Continued)

BORROW PITS

Even in this day of computer technology, at times it is necessary to hand plot and compute areas and volumes for various earth-moving operations. For large cross sectional areas, such as BORROW PITS (Where both originals and finals are taken at a CONSTANT interval), as in the figure below, another method of calculating AREA may be used to expedite the work.



GENERAL METHOD: BY GENERATING A "WEIGHTED AVERAGE SUMMARY OF THE ORDINATES" which describe the area, and multiplying by the common INTERVAL; the AREA of the Cross-section may be found quickly.

The elevation at each end of the PIT is halved and added into a summary. All intervening "shots" are added once, into this summary. When the last "FINAL" shot (98.2) is halved and added into the total, the sign of the total is changed to MINUS and the "ORIGINAL" shots are added into this summary in the same manner.(i.e. end shots, 1/2, internal shots once.) Upon entry of half of the last shot (100.1), the total should read 324.5. Multiply this by the 25 ft. interval and the AREA (8,112.5 s.f.) is solved !

This is a quick and easy way to find the area, but since at any given entry, the display shows the total to this point, there is no way to orient yourself, if a distraction occurs. By writing a very short PROGRAM, however, the last entry is always on display, and the accumulative summary is stored in REGISTER 0: (Or a register of your own choice).

PROGRAM T.I. CALCULATOR

```
GTO 044, Press LRN
2nd LBL D
0 STO 00
R/S
SUM 00
GTO 049
LRN
```

PROGRAM H.P. CALCULATOR

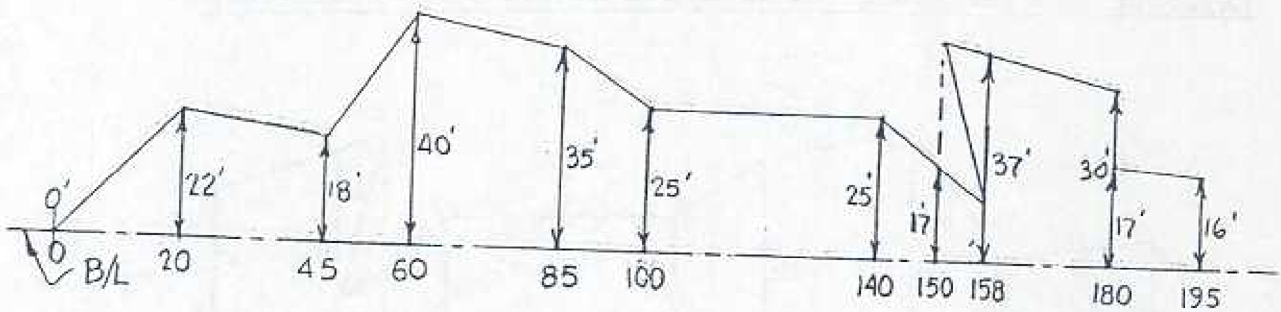
```
GTO CHS 032  g P/R
f LBL C
0 STO 0
f LBL 2, R/S
STO + 0
GTO 2
   g P/R
```

USAGE OF THE ABOVE PROGRAMS: (H.P. used as example: T.I. Similar)

Press f C. Type 100.1,ENTER,2 ÷ (Read 50.05),Press R/S 86.1 R/S, 78.5 R/S, 62.1 R/S, 61.9 R/S, 55.3 R/S, 61.2 R/S, 60.8 R/S, 63.7 R/S, 64.6 R/S, 70.1 R/S, 68.8 R/S, then 98.2 ENTER, 2 ÷ (Read 49.1 R/S, RCL 0 (READ 832.25) CHS (-832.25 STO 0), Press R↓ (READ 49.1) R/S, 96.9 R/S, 97 R/S, 95.7 R/S, 96.8 R/S, 97.9 R/S, 96.1 R/S, 94.3 R/S, 95 R/S, 94.1 R/S, 96.5 R/S, 97.3 R/S, 100.1 ENTER, 2 ÷ (Read 50.05) R/S, RCL 0 (Read 324.5 ENTER 25 X (Read 8,112.5 S.F.)

ELECTRONIC CALCULATOR (Continued)

Here's another program to run this irregular area problem, which is easier to use, since there is no need for calculating distances. It takes 23 program lines on the H.P., or 39 program lines on the T.I.



H.P. PROGRAM	T.I. PROGRAM
131 f LBL .1 (Display 1st Sta)	001 2ND LBL
132 STO 1	002 2ND A (Display Sta)
133 R/S (Enter 1st Ord.)	003 STO
134 STO 2	004 01
135 0	005 R/S
136 STO 0	006 STO
137 f LBL .2	007 02
138 RCL 1	008 0
139 R/S (Enter next Sta.)	009-10 STO, 00
140 STO 1	011 2ND LBL
141 X⇄Y	012 2ND B
142 —	013 RCL
143 ENTER	014 01
144 RCL 2	015 +/-
145 R/S (Enter next Ord.)	016 +
146 STO 2	017 R/S (Enter next Sta.)
147 +	018-20 STO, 01, =
148 ENTER	021-22 STO, 03
149 2	023-24 RCL, 02
150 ÷	025 +
151 X	026 R/S (Enter next Ord.)
152 STO + 0	027-29 STO, 02, =
153 GTO .2	030-32 ÷, 2, =
	033-35 X, RCL, 03
	036-39 =, SUM, 00, 2ND B

U S A G E   O F   A B O V E   P R O G R A M S

With Calculator in RUN mode, Type 1st STA ...(0)

FOR H.P.CALCULATOR — Press GSB .1

FOR T.I. CALCULATOR — Press 2nd A

(For Either) :Enter 1st ORD (0), Press R/S, Read (0)

Enter next STA (20), R/S, Enter ORD (22), Press R/S

Read (20)   Read (-20)

Enter next STA (45), R/S, Enter ORD (18), Press R/S

Continue in like manner and at STA 180, Enter ORD (30), for the BK, then STA 180 AGAIN, enter ORD (17),AHD.

After the final entry (ORD 16)

RCL 0 — Read 4953 S.F.

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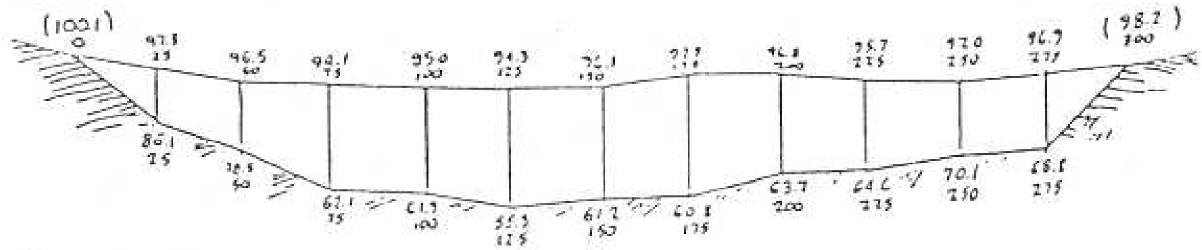
Even in this day of computer technology, at times it is necessary to hand plot and compute areas and volumes for various earth-moving operations. For large cross sectional areas, such as BORROW PITS (Where both originals and finals are taken at a CONSTANT interval), as in the figure below, another method of calculating AREA may be used to expedite the work.



GENERAL METHOD: BY GENERATING A "WEIGHTED AVERAGE SUMMARY OF THE ORDINATES" which describe the area, and multiplying by the common INTERVAL; the AREA of the Cross-section may be found quickly.

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PROGRAM T.I. CALCULATOR

```
GTO 044, Press LRN
2nd LBL D
0 STO 00
R/S
SUM 00
GTO 049
LRN
```

PROGRAM H.P. CALCULATOR

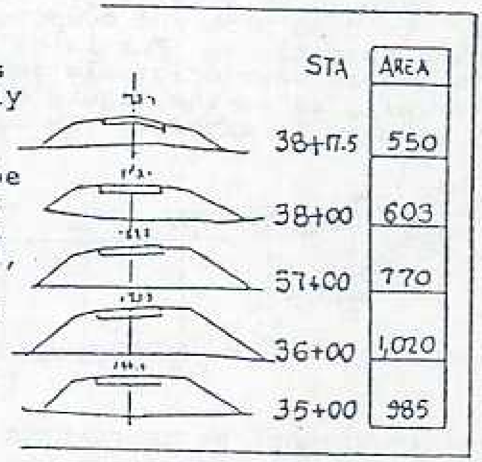
```
GTO CHS 032  g P/R
f LBL C
0 STO 0
f LBL 2, R/S
STO + 0
GTO 2
  g P/R
```

USAGE OF THE ABOVE PROGRAMS: (H.P. used as example: T.I. Similar)

Press f C. Type 100.1,ENTER,2 ÷ (Read 50.05),Press R/S 86.1 R/S, 78.5 R/S, 62.1 R/S, 61.9 R/S, 55.3 R/S, 61.2 R/S, 60.8 R/S, 63.7 R/S, 64.6 R/S, 70.1 R/S, 68.8 R/S, then 98.2 ENTER, 2 ÷ (Read 49.1 R/S, RCL 0 (READ 832.25) CHS (-832.25 STO 0), Press R↓ (READ 49.1) R/S, 96.9 R/S, 97 R/S, 95.7 R/S, 96.8 R/S, 97.9 R/S, 96.1 R/S, 94.3 R/S, 95 R/S, 94.1 R/S, 96.5 R/S, 97.3 R/S, 100.1 ENTER, 2 ÷ (Read 50.05) R/S, RCL 0 (Read 324.5 ENTER 25 X (Read 8,112.5 S.F.)

EARTHWORK VOLUMES BY ELECTRONIC CALCULATOR

This figure represents a cross-section sheet showing the hand plotted x-sections of some fill sections of roadway. Normally the Computer calculates area and volumes of machine-plotted sections, but often hand plots and manual calculations must be done to expedite corrections or revisions to computer earthwork. It is assumed that the AREAS have been previously calculated, (possibly by one of the methods herein), and only the TOTAL volume of the sheet is to be found, using the calculator.



The following method is probably the quickest way to calculate the total volume per sheet:
Area 985 s.f is multiplied by the distance AHEAD to the next station (100 ft.) This yields DOUBLED CUBIC FEET, which is stored. Next, 1020 s.f. times the SUM OF THE DISTANCE BACK PLUS THE DISTANCE AHEAD , (200 ft.) is added to the storage register. This system is followed to the last section on the sheet, where 550 times the distance BACK (17.5 ft.) is summed into the storage register. Now when the value in the register is recalled (536,977.5), it must be divided by 54, (twice 27) to convert to CUBIC YARDS, (9,944.03).

Since the above method involves the multiplication of two values and also division of this product by 2, (which would give CUBIC FEET); the AREA programs shown on page I-4 could be used to solve the page VOLUMES, as shown below:

CALCULATORS TO BE IN "RUN" MODE

USING T.I. PROGRAM

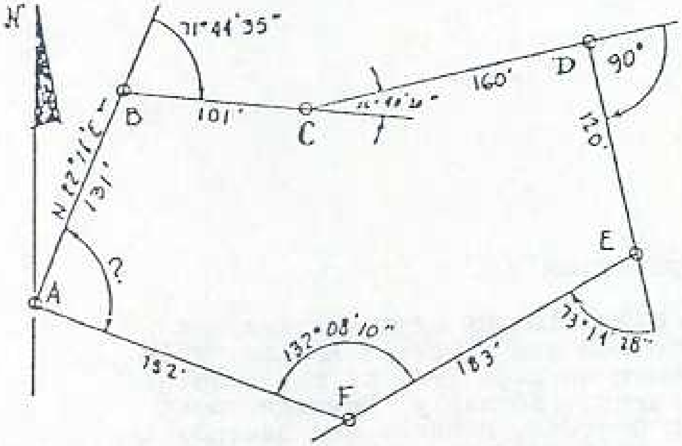
Type 0, Press STO, 0

```
  "   985, Press  C
  "   100,  R/S: Type 1020, R/S
  "   200,  R/S:   "    770, R/S
  "   200,  R/S:   "    603, R/S
  " 117.5,  R/S:   "    550, R/S
  "   17.5, R/S:(Finished)
 RCL 00 (Read 536,977.5)
  ÷ 54 = 9,944.03 C.Y.
```

USING H.P. PROGRAM

Press f CLEAR REG

```
Type 985, Press f B
  "   100,  R/S: Type 1020, R/S
  "   200,  R/S:   "    770, R/S
  "   200,  R/S:   "    603, R/S
  " 117.5,  R/S:   "    550, R/S
  "   17.5, R/S: (Finished)
 RCL 0 (Read 268,488.75)
ENT, 27, ÷ (Read 9,944.03 C.Y.)
```



ANGLE MANIPULATION (ELECTRONIC CALCULATOR) - FOR CALCULATORS THAT HAVE NO [DEG. MIN. SEC. TO DECIMAL OF DEGREE] ROUTINE; ANGLES MAY BE ADDED & SUBTRACTED BY THE METHOD BELOW:

TO ADD, SAY, 95° 57' 11" PLUS 128° 25' 27" PLUS 47° 48' 39", ZEROES ARE SANDWICHED BETWEEN DEGREES AND MINUTES AND BETWEEN MINUTES AND SECONDS THUS:

```
   95° 057' 011"
+ 128° 025' 027"
+  47° 048' 039"
= 270° 130' 077"
+       940  940
= 271° 071' 017"
+       940  000
= 272° 011' 017"
```

IF THE MINUTES OR SECONDS (OR BOTH) READ GREATER THAN 60 IN THE SUM, THE VALUE "940" (WHICH IS 1000 - 60) is ADDED TO THE ANSWER, WHERE NEEDED TO GIVE THE CORRECT ANGLE.............................THE SAME PRINCIPLE IS APPLIED TO THE DIFFERENCE BETWEEN ANGLES, EXCEPT THAT THE "940"'S ARE DEDUCTED WHERE NECESSARY, INSTEAD OF BEING ADDED.

EXAMPLE: IN FIGURE ABOVE, TO SOLVE INTERNAL ANGLE AT B:

```
  180° 000' 000"
-  71° 044' 035"
  108° 955' 965"
-       940  940
  108° 015' 025"
```

THE 940 FACTORS ARE SUBTRACTED AS SHOWN, "RECTIFYING" THE ANGLE. IN THE ABOVE TRAVERSE, THE "ZERO" METHOD MAY BE APPLIED TO SOLVE THE CLOSING ANGLE AT "A" BY SOLVING FOR THE INTERNAL ANGLES: ADDING THEM AND SUBTRACTING THEIR SUM FROM THE THEORETICAL SUM. ((n* - 2) x 180°; (6 - 2) x 180°; = 720°) THE "ZERO" METHOD IS THEN USED TO DETERMINE THE VARIOUS BEARINGS, AS FOLLOWS USING VARIOUS CALCULATORS.

* n = NUMBER OF SIDES IN THE POLYGON

ANGLE MANIPULATION

For BEARING calculations, ANGULAR CLOSURE of Traverses and similar problems, it is necessary to add and subtract ANGLES. This may be done by the "ZERO" method shown on page I-8, if the machine does not have ANGLE conversion features. Normally, however, most calculators have keys which convert Degrees, Minutes and Seconds to DEGREES (as a decimal fraction)--so that addition or subtraction may be done. On both the T.I. and the H.P. machines, the ANGLE is entered as: DEGREES .(period) MINUTES SECONDS. Example: 15° 25' 22" is entered as: 15.2522. To convert to DEGREES, press 2nd DMS on the T.I. or g →H (on the H.P. 15c). Either converts it to 15.4228° so that it may now be used in addition or subtraction. To convert back to DMS, press INV 2ND DMS (for T.I.) or f →HMS (for H.P. 15c).

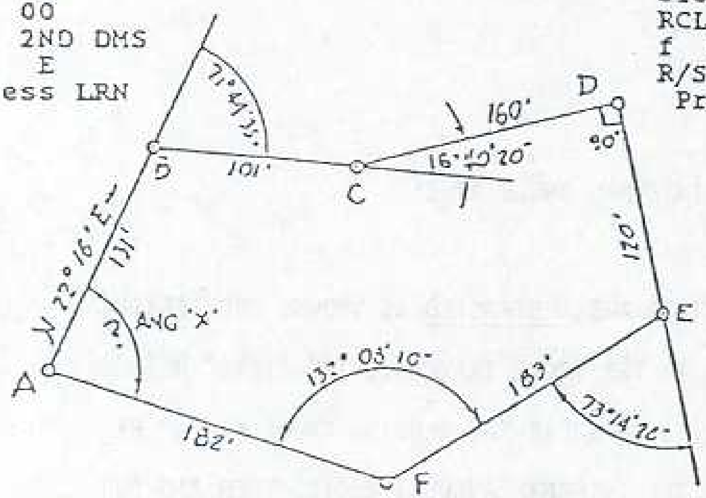
For extensive manipulations with angles, it is convenient to write a short PROGRAM which will utilize these KEYS to convert a displayed ANGLE in DMS and store it accumulatively in a register, then recall the accumulated SUM in the register; convert it back to DMS and STOP to display this TOTAL.

PROGRAM T.I. CALCULATOR

```
     GTO 055
Press LRN
2nd LBL E
2nd DMS
SUM, 00
RCL, 00
INV, 2ND DMS
R/S,  E
  Press LRN
```

PROGRAM H.P. CALCULATOR

```
     GTO CHS 039
Press g  P/R
 f LBL 3
 g  →H
 STO + 0
 RCL 0
 f   →HMS
 R/S, GTO 3
  Press g P/R
```



To solve the missing ANGLE X, add all INTERNAL ANGLES and deduct this SUM from the Theoretical 720°; (n - 2) X 180: n = 6 (no.sides))

USING T.I. PROGRAM

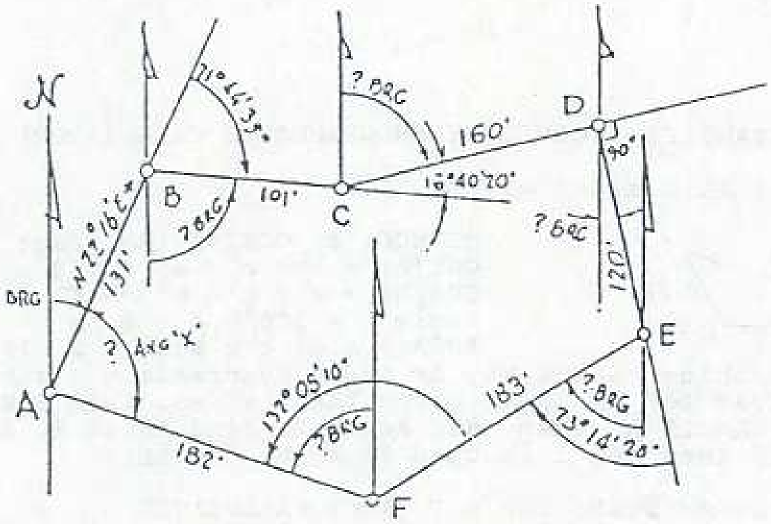
```
Type 0, Press STO 00
  "   180, Press E
  " 71.4435, +/-, R/S
  " 196.4820, R/S
  "   90, R/S,  180, R/S
  " 73.1428,  +/-,  R/S
  " 132.081, R/S(Read 633.4927)
  " 720, +/-, R/S
  (Read-86.1033 or 86°10' 33")
```

USING H.P. PROGRAM

```
Press f CLEAR REG
Type 180, Press GTO 3, R/S
  " 71.4435 CHS, R/S, 196.4020,R/S
  "   90,  R/S,  180,  R/S
  " 73.1428, CHS,       R/S
  "   132.0810, R/S,(Read 633.4927)
  "   720, CHS, R/S
 (Read-86.1033 or 86°10' 33")
```

ANGLE MANIPULATION (Continued)

SOLUTION OF BEARINGS OF LEGS OF A TRAVERSE (From Deflection Angles)



In the figure above, the BEARING of AB is given as N 22°16' E, and since this added to the deflection 71° 44' is greater than 90°, the bearing of BC is in the SE quadrant. The ANGLE Adding program on page I-9 may be used to solve this BEARING, and by proceeding in a clockwise manner around the TRAVERSE, to solve them ALL !

USING THE T.I. CALCULATOR'S ANGLE PROGRAM

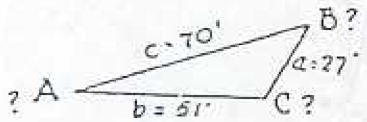
The BEARING of BC is 180° minus the sum of the deflection and the BEARING of AB: 0 STO 00, 180 Press E. 71.4435 +/- R/S: 22.16 +/- R/S.(Read 85.5925) S 85°59' 25" E.
The BEARING CD is 180° minus the sum of the deflection and the previous BEARING.: Type 16.4020, R/S, 180 +/- Press E (or R/S) (Read -77.2015) N 77°20' 15" E.
BEARING DE equals 180° minus the sum of the previous BEARING and 90°. Type 90 +/- R/S, 180, R/S: (Read 12.3945) S 12°39' 45"E.
The BEARING EF is the difference between the deflection and the last BEARING. Type 73.1428, +/-: Press R/S. (Read S 60°34' 43"W).
BEARING FA is the difference of the internal ANGLE and the previous BEARING. Type 132.0810, Press R/S. (Read N 71°33' 27" W).
As a check, the BEARING of AB should be 180° minus the sum of the previous BEARING and ANGLE x (Solved on page I-9 as 86°10' 33"). Type 86.1033: R/S, 180, +/-, R/S. (Read (-) N 22°16' E). CHECK !

USING THE H.P. CALCULATOR'S ANGLE PROGRAM

Using the method detailed above for the T.I. calculator, solve for all BEARINGS, beginning with course BC, and proceeding clockwise.
Press f CLEAR REG. Type 180, Press GTO 3, Press R/S.
Type 71.4435 CHS, Press R/S. Type 22.16, CHS, Press R/S.
(Read 85.5925): BEARING of BC = S 85°59' 25" E.
Type 16.4020, Press R/S: 180 CHS, Press R/S
(Read -77.2015): BEARING of CD = N 77°20' 15" E.
Type 90 Press CHS, R/S: Type 180, Press R/S
(Read 12.3945): BEARING of DE = S 12°39' 45" E.
Type 73.1428, CHS, R/S.(Read BEARING EF -60.3443: S 60°34'43" W).
Type 132.0810, R/S. (Read BEARING FA, 71.3327: N 71°33'27" W).
Type 86.1033 (ANGLE x) R/S: Type 180 CHS, Press R/S.
(Read -22.16: BEARING AB = N 22°16' E..CHECK !).

OBLIQUE TRIANGLES (SOLVED BY PROGRAMMABLE CALCULATOR)

CASE 1. Type SSS (All 3 sides given)



METHOD: By COSINE LAW (Page I)
$COS(A) = b^2 + c^2 - a^2 \div (2 \times b \times c)$
$COS(B) = a^2 + c^2 - b^2 \div (2 \times a \times c)$
Angle C = 180° − A − B
AREA = side c x side b x SIN(A) ÷ :

To program this problem, steps may be saved by creating a subroutin (SBR 1) which solves for an angle given the 3 sides. This SBR is used 1st to solve ANGLE A, then used again to find ANGLE B. ANGLE C is found as above, then SBR 2 is used to solve the AREA.

PROGRAM STEPS FOR H.P.(15C) CALCULATOR

```
   g P/R : f CLEAR PRGM **
f LBL A, STO 1 (Side a on display)
R/S     (Enter side b)
STO 2
R/S, STO 3    (Enter side c)
GSB 1 (Go to subroutine 1)
STO 4 (ANGLE A STOred after RTN from SBR 1)
f LBL .2, RCL 1
RCL 2
STO 1
R ↓
STO 2
RCL 3
GSB 1 (Go to SBR 1 to solve Angle B)
STO 5 (Angle B STOred after RTN from SBR 1)
RCL 4
 +, CHS, 180, +
STO 6 (Angle C STOred in 6)
f LBL 5, GSB 2 (Go to SBR 2 for AREA)
R/S (Return from SBR 2, Read AREA)
RCL 4, f →HMS
R/S  (Read Angle A in DMS)
RCL 5, f →HMS
R/S  (Read Angle B in DMS)
RCL 6, f →HMS
R/S  (Read Angle C in DMS). END MAIN PGM.
g RTN, f LBL 1 (Beg.SBR 1)
g X², RCL 2, g X², +
RCL 1, g X², −, ENTER
2, RCl 2, X, RCL 3, X
÷, g COS-1, g RTN (End SBR 1)
f LBL 2 (Beg.SBR 2)
RCL 2
ENTER
RCL 1
X
RCL 6
SIN
X
2
÷
g RTN (End SBR 2)
  g P/R (Change to RUN mode)
```

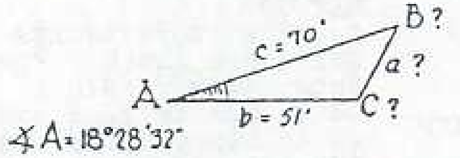
TO RUN THIS (above) PROBLEM

(Calculator is in RUN Mode) :
Press:
f CLEAR PRGM
Type 27 (side a)
Press f A
Type 51 (side b)
Press R/S
Type 70 (side c)
Press R/S
(Wait 8 seconds !)
(Read 565.66 Area)
Press R/S
Read 18°28'32"
Press R/S
Read 36°46'07"(B)
Press R/S
Read 124°45'21"(C)
ALL THRU !!

** NOTE: PREVIOUS PROGRAMS ARE CLEARED TO PROVIDE ROOM FOR OBL. TRIANGLE SERIES. PROGRAMMING HENCEFORTH IS SHOWN FOR H/P ONLY, SINCE H/P IS SHORTER AND THE T.I. PROGRAM MAY BE DONE BY FOLLOWING THE METHOD SHOWN FOR THE H/P.

PROGRAMMING OBLIQUE TRIANGLES (Continued)

CASE 2. TYPE SAS(Two sides and the INCLUDED angle given)



METHOD:
STO angle A in 4
a = $(b^2 + c^2 - (2 \times b \times COS(A)))^{1/2}$
STO a in REG 1, STO b in REG 2
STO c IN REG 3
Since all sides are STOred :
GTO f LBL .2 for complete solution

PROGRAM STEPS FOR H.P.(15C) CALCULATOR

```
(In RUN Mode, Press GTO CHS 066), g P/R (Set LEARN Mode)
f LBL B    (Set label B)...Angle A in DMS on DISPLAY..
g →H (Angle converted to DEC of DEGREES)
STO 4 (Converted Angle A STOred in 4)
R/S (Enter Side b)
STO 2
R/S (Enter Side c)
STO 3
GSB .1 (Go to Subroutine to solve side a)
RCL 3 (Recall side c to display)
GSB .2 (Go to LBL .2 of CASE 1 for complete solution)
f LBL .1 (Set Label for Subroutine to solve side a)
g X²
RCL 2
g X²
+
2
RCL 2
X
RCL 3
X
RCL 4
COS
X
-
√x
STO 1
g RTN (End Program)
   g P/R (Change to RUN Mode)
```

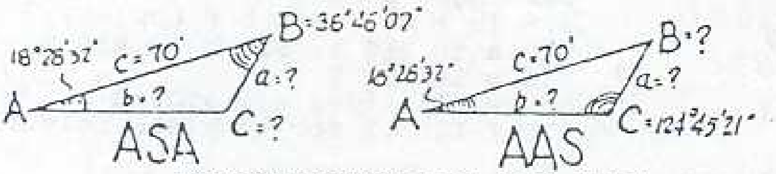
<u>TO RUN THE ABOVE (SAS) TRIANGLE</u>

With Calculator in RUN Mode, Press f CLEAR REG
Type 18.2832 (Angle A in DMS)
Press f B
Type 51 (Side b) Press R/S
  " 70 (Side c)   "   R/S..(Wait 9 seconds)
Read AREA (565.67)
Press R/S, Read Angle A (18°28' 32")
Press R/S, Read Angle B (36°46' 07")
Press R/S, Read Angle C (124°45' 20")
Press RCL 2, Read Side a (27.0001')

PROGRAMMING OBLIQUE TRIANGLES (Continued)

CASE 3. TYPE ASA (Two ANGLES and the Side between them)

CASE 4. TYPE AAS (Two ANGLES and a side other than "between")



METHOD:
Enter & STOre ANGLES
Solve 3rd ANGLE & STO
Enter Side c, STO 3
Go to SBR to find side a
Go to SBR to find side b
GTO LBL .2 for SOLUTION

PROGRAM STEPS FOR H.P. (15C) CALCULATOR

(CASE 3. TYPE ASA)

```
In RUN Mode Press GTO CHS 093: g P/R (Set LEARN Mode)
f LBL C (Side c is on DISPLAY)
STO 3, R/S (Enter ANGLE A in DMS)
g →H, STO 4
R/S (Enter Angle B in DMS), g →H, STO 5
RCL 4, +, CHS, 1, 8, 0, +, STO 6
f LBL .3, GSB 3 (Go to SBR 3 to solve side a)
STO 1 (After return from SBR, STO a in 1)
RCL 4, RCL 5, STO 4, R↓, STO 5, RCL 6
GSB 3 (Go to SBR 3 to solve side b)
STO 2 (After return, STO b in 2)
RCL 5, STO 4, GTO .2 (Go to LBL .2 for complete solution)
f LBL 3 (This is SBR 3. Solves side, given SAS)
SIN, 1/x, RCL 3, X, RCL 4, SIN, X, (Side on display)
g RTN (End programming) ...g P/R (Set RUN Mode)
```

(CASE 4. TYPE AAS)

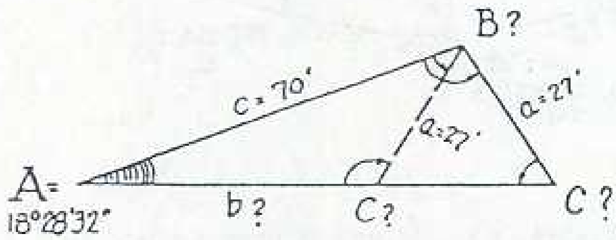
```
In RUN Mode Press GTO CHS 132 : g P/R (Set LEARN Mode)
f LBL D (Side c is on DISPLAY)
STO 3
R/S (Enter ANGLE A in DMS)
g →H, STO 4
R/S (Enter ANGLE C in DMS)
g →H, STO 6
+, CHS
1, 8, 0,
+, STO 5
RCL 6
GTO .3 (Go to LBL .3 for complete solution)
(End Programming)... g P/R (Set RUN Mode)
```

TO RUN THE ABOVE TRIANGLES

```
With Calculator in RUN Mode, Press f CLR REG
Type 70 (Side c)
Press f C (For ASA) or Press f D (For AAS)
Type 18.2832 (ANGLE A in DMS For BOTH ASA & AAS),  Press R/S
(For ASA, Type 36.4607, Angle B in DMS), Press R/S
(For AAS, Type 124.4521, Angle C in DMS), Press R/S
      (WAIT 13 SECONDS for ASA, or 16 seconds for AAS)
Read AREA (565.67)
Press R/S, Read Angle A (18° 28' 32")
Press R/S, Read Angle B (36° 46' 07")
Press R/S, Read Angle C (124° 45' 21")
RCL 2      Read Side  a (27.0001)
RCL 1      Read Side  b (50.9999)
```

PROGRAMMING OBLIQUE TRIANGLES (Continued)

CASE 5. TYPE SSA (Two sides and an ANGLE other than the "INCLUDED")
NOTE: This problem may have either 1 or 2 solutions depending upon the variables submitted. The program compares them and if 2 solutions are required, it solves them.



METHOD:
Enter side a, STO
Enter side c, STO
Enter ANGLE A, DMS, STO
Solve ANG C, SIN law, STO
ANG B = 180° - A - C, STO
Solve side b, SIN law, STO
Compare var. (2nd sol ?)
Solve 2nd sol, or print 0

PROGRAM STEPS FOR H.P. (15C) CALCULATOR

```
In RUN Mode Press GTO CHS 149 : Press g P/R (Set LEARN Mode)
f LBL E    (Side a is on DISPLAY)
STO 1, R/S (Enter side c)
STO 3, R/S (Enter ANG A in DMS)
g →H, STO 4
SIN, X, RCL 1, ÷
g SIN-1, STO 6 (ANG C STOred)
RCL 4, +, 1,8,0, -, CHS
STO 5    (ANG B STOred)
SIN, RCL 1, X, RCL 4, SIN, ÷
STO 2,   (Side b STOred)
GSB 5  (Go to SBR 5 for 1st sol)
RCL 4, 9,0, g x≤y, GTO .5
RCL 1, RCL 3, g x≤y, GTO .5
1,8,0, RCL 6, -
STO 6   (ANG C, 2nd sol STO)
RCL 4, +, 1,8,0, -, CHS
STO 5   (ANG B, 2nd sol STO)
RCL 6, COS, RCL 1, X, 2, X
RCL 2, +
STO 2   (Side b, 2nd sol STO)
GSB 5 (Go to SBR 5 for 2nd sol)
R/S
f LBL .5 (For NO 2nd sol !)
0, R/S  (End programming)
   g P/R    (Set RUN Mode)
```

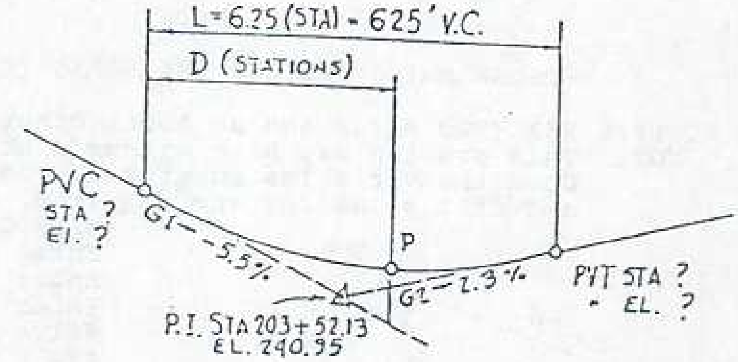
TO RUN THIS PROGRAM FOR THE ABOVE TRIANGLE

With Calculator in RUN Mode, Press f CLR REG
Type 27, (Side a), Press f E. Type 70 (Side c), Press R/S
Type 18.2832 (Angle A in DMS), Press R/S..WAIT 9 Seconds !
Read 907.1090 (Area, 1st solution), Press R/S
Read Angle A (18°28'32"). Press R/S, Read Angle B (106°16'48")
Press R/S, Read Angle C (55°14'40"). RCL 2, Read side b (81.78)
Press R/S, WAIT 7 seconds ! Read 565.67 (Area, 2nd solution)
Press R/S, Read ANG A (18°28'32"). Press R/S
Read ANG B (36°46'08"), Press R/S, Read ANG C (124°45'20")
RCL 2, Read side b (51.0001)...FINISHED

NOTE: IF THERE IS NO 2ND SOLUTION READ "0" (Area)
(IF THERE IS NO SOLUTION AT ALL, READ "Error 0")

VERTICAL CURVES BY ELECTRONIC CALCULATOR

GENERAL METHOD *
(METHODS FOR SPECIFIC MACHINES, ON SUBSEQUENT PAGES)
VALUES SOLVED BELOW ARE ENTERED IN TABLE AT BOTTOM OF PAGE
(CREST CURVES MAY BE SOLVED USING THE SAME METHOD.)



1. SOLVE PVC. STATION: PVT. STATION
PVC. STA = PI. STA. -(L/2) : PVT. STA. = PVC.STA. + L. [(L/2) IS USED 3 TIMES IN FINDING STATIONS & ELEVATIONS, SO IT IS CONVENIENT TO STORE (L/2) IMMEDIATELY.]
6.25 ÷ 2 = 3.125 STO ; 203.5213 - RCL = (200.3963: PVC.STA. 200+39.63) + 6.25 = (PVT. STA. 206 + 64.63)

2. SOLVE PVC. ELEVATION & PVT. ELEVATION
PVC. EL. = PI.EL. - ((L/2)x G1): 240.95 - (RCL x (-5.5)) = 258.1375
PVT. EL. = PI.EL. + ((L/2)x G2): 240.95 + (RCL x 2.3) = 248.1375

3. SOLVE "D" VALUES FOR ALL STATION PLUSES REQUIRED. (NORMALLY EVEN STATIONS AND "PLUS 50" STATIONS, ALSO THE P.I. AND ANY SPECIAL STATIONS NEEDED.)
D= STA OF "P" - STA OF PVC. (NOTE: STORE PVC STA) EXAMPLE: 200.3963 STO :
[C] 200.5 - RCL = 0.1037 (D FOR STA 200+50) [C] 201 - RCL = 0.6037 (D FOR STA 201+0)
(REPEAT SEQUENCE FOR ALL STATIONS REQUIRED.)

4. SOLVE "K" AND STORE FOR USE IN SOLVING FINISHED GRADE ELEVATIONS
K=A/2L, WHERE A (ALGEBRAIC DIFFERENCE) = G1 - G2 :(SIGN OF GRADES ARE INSERTED:)
K = (-5.5 - 2.3) ÷ (2 x 6.25); K= - .624 [STO1]. IF 2 MEMORY REGISTERS ARE AVAILABLE, STORE PVC. ELEV. ALSO. (258.1375 [STO2]).

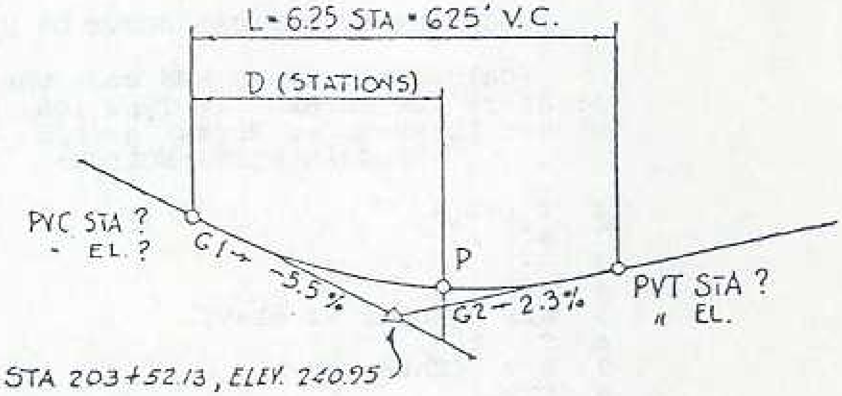
5. SOLVE FIN. GR. ELEV. FOR ALL STATION PLUSES REQ'D. USING:
FIN. GR. EL = (DK CHSN + G1) x D + PVC EL : EXAMPLE: (USING L FOR TRIAL "D")
THIS SHOULD SOLVE FOR THE ELEVATION OF THE PVT! (6.25 x [RCL1] CHSN + (- 5.5)) x 6.25 + [RCL2] = 248.1375: CHECKS! SYSTEM WORKS! - NOW SOLVE FOR ALL STATION PLUSES REQD., SUBSTITUTING VALUES OF "D" FOR 6.25

STATION PLUS	"D" (STA.)	FINISH GR. ELEV	STATION PLUS	"D" (STA)	FINISH GR. ELEV.
PVC.200+39.63	0	258.1375	204+00	3.6037	246.4208
200+50	.1037	257.5739	204+50	4.1037	246.0755
201+00	.6037	255.0446	205+00	4.6037	246.0422
201+50	1.1037	252.8273	205+50	5.1037	246.3209
202+00	1.6037	250.9220	206+00	5.6037	246.9117
202+50	2.1037	249.3287	206+50	6.1037	247.8144
203+00	2.6037	248.0474	PVT206+64.63	6.25	248.1375
203+50	3.1037	247.0781			
PI.203+52.13	3.125	247.0438			

* ALSO SEE PAGE I-22

VERTICAL CURVES BY ELECTRONIC CALCULATOR

SPECIFIC MACHINE EXAMPLES SHOWN BELOW FOLLOW THE "GENERAL METHOD", PAGE 1-1 (THE SAME ROUTINES WILL SOLVE CREST V.C.S ALSO)



1. MANUAL SOLUTION, USING T.I. (59) CALCULATOR

(L) 6.25 STO 00 ÷ 2 = (3.125) STO 01 :CHS + 203.5213 (P.I. STA) = 200.3963 (PVC STA), STO 02: +RCL 00 = 206.6463 (PVT STA) STO 03 RCL 01 X 5.5 CHS (G1) STO 04 = CHS + 240.95 (PI EL) STO 05 = 258.1375 (PVC EL) STO 06

RCL 01 X 2.3 (G2) = + RCL 05 = 248.1375 (PVT EL) STO 07
SOLVE "D" for each STATION required and enter in Table, THUS:
200.5 (1ST STA) - RCL 02 = .1037. (This is "D" for STA 200+50)
Record in Table below, and solve all "D's " as above.
(G1) RCL 04 - 2.3 (G2) = ÷ 2 ÷ RCL 00 = -.624 ("K") STO 08
SOLVE for FINISHED GRADE for each "D" as follows:
Enter .1037 (D) STO 09 X RCL 08 = CHS + RCL 04 (G1) = X RCL 09 + RCL 06 = 257.5739 (El. at STA 200+50)

2. MANUAL SOLUTION, USING H.P. (15C) CALCULATOR

(L) 6.25 STO 0, 2 ÷ STO 1, CHS, 203.5213 (PI STA) +, Read PVC STA (200.3963) STO 2, RCL 0, +, (READ PVT STA) 206.6463 STO 3 RCL 1, 5.5 CHS (G1) STO 4 X CHS, 240.95 (PI EL) STO 5, +, Read PVC EL (258.1375) STO 6
RCL 1, 2.3(G2) X, RCL 5, +, Read 248.1375 (PVT EL) STO 7
SOLVE "D" for each STATION required and enter in Table, THUS:
200.5 (STA), RCL 2, -, Read .1037 ("D" for STA 200+50)
(Solve K) RCL 4,2.3 (G2) -, 2, ÷, RCL 0 ÷. Read -.624 (K) STO 8
SOLVE for FINISHED GRADE for each "D" as follows:
(D) .1037, STO 9, RCL 8, X, CHS,RCL 4, +, RCL 9, X, RCL 6, + Read 257.5739 (El at STA 200+50)

FILL IN TABLE WITH DATA SOLVED IN 1 OR 2 ABOVE (CHECK PREVIOUS PAGE)

STATION PLUS	D (STA)	FIN. GRADE EL.	STATION PLUS	D (STA)	FIN.GRADE EL.

PROGRAMMING VERTICAL CURVE ON H/P CALCULATOR

(Calculator is in RUN mode when turned on.)
A: Store 100 in REG .1: Type 100, Press STO .1
B: Set LEARN mode: Press g P/R

PROGRAM STEPS FOLLOW:

```
1  f LBL A
2  RCL .1
3  ÷
4  STO 1
5  R/S  (Enter PI elev)
6  STO 2
7  R/S  (Enter gr 1)
8  STO 3
9  R/S  (Enter gr 2)
10 STO 4
11 R/S  (Enter L in feet)
12 RCL .1
13 ÷
14 STO 5
15 2
16 ÷
17 STO 6
18 CHS
19 RCL 1
20 +
21 STO 7  (PC STA stored)
22 RCL 5
23 +
24 STO 8  (PT STA stored)
25 RCL 6
26 RCL 3
27 X
28 CHS
29 RCL 2
30 +
31 STO 9  (PC Elev.stored)
32 RCL 6
33 RCL 4
34 X
35 RCL 2
36 +
37 STO 0 (PT Elev.stored)
38 RCL 3
39 RCL 4
40 -
41 2
42 ÷
43 RCL 5
44 ÷
45 STO .2
46 f LBL B
47 RCL .2
48 R/S (Enter STA)
49 RCL .1
50 ÷
51 RCL 7
52 -
53 STO .3
54 RCL .2
55 X
56 CHS
57 RCL 3
58 +
59 RCL.3
60 X
61 RCL 9
62 +
63 STO .4
64 R/S (Read ELEV)
65 GTO f B
```

Press: g P/R (Back to RUN)

TO RUN PROGRAM: (Using as an example the V.C. on page I-16)

Enter 100, Press STO .1

Type: 20352.13 (PI sta in ft.): Press f A
Type: 240.95 (P.I.Elev.): Press R/S
Type: 5.5 CHS (Grade 1): Press R/S
Type: 2.3 (Grade 2):........... Press R/S
Type: 625 (L of VC in ft.) Press R/S
READ: (-.624) constant "K"
Type: 20450 (STATION in ft.) Press R/S
READ: 246.0755 (Fin.Grade Elev)

FOR NEXT STATION: Press R/S
READ: (-.624) ("K" again)
Type: 20500 (NEXT STATION in ft) Press R/S
READ: 246.0422 (Fin.Grade Elev)

CONTINUE FOR ALL STATIONS DESIRED ON THE CURVE !

PROGRAMMING VERTICAL CURVE ON T.I.CALCULATOR

(Calculator is in RUN mode when turned on.)

A: STO 100 IN 20: TYPE 100 Press STO 20.
B: Change to LEARN mode: Press LRN

PROGRAM STEPS FOLLOW:

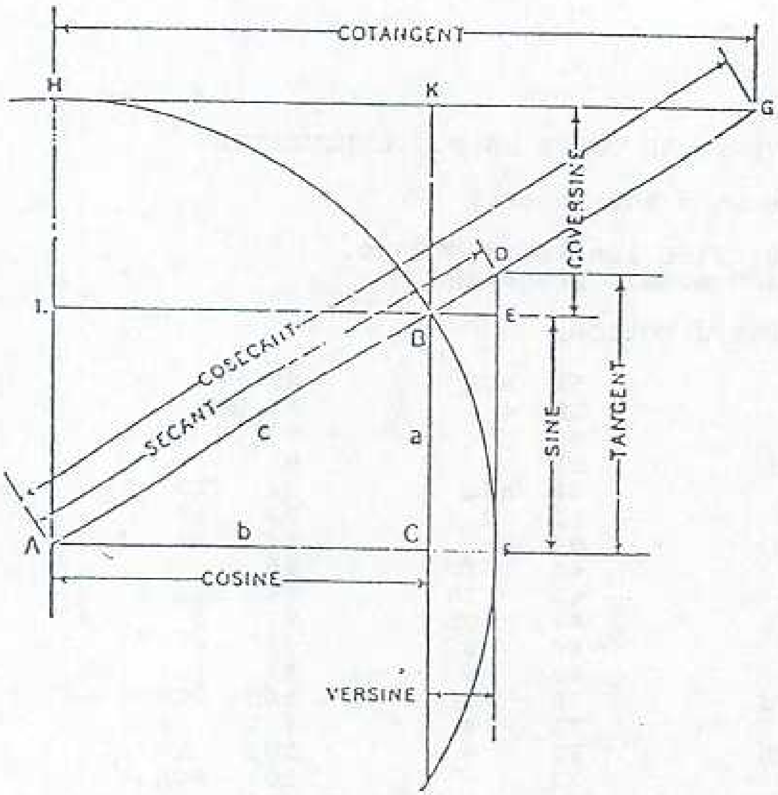
				58	RCL	88	-
0	2nd Lbl	29	+/-	59	4	89	RCL
1	A	30	+	60	=	90	7
2	÷	31	RCL	61	+	91	=
3	RCL	32	1	62	RCL	92	STO
4	20	33	=	63	2	93	12
5	=	34	STO	64	=	94	X
6	STO	35	7	65	STO	95	(
7	1	36	+	66	10	96	RCL
8	R/S	37	RCL	67	RCL	97	3
9	STO	38	5	68	3	98	-
10	2	39	=	69	-	99	(
11	R/S	40	STO	70	RCL	100	RCL
12	STO	41	8	71	4	101	12
13	3	42	RCL	72	=	102	X
14	R/S	43	6	73	÷	103	RCL
15	STO	44	X	74	2	104	11
16	4	45	RCL	75	÷	105	)
17	R/S	46	3	76	RCL	106	)
18	÷	47	=	77	5	107	+
19	RCL	48	+/-	78	=	108	RCL
20	20	49	+	79	STO	109	9
21	=	50	RCL	80	11	110	=
22	STO	51	2	81	RCL	111	STO
23	5	52	=	82	11	112	13
24	÷	53	STO	83	R/S	113	R/S
25	2	54	9	84	÷	114	GTO
26	=	55	RCL	85	RCL	115	00
27	STO	56	6	86	20	116	81
28	6	57	X	87	=		

End of program :Go to RUN mode.....Press LRN

TO RUN PROGRAM: (Using as example the V.C. on page I-16)
Enter 100, Press STO 20
Type 20352.13 (P.I.Sta): Press A
Type 240.95 (P.I.Elev): Press R/S
Type 5.5 +/- (Grade 1): Press R/S
Type 2.3 (Grade 2) : Press R/S
Type 625 (V.C. Curve L, in feet):Press R/S
READ: -0.624 (Constant "K")
Type 20450 (Desired Station in feet):Press R/S
READ: 246.0755 (Elev @ Sta 204+50)
FOR NEXT STATION: Press R/S
READ: -0.624 ("K" again)
Type 20500 (Next station, in feet):Press R/S
READ: 246.0422 (Elev @ Sta 205+00)

CONTINUE FOR ALL STATIONS DESIRED ON THE CURVE !

THE RIGHT ANGLE TRIANGLE



$$A + B + C = 180°$$

$$a^2 = c^2 - b^2$$

$$b^2 = c^2 - a^2$$

$$c^2 = a^2 + b^2$$

$\text{Sin } A = \frac{a}{c} = \text{Cos } B$

$\text{Cos } A = \frac{b}{c} = \text{Sin } B$

$\text{Tan } A = \frac{a}{b} = \text{Cot } B$

$\text{Cot } A = \frac{b}{a} = \text{Tan } B$

$\text{Sec } A = \frac{c}{b} = \text{Cosec } B$

$\text{Cosec } A = \frac{c}{a} = \text{Sec } B$

$a = c \text{ Sin } A = b \text{ Tan } A$

$a = c \text{ Cos } B = b \text{ Cot } B$

$b = c \text{ Cos } A = a \text{ Cot } A$

$b = c \text{ Sin } B = a \text{ Tan } B$

$c = \frac{a}{\text{Sin } A} = \frac{b}{\text{Cos } A}$

$c = \frac{a}{\text{Cos } B} = \frac{b}{\text{Sin } B}$

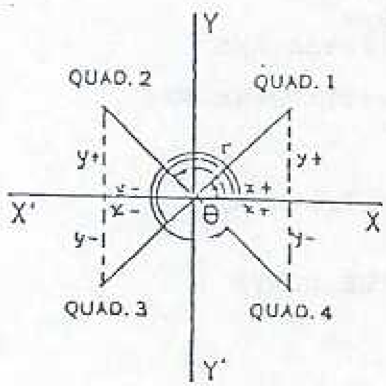
$\text{Vers } A = \frac{c - b}{c} = \text{Covers } B$

$\text{Covers } A = \frac{c - a}{c} = \text{Versin } B$

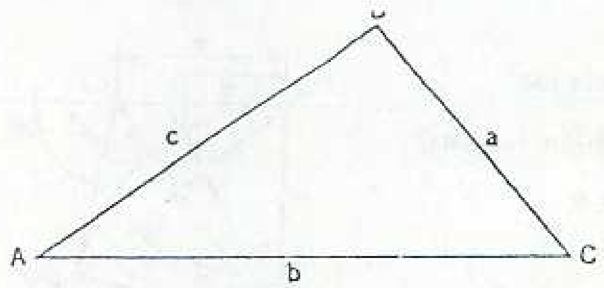
$\text{Exsec } A = \frac{c - b}{b} = \text{Coexsec } B$

$\text{Coexsec } A = \frac{c - a}{a} = \text{Exsec } B$

$\text{Area} = \frac{ab}{2}$



QUAD	SIN	COS	TAN	COT	SEC	CSEC
NO. 1	+	+	+	+	+	+
NO. 2	+	—	—	—	—	+
NO. 3	—	—	+	+	—	—
NO. 4	—	+	—	—	+	—



THE OBLIQUE TRIANGLE

Case 1 Given one side a and two angles A, B, the third angle C is found from $A + B + C = 180°$ and the other two sides b and c by the law of sines.

$$b = \frac{a}{\text{Sin } A} \times \text{Sin } B$$

$$c = \frac{a}{\text{Sin } A} \times \text{Sin } (A + B) = \frac{a}{\text{Sin } A} \times \text{Sin } C \qquad C = 180° - (A + B)$$

Case 2 Given two sides a, b, and the angle opposite one of them A, the angle opposite the other given side B is found by the law of sines; the third angle C is found from the relation $A + B + C = 180°$; the third side c is found by the law of sines.

$$\text{Sin } B = \frac{\text{Sin } A}{a} \times b \qquad C = 180° - (A + B) \qquad c = \frac{a}{\text{Sin } A} \times \text{Sin } C = \frac{b}{\text{Sin } B} \times \text{Sin } C$$

$$\text{Area} = \tfrac{1}{2}\, ab \text{ Sin } C$$

Case 3 Given two sides a, b, and the included angle C the third side c is found by the law of cosines and the remaining angles B, A by either the law of cosines or the law of sines.

$$c = \sqrt{a^2 + b^2 - 2\, ab \text{ Cos } C} \qquad \text{Sin } A = \frac{a}{c} \times \text{Sin } C \qquad B = 180° - (A + C)$$

$$\text{Cos } A = \frac{b^2 + c^2 - a^2}{2\, bc} \qquad \text{Cos } B = \frac{a^2 + c^2 - b^2}{2\, ac} \qquad \text{Area} = \tfrac{1}{2}\, ab \text{ Sin } C$$

Case 4 Given the three sides a, b, c, the three angles A, B, C are found by the law of cosines; or one angle A is found by the law of cosines and then the others by the law of sines.

In the following $s = \tfrac{1}{2}(a + b + c)$

$$\text{Sin } \tfrac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{bc}} \qquad \text{Cos } A = \frac{b^2 + c^2 - a^2}{2\, bc}$$

$$\text{Tan } \tfrac{1}{2} B = \sqrt{\frac{(s-a)(s-c)}{s(s-b)}} \qquad \text{Cos } B = \frac{a^2 + c^2 - b^2}{2\, ac}$$

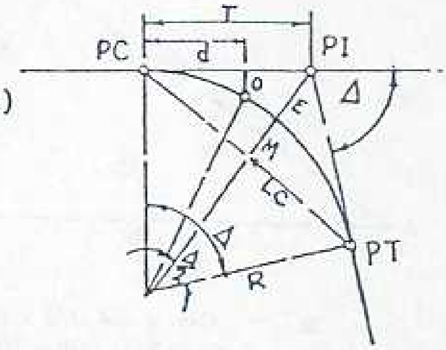
$$C = 180° - (A + B)$$

$$\text{Sin } 1/2\ C = \sqrt{\frac{(s-a)\ (s-b)}{ab}}$$

$$\text{Cos } B = \frac{c - b \text{ Cos } A}{a}$$

$$\text{Area} = \sqrt{s(s-a)(s-b)(s-c)}$$

$$\text{Cos } C = \frac{b - c \text{ Cos } A}{a}$$



CURVE FORMULAE

RADIUS: $R = 5729.58 \div D$ or $R = 100 \div (D \text{ in Radians})$

DEGREE: $D = 100\Delta \div L$ or $D = 5729.58 \div R$

TANGENT: $T = R \tan(\Delta/2)$

LENGTH: $L = 100\Delta \div D$ or $L = R\ (\Delta \text{ in Radians})$

LONG CHORD: $LC = 2R \sin(\Delta/2)$

MIDDLE ORDINATE: $M = R(1 - \cos(\Delta/2))$

EXTERNAL: $E = R \div (\cos(\Delta/2)) - R$, or $E = T \tan(\Delta/4)$

TANGENT OFFSET: $O = R - \sqrt{R^2 - d^2}$

DEFLECTION ANGLE (In Degrees) $\measuredangle = 5\,D \times \text{ARC (Ft.)} \div 1000$

DEFLECTION ANGLE (In Minutes) $\measuredangle = .3\,D \times \text{ARC (Ft.)}$

EXAMPLE

GIVEN: PI STA. 83 + 40.70; $\Delta = 45° \ 20'$; $D = 6° \ 30'$

FIND: RADIUS = 5729.58 ÷ 6.5 = 881.47

TANGENT = 881.47 x .41762565 = 368.12

LENGTH = 881.47 x .79121592 = 697.43

LONG CHORD = 2 x 881.47 x .38536926 = 679.38

MIDDLE ORDINATE = 881.47 x .07723755 = 68.08

EXTERNAL = (881.47 ÷ .92276244) - 881.47 = 73.78

TANGENT OFFSET (d = 300): $O = 881.47 - \sqrt{686,987.56} = 52.62$

PC STATION = PI STA. 83+40.70 - 368.12 = STA.79+72.58

PT STATION = PC STA. 79+72.58 + 697.43 = STA.86+70.01

DEFLECTIONS:

(To Sta.80+00) = .3 x 6.5 x 27.42 = 53.469' = 0° 53' 28"

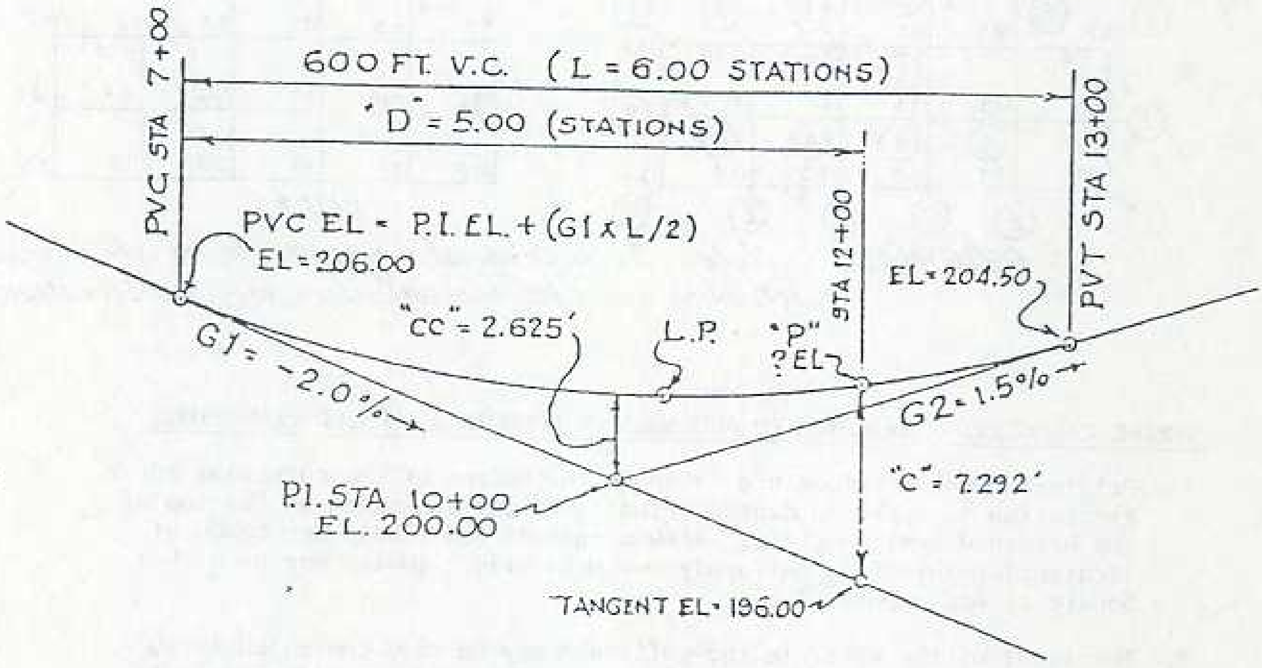
(For 100' Sta.) = 5 x 6.5 x 100 ÷ 1000 = 3.25° or 3° 15'

(For 6 Stations, to STA. 86+00) = 6 x 3.25 = 19.5° = 19° 30' 00"

(To PT STA.86+70.01) = 5 x 6.5 x 70.01 ÷ 1000 = 2.2753° = 2° 16' 31"

(Sum of Deflections should equal $\Delta/2$, (22° 40')) = 22° 39' 59"

V E R T I C A L   C U R V E   F O R M U L A E

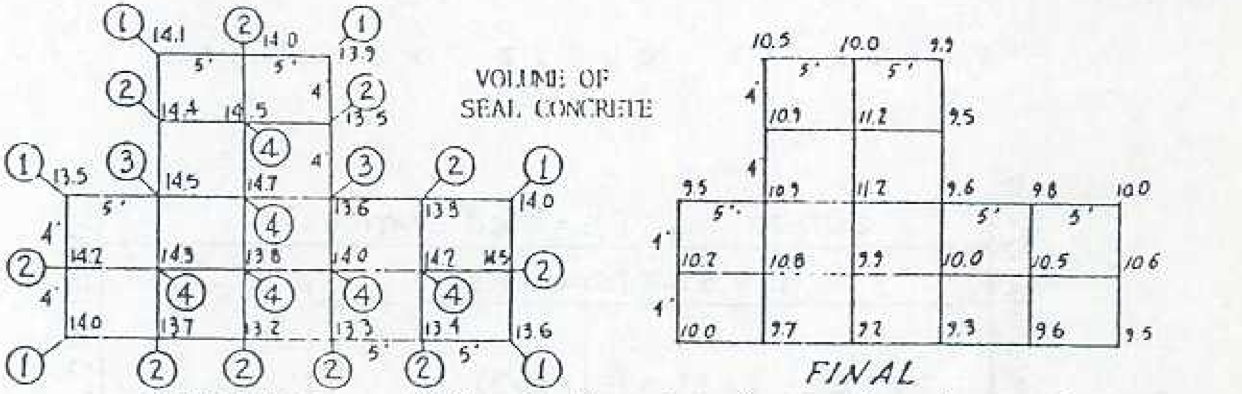


L = LENGTH OF V.C. IN STATIONS. (EXAMPLE, 6)
A = ALGEBRAIC DIFFERENCE IN GRADES (G1-G2)
A = " " " " -2.0 -(1.5) = -3.5
CC = CENTER CORRECTION. = AL/8 = -3.5X6/8 = - 2.625
C = CORRECTION FROM TANGENT ELEV. TO THE CURVE FOR ANY POINT "P"
C = D^2 A/2L OR C = D^2 K, WHERE K = A/2L: (K = -3.5/12 = -.29167)
C = 5^2 (-.291670): C = -7.292
FINISH GRADE ELEV. = TANGENT ELEV. MINUS "C"
" " " = PI ELEV.+((D-L/2)G1) - "C"
" " " = 200 + ((5-3)X(-2.0)-(-7.292))=203.292

ANOTHER METHOD((SEE I (15))(APPLICABLE TO ELECTRONIC CALCULATOR)

FINISH GRADE ELEV. = PVC ELEV + Dx(G1-DK)
" " " = 206.0 + 5X((-2.0) - (5X(-.29167))) = 203.292
STA OF LOW (OR HIGH) POINT (I.E. D FROM PVC) = LG1/A = 3.429(STA)
" " " " " " STA 7 + 3.429 = STA 10 + 42.90
ELEV. OF LOW OR HIGH POINT = PI ELEV + (LXG1X(G1-A)/2A)
" " " " " " = 200 + (6X(-2)X((-2)-(-3.5))/2X(-3.5))
" " " " " " = 202.57

NOTE: BOTH SAG AND CREST CURVES MAY BE PROCESSED BY THE ABOVE IF ALL SIGNS (+, -) ARE OBSERVED.



ORIGINAL   FINAL

Note: Both Original & Final sections show soundings taken when water level in cofferdam was 0.0 Elevation.

VOLUME CALCULATION BY WEIGHTED AVERAGES OF SOUNDINGS, RODS, OR ELEVATIONS

1. Original Cross Sections are taken on the bottom of the cofferdam after excavation to approved depth. Final sections are taken on the top of the hardened seal concrete. Both originals and finals are taken at identical points on a uniformly measured grid. (Units may be either Square or Rectangular.)

2. The level of the water in the cofferdam may be used conveniently to record soundings, but the same level must be used for both originals and finals (as in this example) or actual elevations determined from the soundings be determined for both. (Of course the recorded "shots" may also be minus rods from the H. I. elevation of a transit or level. In this case the actual elevations are used in the volume computations.)

3. The Volume in cubic yards is determined by multiplying each "shot" (sounding, rod, or elevation) of the ORIGINALS by its WEIGHT FACTOR (circled figure), and adding these products. From this sum is subtracted a similar sum of the products of the FINAL "shots" times the weight factors. This difference is multiplied by the area (square feet) of the UNIT rectangle (or square) and divided by 108.* See example below.

FACTOR   ORIGINAL 'SHOTS'

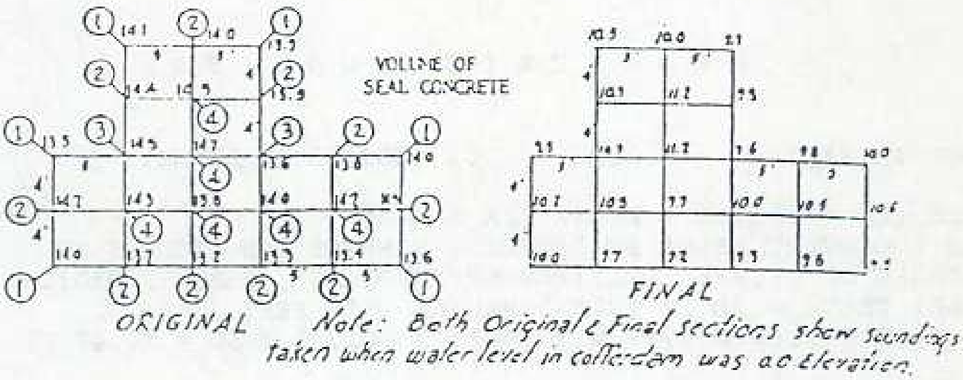
```
1 x (14.1 + 13.9 + 13.5 + 14.0 + 14.0 + 13.6) = --------------------------- 83.1
2 x (14.0 + 14.4 + 13.5 + 13.8 + 14.2 + 14.5 + 13.7 + 13.2 + 13.3 + 13.4) = 276.0
3 x (14.5 + 13.6) = ---------------------------------------------------------- 84.3
4 x (14.5 + 14.7 + 14.3 + 13.8 + 14.0 + 14.2) = ---------------------------342.0
                                                                           785.4
```

FACTOR   FINAL 'SHOTS'

```
1 x (10.5 + 9.9 + 9.5 + 10.0 + 10.0 + 9.5) = ------------------------------ 59.4
2 x (10.0 + 10.9 + 9.5 + 9.8 + 10.2 + 10.6 + 9.7 + 9.2 + 9.3 + 9.6) = ------197.6
3 x (10.9 + 9.6) = ----------------------------------------------------------- 61.5
4 x (11.2 + 11.2 + 10.8 + 9.9 + 10.0 + 10.5) = ----------------------------254.4
                                                                           572.9
```

VOLUME = (785.4 - 572.9) x (4' x 5') ÷ 108* = 39.352 C.Y.

*(4 x 27)



VOLUME CALCULATION BY WEIGHTED AVERAGES OF SOUNDINGS, RODS, OR ELEVATIONS

PROGRAMMING VOLUME CALCULATIONS BY "WEIGHTED AVERAGE"

This example serves to illustrate that "Keystroke Programming" is practical even for seldom encountered problems such as this relatively rare VOLUME calculation. The PROGRAM to do this is short and simple, yet saves time & promotes accuracy in the computations.

W E I G H T E D   A V E R A G E   P R O G R A M S

USING T.I.(59) CALCULATOR	USING H.P.(15C) CALCULATOR
Press RST, LRN (Set LEARN Mode)	Press f CLEAR PRGM (Reset to 0)
2nd LBL, A, 0, STO 00, STO 03	" g P/R (Set LEARN Mode)
R/S (Enter WEIGHT FACTOR)	f LBL A, 0, STO 0, STO 3, f LBL 1
STO 01, X	R/S (Enter WEIGHT FACTOR)
R/S (Enter Elevation)	STO 1, R/S (Enter Elevation)
STO 02, =, SUM 00, 1, SUM 03	STO 2, X, STO + 0, 1, STO + 3
RCL 01, GTO 007 (End Program)	RCL 1, GTO 1 (End Program)
Press LRN (Set RUN Mode)	Press g P/R (Set RUN Mode)

USING THESE PROGRAMS FOR THE ABOVE SEAL CONCRETE VOLUME PROBLEM
Both calculators are in RUN Mode

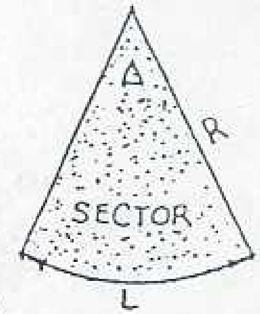
Press A (For T.I.) or Press f A (For H.P.)
(Both Calculators)

Read (0) Enter 1 (1st Orig.Wt.Fctr), Press R/S, Enter 14.1 (1st Original Sounding), Press R/S
Read (1) Press R/S, Enter 13.9 (2nd Orig Sounding), Press R/S
Read (1) Press R/S, Enter 13.5 (Next Orig Sounding),Press R/S
(Continue as above for all "1" Factors, after last "R/S") then:
Read (1) Change to (2) and Press R/S, Enter 14.0, Press R/S
Read (2) Press R/S, Enter 14.4 (Next Orig Sounding),Press R/S
(Continue as above for all "2","3",&"4" Factors), At last R/S
Read (4) Press RCL 00 (for TI) or Press RCL 0 (for HP)
Read 785.4...STO 04 (for TI) or STO 4 (for HP)

Press A (For T.I.) or Press f A (For H.P.)
Enter 1 (1st Final Wt.Factr), Press R/S Enter 10.5 (1st Final Sounding) Press R/S
Repeat the above sequence for all points on the FINAL grid, then when the last R/S reads "4" :
Press RCL 00 (for TI) or Press RCL 0 (for HP): (Read 572.9)
For TI : +/-, +, RCL 04 = X 4 X 5 ÷ 108 = (Read 39.352 C.Y.)

For HP: CHS, RCL 4, +, 4, X, 5, X, 108, ÷ (Read 39.352 C.Y.)

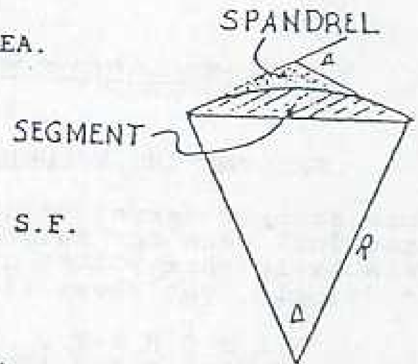
G E O M E T R I C   G O O D I E S



ONE DEGREE IN RADIANS = $\pi/180^\circ$ = .0174532925 (RADIANS)

ARC LENGTH (L) = RADIUS X DELTA (IN RADIANS)
METHOD : CONVERT DELTA IN DEGREES, MINUTES AND SECONDS TO DECIMALS OF DEGREE. MULTIPLY BY "RADIANS", THEN BY RADIUS.
EXAMPLE: DELTA = $30^\circ 20' 28''$ AND RADIUS = 50 FEET.
30 + (20 + (28/60))/60 = 30.3411° X .01745 X 50 = 26.47 FT.

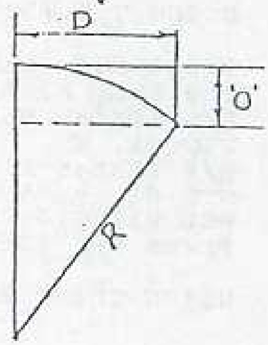
AREA OF SECTOR = $R^2/2$ X DELTA (IN RADIANS).
EXAMPLE: $\Delta = 34^\circ 32' 24''$ AND R = 75 FT. FIND AREA.
AREA = 34 + (32+(24/60))/60 = 34.5400°
X .01745 X $75^2/2$ = 1695.16 S.F.



AREA OF SEGMENT = $R^2/2$ X(Δ IN RADIANS - SINΔ)
EXAMPLE: $\Delta = 36^\circ 20'$ AND RADIUS = 60 FEET.
AREA=$60^2/2$ X((36.3333 X.01745)-.59248)=74.76 S.F.

AREA OF SPANDREL = R^2 X (TAN$\frac{\Delta}{2}$ - $\frac{\Delta}{2}$ RADIANS).

EXAMPLE: $\Delta = 36^\circ 20'$ AND RADIUS = 60 FEET.
AREA = 60^2X (TAN(18.1667) -18.1667 RADIANS) =
AREA = 60^2X (.32814 - .31701) = 40.07 SQ.FT.



TANGENT OFFSET : "O" = R $-\sqrt{R^2 - D^2}$.
EXAMPLE: R = 50 FT. AND D = 30 FT. SOLVE FOR "O"

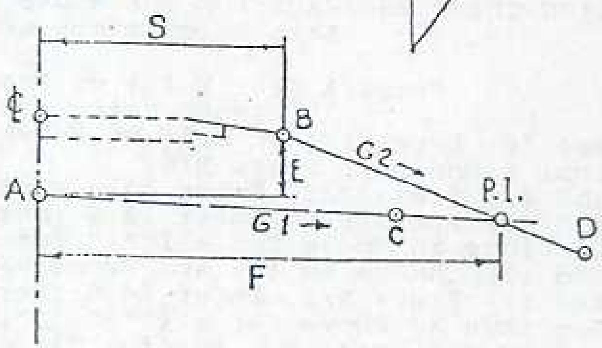
TAN OFFSET "O" = 50 $-\sqrt{2500 - 900}$:   "O" = 10 FT.

INTERSECT GRADES

T.	X	Y
℄	0	179.35
A	0	176.18
B	22	178.51
C	32	175.54
D	50	173.84

GIVEN:

S=22:
E=2.33
G1=1/50=.02
G2=1/6= .1667



(IF G1 IS UNK), G1=(AY-CY)/(CX-AX)

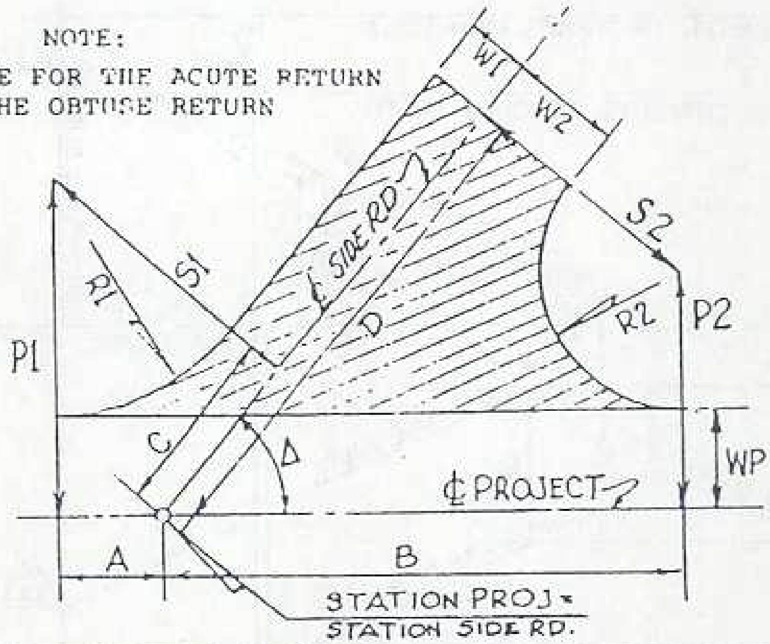
(IF G2 IS UNK), G2=(BY-DY)/(DX-BX)

=(E +(S X G2))/(G2 - G1)= (2.33 + (22 X.1667))/(.1667-.02)= 40.88 FT.

LEV OF PI = AY - (F X G1): EL = 176.18 - (40.88 X .02) = 175.36

T U R N O U T   C A L C U L A T I O N S

NOTE:
P1,R1,S1, ARE FOR THE ACUTE RETURN
& P2,R2,S2 THE OBTUSE RETURN



S T A T I O N I N G	
ALONG PROJECT (P)	ALONG SIDE ROAD (S)
A=(S1/SINΔ) - (P1/TANΔ)	C=(P1/SINΔ) - (S1/TANΔ)
B=(S2/SINΔ) + (P2/TANΔ)	D=(P2/SINΔ) + (S2/TANΔ)

A R E A   O F   T U R N O U T

*RDWY : $((2 \times R2/\tan\frac{\Delta}{2}) + ((W1+W2)/\tan\Delta)) \times (W1+W2)/2$ = SQ.FT.
R1 SPANDREL : $R1^2 \times (\tan\frac{\Delta}{2} - \frac{\Delta}{2}$ RADIANS) = SQ.FT.
R2 SPANDREL : $R2^2 \times (\cot\frac{\Delta}{2} - (\frac{180-\Delta}{2})$ RADIANS) = SQ.FT.
TOTAL SQ.FT.

E X A M P L E

Δ=50°: WP=12': W1=7': W2=13': R1=28': R2=16': PI STA=150+00 PROJ =10+00 S.R.
FIND : P1 = 40': S1 = 35': P2 = 28': S2 = 29'

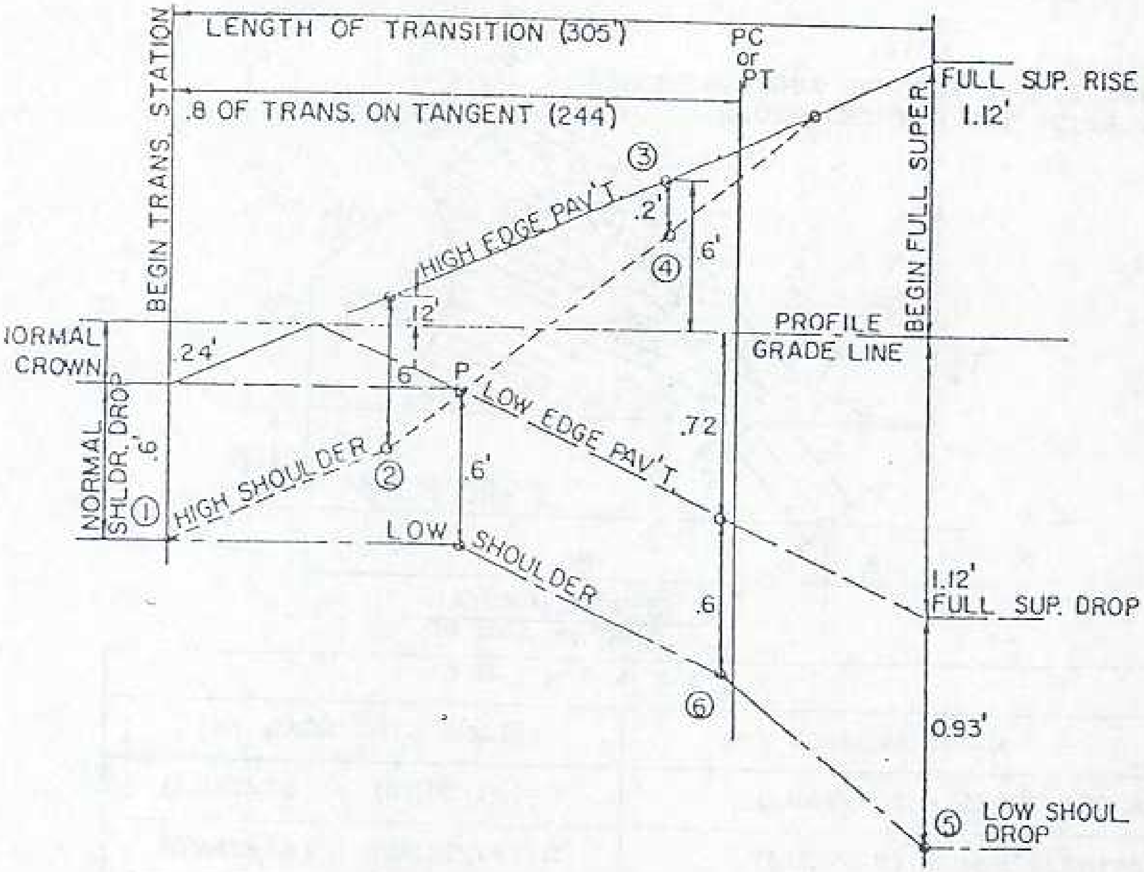
SOLUTION: STATIONS:
PROJECT: A=12.13, STA 149+87.87: B=61.35, STA 150+61.35
SIDE RD: C=22.85, STA 10+22.85: D=60.89, STA 10+60.89

SOLUTION: AREA:
AREA RDWY = 854.06 SQ. FT.
AREA R1 SPANDREL = 23.57 SQ. FT.
AREA R2 SPANDREL = 258.63 SQ. FT.

TOTAL AREA = 1136.26 SQ. FT.

* If D < C, THEN RDWY AREA CHANGES TO:
$((2 \times R1 \times \tan \Delta/2) - (W1+W2)/\tan\Delta)) \times (W1+W2)/2$

SUPERELEVATION TRANSITIONS



1. DETERMINE NORMAL CROWN (MULTIPLY WIDTH X PAVEMENT SLOPE) 12' X .02 = 0.24'
2. DETERMINE SUPERELEVATION (MULTIPLY WIDTH X SUPER. RATE*) 12 X .093* = 1.116
3. ADD NORMAL CROWN PLUS SUPERELEVATION = TOTAL RISE = 0.24 + 1.116 = 1.356'
4. FIND TRANSITION LENGTH (HIGH SIDE) MULTIPLY TOTAL RISE BY SLOPE RATIO* 1.356 x 225* = 305.10 (USE 305)

GRAPHIC SOLUTION:

5. PLOT THESE FACTORS USING AN EXAGGERATED SCALE, AS 1" = 50 FEET HORIZ. AND 1" = .5 FT. VERTICAL REFER DIMENSIONS TO A HORIZONTAL PROFILE GRADE LINE
6. DRAW A HEAVY LINE FROM NORMAL CROWN TO HIGH SIDE (BEGIN FULL SUPEREL.) THIS REPRESENTS THE ELEVATION OF THE EDGE OF PAVEMENT (HIGH SIDE) RELATIVE TO THE PROFILE GRADE LINE.
7. LAY OUT THE FULL SUPER. DROP AS SHOWN AND CONNECT THIS POINT TO THE POINT WHERE THE EDGE PAVEMENT (HIGH SIDE) CROSSES THE PROFILE GRADE LINE. DRAW THIS LINE LIGHTLY.
8. EXTEND A DASHED LINE HORIZONTALLY FROM NORMAL CROWN TO INTERSECT THE PREVIOUS LIGHT LINE. LABEL THIS POINT "P". CONTINUE THIS LINE SLOPING DOWNWARD, FOLLOWING THE LIGHT LINE TO FULL SUPER. DROP. THIS LINE REPRESENTS THE ELEVATION OF THE LOW EDGE OF PAVEMENT RELATIVE TO THE PROFILE GRADE LINE.
9. THE NORMAL SHOULDER DROP IS FOUND BY MULTIPLYING THE SHOULDER WIDTH BY .06 (EXAMPLE: 10 x .06 = .6). THIS DROP IS LAID OFF VERTICALLY BELOW THE NORMAL CROWN LINE AT THE BEGIN TRANSITION STATION. LABEL THIS POINT (1).

*SUPERELEVATION RATE AND SLOPE RATIO ARE OBTAINED FROM INDEX 510, 511

SUPERELEVATION TRANSITIONS (CONT'D)

10. THE BEHAVIOR OF THE SHOULDER ON THE HIGH SIDE IS COMPLEX, BUT MAY BE PLOTTED AS FOLLOWS: MULTIPLY THE PAVEMENT WIDTH BY .01 (EXAMPLE 12 x .01 = .12). LOCATE THE POINT WHERE THE HIGH EDGE OF PAV'T. ATTAINS THIS DISTANCE ABOVE PROFILE GRADE LINE. LAY OUT THE SHOULDER DROP (.6) VERTICALLY BELOW, AND LABEL THIS POINT (2). NEXT, MULTIPLY PAV'T WIDTH BY .05 (12 x .05 = .6) AND FIND THE POINT WHERE THE HIGH EDGE OF PAV'T. REACHES THIS DISTANCE ABOVE P.G.L. LABEL THIS POINT (3). BELOW THIS POINT LAY OFF A DISTANCE EQUAL TO .02 x SHOULDER WIDTH (.02 x 10 = .2) LABEL THIS POINT (4). CONNECT (1), (2), (4) with A DOTTED LINE AND EXTEND THIS SLOPE TO INTERSECT THE HIGH EDGE OF PAV'T. FROM HERE THE SHOULDER LINE AND HIGH EDGE PAVEMENT LINE ARE IDENTICAL.

11. MULTIPLY THE SHOULDER WIDTH BY SUPEREL. RATE OR BY .06 (WHICHEVER IS LARGEST): (EXAMPLE 10 x .093 = .93'). LAY OFF THIS DISTANCE VERTICALLY BELOW THE LOW PAVEMENT EDGE AT FULL SUPEREL. STATION. LABEL THIS POINT (5).

12. ESTABLISH THE POINT WHERE THE CROSS SLOPE OF THE LOW LANE EXCEEDS THE NORMAL SHOULDER SLOPE OF .06 FT./FT. AS FOLLOWS: MULTIPLY SHOULDER SLOPE BY LANE WIDTH (.06 x 12 = .72'). LOCATE THE STATION AT WHICH THE LOW EDGE OF PAV'T. IS .72 FT. BELOW PROFILE GRADE LINE. AT THIS POINT PLOT THE LOW SHOULDER .6 FT. BELOW THE EDGE OF PAV'T. LABEL THIS POINT (6). NOW TRACE A DASH-DOT LINE AS FOLLOWS: EXTEND THE NORMAL SHOULDER LINE HORIZONTALLY TO A POINT DIRECTLY BELOW POINT "P", SLOPE DOWNWARD TO POINT 6, THEN TO POINT 5. THIS DASH-DOT LINE REFLECTS THE ELEVATION OF THE LOW SHOULDER RELATIVE TO THE PROFILE GRADE LINE.

13. MULTIPLY THE TRANSITION LENGTH (HIGH SIDE) BY .8 (EXAMPLE 305 x .8 = 244'). LAY OUT THIS DISTANCE FROM BEG. TRANS. ALONG THE PROFILE GRADE LINE. DRAW A VERTICAL LINE THROUGH THIS POINT. THIS REPRESENTS THE PC STATION.

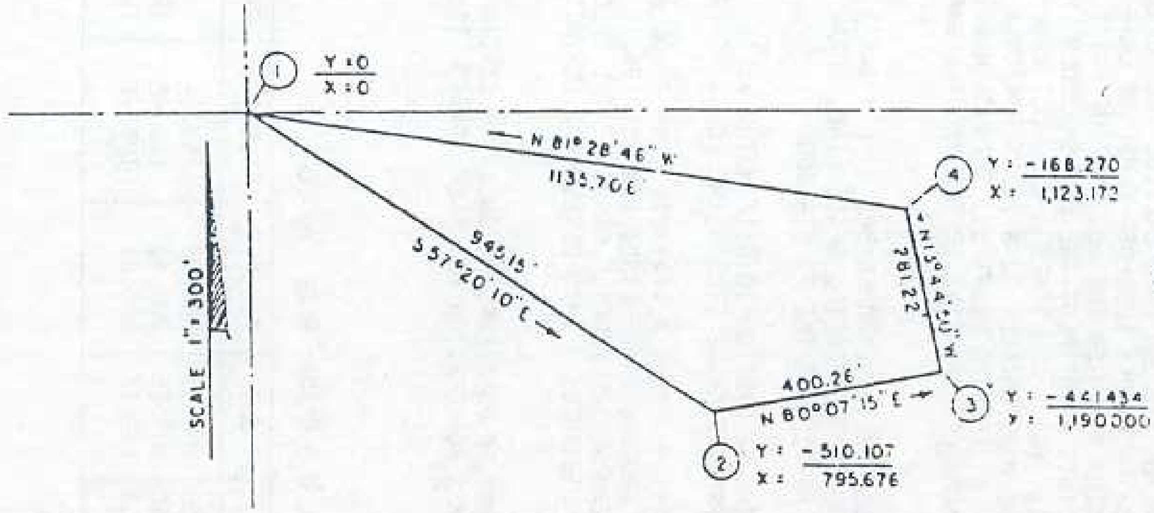
14. SUBTRACT THE DISTANCE ABOVE (244) FROM THE PC STATION TO ATTAIN THE BEGIN. TRANS. STA. ESTABLISH ACTUAL STATION TICS ON PROFILE GRADE LINE USING PC AS REFERENCE.

15. TO USE, PLOT REQUIRED STATIONS ON TRANSITION. DRAW A VERTICAL LINE THROUGH EACH AND READ DISTANCES (ABOVE OR BELOW PROFILE GRADE LINE) FOR BOTH PAV'T. EDGES AND SHOULDERS. FROM PROFILE, DETERMINE THE PROFILE GRADE AT THE SPECIFIED STATION, AND ADD OR SUBTRACT THE SCALED DISTANCES. THIS GIVES TRUE ELEVATIONS FOR PLOTTING THE CROSS SECTION.

16. FOR THE PT TRANSITION, THE SAME SKETCH MAY BE USED,ERASING ONLY THE STATION TICS. LOCATE THE PT STATION AT THE FORMER PC LOCATION AND MARK STATION TICS (INCREASING FROM RIGHT TO LEFT).

EXAMPLE:
5 DEG. CURVE RT: PC STA 115+25.69; PT 122+75.94
2 - 12' LANES: 10' SHOULDERS; DESIGN SPEED 55 MPH; 0.0 GRADE; ELEV. 200.00

STA.	LT.SHO.	LT.E.PVT.	RT.E.PVT.	RT.SHO.	STA.	LT.SHO.	LT.E.PVT.	RT.E.PVT.	RT.SHO.
113+0	199.25	199.84	199.76	199.16	122+50	200.96	200.96	199.04	198.23
114+0	199.83	200.29	199.71	199.11	123+50	200.25	200.52	199.48	198.89
115+0	200.65	200.73	199.27	198.66	124+50	199.47	200.07	199.76	199.16
116+0	201.12	201.12	198.88	197.95					

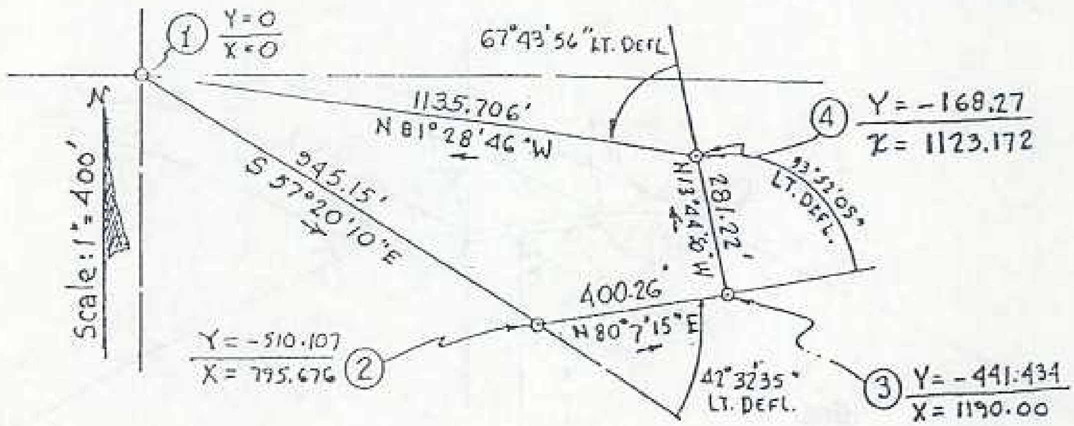


COORDINATES AND AREA BY "DMD"

CSE	DISTANCE	BEARING	COSINE	SINE	LATITUDE (COS x DIST.)		DEPARTURE (SINE x DIST.)		COORDINATES		DOUBLE MERIDIAN DISTANCE	DOUBLE AREA
					NORTH	SOUTH	EAST	WEST	NORTH	EAST		
00					+	−	+	−	Y 0.0	X 0.0		
1-2	945.150	S57°20'10" E	.53970984	.84185110		-510.1068	795.6756		-510.1068	795.6756	795.6756	(-) 405,879.488
2-3	400.260	N80°07'15" E	.17157089	.98517177	68.6730		394.3249		-441.4338	1,190.0004	1,985.6770	136,362.260
3-4	281.220	N13°44'50" W	.97135359	.23763880	273.1641			-66.8288	-168.2697	1,123.1716	2,313.1721	631,875.468
4-1	1,135.706	N81°28'46" W	.14816422	.98896277	168.2710			-1,123.1711	+ 0.0013	0.0007	1,123.1723	188,997.329
				TOTALS	510.1081	-510.1068	1190.0005	-1,189.9999				551,355.57
		ERROR OF CLOSURE			-0.0013		+0.0006				÷ 2 =	275,677.78 S.F.

NOTE: "DMD", (DOUBLE MERIDIAN DISTANCE) IS DETERMINED THUS: (NEW DMD) = (PREVIOUS) DMD PLUS DEPARTURE OF PREVIOUS COURSE, PLUS DEPARTURE OF NEW COURSE.
DOUBLE AREAS ARE PRODUCTS OF DMD TIMES LATITUDE. (SIGN DETERMINED BY LATITUDE).
TOTAL AREA IS ONE HALF THE SUM OF ALL DOUBLE AREAS.

H.P. (15-C) PROGRAM FOR TRAVERSE



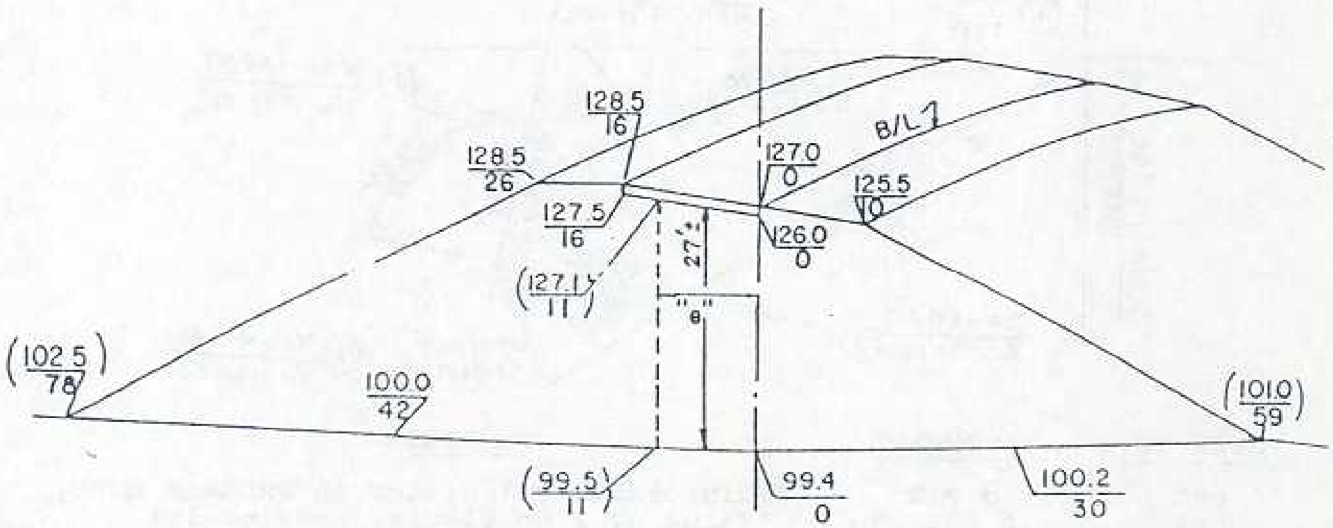
STEP NO.	COMMAND	REMARKS
000	g P/R	(This places calculator in PROGRAM MODE)
001	f LBL .3	(Value of X on display previously)
002	STO 1	
003	R/S	(Stop to enter value of Y)
004	STO 2	
005-6	0, STO 0	
007	f LBL .4	
008-9	RCL 2, STO .2	
010-11	RCL 1, STO .1	*(CLOCKWISE from NORTH)
012	R/S	(Stop to enter AZI in D.MS)*
013	g2	(Converts D.MS to Dec Deg)
014	R/S	(Stop to enter DISTANCE)
015	f 1	(Polar coord to Rect.(X & Y))
016	STO + 2	
017	X⇄Y	(Exchange Stack Registers)
018-19	STO + 1, RCL 1	
020	R/S	(Stop to read X coordinate)
021-22	RCL 2, R/S	(Stop to read Y coordinate)
023-31	RCL .2, −, ENTER, RCL .1, RCL 1, +, X, 2, ÷	
032	STO + 0	(Incremental Area Stored Accum.)
033	GTO .4	(Now press g P/R to goto RUN MODE)

USING THIS PROGRAM TO SOLVE THE TRAVERSE (ABOVE)

With calculator in RUN MODE, type 0, press GSB .3 . Type 0, press R/S. Next determine the AZI (Clockwise from N), of the 1st course, which is 122 deg, 39 min, 50 sec. Type 122.3950 & press R/S.(Read 122.6639).Now enter DIST (945.15).press R/S. Read 795.676 (X coord of Pt 1). Press R/S. Read -510.107 (Y coord) Press R/S again. Read 795.676 again. Now type the AZI of 2nd cou. in D.MS (80.0715), press R/S. Read 80.1208 (deg). Type the DIST 400.26 and press R/S. Read 1190.000 (X coord, PT 3). Press R/S, Read -441.433 (Y coord,PT 3).
Press R/S again, Read 1190 once more. This is the signal to enter the AZI for the next course. This bearing lies in the NW quadrant, and may be entered either as 346 deg 15 min 10 sec, or as a NEG AZI (-13.4450). Repeat the above process for this course and for the final course. Upon pressing the final R/S --after having read the 2nd display of the final X coord, the TOTAL AREA is complete, and may be accessed by pressing RCL 0.

(Do so, and read the TOTAL AREA as 275,677.78 SQ.FT.)

FINDING THE APPROXIMATE CENTROID OF X-SECTIONS



IN ORDER TO APPLY THE VOLUMETRIC CURVE CORRECTION TO HAND PLOTTED EARTHWORK VOLUMES, THE DIMENSION "e" IS REQUIRED. THIS IS THE DISTANCE FROM THE BASELINE TO THE CENTROID (CENTER OF GRAVITY) OF THE CROSS SECTION. TO FIND THE EXACT CENTROID BY TAKING MOMENTS ABOUT THE B/L IS TOO TIME CONSUMING TO DO BY "HAND METHODS". HOWEVER, THE "CENTER OF AREA" MAY BE READILY FOUND INSTEAD; AND IN TYPICAL ROADWAY SECTIONS IS CLOSE ENOUGH TO THE CENTROID TO BE UTILIZED IN MAKING VOLUME-CURVE CORRECTIONS.

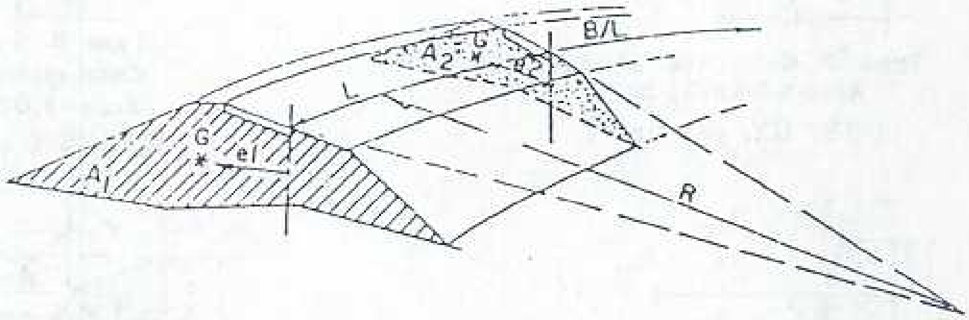
THE AREAS LEFT AND RIGHT OF THE B/L ARE FOUND SEPARATELY. IN DESIGN THESE MAY BE FOUND WITH A PLANIMETER OR BY "STRIPPING", BUT FOR FINAL PAY QUANTITIES, THE AREAS ARE CALCULATED FROM THE COORDINATES (ELEVATION VS DISTANCE FROM B/L). (AREA METHODS ARE SHOWN IN THE ELECTRONIC CALCULATOR SECTION). THE SMALLER AREA IS DEDUCTED FROM THE LARGER AND THE DIFFERENCE IS HALVED. THIS AREA IS DIVIDED BY THE HEIGHT OF AN ORDINATE NEAR THE ESTIMATED CENTER, WHICH GIVES A TRIAL VALUE OF "e". EXAMPLE:

(IN FIG. ABOVE) AREA LEFT = 1486.6 S.F.
MINUS AREA RIGHT − 900.35 S.F.

DIFFERENCE = 58625 S.F. ÷ 2 = 293.125 S.F. GUESSING CENTER TO BE ABOUT 12 FT. LEFT, A SCALED ORDINATE (FROM BOTTOM OF BASE TO GROUND AT 6 FT. LEFT) MEASURES 27 FT.

293.125 S.F. ÷ 27 = 10.8 . PICKING OFF ELEVATIONS 127.1 & 99.5 (at 11' LT.) THIS AREA IS FOUND TO BE 298 (TOO MUCH BY 5 S.F.). SINCE AN ORDINATE HERE IS 28 FT., USE 11 FEET LEFT FOR "e". (EXACT CENTROID FOUND BY MOMENTS ABT. B/L = -10.35 FT.)

VOLUMETRIC CORRECTION FOR CURVATURE



$$C = L(A1e1 + A2e2) \div (54R)$$

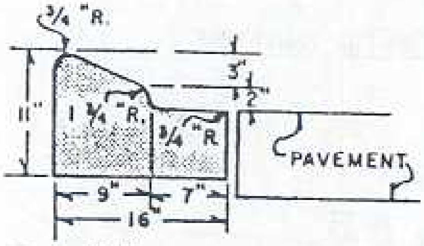
C(CU.YDS) VOLUMETRIC CORRECTION FOR CURVATURE - MAY BE POSITIVE OR NEGATIVE ACCORDING TO THE NET VALUE WITHIN THE PARENTHESES.
L(FT) BASELINE DISTANCE BETWEEN CROSS SECTIONS.
R(FT) RADIUS TO THE STATIONED BASELINE.
A1(SQ.FT) AREA OF THE FIRST CROSS SECTION OF ANY PAIR CONSIDERED.
A2(SQ.FT) AREA OF THE SECOND CROSS SECTION OF ANY PAIR CONSIDERED.
e1(FT) ECCENTRICITY (DISTANCE FROM B/L TO CENTROID) OF FIRST SECTION.
e2(FT) ECCENTRICITY OF SECOND SECTION. NOTE: "e" VALUES MAY BE POSITIVE OR NEGATIVE. "e" IS NEGATIVE IF CENTROID "G" (CENTER OF GRAVITY) LIES TO RIGHT OF B/L OF A RIGHT CURVE OR TO LEFT OF B/L OF A LEFT CURVE.

EXAMPLE: IN ABOVE FIGURE, IF R=310 FT., L=100 FT., A1 = 1080 S.F. A2 = 890 S.F., e1 = +8 FT. AND e2 = +10 FT., THEN:

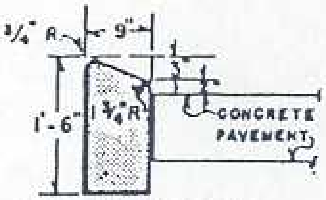
(THE VOLUME OF EARTH IS FIRST CALCULATED BY AVERAGE END AREA METHOD, AS IF ON A TANGENT ALIGNMENT: THE CORRECTIONS ARE THEN COMPUTED USING THE ABOVE FORMULA.)

"TANGENT" VOLUME (A1 + A2) x L ÷ 54* = C.Y.	
"TANGENT" VOLUME (1080 + 890) x 100 ÷ 54 =	3648.15 C.Y.
CORRECTION: ((A1 x e1) + (A2 x e2)) x L ÷ 54 ÷ R=	
((1080 x 8) + (890 x 10)) x 100 ÷ 54 ÷ 310 =	+104.78 C.Y.
TOTAL VOLUME	3752.93 C.Y.

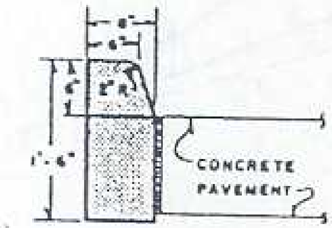
* (A1 + A2) ÷ 2 x L ÷ 27 = (A1 + A2)L ÷ 54



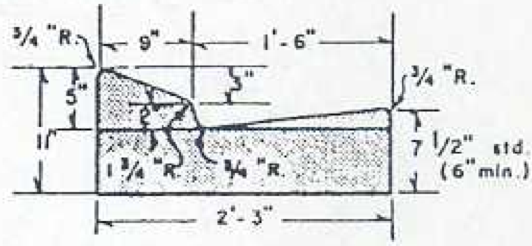
Type "A" Concrete Channelizing
Area = 0.88193 Sq.ft.
.0327 C.Y. per lin. ft.



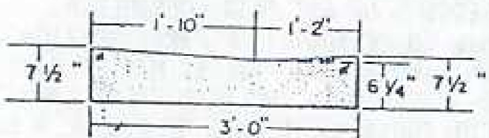
Type B Concrete
Channelizing Curb –
Area = 1.02748 sq.ft.
.0381 C.Y. per lin. ft.



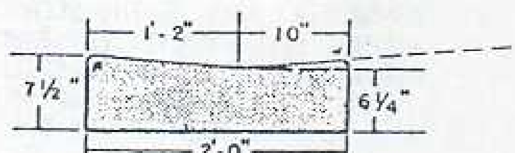
Type D Concrete
Median Curb –
Area = 0.9556 sq.ft.
.0354 C.Y. per lin. ft.



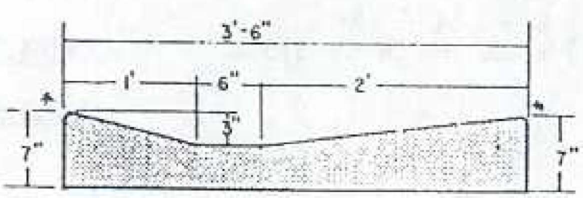
Type "E" Curb and Gutter
Area = 1.43401 sq.ft.
Vol. = .0531 C.Y. per lin. ft.



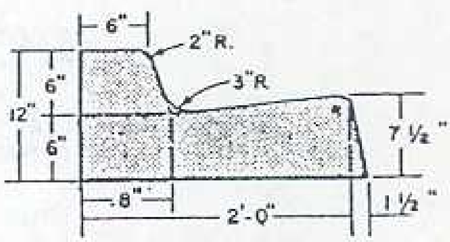
Section "A-A" of Valley
Gutter –
Area = 1.71676 sq.ft.
Vol. = .0636 C.Y. per lin. ft.



Concrete Drop Curb
Area = 1.14369 sq.ft.
Vol. = .0424 C.Y. per lin. ft.

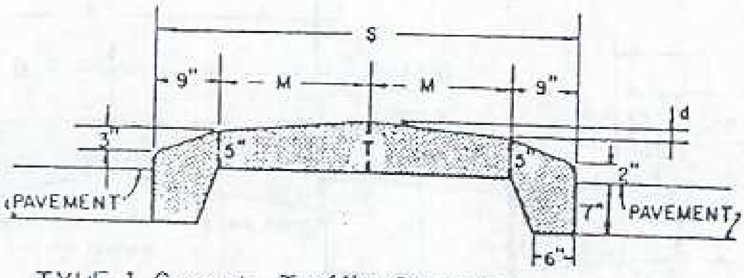


Shoulder Gutter
Area = 1.5391 sq. ft.
Vol. = .0570 C.Y. per lin. ft.



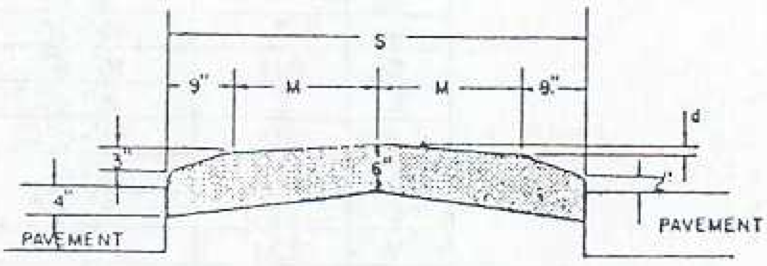
Type "F" Curb and Gutter
6" Curb Adjacent to
Flexible Pavement –
Area = 1.41842 sq.ft.
Vol. = .0525 C.Y. per lin. ft.

NOTE: * = 3/4" Radius



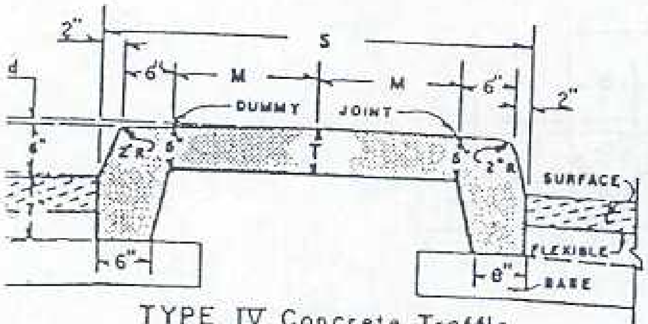
TYPE I Concrete Traffic Separator

S	d	M	T	C.Y. per lin. ft.
4'	1/4"	1'-3"	5 1/4"	.0826 C.Y.
6'	1/2"	2'-3"	5 1/2"	.1160 "
8'-6"	3/4"	3'-6"	5 3/4"	.1592 "

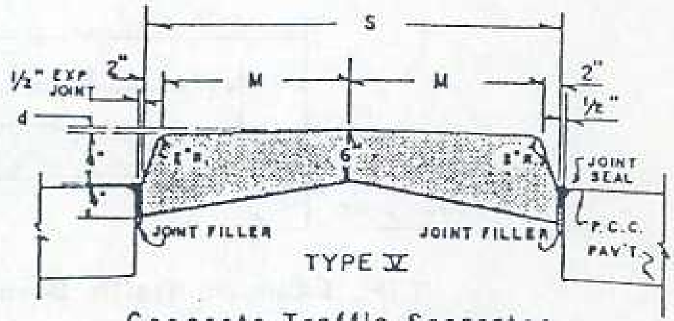


TYPE II Concrete Traffic Separator

S	d	M	T	C.Y. per lin. ft.
4'	1/4"	1'-3"	-	.0849 C.Y.
6'	1/2"	2'-3"	-	.1306 "
8'-6"	3/4"	3'-6"	-	.1879 "



TYPE IV Concrete Traffic Separator



Concrete Traffic Separator

S	d	M	T	C.Y. per lin. ft.
4'	1/4"	1'-4"	5 1/4"	.0887 C.Y.
6'	1/2"	2'-4"	5 1/2"	.1225 "
8'-6"	3/4"	3'-7"	5 3/4"	.1662 "

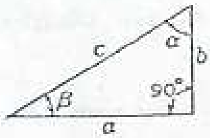
S	d	M	T	C.Y. per lin. ft.
4'	1/4"	1'-10"	-	.0954 C.Y.
6'	1/2"	2'-10"	-	.1446 "
8'-6"	3/4"	4'-1"	-	.2062 "

CURB DEDUCTION FOR INLETS		
TYPE	INDEX NO.	DEDUCTION (FT.)
1	210	13'-0"
2	"	20'-0"
3	"	9'-0"
4	"	12'-0"
5	211	10'-6"
6	"	16'-0"
7	212	13'-0"
8	213	13'-0"
S	220	5'-4"
V	221	"

Ia. Plane Rectilinear Figures

Notation. Lines, $a, b, c, \ldots$; angles, $\alpha, \beta, \gamma, \ldots$; altitude (perpendicular height), h; side, s; diagonals, $d, d_1, \ldots$; perimeter, p; radius of inscribed circle, r; radius of circumscribed circle, R; area, A.

1. Right Triangle



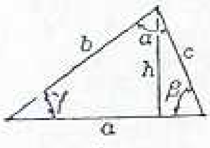
(One angle 90°)

$p = a + b + c$; $c^2 = a^2 + b^2$;

$A = \frac{ab}{2} = \frac{a^2}{2}\tan\beta = \frac{c^2}{4}\sin 2\beta = \frac{c^2}{4}\sin 2\alpha.$

For additional formulas, see *General Triangle* below, and also trigonometry.

2. General Triangle (and Equilateral Triangle)



For General Triangle:

$p = a + b + c.$ Let $s = \frac{1}{2}(a + b + c)$.

$r = \frac{\sqrt{s(s-a)(s-b)(s-c)}}{s}$; $R = \frac{a}{2\sin\alpha} = \frac{abc}{4rs}$;

$A = \frac{ah}{2} = \frac{ab}{2}\sin\gamma = \frac{b^2\sin\gamma\sin\alpha}{2\sin\beta} = rs = \frac{abc}{4R}$ $= \sqrt{s(s-a)(s-b)(s-c)}$

Length of median to side $c = \frac{1}{2}\sqrt{2(a^2 + b^2) - c^2}$

Length of bisector of angle $\gamma = \frac{\sqrt{ab[(a+b)^2 - c^2]}}{a + b}$

For Equilateral Triangle ($a = b = c = s$ and $\alpha = \beta = \gamma = 60°$):

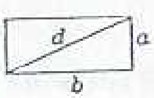
(Equal sides and equal angles) Note: This "s" is "side" (NOT $\frac{a+b+c}{2}$)!

$p = 3s$; $r = \frac{s}{2\sqrt{3}}$; $R = \frac{s}{\sqrt{3}} = 2r$;

$h = \frac{s\sqrt{3}}{2}$; $s = \frac{2h}{\sqrt{3}}$; $A = \frac{s^2\sqrt{3}}{4}$.

For additional formulas, see trigonometry.

3. Rectangle (and Square)



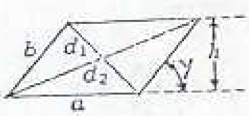
For Rectangle:

$p = 2(a + b)$; $d = \sqrt{a^2 + b^2}$; $A = ab$.

For Square ($a = b = s$): Note: "s" = side.

$p = 4s$; $d = s\sqrt{2}$; $s = \frac{d}{\sqrt{2}}$; $A = s^2 = \frac{d^2}{2}$.

4. General Parallelogram (Rhomboid) (and Rhombus)



For General Parallelogram (Rhomboid):

(Opposite sides parallel)

$p = 2(a + b)$; $d_1 = \sqrt{a^2 + b^2 - 2ab\cos\gamma}$;

$d_2 = \sqrt{a^2 + b^2 + 2ab\cos\gamma}$; $d_1^2 + d_2^2 = 2(a^2 + b^2)$;

$A = ah = ab\sin\gamma$.

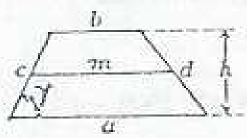
For Rhombus ($a = b = s$): Note: "s" = side.

(Opposite sides parallel and all sides equal)

$p = 4s$; $d_1 = 2s\sin\frac{\gamma}{2}$; $d_2 = 2s\cos\frac{\gamma}{2}$; $d_1^2 + d_2^2 = 4s^2$;

$d_1 d_2 = 2s^2\sin\gamma$; $A = sh = s^2\sin\gamma = \frac{d_1 d_2}{2}$.

5. General Trapezoid (and Isosceles Trapezoid)



Let mid-line bisecting non-parallel sides $= m$. Then $m = \frac{a + b}{2}$.

For General Trapezoid:

(Only one pair of opposite sides parallel)

$p = a + b + c + d$; $A = \frac{(a + b)h}{2} = mh$.

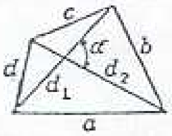
For Isosceles Trapezoid ($d = c$):

(Non-parallel sides equal)

$A = \frac{(a + b)h}{2} = mh = \frac{(a + b)c\sin\gamma}{2}$

$= (a - c\cos\gamma)c\sin\gamma = (b + c\cos\gamma)c\sin\gamma.$

6. General Quadrilateral (Trapezium)

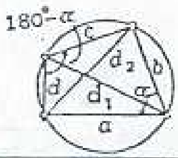


(No sides parallel)

$p = a + b + c + d$

$A = \frac{1}{2} d_1 d_2 \sin \alpha$ = sum of areas of the two triangles formed by either diagonal and the four sides.

7. Quadrilateral Inscribed in Circle



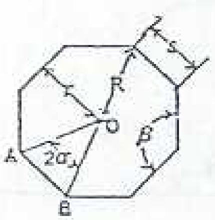
(Sum of opposite angles = 180°)

$ac + bd = d_1 d_2.$

Let $s = \frac{1}{2}(a + b + c + d) = \frac{p}{2}$ and α = angle between sides a and b.

$A = \sqrt{(s-a)(s-b)(s-c)(s-d)} = 1/2\,(ab + cd)\sin\alpha.$

8. Regular Polygon (and General Polygon)



For Regular Polygon:

(Equal sides and equal angles)

Let n = number of sides.

Central angle $= 2\alpha = \frac{2\pi}{n}$ radians;

Vertex angle $= \beta = \frac{(n-2)}{n}\pi$ radians.

$p = ns;\ s = 2r\tan\alpha = 2R\sin\alpha;$

$r = \frac{s}{2}\cot\alpha;\ R = \frac{s}{2}\csc\alpha;$

$A = \frac{nsr}{2} = nr^2\tan\alpha = \frac{nR^2}{2}\sin 2\alpha = \frac{ns^2}{4}\cot\alpha$ = sum of areas of the n equal triangles such as OAB.

For General Polygon:

A = sum of areas of constituent triangles into which it can be divided.

Ib. Plane Curvilinear Figures

Notation. Lines, $a, b, \ldots$; radius, r; diameter, d; perimeter, p; circumference, c; central angle in radians, θ; arc, s; chord of arc (s), l; chord of half arc $(s/2)$, l'; rise, h; area, A.

9. Circle (and Circular Arc)

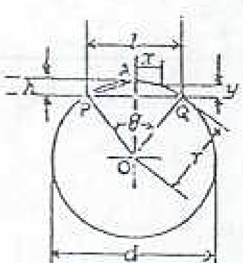
For Circle:

$d = 2r;\ c = 2\pi r = \pi d;\ A = \pi r^2 = \frac{\pi d^2}{4} = \frac{c^2}{4\pi}.$

For Circular Arc:

Let arc $PAQ = s$; and chord $PA = \left(\text{chord of } \frac{s}{2}\right) = l'$. Then,

$s = r\theta = \frac{d\theta}{2};\ s = \frac{8l' - l}{3}.$ (The latter equation is Huyghen's approximate formula. For θ small, error is very small; for $\theta = 120°$, error equals about 1 part in 400; for $\theta = 180°$, error is less than 1.25%.)



$l = 2r\sin\frac{\theta}{2};\ l = 2\sqrt{2hr - h^2}$ (approximate formula)

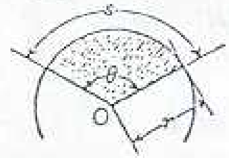
$r = \frac{s}{\theta} = \frac{l}{2\sin\frac{\theta}{2}};\ r = \frac{4h^2 + l^2}{8h}$ (approximate formula)

$h = r \mp \sqrt{r^2 - \frac{l^2}{4}}$ ($-$ if $\theta \leq 180°$; $+$ if $\theta \geq 180°$) $= r\left(1 - \cos\frac{\theta}{2}\right)$

$h = r \operatorname{versin}\frac{\theta}{2} = 2r\sin^2\frac{\theta}{4} = \frac{l}{2}\tan\frac{\theta}{4} = r + y - \sqrt{r^2 - x^2}.$

Side ordinate $y = h - r + \sqrt{r^2 - x^2}.$

10. Circular Sector (and Semicircle)



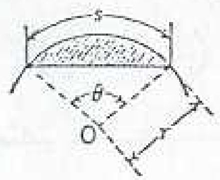
For Circular Sector:

$$A = \frac{\theta r^2}{2} = \frac{sr}{2}. \quad (\theta \text{ in Radians})$$

For Semicircle:

$$A = \frac{\pi r^2}{2}.$$

11. Circular Segment



$$A = \frac{r^2}{2}(\theta - \sin\theta) \quad (\theta \text{ in Radians}) \text{ Exact Formula.}$$

$$A = 1/2\,[sr \mp l\,(r - h)]\ (- \text{ if } h \leq r;\ + \text{ if } h \geq r).$$

$A = \dfrac{2lh}{3}$ or $\dfrac{h}{15}(8l' + 6l)$. (Approximate formulas. For h small compared with r, error is very small; for $h = \dfrac{r}{4}$, first formula errs about 3.5% and second less than 1.0%.)

12. Annulus

(Surface between two concentric circles)

$$A = \pi(r_1^2 - r_2^2) = \pi(r_1 + r_2)(r_1 - r_2);$$

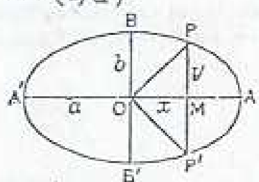
(θ in Radians)

$$A \text{ of sector } ABCD = \frac{\theta}{2}(r_1^2 - r_2^2) = \frac{\theta}{2}(r_1 + r_2)(r_1 - r_2)$$

$$A \quad " \quad " \quad = \frac{t}{2}(s_1 + s_2).$$

13. Ellipse

∡1 = arcos(x/a)
∡2 = arsin(x/a)



Note: In these FORMULAE, ANGLES ∡1 & ∡2 must be expressed IN RADIANS

$$p = \pi(a + b)\left(1 + \frac{R^2}{4} + \frac{R^4}{64} + \frac{R^6}{256} + \ldots\right) \text{ where } R = \frac{a - b}{a + b}.$$

$$p = \pi(a + b)\,\frac{64 - 3R^4}{64 - 16R^2} \text{ (approximate formula).}$$

$$A = \pi ab;\ A \text{ of quadrant } AOB = \frac{\pi ab}{4};$$

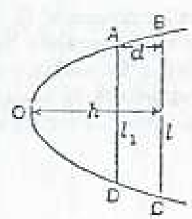
$$A \text{ of sector } AOP = \frac{ab}{2} \times (\measuredangle 1):\quad A \text{ of sector } POB = \frac{ab}{2} \times (\measuredangle 2):$$

$$A \text{ of section } BPP'B' = xy + ab \times (\measuredangle 2):$$

$$A \text{ of segment } PAP'P = -xy + ab \times (\measuredangle 1):$$

For additional formulas, see analytic geometry.

14. Parabola



$$\text{Arc } BOC = s = 1/2\sqrt{l^2 + 16h^2} + \frac{l^2}{8h}\log_e\frac{4h + \sqrt{l^2 + 16h^2}}{l}.$$

Let $R = \dfrac{h}{l}$. Then,

$$s = l\left(1 + \frac{8R^2}{3} - \frac{32R^4}{5} + \ldots\right) \text{ (approximate formula).}$$

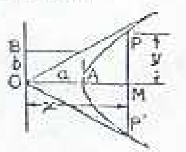
$$d = \frac{h}{l^2}(l^2 - l_1^2);\ l_1 = l\sqrt{\frac{h - d}{h}};\ h = \frac{dl^2}{l^2 - l_1^2};$$

$$A \text{ of segment } BOC = \frac{2hl}{3};$$

$$A \text{ of section } ABCD = \frac{2}{3}d\left(\frac{l^3 - l_1^3}{l^2 - l_1^2}\right).$$

For additional formulas, see analytic geometry.

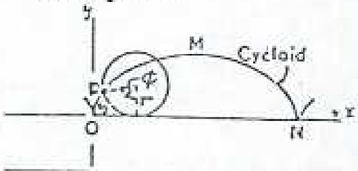
15. Hyperbola



$$A \text{ of figure } OPAP'O = ab\log_e\left(\frac{x}{a} + \frac{y}{b}\right) = ab\cosh^{-1}\frac{x}{a}: \ (\measuredangle \text{ in RADIANS})$$

$$A \text{ of segment } PAP' = xy - ab\log_e\left(\frac{x}{a} + \frac{y}{b}\right) = xy - ab\cosh^{-1}\frac{x}{a}$$

16. Cycloid

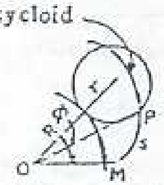


$\text{Arc } OP = s = 4r\left(1 - \cos\frac{\phi}{2}\right)$; $\text{Arc } OMN = 8r$;

A under curve $OMN = 3\pi r^2$.

Coord. of p : $x = r(\phi - \sin\phi)$: $y = r(1 - \cos\phi)$

17. Epicycloid

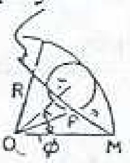


$\text{Arc } MP = s = \frac{4r}{R}(R + r)\left(1 - \cos\frac{R\phi}{2r}\right)$;

$\text{Area } MOP = A = \frac{r}{2R}(R + r)(R + 2r)\left(\frac{R\phi}{r} - \sin\frac{R\phi}{r}\right)$.

For additional formulas, see analytic geometry.

18. Hypocycloid

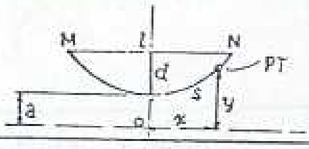


$\text{Arc } MP = s = \frac{4r}{R}(R - r)\left(1 - \cos\frac{R\phi}{2r}\right)$;

$\text{Area } MOP = A = \frac{r}{2R}(R - r)(R - 2r)\left(\frac{R\phi}{r} - \sin\frac{R\phi}{r}\right)$.

For additional formulas, see analytic geometry.

19. Catenary

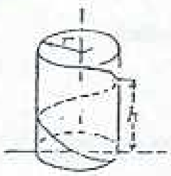


If d is small compared with l:

$\text{Arc } MPN = s = l\left[1 + \frac{2}{3}\left(\frac{2d}{l}\right)^2\right]$ (approximately).

$y = \frac{a}{2}\left(e^{\frac{x}{a}} + e^{-\frac{x}{a}}\right)$

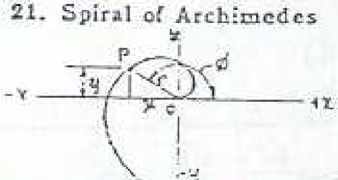
20. Helix



Let length of helix $= s$; radius of coil ($=$ radius of cylinder in figure) $= r$; Height advanced in one revolution $=$ pitch $= h$; and number of revolutions $= n$. Then,

$s = n\sqrt{(2\pi r)^2 + h^2}$.

21. Spiral of Archimedes

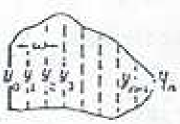


Let $r = a\phi$ Then,

$\text{Arc } OP = s = \frac{a}{2}\left[\phi\sqrt{1 + \phi^2} + \log_e\left(\phi + \sqrt{1 + \phi^2}\right)\right]$.

$x = a\phi(\cos\phi)$: $y = a\phi(\sin\phi)$

22. Irregular Figure



Divide the figure into an *even* number, n, of strips by means of $(n + 1)$ ordinates, y, spaced equal distances, w. The area can then be determined approximately by any of the following formulas, which are presented in the order of usual increasing approach to accuracy. In any of the first three cases, the greater the number of strips used, the more nearly accurate will be the result.

(Approximate Formulas)

Trapezoidal Rule.........
$A = w\left[\frac{y_0 + y_n}{2} + y_1 + y_2 + \ldots + y_{n-1}\right]$;

Durand's Rule...........
$A = w[0.4(y_0 + y_n) + 1.1(y_1 + y_{n-1}) + y_2 + y_3 + \ldots + y_{n-2}]$;

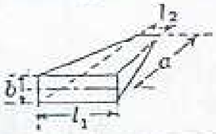
Simpson's Rule...........
(n *must* be even)
$A = \frac{w}{3}[(y_0 + y_n) + 4(y_1 + y_3 + \ldots + y_{n-1}) + 2(y_2 + y_4 + \ldots + y_{n-2})]$;

Weddle's Rule...........
(for 6 strips only)
$A = \frac{3w}{10}[5(y_1 + y_5) + 6y_3 + y_0 + y_2 + y_4 + y_6]$;

Ic. Solids Having Plane Surfaces

Notation. Lines, $a, b, c, \ldots$; altitude (perpendicular height), h; slant height, s; perimeter of base, p_b or p_B; perimeter of a right section, p_r; area of base A_b or A_B; area of a right section, A_r; total area of lateral surfaces, A_l; total area of all surfaces, A_t; volume, V.

23. Wedge (and Right Triangular Prism)



For Wedge:

(Narrow-side rectangular); $V = \frac{ab}{6}(2l_1 + l_2)$.

For Right Triangular Prism (or wedge having parallel triangular bases perpendicular to sides) $l_2 = l_1 = l$:

$V = \frac{abl}{2}$.

24. Rectangular Prism (or Rectangular Parallelepiped) (and Cube)

For Rectangular Prism or Rectangular Parallelepiped:

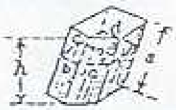
$A_l = 2c(a + b)$; $A_t = 2(dc + ac + bc)$;

$V = A_r c = abc$.

For Cube (letting $b = c = a$):

$A_t = 6a^2$; $V = a^3$; Diagonal $= a\sqrt{3}$.

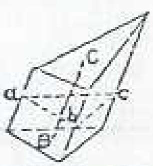
25. General Prism



$A_l = hp_b = sp_r = s(a + b + \ldots + n)$;

$V = hA_b = sA_r$.

26. General Truncated Prism (and Truncated Triangular Prism)



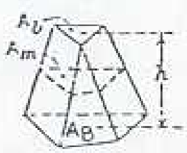
For General Truncated Prism:

$V = A_r \cdot$(length of line BC joining centers of gravity of bases).

For Truncated Triangular Prism:

$V = \frac{A_r}{3}(a + b + c)$.

27. Prismatoid



Let area of mid-section $= A_m$.

$V = \frac{h}{6}(A_B + A_b + 4A_m)$.

28. Right Regular Pyramid (and Frustum of Right Regular Pyramid)

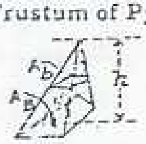
For Right Regular Pyramid:

$A_l = \frac{sp_B}{2}$; $V = \frac{hA_B}{3}$.

For Frustum of Right Regular Pyramid:

$A_l = \frac{s}{2}(p_B + p_b)$; $V = \frac{h}{3}(A_B + A_b + \sqrt{A_B A_b})$.

29. General Pyramid (and Frustum of Pyramid)



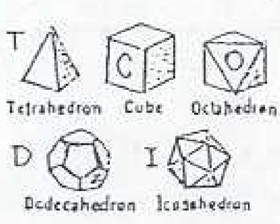
For General Pyramid:

$V = \frac{hA_B}{3}$.

For Frustum of General Pyramid:

$V = \frac{h}{3}(A_B + A_b + \sqrt{A_B A_b})$.

30. Regular Polyhedrons



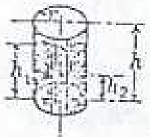
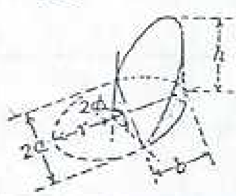
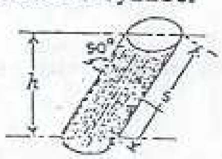
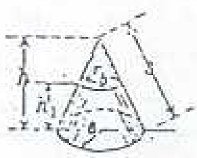
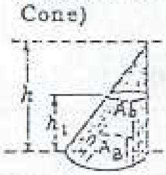
Let edge $= a$, and radius of inscribed sphere $= r$. Then,

$r = \frac{3V}{A_t}$, and:

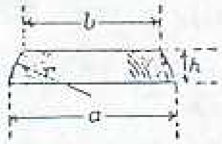
Number of Faces		Form of Faces	Total Area A_t	Volume V
T	4	Equilateral triangle	$1.7321\,a^2$	$0.1179\,a^3$
C	6	Square	$6.0000\,a^2$	$1.0000\,a^3$
O	8	Equilateral triangle	$3.4641\,a^2$	$0.4714\,a^3$
D	12	Regular pentagon	$20.6457\,a^2$	$7.6631\,a^3$
I	20	Equilateral triangle	$8.6603\,a^2$	$2.1817\,a^3$

Id. Solids Having Curved Surfaces

Notation. Lines, a, b, c, . . . ; altitude (perpendicular height), h, h_1, . . . ; slant height, s; radius, r; perimeter of base, p_b; perimeter of a right section, p_r; angle in radians, ϕ; arc, s; chord of segment, l; rise, h; area of base, A_b or A_B; area of a right section, A_r; total area of convex surface, A_l; total area of all surfaces, A_t; volume, V.

31. Right Circular Cylinder (and Truncated Right Circular Cylinder) 	*For Right Circular Cylinder:* $A_l = 2\pi r h;\ A_t = 2\pi r\,(r + h);$ $V = \pi r^2 h.$ *For Truncated Right Circular Cylinder:* $A_l = \pi r\,(h_1 + h_2);\ A_t = \pi r\left[h_1 + h_2 + r + \sqrt{r^2 + \left(\frac{h_1 - h_2}{2}\right)^2}\right];$ $V = \frac{\pi r^2}{2}\,(h_1 + h_2).$
32. Ungula (Wedge) of Right Circular Cylinder 	$A_l = \frac{2rh}{b}\,[a + (b - r)\phi];$ $V = \frac{h}{3b}\,[a\,(3r^2 - a^2) + 3r^2\,(b - r)\phi]$ $= \frac{hr^3}{b}\left[\sin\phi - \frac{\sin^3\phi}{3} - \phi\cos\phi\right].$ *For Semicircular Base* (letting $a = b = r$): $A_l = 2rh;\ V = \frac{2r^2h}{3}.$
33. General Cylinder 	$A_l = p_b h = p_r s;$ $V = A_b h = A_r s.$
34. Right Circular Cone (and Frustum of Right Circular Cone) 	*For Right Circular Cone:* $A_l = \pi r_B s = \pi r_B\sqrt{r_B^2 + h^2};\ A_t = \pi r_B\,(r_B + s);$ $V = \frac{\pi r_B^2 h}{3}.$ *For Frustum of Right Circular Cone:* $s = \sqrt{h_1^2 + (r_B - r_b)^2};\ A_l = \pi s\,(r_B + r_b);$ $V = \frac{\pi h_1}{3}\,(r_B^2 + r_b^2 + r_B r_b).$
35. General Cone (and Frustum of General Cone) 	*For General Cone:* $V = \frac{A_B h}{3}.$ *For Frustum of General Cone:* $V = \frac{h_1}{3}\left(A_B + A_b + \sqrt{A_B A_b}\right).$
36. Sphere 	Let diameter $= d$. $A_t = 4\pi r^2 = \pi d^2;$ $V = \frac{4\pi r^3}{3} = \frac{\pi d^3}{6}.$
37. Spherical Sector (and Hemisphere) 	*For Spherical Sector:* $A_t = \frac{r}{2}\,(4h + l);\ V = \frac{2\pi r^2 h}{3}.$ *For Hemisphere* (letting $h = \frac{l}{2} = r$): $A_t = 3\pi r^2;\ V = \frac{2\pi r^3}{3}.$

38. Spherical Zone (and Spherical Segment)



For Spherical Zone Bounded by Two Planes:

$A_l = 2\pi rh;\ A_t = \frac{\pi}{4}(8rh + a^2 + b^2).$

For Spherical Zone Bounded by One Plane ($b = 0$):

$A_l = 2\pi rh = \frac{\pi}{4}(4h^2 + a^2);$

$A_t = \frac{\pi}{4}(8rh + a^2) = \frac{\pi}{2}(2h^2 + a^2).$

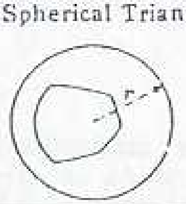
For Spherical Segment with Two Bases:

$V = \frac{\pi h}{24}(3a^2 + 3b^2 + 4h^2).$

For Spherical Segment with One Base ($b = 0$):

$V = \frac{\pi h}{24}(3a^2 + 4h^2) = \pi h^2\left(r - \frac{h}{3}\right).$

39. Spherical Polygon (and Spherical Triangle)



For Spherical Polygon:

Let sum of angles in radians = θ and number of sides = n.

$A = [\theta - (n - 2)\pi]r^2$

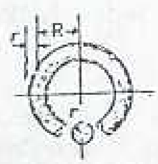
(The quantity $[\theta - (n - 2)\pi]$ is called "spherical excess.")

For Spherical Triangle ($n = 3$):

$A = (\theta - \pi)r^2$

For additional formulas, see trigonometry.

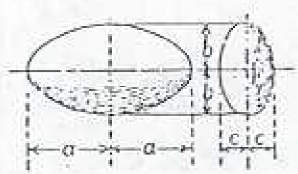
40. Torus



$A_l = 4\pi^2 Rr;$

$V = 2\pi^2 Rr^2.$

41. Ellipsoid (and Spheroids)



For Ellipsoid:

$V = \frac{4}{3}\pi abc.$

For Prolate Spheroid:

Let $c = b$ and $\frac{\sqrt{a^2 - b^2}}{a} = \epsilon.$

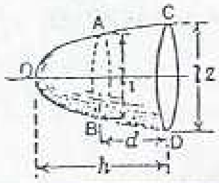
$A_t = 2\pi b^2 + 2\pi ab\frac{\sin^{-1}\epsilon}{\epsilon};\ V = \frac{4}{3}\pi ab^2.$

For Oblate Spheroid:

Let $c = a$ and $\frac{\sqrt{a^2 - b^2}}{a} = \epsilon.$

$A_t = 2\pi a^2 + \frac{\pi b^2}{\epsilon}\ln\left(\frac{1+\epsilon}{1-\epsilon}\right);\ V = \frac{4}{3}\pi a^2 b.$

42. Paraboloid of Revolution



A_l of segment $DOC = \frac{2\pi l}{3h^2}\left[\left(\frac{l^2}{16} + h^2\right)^{3/2} - \left(\frac{l}{4}\right)^3\right].$

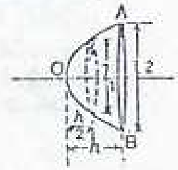
For Paraboloidal Segment with Two Bases:

V of $ABCD = \frac{\pi d}{8}(l^2 + l_1^2).$

For Paraboloidal Segment with One Base ($l_1 = 0$ and $d = h$):

V of $DOC = \frac{\pi hl^2}{8}.$

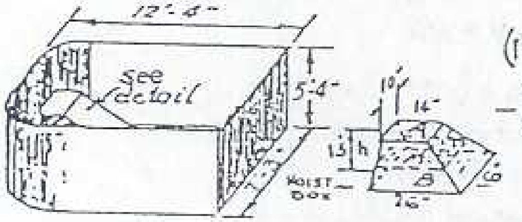
43. Hyperboloid of Revolution



V of segment $AOB = \frac{\pi h}{24}(l^2 + 4l_1^2).$

TYPICAL EXAMPLES

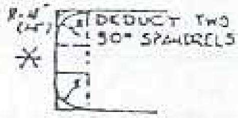
1. COMPUTATION OF TRUCK VOLUMES



$(12.3333' \times 7.25' - (1.5^2 \times .4292^{*})) \times 5.3333' = 471.734$ Cu. Ft.

$- \dfrac{(10'' \times 14'') + 4 \times (13'' \times 20'') + (16'' \times 16'')}{6 \times 144\square''} ^{**} \times 1.5' = -\ 2.771$ "

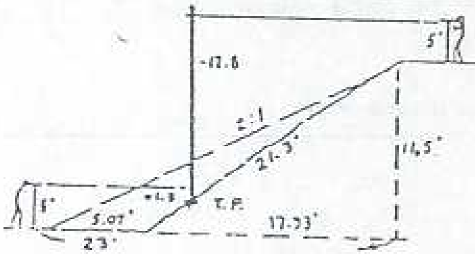
NET VOLUME = 468.963 *Cu. Ft.*



** PRISMOIDAL FORMULA

$\dfrac{\text{Area "A"} + 4 \times \text{Area "M"} + \text{Area "B"}}{6} \times h$

2. ROUGH CHECKING FILL SLOPES



Suspecting "Lean" slopes, an inspector checks out a 2:1 fill section, which appears to be average for a 500' foot stretch of a project.

Using a 5' Jacob's Staff and a Locke Level, he reads the following:

12.8 ft. (shoulder to turning point) and 1.3 ft. (toe of slope to T.P.) He then pulls a tape tight along the slope and reads 21.3' shoulder to toe.

If slopes should be flushed, where should the toe stake be located (from present toe)? At $1.50 per cubic yard, about what deduction for this "lean' section should be made to the Final Estimate if contractor does not flush the slopes?

ANS. 12.8' - 1.3' = 11.5' RISE (height of fill) x 2 = 23' (theo "run")
By Pythagoras; $(21.3)^2 - (11.5)^2 = 321.44$; $\sqrt{\ } = 17.93'$ (Actual "run")
Slope stake = 23.00 - 17.93 = 5.07 ft.
Volume = 5.07' x 11.5 ÷ 2 = 29.15 SF x 500' ÷ 27 = 539.86 C.Y.
@ 1.50 = $809.79

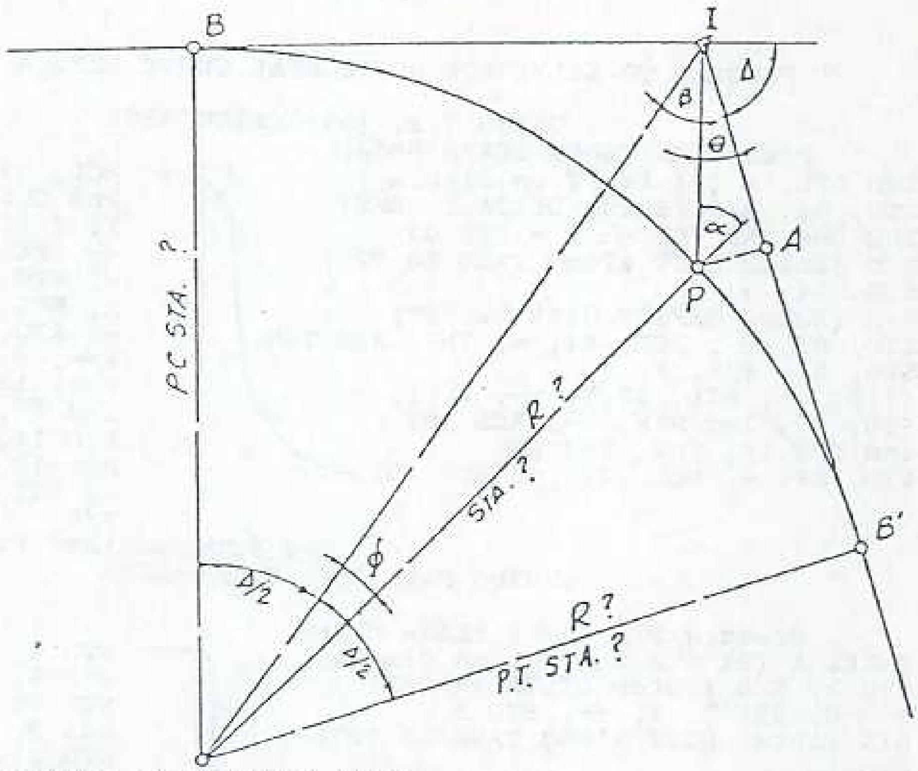
3. INTERPOLATION USING ELECTRONIC CALCULATOR
EXAMPLE: If the area of a cross section at station 10+00 is 6720, and the area at station 11+00 is 5035; what is the area of a section at 10+23.78?
METHOD: Enter 1st Quan: 6720 STO IN MEM: 1st Quan. on Display
Subtract 2nd Quan: -5035 = 1685; Difference on Display
Multiply by Ratio: X .2378 = 400.693
STO in - MEM *: Recall MEM : 6319.307 Ans.

* Accumulate Negatively

This method works regardless of which is the larger number!

Try These:	1st Quan.	2nd Quan.	Ratio	ANSWER
	755	987	.872	957.3
	-255	5	.45	- 138
S.F. I (52)	72856	-37821	39.28	29470.6
TABLE: P. IV (14)	.359723 *	.360721 *	.93479	.3606559

TYPICAL EXAMPLES



4. HORIZONTAL CURVE THRU A POINT

IN THE PRELIMINARY LOCATION OF A SECONDARY ROAD, IT WAS DEEMED NECESSARY TO SOLVE FOR THE RADIUS OF A CURVE WHICH PASSED THRU POINT "P" LOCATED ON THE ALIGNMENT SKETCHED HEREIN. THIS WAS DONE IN ORDER TO KEEP FROM DESTROYING A HISTORICAL LANDMARK.

GIVEN: Δ = 72° 24' 28"; IA = 587.13'; AP = 195.17'; PI STATION 100+25

SOLVE: RADIUS, PC STATION, PT. STATION & STATION OF POINT "P"

SOLUTION: SOLVE: θ ; TAN θ =AP/IA; = 195.17/587.13; θ = 18° 23' 15"

SOLVE: IP; IP = IA/COS θ ; = 587.13/.94894480 = IP = 618.7188'

SOLVE: β ; = (180° - Δ) ÷ 2 = 53° 47' 46" - θ = β = 35°24'31"

SOLVE Δ/2 = 72° 24' 28"/2 = 36° 12' 14"

α =ARCSIN (SIN β/COS Δ/2) : SIN 35° 24' 31"/COS 36° 12' 14" : α = 45° 53'35"

ϕ = α - β : 45° 53' 35" - 35° 24' 31"; : ϕ = 10° 29'04"

R = IP (SIN β)/SIN ϕ : 618.7188 x SIN 35° 24' 31"/SIN 10°29'04": R = 1970.0334'

IB = R(TAN Δ/2) = 1970.0334 x TAN 36° 12' 14"; IB = 1442.0513'

PC STA = PI STA - IB; PC STA = 100+25 - 1442.0517 = STA 85+82.95

PT STA = PC STA + R (RAD Δ) = 8582.95 + R x 1.26375412 = STA 110+72.59

STA OF P = PC STA + R (RAD(Δ/2 + ϕ)) = PC STA + R x .81486710 = STA 101+88.27 .

PROGRAM TO SOLVE FOR HORIZONTAL CURVE THRU A FIXED POINT

USING T.I. (59) CALCULATOR

```
    Press LRN (Sets LEARN Mode)
2ND LBL, A (PI in FT on display)
STO, 01, R/S (Enter DELTA in DMS)
2ND DMS, STO 02 ÷ 2 = STO 03
R/S (Enter DIST along TANG to "P")
STO, 04
R/S (Enter OFFSET dist to "P")
STO, 05, ÷, RCL, 04, =, INV, 2nd TAN
STO, 06, +/-, +
((180, -, RCL, 02,), ÷, 2, ), =
STO, 07, 2nd SIN, ÷, RCL, 03
2nd COS, =, INV, 2nd SIN
STO, 08, -, RCL, 07, =, STO, 09
   → RCL, 04, ÷, RCL, 06
2nd COS, =, STO, 10
X, ( RCL, 07, 2nd SIN)
÷, RCL, 09, 2nd SIN,
=, STO, 11 (RADIUS)
X, RCL, 03, 2nd TAN
=, STO, 12 (TANGENT)
+/-, +, RCL, 01, =
STO, 13 (PC STA)
2nd π, ÷, 180, =
STO 14, X, RCL 2, X
RCL 11, =, STO 15 (L)
+, RCL 13, =, STO 16
R/S
End programming  Press LRN
```

USING H.P.(15C) CALCUALTOR

```
    Press g P/R (Sets LEARN Mode)
f LBL A (PI Sta in feet on display)
STO 1, R/S (Enter DELTA in DMS)
g →H, STO 2, 2, ÷, STO 3
R/S (Enter DIST along TANG to "P")
STO 4
R/S (Enter OFFSET dist to "P")
STO 5, RCL 4, ÷, g TAN-1
STO 6, 1,8,0, RCL 2, -, 2, ÷, x⇌y, -
STO 7, SIN, RCL 3, COS, ÷, g SIN-1
   → STO 8, RCL 7, -, STO 9
RCL 4, RCL 6, COS, ÷
STO 0, RCL 7, SIN, X
RCL 9, SIN, ÷
STO .1, (RADIUS)
RCL 3, TAN, X, STO .2
CHS, RCL 1, +, STO .3
RCL 2, f→RAD, RCL .1
X, STO .5, +, STO .6
R/S
End Programming, Press g P/R
```

USING THE ABOVE PROGRAMS TO SOLVE PROBLEM (Page I-45)

USING T.I. (59) CALCULATOR   USING H.P.(15C) CALCULATOR

(Both calculators in RUN Mode)

For both calculators.....Type 10025 (PI Station in feet)

Press A   Press f A

For both calculators...Type 72.2428 (DELTA in DMS), Press R/S

" " " Type 587.13 (DIST along TANG to "P"), " R/S

" " " " 195.17 (OFFSET from TAN to "P"), " R/S

WAIT 8 SECONDS   WAIT 12 SECONDS

For both calculators...Read 11072.59 (PT STA 110+72.59)

RCL 11 Read 1970.03 (RADIUS) .... RCL .1 (Read SAME)
RCL 12 Read 1442.05,(TANGENT).......... RCL .2 (Read SAME)
RCL 13 Read 85+82.95 (PC.STA).......... RCL .3 (Read SAME)
RCL 15 Read 2489.64 (LENGTH) .... RCL .5 (Read SAME)
RCL 16 Read 110+72.59 (PT STA again)....RCL .6 (Read SAME)

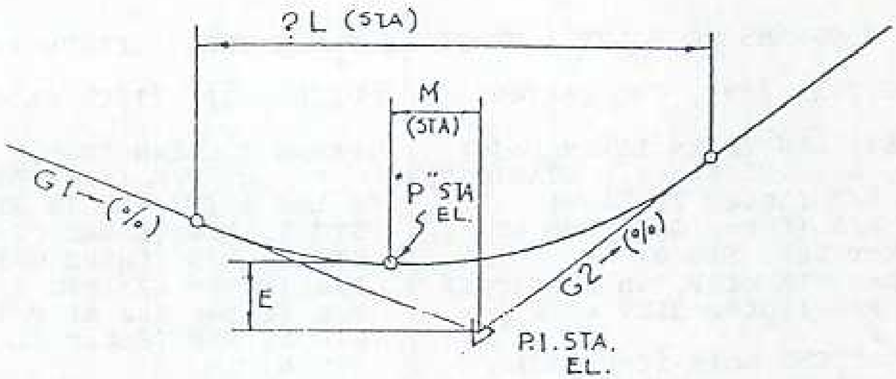
TO FIND STATION OF POINT "P"

(T.I.)	(H.P.)
* RCL 03 + RCL 09 =	RCL 3, RCL 9, + *
X RCL 14 X RCL 11	f →RAD, RCL .1, X
+ RCL 13 =	RCL .3, +

For both calculators, Read (Sta 101+88.26)

* NOTE: If point "P" lies along the BACK tangent (i.e. Back of the PI station), Code "-" instead of "+"

TYPICAL EXAMPLES



5. VERTICAL CURVE THRU A POINT

GIVEN: PI STATION & ELEVATION, STATION & ELEVATION OF POINT "P", GRADE 1 & GRADE 2

SOLVE: LENGTH OF THE VERTICAL CURVE WHICH PASSES THRU POINT "P" AND IS TANGENT TO GRADE 1 AND GRADE 2.

GENERAL METHOD: DEFINE: M = DISTANCE IN STATIONS FROM P.I. TO POINT "P"

E = ELEVATION OF "P" MINUS P.I. ELEVATION

A (ALGEBRAIC DIFFERENCE IN GRADES) = G1 - G2 (SIGNS OF BOTH GRADES MUST BE INCLUDED IN THE CALCULATION, AND THE SIGN OF A IS VITAL.)

$a = -A/4$; $b = AM - 2E - {}^{*}2G1M$: $c = -A(M)^2$

SOLVE FOR "L" (LENGTH OF V.C. IN STATIONS) BY SUBSTITUTING FOR a, b & c IN ONE OF THE QUADRATIC FORMULAE BELOW:

FOR SAG CURVES $L = (-b + \sqrt{b^2 - 4ac}) \div 2a$

FOR CREST CURVES $L = (-b - \sqrt{b^2 - 4ac}) \div 2a$

EXAMPLE 1 (SAG CURVE) PI STA. 100+00 El. 200.00;
STA. OF "P" 98+39.5, EL. 210.14; GRADE 1 = - 3.5, GRADE 2 = 4.75

E = 210.14 - 200 E = 10.14; A = (-3.5) - (4.75); A = -8.25: M = 1.605 STA

a = - (-8.25)/4 ; a = +2.0625

b = (-8.25) x 1.605 - (2 x 10.14) - (2 x (-3.5) x 1.605): b = -22.286

$c = -(-8.25) \times (1.605)^2$; c = 21.2522

$L = (-(-22.286) + \sqrt{(-22.286)^2 - (4 \times 2.0625 \times 21.2522)}) \div (2 \times 2.0625)$

$L = (22.286 + \sqrt{321.346}) \div 4.125$; $L = (22.286 + 17.926) \div 4.125 = 9.748$ STA. L = 975'VC

EXAMPLE 2 (CREST CURVE) P.I. STA 100 + 00, EL. 200.00, STA "P" 99+00, EL. 197.28
G1 = - 1.5; G2 = - 9.0: E = 197.28 - 200.00 = -2.72; A = (-1.5) - (-9.0) = +7.5:
M = 1.0 STA a = - (7.5)/4 = - 1.875; b = 7.5 x 1 - 2(-2.72) - (2 x (-1.5) x 1)= +15.94;
$c = -(7.5 \times 1^2) = -7.5$

$L = (-15.94 - \sqrt{(15.94)^2 - (4 \times (-1.875) \times (-7.5))} \div (2 \times (-1.875))$

$L = (-15.94 - \sqrt{197.83}) \div (-3.75)$; $L = (-15.94 - 14.065) \div -3.75$: L=8.001 = 800'VC

* NOTE: IF POINT "P" LIES AHEAD (TO THE RIGHT) OF THE P.I., SUBSTITUTE $\overset{(-)}{G2}$ FOR G1.

PROGRAMS TO SOLVE A VERTICAL CURVE THRU A FIXED POINT

USING T.I. (59) CALCULATOR

```
Press RST, LRN (sets LEARN Mode)
2ND LBL, A ...PI Sta (in STATIONS)
STO 01, R/S (Enter PI Elev)
STO 02, R/S (Enter G1), STO 03
R/S (Enter G2), STO 04
R/S (Enter STA of P, in STATIONS)
STO 05, R/S (Enter ELEV of P )
STO 06, 1
R/S (Enter CHS only if CREST)
STO 15, RCL 06, -, RCL 02, =
STO 07 (E),RCL 01, -, RCL 05, =
STO  08 (M), INV, 2nd x  t, C
STO 18, RCL 3, -, RCL 4, =
STO 09, +/-, ÷, 4, =
STO 10 (a), RCL 9 X RCL 18 =, -
(2 X RCL 7) = STO 20, RCL 08
INV 2nd x≥t, B
RCL 20 - (2 X RCL 3, X
RCL 18), = STO 11 (b)
RCL 8 x², X RCL 9 =, +/-, STO 12
X, 4, X, RCL 10, =, +/-, +
RCL 11, x², = √x , STO 13 X
RCL 15, =, -, RCL 11, =, ÷
(2 X RCL 10) = STO 14, R/S
2nd LBL  C, +/-, GTO 042
2nd LBL  B, RCL 20 - (2 X RCL 04
X RCL 08) =, GTO 092
End Programming, Press LRN
```

USING H.P. (15C) CALCULATOR

```
Press f CLEAR PRGM,
  "    g  P/R (Sets LEARN Mode)
f LBL A (PI Sta IN STATIONS)
STO 1, R/S (Enter PI Elev)
STO 2, R/S (Enter G1), STO 3
R/S (Enter G2) STO 4
R/S (Enter Sta of P in STAT)
STO 5, R/S (Enter El of P)
STO 6, 1
R/S (Enter CHS if CREST)
STO .5, RCL 6, RCL 2 -,STO 7
RCL 1, RCL 5 - STO 8 (M)
0, x⇄y, g x≤y, f C
f LBL 1, STO .8
RCL 3, RCL 4, -, STO 9 (A)
CHS, 4, ÷, STO .0 (a), RCL 9
RCL .8, X, RCL 7, 2, X, -
STO 0, 0, RCL 8, g x≤y, f B
RCL 0, 2, RCL 3 X RCL 8 X, -
f LBL 2, STO .1 (b), RCL 8
g x², RCL 9
X, CHS, STO .2 (c)
4, X, RCL .0,
X CHS, RCL .1
g x², +, √x , STO .3
RCL .5 X RCL .1, -
2, RCL .0, X, ÷, STO .4, R/S
f LBL C, CHS, GTO 1
f LBL B, RCL 0, 2, RCL 4 X
RCL 8, X, -, GTO 2
End Programming, Press g P/R
```

USING THE ABOVE PROGRAMS TO SOLVE THE V.C. THRU A POINT (Page I-47)

USING THE T.I.(59) CALCULATOR — USING THE H.P.(15C) CALCULATOR

With both calculators in RUN Mode: Enter PI Sta in STA (100)

Press A (T.I.) — Press f A (H.P.)

(FOR BOTH CALCULATORS)

Enter PI Elevation (200) and Press R/S
Enter G1 (3.5, +/-, or CHS)..Press R/S
Enter G2 (4.75) ....Press R/S
Enter Sta of P (98.395)......Press R/S
Enter Elev of P (210.14).....Press R/S

READ "1" If this were a CREST, a "+/-" or "CHS" would be entered, since this is a SAG, simply Press R/S

WAIT 6 SECONDS (T.I.) — WAIT 7 SECONDS (H.P.)

READ: 9.7485 (Stations) OR 975 FT V.C.

TYPICAL EXAMPLES

6. CONCRETE VOLUME BY "SOLID OF REVOLUTION" (AREA TRANSLATED ALONG A THEORETICAL PATH WHOSE RADIUS IS DEFINED TO THE CENTROID (CENTER OF GRAVITY) OF THE CROSS SECTION.)

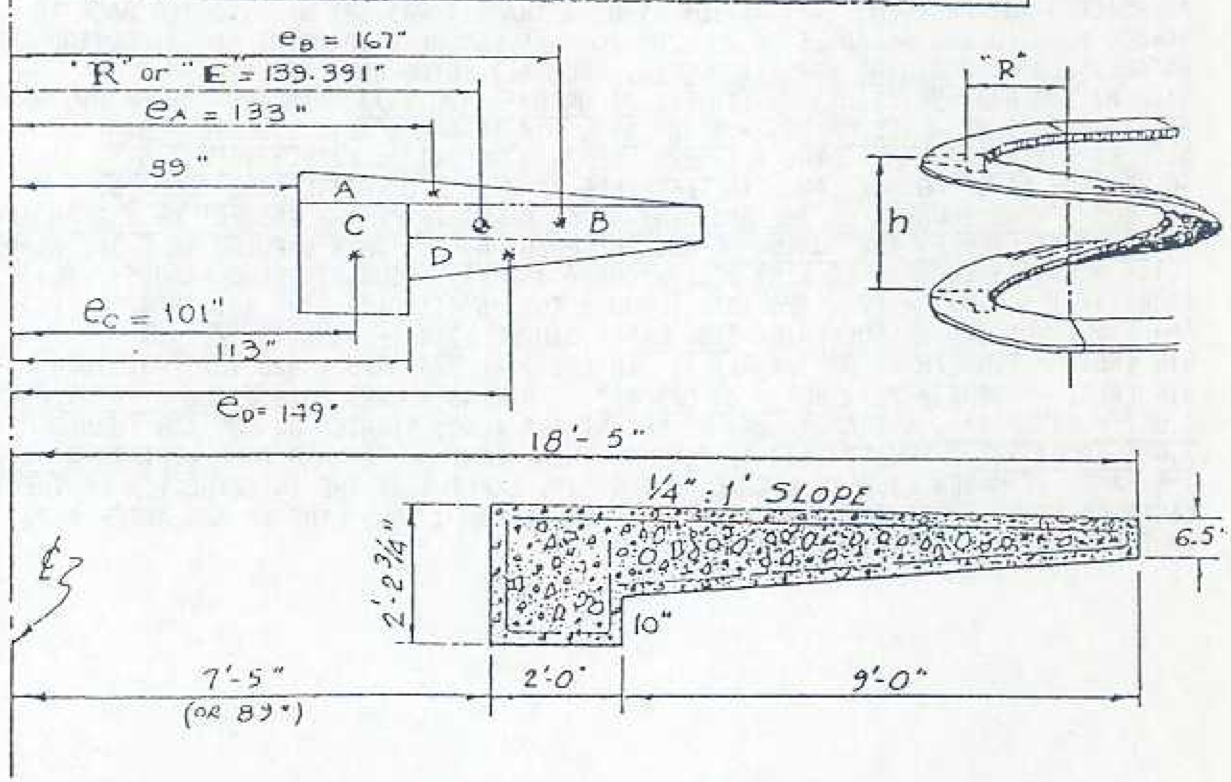
PROBLEM: COMPUTE THE PAY QUANTITY OF STRUCTURAL CONCRETE IN A "SPIRAL" (ACTUALLY HELICAL) PEDESTRIAN RAMP. THE RAMP'S CROSS SECTION IS DIMENSIONED BELOW. THE PITCH(h) OF THE RAMP IS 11.52' AND THE NUMBER OF TURNS,(n), IS ONE AND A HALF. TAKE MOMENTS ABOUT THE C/L, SO THAT "E" WILL EQUAL "R" IN THE EQUATION FOR THE LENGTH (S) OF THE HELIX. THIS IS DONE AS FOLLOWS: DIVIDE THE CROSS SECTION INTO TRIANGLES AND RECTANGLES LABELED A, B, C, D AS SHOWN. PREPARE A TABLE AS BELOW AND CALCULATE THE AREAS AND "e" DISTANCES FOR EACH SECTION. "e" (ECCENTRICITY) IS THE DISTANCE FROM THE C/L TO THE CENTROID (CENTER OF GRAVITY) OF THE SECTION. (THE CENTROID OF A TRIANGLE IS 1/3 OF THE BASE FROM THE RIGHT ANGLE, AND THE CENTROID OF A RECTANGLE IS HALFWAY.) MULTIPLY THE AREA OF EACH SECTION BY ITS "e" DISTANCE AND RECORD UNDER "PRODUCT".
"R" OR "E", THE COMPOSITE CENTROID DISTANCE, IS FOUND BY DIVIDING THE SUM OF THE PRODUCTS BY THE SUM OF THE AREAS. (259894.5 ÷ 1864.5 = 139.391 INCHES "R")
THE VOLUME OF CONCRETE IS CALCULATED BY MULTIPLYING THE LENGTH "S", OF A HELIX WHICH PASSES THRU THE COMPOSITE CENTROID, BY THE AREA OF THE CROSS SECTION.

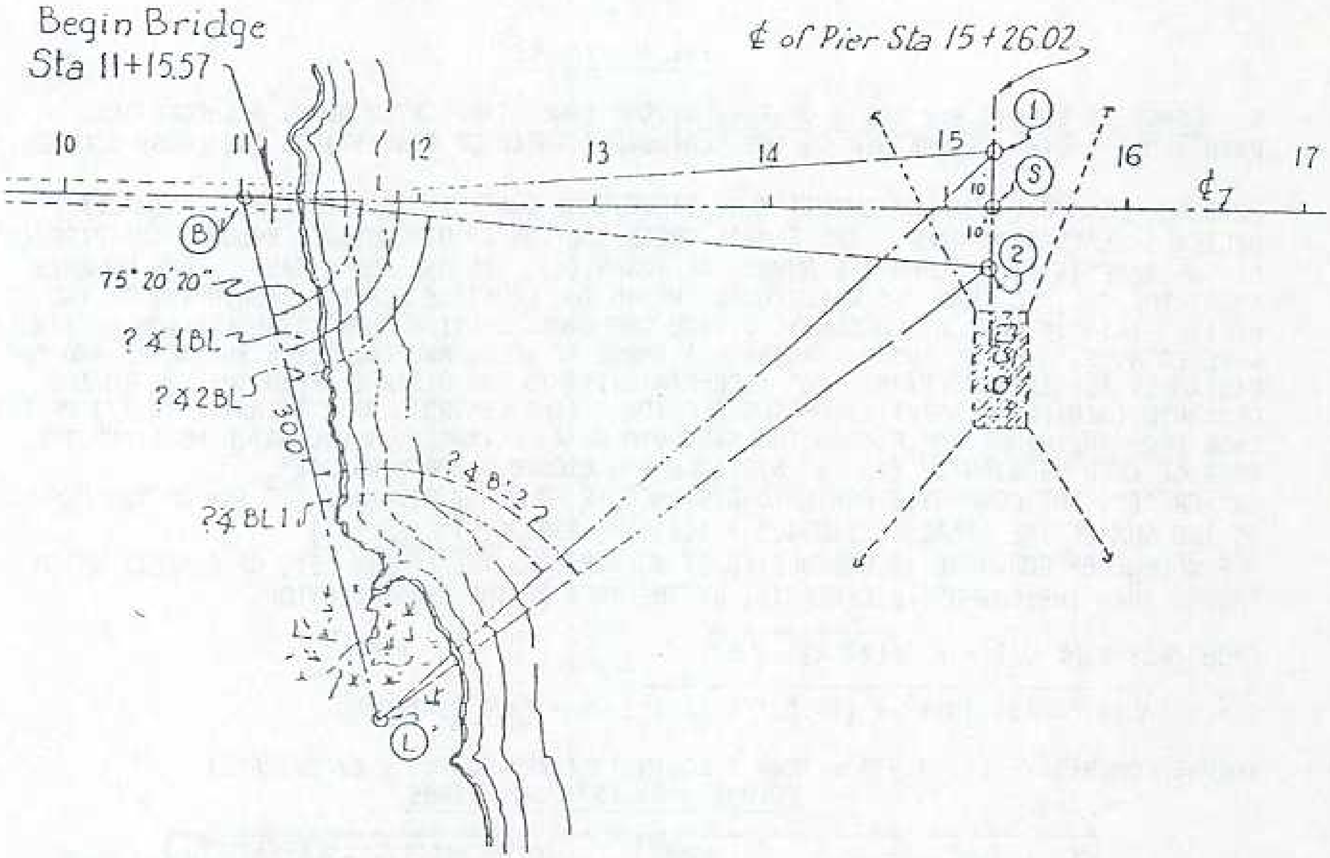
FROM PAGE I 40 , $S = n\sqrt{(2\pi R)^2 + H^2}$

$S = 1.5\sqrt{(2\pi \times 139.391)^2 + (11.52' \times 12")^2}$; S = 1329.99 INCHES

VOLUME CONCRETE = (1329.99" x 1864.5 SQ.IN.) ÷ (1728 CU.IN. x 27 CU. FT.)
VOLUME = 53.150 CUBIC YARDS

SECTION	DIMENSIONS	AREA SQ.IN.	ECCENTRICITY "e" (INCHES)	PRODUCT (AREA x "e")
A	2.75"x11'x12"/2=	181.500	89"+(11'x12")÷3=133"	24139.50
B	6.5"x9'x12"=	702.00	113"+(9'x12")÷2=167"	117234.00
C	24"x24"=	576.00	89"+(2'x12")÷2=101"	58176.00
D	7.5"x9'x12"/2=	405.00	113"+(9'x12")÷3=149"	60345.00
	TOTALS	1864.50		259894.50

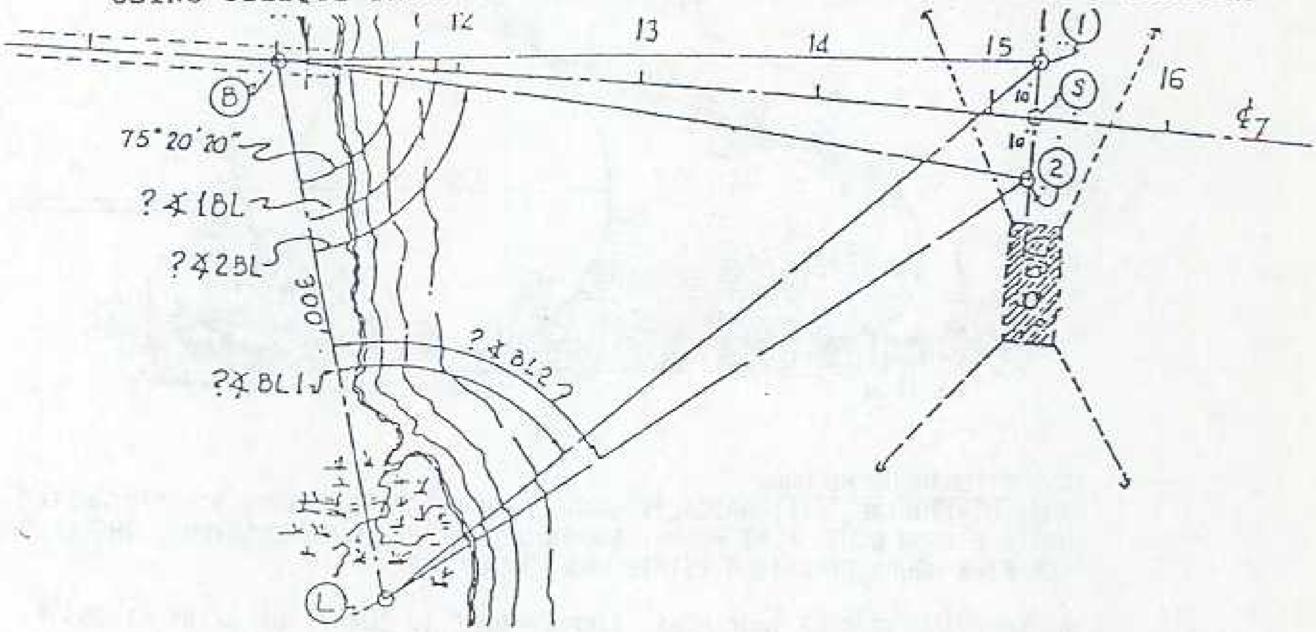




7. LOCATING PILING BY TRIANGULATION

TWO KEY PILES IN A CHANNEL SPAN PIER OF A BRIDGE ARE TO BE AT STATION 15+26.02. A BARGE IS ANCHORED IN THE APPROXIMATE AREA WITH 4 ANCHORS, SO THAT THE PILE DRIVER MAY BE POSITIONED EXACTLY BY DIRECTIONS FROM TWO TRANSITS ON SHORE. ANGLES 1BL, 2BL, BL1, AND BL2 MUST BE SOLVED TO ACCOMPLISH THIS. HERE IS HOW ONE ENGINEER APPROACHED THE PROBLEM: AT STATION 11+00 A TRANSIT WAS SET UP, SIGHTED BACK TO 10+00; PLUNGED, AND AN ANGLE OF 75° 20' 20" WAS RECORDED TO POINT "L"; (PREVIOUSLY ESTABLISHED BY CHAINING EXACTLY 300 FT. FROM B.) SIDE BS = 426.02'. SIDE B1 (OR B2) = $\sqrt{(426.02)^2 + (10)^2}$; B1 OR B2 = 426.1373'. ANGLES 1BS or 2BS = ARCTAN 10/426.02; ∢ 1BS OR 2BS = 1°20' 41". IN TRIANGLE BL1, SIDE BL = 300' SIDE B1 = 426.1373 AND ∢ 1BL = (75°20' 20" + 1°20' 41"): ∢ 1BL = 76°41' 01" SOLVE SIDE L1 BY COSINE LAW. IN REFERENCE TO ∢ 1BL: OPPOSITE SIDE SQUARED = THE SUM OF THE SQUARES OF THE ADJACENT SIDES MINUS TWICE THE PRODUCT OF THE ADJACENT SIDES MULTIPLIED BY THE COSINE OF THE INCLUDED ANGLE. THIS APPLIED TO ∢ 1BL READS: $(L1)^2 = (B1)^2 + (BL)^2 - (2 \times B1 \times BL \times \cos(∢ 1BL))$. SUBSTITUTING VALUES: $(L1)^2 = (426.1373)^2 + (300)^2 - (2 \times 426.1373 \times 300 \times \cos 76°41' 01")$ L1 = 461.1964' ANGLE BL1 MAY NOW BE SOLVED BY SINE LAW: SIN (BL1)/B1 = SIN (1BL)/L1, OR SIN (BL1) = SIN (76°41'01") x B1/L1; SIN (BL1) = .97311278 x 426.1373/461.1964 SIN (BL1) = .89913887; ∢ BL1 = 64°02' 42". HAVING SOLVED BOTH ∢ 1BL = 76°41'01" AND ∢ BL1 = 64°02'42", A TRANSIT MAY BE SET AT "L" ALSO; SIGHTED ON "B" AND TURNED RIGHT 64°02'42". THE TRANSIT AT "B" MAY THEN SIGHT ON "L" AND TURN LEFT 76°41'01". THE BARGE IS MANEUVERED TO LOCATE PILING "1", EXACTLY AT THE INTERSECTION OF THE TWO LINES OF SIGHT. USING THE ABOVE METHOD, SOLVE FOR ∢ 2BL, SIDE 2L AND ANGLE BL2, SO THAT PILING "2" MAY BE DRIVEN!

USING OBLIQUE TRIANGLE PROGRAMS TO SOLVE PILING LOCATION PROBLEM



ALL THE TRIANGLES IN THIS PROBLEM MAY BE SOLVED USING CASE 2 (SAS) (Two sides and the included angle). Programs on pages I-11 - I-14

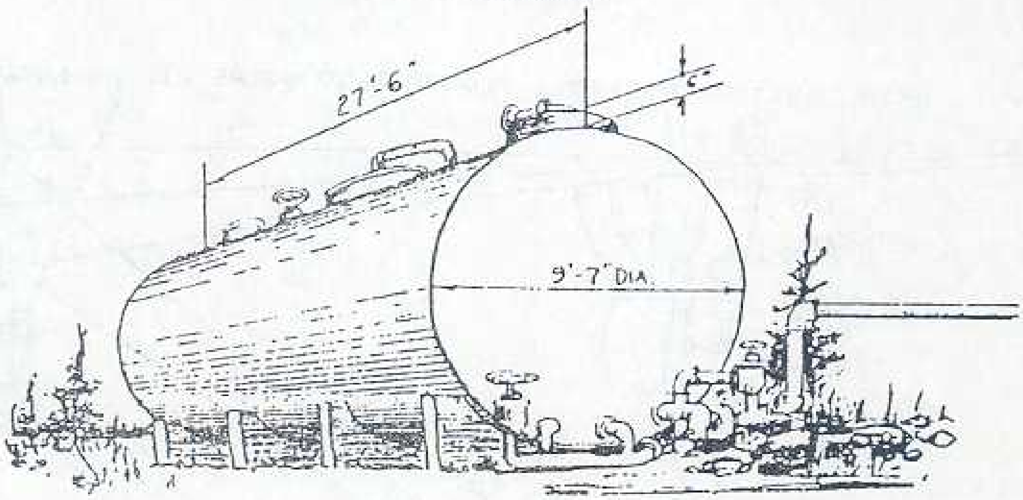
HP (15C) IS USED FOR DEMONSTRATION, BUT TI (59) MAY BE USED FOLLOWING SAME PROCEDURE. (Making allowance for STO No. differences)

In Triangle BS1 (and BS2): Solve for Angle SB1 & Side 1B
Enter 90°, Press f B, Enter 10 (Side 1S), Press R/S
Enter Side BS, 426.02, Press R/S
(9 second pause..Read AREA (2130.10)..Not needed !)
Press R/S, (Read 90°),..Angle BS1 again !
" R/S, (Read 1°20'41") Angle SB1, (STO .9)
" R/S, (" 88°39'19") Angle B1S, Not needed !
RCL 2 (Read 426.1373, Side 1B)..(STO .8)

In Triangle LB1: (Solve for Angle LB1)
Enter 75.2020° (Angle LBS), g →H, RCL .9, g →H, +
(Read 76.6836°) Press f →HMS, (Read 76°41'01")..Ans.
(Now solve for Angle BL1)
(With Angle LB1 on display): Press f B (Read 76.6836°)
RCL .8 (426.1373', Side 1B), Press R/S
Enter 300'(Side BL), Press R/S..Wait 9 seconds....
(Read 62,201.97 s.f. Area)...Not required !
Press R/S, (Read 76°41'01") Angle LB1 again
" R/S, (" 64°02'43") Angle BL1 (ANSWER !)
" R/S, (" 39°16'17") Angle B1L
RCL 2 (" 461.1962 ft) Side L1

In Triangle LB2: (Solve for Angle LB2)
Enter 75.2020' (Angle LBS) g →H, RCL .9, g →H, -
(Read 73.9942°), Press f →HMS, (Read 73°59'39")..Ans.
(Now to solve for Angle BL2)
(With Angle LB2 on display): Press f B (Read 73.9942°)
RCL .8 (426.1373', Side 2B), Press R/S
Enter 300'(Side BL) Press R/S..Wait 9 seconds....
(Read 61,442.65 s.f. Area)..Not required !
Press R/S, (Read 73°59'39") Angle LB2 again !
" R/S, (Read 65°59'07") Angle BL2 (ANSWER !)
" R/S. (Read 40°01'14") Angle B2L
RCL 2 (" 448.4336 ft) Side L2

TYPICAL EXAMPLES



8. BITUMINOUS RECORDS

THIS HORIZONTAL, CYLINDRICAL STORAGE TANK IS 27'-6" LONG, 9'-7" DIAMETER, HAS A 6 INCH DOME, FLAT HEADS, AND COILS IN THE LOWER QUARTER. THE RECORDS FOR FIVE HOURS OPERATION (STATE WORK ONLY) ARE:

A. OPENING STORAGE TANK MEAS. (TOP OF DOME TO SURF.) 67 3/16" AT 295°F.
B. TRANSPORT 1 DELIVERS 6050 GALLONS AT 287°F.
C. TRANSPORT 2 DELIVERS 5796 GALLONS AT 290°F.
D. TRANSPORT 3 DELIVERS 4877 GALLONS at 243°F.
E. CLOSING STO. TANK (PRIVATE WORK, TOP OF DOME TO SURF.) 35 7/16" AT 288°F.

CALCULATIONS: SEE TABLE "CYLINDRICAL TANK IN HORIZ. POS." P IV 13-17

K = LENGTH [IN FT] x (D INCHES)^2 x 12 ÷ 231
K = 27.5' x ((9 x 12) + 7)^2 x 12 ÷ 231; K = 27.5 x (115)^2 x 12 ÷ 231
K = 18,893

B/D RATIO [OPENING] ((3 ÷ 16) + 67 - 6) ÷ 115 = .53206521
(TABLE P IV 14), B/D LIES BETWEEN .533 AND .532
.533 - .53206521 = .0009348 ÷ .001 = .93479
USING .93479 AS THE "RATIO":
FIND COEFF.: (INTERPOLATE AS PER PAGE 146) = .36065592
VOL. = K x COEF.; 18,893 x .36065592 = 6814 GAL. AT 295°F.

A. OPEN. STO. TANK: 6814 GAL AT 295°F. x .9240* = 6,296 GAL. AT 60°F.
B. TRANSPORT: 6050 GAL. AT 287°F. x .9264* = 5,605 GAL. AT 60°F.
C. TRANSPORT: 5796 GAL. AT 290°F. x .9255* = 5,364 GAL. AT 60°F.
D. TRANSPORT: 4877 GAL. AT 243°F. x .9398* = 4,583 GAL. AT 60°F.
B/D RATIO [CLOSING] ((7 ÷ 16) + 35 - 6) ÷ 115 =
.25597826
INTERPOLATE COEFF. (AS ABOVE) = .62665395
VOL. = K x COEF.; 18,893 x .62665395 =
11,839 GAL. AT 288°F.
E. CLOSING STO. TANK: 11,839 GAL. AT 288°F x .9261* = -10,964 GAL. AT 60°F.
PAY QUANTITY = 10,884 GAL. AT 60°F.

* SEE TABLE 1 PAGE IV 1, VOLUME CORRECTION FOR TEMPERATURE

TYPICAL DEPOSITS OF FLORIDA SOILS

* LOCATION 1 = WEST, (District 3; Counties 46 thru 61.)
" 2 = NORTH, (Districts 2 & 5; Counties 26 thru 39, 71-74, 76, 78, 79.)
" 3 = CENTRAL, (Districts 1, 4, 5; Counties 70, 2, 6, 8-10, 88, 11, 13, 75, 92, 14-16, 18, 77.)
" 4 = SOUTH, (Districts 1, 4; Counties 86, 1, 3-5, 7, 12, 17, 87, 89, 90, 91, 93, 94.)

SOIL DESCRIPTION	LOCATION * CODE	A.A.S.H.T.O CLASSIFICAT.	IN PLACE DENSITY Lbs./Cu. Ft.	COMP. DRY DENSITY Lbs./Cu. Ft.	LOOSE DRY DENSITY Lbs./Cu. Ft.	OPTIMUM MOISTURE %
SHELL	3 & 4	A-1-a	100-110	115-125	80-90	10-13
SHELL	3 & 4	A-1-b	100-110	114-123	80-90	10-13
MARL	4	A-1-b	103-112	115-125	85-95	9-12
LIMESTONE	1,2,3	A-1-b	102-110	111-118	90-100	11-15
LIMESTONE	4	A-1-b	102-110	120-130	100-106	11-13
FINE SAND	1	A-3	100-105	100-110	90-95	10-16
" "	2	A-3	100-105	105-110	85-100	10-14
" "	3	A-3	100-105	98-115	85-90	10-16
FINE SAND	4	A-3	100-105	101-108	92-97	11-13
CLAYEY SAND	1	A-2-4	100-108	108-122	85-90	9-13
" "	2	A-2-4	100-108	108-114	85-100	10-16
" "	3	A-2-4	100-108	116-121	85-90	11-12
CLAYEY SAND	4	A-2-4	100-108	110-114	88-93	12-14
SAND CLAY	1	A-2-6	100-115	107-120	80-85	10-18
" "	2	A-2-6	100-105	105-112	85-100	14-18
" "	3	A-2-6	100-105	116-121	85-90	11-12
SAND CLAY	4	A-2-6	100-113	105-115	85-95	10-13
SAND CLAY	1	A-2-7	100-115	103-121	80-85	13-20
SAND CLAY	3 & 4	A-2-7	100-113	108-115	85-95	9-12
SILTY CLAY	1	A-4	105-108	104-112	80-85	10-14
SILTY CLAY	2	A-4	105-108	102-114	90-100	14-18
SILTY MARL	4	A-4	102-110	113-122	80-90	11-14
CLAY	1	A-6	100-110	107-120	80-85	10-18
"	2	A-6	100-110	100-110	90-100	14-18
"	3	A-6	100-110	112-114	90-100	14-18
"	4	A-6	100-110	112-118	95-105	10-13
"	1	A-7	95-100	103-121	80-85	13-20
"	2	A-7	95-100	98-105	85-95	16-20
"	3	A-7	95-100	112-114	85-95	13-14
CLAY	4	A-7	95-100	112-114	90-100	12-14
MUCK	1,2,3,4	A-8	40-50	45-55	40-50	70-100

MATERIAL	AVERAGE WEIGHT PER CUBIC YARD(WET)	MOISTURE CONTENT	BASIS FOR WEIGHT DETERMINATION	REMARKS
Sand for Concrete	2867 Lbs.	3%	Dry Rodded Wt.	Generally the same State-wide, Ortona Mines vary somewhat - up to 3100 Lbs./cu.yd.
Sand for Bituminous Mixes	2279 Lbs.	5%	Dry Loose Wt.	Variable state-wide
Limerock - Ocala	2449 Lbs.	15%	Actual Truck Weights	Considerable variance not only from mine to mine, but within the mines-ranges from 2100 to 2850 Lbs./cu.yd.
Limerock-Miami Oolite	2843 Lbs.	15%	Dry Loose Weight	Considerable variance
Key West	2362	8%	Dry Loose Weight	
Crushed Stone-Live Oak				
No. 6	2550 Lbs.	4.4%	Wet Loose Weight	Although wet loose weights are used as a basis for determining weight per cubic yard, the dry-rodded weight gives a result very close to those listed (i.e.,No. 9 stone 2538 lbs./cu.yd. - based on dry rodded weight)
No. 9	2550 Lbs.	4.4%	" " "	
No. 10-A	2510 Lbs.	4.4%	" " "	
No. 11	2560 Lbs.	4.4%	" " "	
No. 15	2490 Lbs.	4.4%	" " "	
No. 16-A	2500 Lbs.	4.4%	" " "	
No. 16-B	2430 Lbs.	4.4%	" " "	
Brooksville Area				
No. 6	2538 Lbs.	4%	Dry Rodded Weight	
No. 9	2610 Lbs.	4%	" " "	
No. 11	2470 Lbs.	4%	" " "	
No. 15	2497 Lbs.	4%	" " "	
Miami Area				
No. 6	2570 Lbs.	7%	Dry Rodded Weight	Other grades of stone are assumed to be within this range.
No. 9	2511 Lbs.	7%	" " "	
Key West Area				
No. 9	2362 Lbs.	8%	Dry Rodded Weight	Weights assumed to be the same for other grades of stone.

MATERIAL	AVERAGE WEIGHT PER CUBIC YARD(WET)	MOISTURE CONTENT	BASIS FOR WEIGHT DETERMINATION	REMARKS
(Crushed Stone Cont'd)				
Sunniland Area				
No. 9	2281 Lbs.	7%	Dry Rodded Wt.	Assumed to be the same for other grades of stone
Ft. Myers Area				
No. 9	2626 Lbs.	7%	Dry Rodded Wt.	Material is quite variable-but assume no variance between grades of stone.
Gravel				
Chattahoochee Area				
No. 9	2889 Lbs.	1%	Dry Rodded Wt.	Only source in State
Slag-Phosphate				
No. 11	2527 Lbs.	4%	Dry Rodded Weight	Information is from source at Victor,Fla. - Information on Slag from Nichols not available.
No. 15	2470 Lbs.	4%	" " "	
Birmingham				
No. 9	2246 Lbs.	4%	Dry Rodded Wt.	Considerable variance in the stone from 1998 Lbs. to 2916 Lbs/cu yd. but not between grades of stone.
No. 11	2246 Lbs.	4%	" " "	
No. 12	2246 Lbs.	4%	" " "	
No. 15	2246 Lbs.	4%	" " "	
Solite Aggregate				
3/4" to No. 4	1485 Lbs.	17%	Dry Rodded Wt.	
Screenings	2781 Lbs.	6%	Dry Rodded Wt.	Same State-wide.
Fill Dirt				
Sandy	2565 Lbs.	2%	Dry Loose Wt.	Material weight varies according to clay content
Clayey	2187 Lbs.	10.5%	Dry Loose Wt.	
Mineral Filler	2430 Lbs.	0%	Actual Weight	Uniform
Shell Base Material	2462 Lbs.	11%	Dry Rodded Wt.	Quite variable
Cemented Coquina	2916 Lbs.	10%	Dry Rodded Wt.	

OUT-OF-STATE MATERIALS WHICH ARE FREQUENTLY HAULED BY TRUCKS WITHIN FLORIDA

Crushed Stone-Central Alabama				
No. 11	2781 Lbs.	2%	Dry Rodded Wt.	
No. 15	2646 Lbs.	2%	Dry Rodded Wt.	
Gravel-Montgomery, Alabama				
No. 9	2862 Lbs.	1%	Dry Rodded Wt.	
S.W. Alabama				
No. 9	2943 Lbs.	1%	Dry Rodded Wt.	

Calculation of the compacted thickness of a stabilized Subgrade or Base when adding Stabilizing Material.

Given:

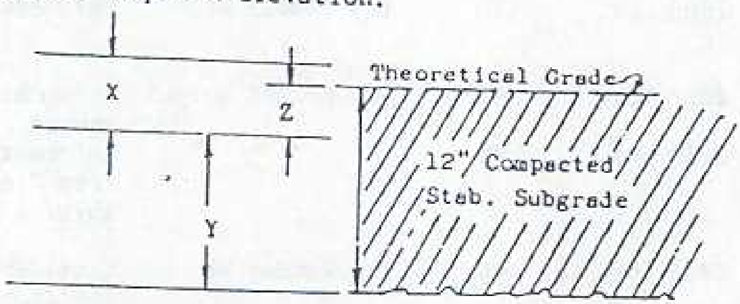
(1) Dry loose density of stabilizing Material = 95 Lbs./Cu. Ft.
(2) Compacted Subgrade dry Density = 105 Lbs./Cu. Ft.
(3) Compacted dry density "BLEND" of the stabilizing Material and Subgrade Material = 108 Lbs./Cu. Ft.
(4) Stabilizing Material To Be Added = 25%

Required:

x = Thickness of Stabilizing Material to be added

y = Thickness (inches) of compacted subgrade material to be Stabilized so that the finished Stabilized Subgrade will compact to 12-Inches.

z = Depth (inches) below theoretical grade to finish the subgrade to, before the stabilizing material is added so that the stabilized subgrade when compacted will finish to the required elevation.



Stabilizing Material Per Inch of Depth (Dry Wt.) per Square Foot:

$\frac{95 \text{ Lbs.}}{12 \text{ Inches}}$ = 7.92 Lbs. Per Inch/Square Ft.

25% X 108 = 27 Lbs./Cubic Ft.

For 12-Inch Stabilizing:

$X = \frac{27}{7.92} =$ 3.41 Inches Per Square Foot.

$Y = \frac{108 \text{ Lbs./Cu. Ft.} - 27 \text{ Lbs./Cu. Ft.}}{105 \text{ Lbs./Cu. Ft.}} \times 12''/\text{ft.}^2 = 9.26$ Inches

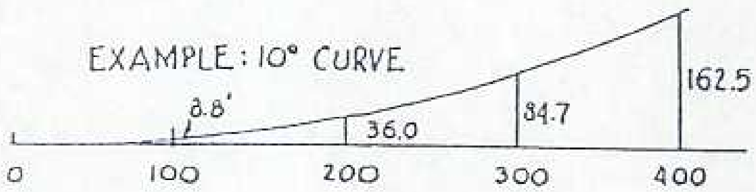
Z = 12-Inches - 9.26 Inches - 2.74 Inches

OR: $\frac{\text{Lbs. per cu. ft. Stab. Subgrade X Thickness X Width X Percent}}{\text{Dry-loose density of Stab. Material}} =$

equals: Cu. Ft. Stab. Matl. needed per linear ft. of roadway

NOTE: This is an approximate quantity based on theoretical variables. It will be the responsibility of those controlling the work to ensure that additional material is added as required.

T A N G E N T   O F F S E T S



CUR DEG MIN	RADIUS FT	100	200	300	400	500	600	700	800	900
		DISTANCES FROM PC AND TANGENT OFFSETS IN (FEET)								
0.15	22918.31	0.2	0.9	2.0	3.5	5.5	7.9	10.7	14.0	17.7
0.30	11459.16	0.4	1.7	3.9	7.0	10.9	15.7	21.4	28.0	35.4
0.45	7639.44	0.7	2.6	5.9	10.5	16.4	23.6	32.1	42.0	53.2
1. 0	5729.58	0.9	3.5	7.9	14.0	21.9	31.5	42.9	56.1	71.1
1.15	4583.66	1.1	4.4	9.8	17.5	27.4	39.4	53.8	70.4	89.2
1.30	3819.72	1.3	5.2	11.8	21.0	32.9	47.4	64.7	84.7	107.5
1.45	3274.04	1.5	6.1	13.8	24.5	38.4	55.4	75.7	99.2	126.1
2. 0	2864.79	1.7	7.0	15.8	28.1	44.0	63.5	86.8	114.0	145.0
2.15	2546.48	2.0	7.9	17.7	31.6	49.6	71.7	98.1	128.9	164.3
2.30	2291.83	2.2	8.7	19.7	35.2	55.2	79.9	109.5	144.2	184.1
2.45	2083.48	2.4	9.6	21.7	38.8	60.9	88.3	121.1	159.7	204.4
3. 0	1909.86	2.6	10.5	23.7	42.4	66.6	96.7	132.9	175.6	225.4
3.15	1762.95	2.8	11.4	25.7	46.0	72.4	105.2	144.9	192.0	247.0
3.30	1637.02	3.1	12.3	27.7	49.6	78.2	113.9	157.2	208.8	269.6
3.45	1527.69	3.3	13.1	29.7	53.3	84.1	122.7	169.8	226.2	293.2
4. 0	1432.39	3.5	14.0	31.8	57.0	90.1	131.7	182.7	244.2	318.1
4.15	1348.14	3.7	14.9	33.8	60.7	96.1	140.9	196.0	263.0	344.4
4.30	1273.24	3.9	15.8	35.8	64.5	102.3	150.2	209.7	282.7	372.6
4.45	1206.23	4.2	16.7	37.9	68.3	108.5	159.8	223.9	303.5	403.[illegible]
5. 0	1145.92	4.4	17.6	40.0	72.1	114.8	169.6	238.7	325.5	436.6
5.15	1091.35	4.6	18.5	42.0	75.9	121.3	179.7	254.1	349.0	474.1
5.30	1041.74	4.8	19.4	44.1	79.9	127.8	190.1	270.2	374.5	517.1
5.45	996.45	5.0	20.3	46.2	83.8	134.5	200.9	287.3	402.4	568.8
6. 0	954.93	5.3	21.2	48.3	87.8	141.4	212.0	305.4	433.5	635.7
6.15	916.73	5.5	22.1	50.5	91.9	148.4	223.6	324.8	469.1	742.4
6.30	881.47	5.7	23.0	52.6	96.0	155.5	235.7	345.8	511.3	
6.45	848.83	5.9	23.9	54.8	100.2	162.9	248.4	368.7	565.1	
7. 0	818.51	6.1	24.8	57.0	104.4	170.5	261.8	394.3	645.4	
7.15	790.29	6.4	25.7	59.2	108.7	178.3	275.9	423.5		
7.30	763.94	6.6	26.6	61.4	113.1	186.4	291.1	458.0		
7.45	739.30	6.8	27.6	63.6	117.6	194.7	307.4	501.5		
8. 0	716.20	7.0	28.5	65.9	122.1	203.4	325.1	564.7		
8.15	694.49	7.2	29.4	68.1	126.8	212.5	344.7			
8.30	674.07	7.5	30.4	70.4	131.5	222.0	366.9			
8.45	654.81	7.7	31.3	72.8	136.4	232.0	392.6			
9. 0	636.62	7.9	32.2	75.1	141.4	242.6	423.8			
9.15	619.41	8.1	33.2	77.5	146.5	253.8	465.6			
9.30	603.11	8.3	34.1	79.9	151.7	265.9	541.9			
9.45	587.65	8.6	35.1	82.3	157.1	278.9				
10. 0	572.96	8.8	36.0	84.8	162.7	293.2				

SECTION II

BRIDGE

DIAPHRAGM VOLUMES - ENDS ONLY

TYPE II BEAMS - END DIAPHRAGM VOLUMES FOR 8 INCH WEBS
VOLUME = 1.66667S - 1.2083

VOLUME IN CU.FT.

S = BEAM SPACING (FT)

BEAM SPACING FEET / INCH	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.0	5.4504	7.1250	8.7917	10.4584	12.1250	13.7917	15.4584
1.0	5.5972	7.2639	8.9306	10.5972	12.2639	13.9306	15.5973
2.0	5.7361	7.4028	9.0695	10.7362	12.4029	14.0695	15.7362
3.0	5.8750	7.5417	9.2084	10.8750	12.5417	14.2084	15.8750
4.0	6.0139	7.6806	9.3472	11.0139	12.6806	14.3472	16.0139
5.0	6.1528	7.8195	9.4862	11.1529	12.8195	14.4862	16.1529
6.0	6.2917	7.9584	9.6250	11.2917	12.9584	14.6250	16.2917
7.0	6.4306	8.0972	9.7639	11.4305	13.0972	14.7639	16.4305
8.0	6.5695	8.2361	9.9028	11.5695	13.2362	14.9028	16.5695
9.0	6.7083	8.3750	10.0417	11.7084	13.3750	15.0417	16.7084
10.0	6.8472	8.5139	10.1805	11.8472	13.5139	15.1805	16.8472
11.0	6.9861	8.6528	10.3195	11.9862	13.6529	15.3195	16.9862

FOR END WEBS ON BEAMS ADD 0.8542 CU.FT. PER END OF BEAM

TYPE III BEAMS - END DIAPHRAGM VOLUMES FOR 8 INCH WEBS
VOLUME = 2.11112S - 1.8773

VOLUME IN CU.FT.

S = BEAM SPACING (FT)

BEAM SPACING FEET / INCH	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.0	6.5672	8.6783	10.7894	12.9005	15.0117	17.1228	19.2339
1.0	6.7431	8.8542	10.9653	13.0765	15.1876	17.2987	19.4098
2.0	6.9190	9.0302	11.1413	13.2524	15.3635	17.4746	19.5858
3.0	7.0950	9.2061	11.3172	13.4283	15.5394	17.6506	19.7617
4.0	7.2709	9.3820	11.4931	13.6042	15.7154	17.8265	19.9376
5.0	7.4468	9.5579	11.6691	13.7802	15.8913	18.0024	20.1135
6.0	7.6227	9.7339	11.8450	13.9561	16.0672	18.1783	20.2895
7.0	7.7987	9.9098	12.0209	14.1320	16.2431	18.3543	20.4654
8.0	7.9746	10.0857	12.1968	14.3080	16.4191	18.5302	20.6413
9.0	8.1505	10.2616	12.3728	14.4839	16.5950	18.7061	20.8172
10.0	8.3264	10.4376	12.5487	14.6598	16.7709	18.8820	20.9932
11.0	8.5024	10.6135	12.7246	14.8357	16.9469	19.0580	21.1691

FOR END WEBS ON BEAMS ADD 1.2951 CU.FT. PER END OF BEAM

TYPE IV BEAMS - END DIAPHRAGM VOLUMES FOR 8 INCH WEBS
VOLUME = 2.55557S - 2.68981

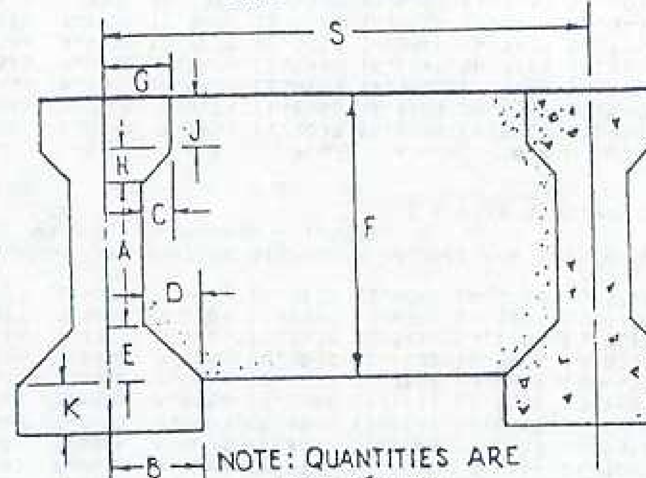
VOLUME IN CU.FT.

S = BEAM SPACING (FT)

BEAM SPACING FEET / INCH	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.0	7.5325	10.0880	12.6436	15.1992	17.7548	20.3103	22.8659
1.0	7.7454	10.3010	12.8566	15.4121	17.9677	20.5233	23.0788
2.0	7.9584	10.5140	13.0695	15.6251	18.1807	20.7363	23.2918
3.0	8.1714	10.7269	13.2825	15.8381	18.3936	20.9492	23.5048
4.0	8.3043	10.9399	13.4955	16.0510	18.6066	21.1622	23.7177
5.0	8.5973	11.1529	13.7084	16.2640	18.8196	21.3751	23.9307
6.0	8.8103	11.3658	13.9214	16.4770	19.0325	21.5881	24.1437
7.0	9.0232	11.5788	14.1344	16.6899	19.2455	21.8011	24.3566
8.0	9.2362	11.7918	14.3473	16.9029	19.4585	22.0140	24.5696
9.0	9.4491	12.0047	14.5603	17.1159	19.6714	22.2270	24.7826
10.0	9.6621	12.2177	14.7732	17.3288	19.8844	22.4400	24.9955
11.0	9.8751	12.4307	14.9862	17.5418	20.0974	22.6529	25.2085

FOR END WEBS ON BEAMS ADD 1.8264 CU.FT. PER END OF BEAM

END DIAPHRAMS



NOTE: QUANTITIES ARE FOR 8"WEBS

VOLUMES IN CU.FT. ARE SHOWN IN THE TABLES TO THE LEFT

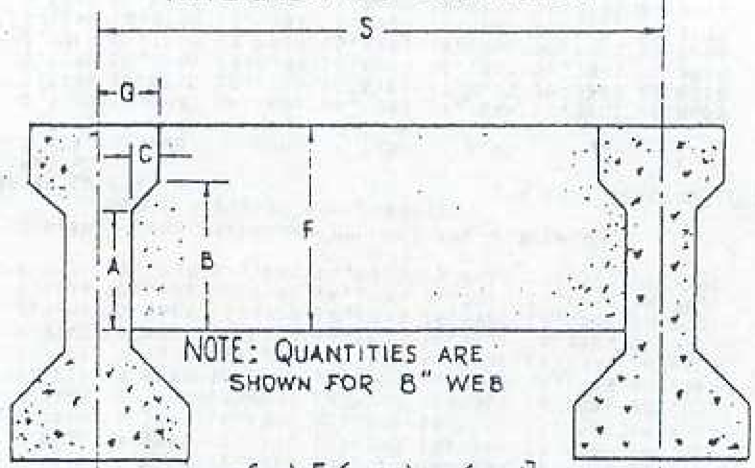
TABLES USE THE FOLLOWING FORMULAE:

TYPE II 1.6667S−1.2083 = CU.FT.

TYPE III 2.111S − 1.8773 = CU.FT.

TYPE IV 2.555S − 2.6898 = CU.FT.

INTERMEDIATE DIAPHRAGM



VOLUME(C.F.)=[F(S-2G)+C(A+B)] x 8÷12

CONCRETE QUANTITIES FOR DIAPHRAMS USING BEAMS OF THE SAME TYPE ARE SHOWN IN THE TABLES TO THE RIGHT→

FOR COMBINATIONS OF UNLIKE BEAMS DEDUCT THE CU.FT. SHOWN BELOW FROM THE STANDARD VOLUME TABULATED FOR THE SMALLER BEAM.

COMBINATION OF BEAMS	DEDUCTION FROM STD. SMALL BEAM QUANTITY
III II	.1395 CU. FT.
IV II	.3032 "
IV III	.1787 "

DIAPHRAGM VOLUMES - INTERMEDIATE ONLY

TYPE II BEAMS - INTERMEDIATE DIAPHRAGM VOLUMES FOR 8 INCH WEBS
VOLUME = 1.222235 - 0.81945

VOLUME IN CU.FT. S = BEAM SPACING (FT)

BEAM SPACING FEET / INCH	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.0	4.0695	5.2917	6.5139	7.7362	8.9584	10.1806	11.4029
1.0	4.1713	5.3935	6.6158	7.8380	9.0602	10.2825	11.5047
2.0	4.2732	5.4954	6.7176	7.9399	9.1621	10.3843	11.6066
3.0	4.3750	5.5973	6.8195	8.0417	9.2639	10.4862	11.7084
4.0	4.4769	5.6991	6.9213	8.1436	9.3658	10.5880	11.8103
5.0	4.5787	5.8010	7.0232	8.2454	9.4677	10.6899	11.9121
6.0	4.6806	5.9028	7.1250	8.3473	9.5695	10.7917	12.0140
7.0	4.7824	6.0047	7.2269	8.4491	9.6714	10.8936	12.1158
8.0	4.8843	6.1065	7.3288	8.5510	9.7732	10.9954	12.2177
9.0	4.9861	6.2084	7.4306	8.6528	9.8751	11.0973	12.3195
10.0	5.0880	6.3102	7.5325	8.7547	9.9769	11.1991	12.4214
11.0	5.1898	6.4121	7.6343	8.8565	10.0788	11.3010	12.5232

TYPE III BEAMS - INTERMEDIATE DIAPHRAGM VOLUMES FOR 8 INCH WEBS
VOLUME = 1.583335 - 1.30903

VOLUME IN CU.FT. S = BEAM SPACING (FT)

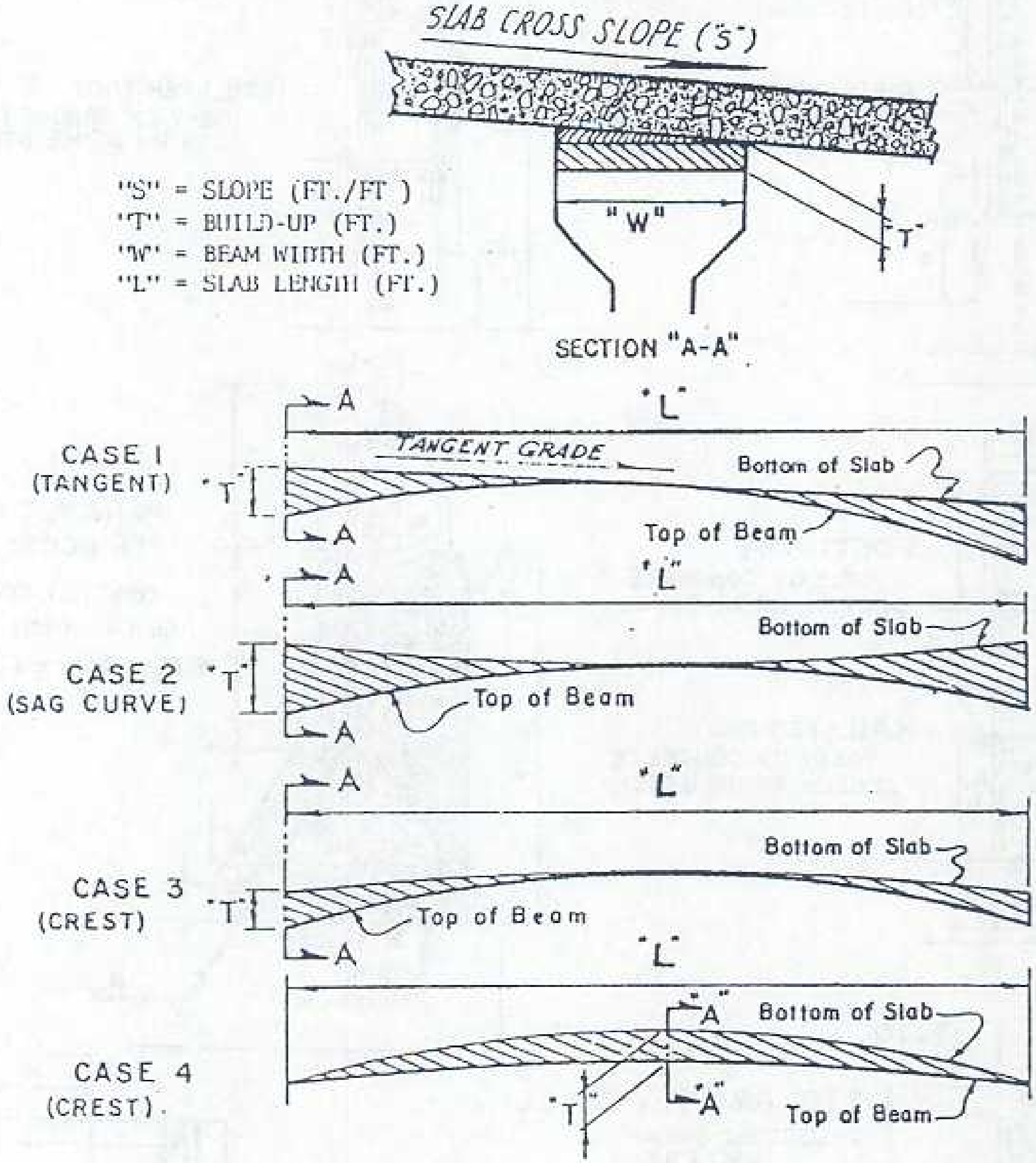
BEAM SPACING FEET / INCH	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.0	5.0243	6.6076	8.1910	9.7743	11.3576	12.9409	14.5243
1.0	5.1562	6.7396	8.3229	9.9062	11.4895	13.0729	14.6562
2.0	5.2882	6.8715	8.4548	10.0382	11.6215	13.2048	14.7882
3.0	5.4201	7.0035	8.5868	10.1701	11.7534	13.3368	14.9201
4.0	5.5521	7.1354	8.7187	10.3021	11.8854	13.4687	15.0520
5.0	5.6840	7.2673	8.8507	10.4340	12.0173	13.6007	15.1840
6.0	5.8160	7.3993	8.9826	10.5660	12.1493	13.7326	15.3159
7.0	5.9479	7.5312	9.1146	10.6979	12.2812	13.8645	15.4479
8.0	6.0798	7.6637	9.2465	10.8298	12.4132	13.9965	15.5798
9.0	6.2118	7.7951	9.3784	10.9618	12.5451	14.1284	15.7118
10.0	6.3437	7.9271	9.5104	11.0937	12.6771	14.2604	15.8437
11.0	6.4757	8.0590	9.6423	11.2257	12.8090	14.3923	15.9757

TYPE IV BEAMS - INTERMEDIATE DIAPHRAGM VOLUMES FOR 8 INCH WEBS
VOLUME = 1.944465 - 1.90743

VOLUME IN CU.FT. S = BEAM SPACING (FT)

BEAM SPACING FEET / INCH	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.0	5.8704	7.8149	9.7593	11.7038	13.6483	15.5927	17.5372
1.0	6.0324	7.9769	9.9214	11.8658	13.8103	15.7547	17.6992
2.0	6.1945	8.1389	10.0834	12.0279	13.9723	15.9168	17.8612
3.0	6.3565	8.3010	10.2454	12.1899	14.1344	16.0788	18.0233
4.0	6.5186	8.4630	10.4075	12.3519	14.2964	16.2409	18.1853
5.0	6.6806	8.6251	10.5695	12.5140	14.4584	16.4029	18.3474
6.0	6.8426	8.7871	10.7316	12.6760	14.6205	16.5649	18.5094
7.0	7.0047	8.9491	10.8936	12.8381	14.7825	16.7270	18.6714
8.0	7.1667	9.1112	11.0556	13.0001	14.9446	16.8890	18.8335
9.0	7.3288	9.2732	11.2177	13.1621	15.1066	17.0511	18.9955
10.0	7.4908	9.4352	11.3797	13.3242	15.2686	17.2131	19.1576
11.0	7.6528	9.5973	11.5418	13.4862	15.4307	17.3751	19.3196

VOLUME OF CONCRETE IN BUILD-UPS OVER PRESTRESSED BEAMS

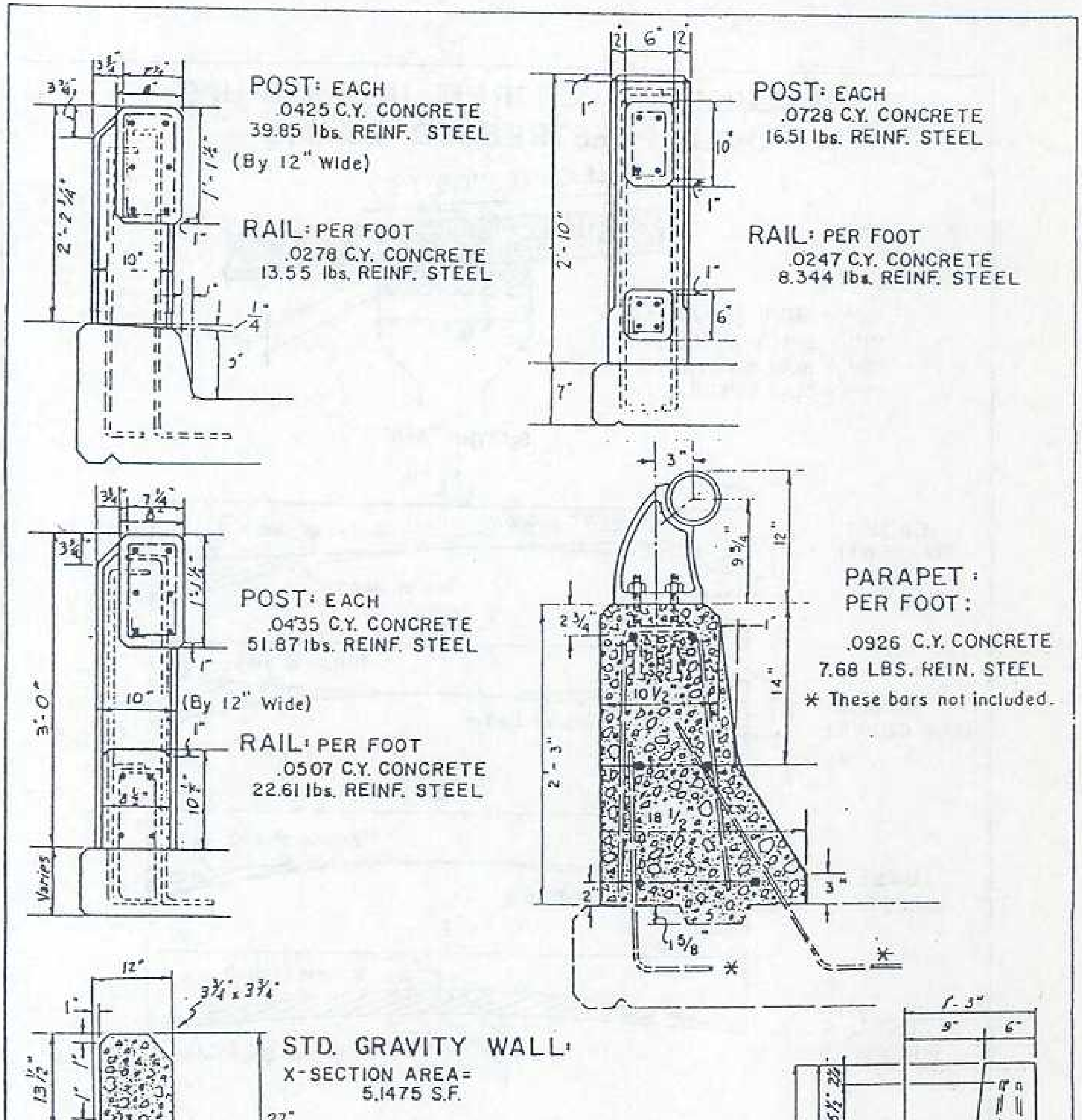


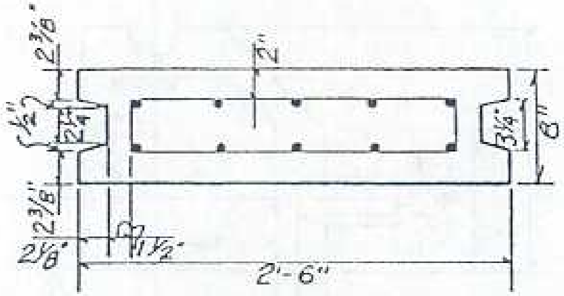
VOLUME CONCRETE (CU. FT.)

CASE 1,2, & 3		CASE 4	
GENERAL FORMULA:	$V = L(SW^2/2 + WT/3)$	GENERAL FORMULA:	$V = L(SW^2/2 + 2WT/3)$
TYPE II	$= L(S/2 + T/3)$	TYPE II	$= L(S/2 + 2T/3)$
TYPE III	$= L/9(8S + 4T)$	TYPE III	$= 8L/9(S + T)$
TYPE IV	$= L/9(12.5S + 5T)$	TYPE IV	$= L/9(12.5S + 10T)$
TYPE V & VI	$= L(6.125\ S + 7T/6)$	TYPE V & VI	$= L(6.125S + 21T/9)$

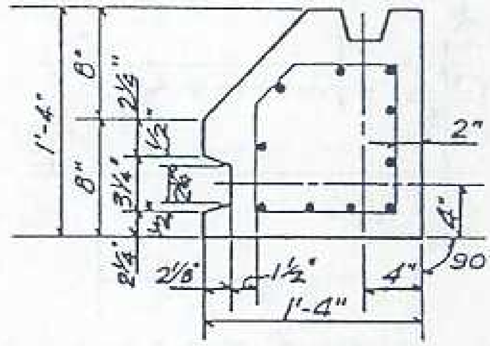
NOTE: The volume of concrete in the build-ups shall be included in the Concrete Quantities on the Superstructure Detail Sheets.

The depth of Diaphragms shall include the dimension "T" when computing concrete volumes.

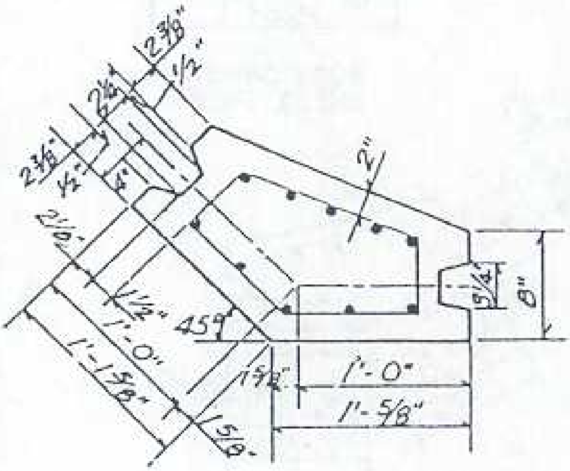

POST: EACH
.0425 C.Y. CONCRETE
39.85 lbs. REINF. STEEL
(By 12" Wide)
RAIL: PER FOOT
.0278 C.Y. CONCRETE
13.55 lbs. REINF. STEEL
2'-2 1/4"
1'-1 1/2"
10"
1"
1/4"
5"
POST: EACH
.0728 C.Y. CONCRETE
16.51 lbs. REINF. STEEL
RAIL: PER FOOT
.0247 C.Y. CONCRETE
8.344 lbs. REINF. STEEL
2 6" 2
2'-10"
10"
1"
6"
7"
POST: EACH
.0435 C.Y. CONCRETE
51.87 lbs. REINF. STEEL
(By 12" Wide)
RAIL: PER FOOT
.0507 C.Y. CONCRETE
22.61 lbs. REINF. STEEL
3'-0"
Varies
10"
10 1/2"
PARAPET:
PER FOOT:
.0926 C.Y. CONCRETE
7.68 LBS. REIN. STEEL
* These bars not included.
3"
12"
9 3/4"
2 3/4"
14"
2'-3"
10 1/2
18 1/2
1 5/8"
STD. GRAVITY WALL:
X-SECTION AREA=
5.1475 S.F.
CENTROID (HORIZ.)=
7.41" from face
CONCRETE=
0.1906 C.Y./FT.
12"
3 3/4" x 3 3/4"
13 1/2"
27"
27"
21"
1 1/2"
CENTROID
7.41"
BARRIER:
PER FOOT
0.07594 C.Y.
CONCRETE
20.744 lbs.
REINF. STEEL
1'-3"
9"
6"
2'-8"
1'-7"
7"
10" Rad.
10"
11"
3"



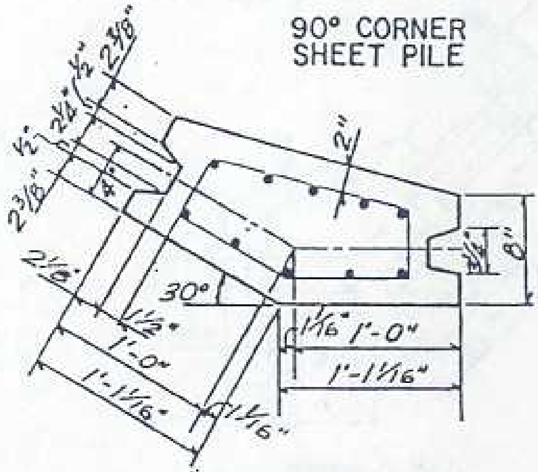
STANDARD 8"x30" PILE



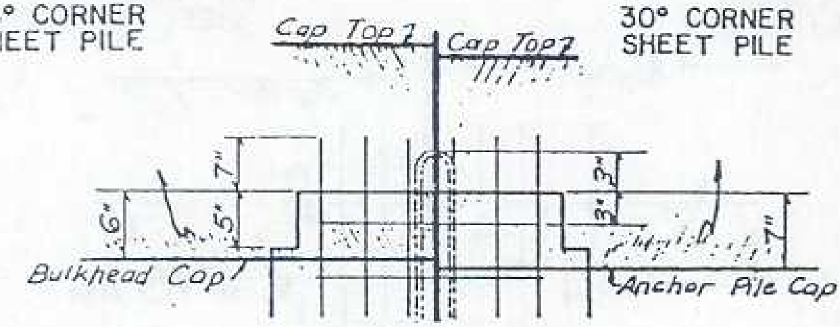
90° CORNER SHEET PILE



45° CORNER SHEET PILE



30° CORNER SHEET PILE

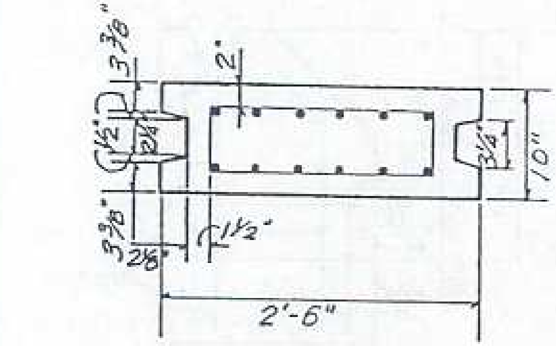


PILE IMBEDMENT

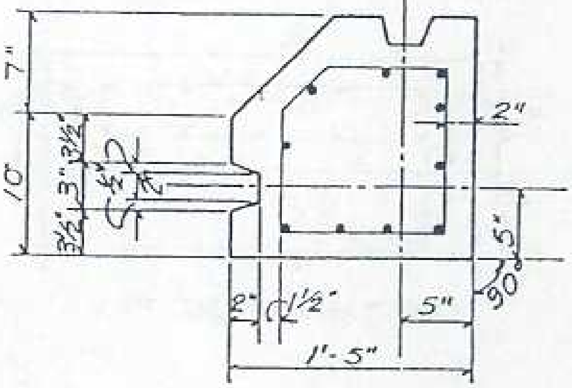
CONCRETE DEDUCTS for BULKHEADS, in cu. ft. (per pile)						
LOCATION / TYPE	STANDARD	90°	45°	30°		
BULKHEAD	0.73495	0.66633	0.69163	0.66776		
ANCHOR	0.86032	———	———	———		

*NOTE: 6" Imbedment for Bulkhead Cap & 7" for Anchor Pile Cap.

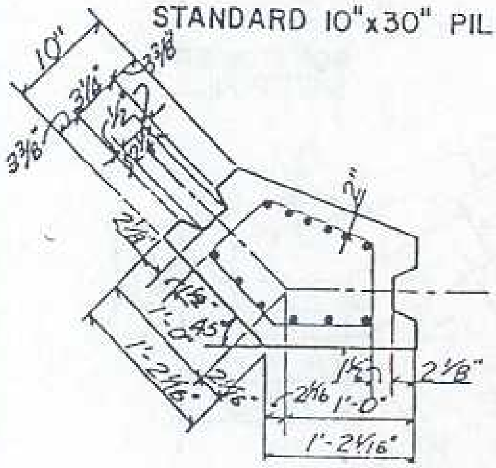
PRECAST CONCRETE SHEET PILING (8"x30")



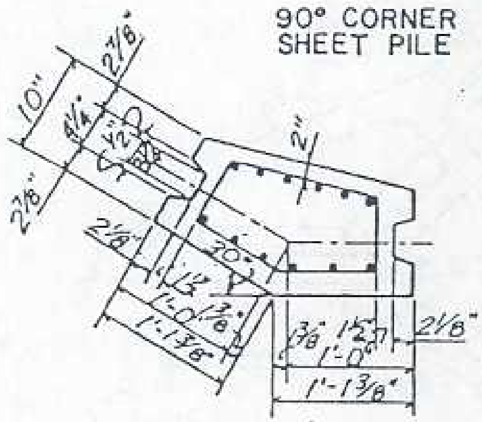
STANDARD 10"x30" PILE



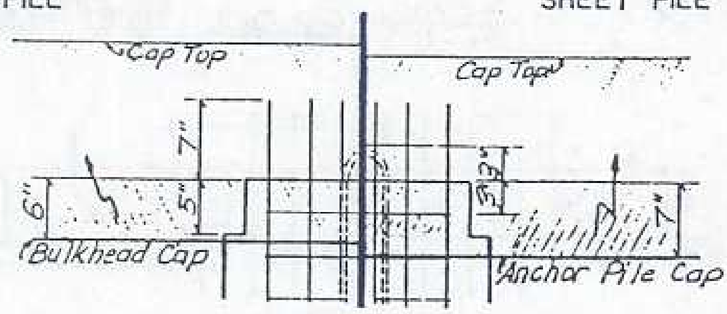
90° CORNER SHEET PILE



45° CORNER SHEET PILE



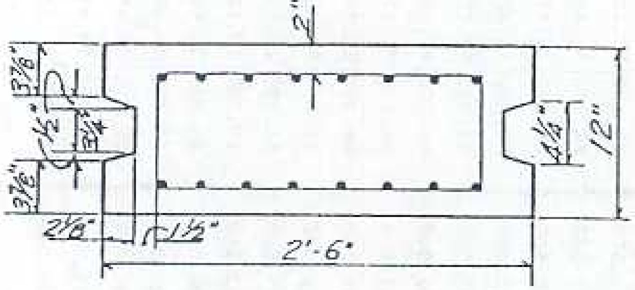
30° CORNER SHEET PILE



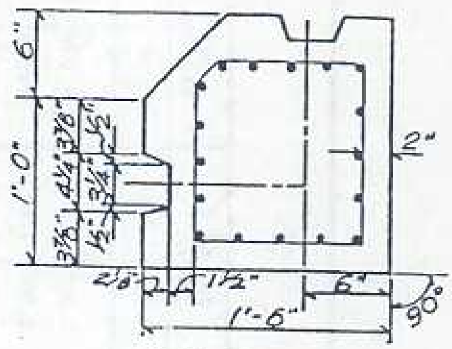
PILE IMBEDMENT

CONCRETE DEDUCTS for BULKHEADS; In cu. ft. (per pile)						
	STANDARD	90°	45°	30°		
BULKHEAD	0.91869	0.79109	0.82516	0.81859		
ANCHOR	1.07386					

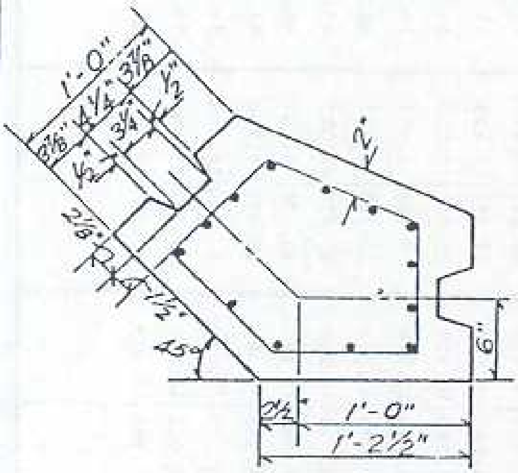
PRECAST CONCRETE SHEET PILING (10"x30")



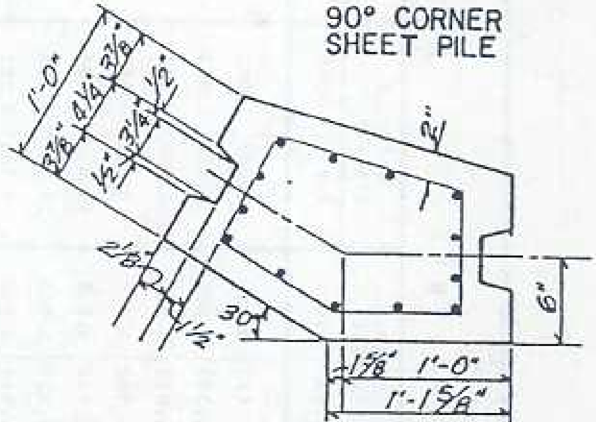
STANDARD 12"x30" PILE



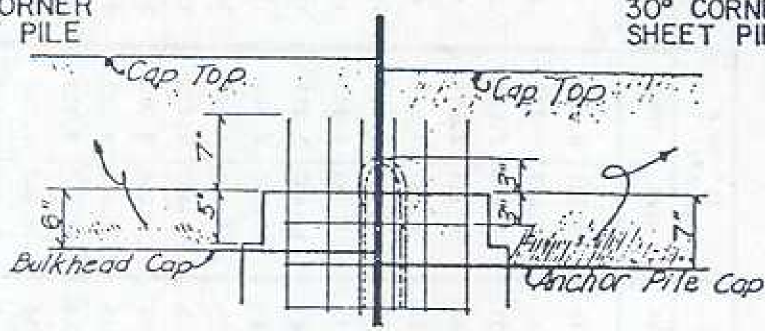
90° CORNER
SHEET PILE



45° CORNER
SHEET PILE



30° CORNER
SHEET PILE



PILE IMBEDMENT

CONCRETE DEDUCTS for BULKHEADS; In cu. ft. (per pile)						
	STANDARD	90°	45°	30°		
BULKHEAD	1.10243	0.90186	0.95972	0.94442		
ANCHOR	1.29232					

PRECAST CONCRETE SHEET PILING (12"x30")

PILE WEIGHTS

PILE	12" SQ.@ 150.00#/FT.		14" SQ.@ 204.17#/FT.		16" SQ.@ 266.67#/FT.		18" SQ.@ 337.50#/FT.		20" SQ.@ 416.67#/FT.		24" SQ.@ 600.00#/FT.		54" O @ 810.00#/FT.	
LENG	KIPS	TONS	KIPS	TONS	KIPS	TONS	KIPS	TONS	KIPS	TONS	KIPS	TONS	KIPS	TONS
5	0.750	0.375	1.021	0.510	1.333	0.667	1.688	0.844	2.083	1.042	3.000	1.500	4.050	2.025
10	1.500	0.750	2.042	1.021	2.667	1.333	3.375	1.688	4.167	2.083	6.000	3.000	8.100	4.050
15	2.250	1.125	3.063	1.531	4.000	2.000	5.063	2.531	6.250	3.125	9.000	4.500	12.150	6.075
20	3.000	1.500	4.083	2.042	5.333	2.667	6.750	3.375	8.333	4.167	12.000	6.000	16.200	8.100
25	3.750	1.875	5.104	2.552	6.667	3.333	8.438	4.219	10.417	5.208	15.000	7.500	20.250	10.125
30	4.500	2.250	6.125	3.063	8.000	4.000	10.125	5.063	12.500	6.250	18.000	9.000	24.300	12.150
35	5.250	2.625	7.146	3.573	9.333	4.667	11.813	5.906	14.583	7.292	21.000	10.500	28.350	14.175
40	6.000	3.000	8.167	4.083	10.667	5.333	13.500	6.750	16.667	8.333	24.000	12.000	32.400	16.200
45	6.750	3.375	9.188	4.594	12.000	6.000	15.188	7.594	18.750	9.375	27.000	13.500	36.450	18.225
50	7.500	3.750	10.208	5.104	13.333	6.667	16.875	8.438	20.833	10.417	30.000	15.000	40.500	20.250
55	8.250	4.125	11.229	5.615	14.667	7.333	18.563	9.281	22.917	11.458	33.000	16.500	44.550	22.275
60	9.000	4.500	12.250	6.125	16.000	8.000	20.250	10.125	25.000	12.500	36.000	18.000	48.600	24.300
65	9.750	4.875	13.271	6.635	17.333	8.667	21.938	10.969	27.083	13.542	39.000	19.500	52.650	26.325
70	10.500	5.250	14.292	7.146	18.667	9.333	23.625	11.813	29.167	14.583	42.000	21.000	56.700	28.350
75	11.250	5.625	15.313	7.656	20.000	10.000	25.313	12.656	31.250	15.625	45.000	22.500	60.750	30.375
80	12.000	6.000	16.333	8.167	21.333	10.667	27.000	13.500	33.333	16.667	48.000	24.000	64.800	32.400
85	12.750	6.375	17.354	8.677	22.667	11.333	28.688	14.344	35.417	17.708	51.000	25.500	68.850	34.425
90	13.500	6.750	18.375	9.188	24.000	12.000	30.375	15.188	37.500	18.750	54.000	27.000	72.900	36.450
95	14.250	7.125	19.396	9.698	25.333	12.667	32.063	16.031	39.583	19.792	57.000	28.500	76.950	38.475
100	15.000	7.500	20.417	10.208	26.667	13.333	33.750	16.875	41.667	20.833	60.000	30.000	81.000	40.500

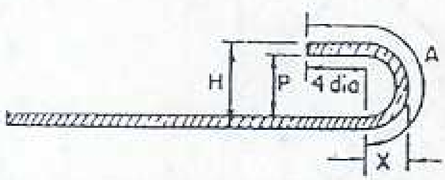
REINFORCING BARS

LBS./FT.	DIAMETER INCHES	SIZE	NO.	AREA SQ. INCHES	PERIMETER
.167	.250	(1/4)	2	.05	.786
.376	.375	(3/8)	3	.11	1.178
.668	.500	(1/2)	4	.20	1.571
1.043	.625	(5/8)	5	.31	1.963
1.502	.750	(3/4)	6	.44	2.356
2.044	.875	(7/8)	7	.60	2.749
2.670	1.000	(1)	8	.79	3.142
3.400	1.128	[1]	9	1.00	3.544
4.303	1.270	[1 1/8]	10	1.27	3.990
5.313	1.410	[1 1/4]	11	1.56	4.430
7.650	1.692	[1 1/2]	14S	2.25	5.316
13.600	2.256	[2]	18S	4.00	7.088

FRACTIONS TO DECIMALS			
1/32	= .03125	17/32	= .53125
1/16	= .0625	9/16	= .5625
3/32	= .09375	19/32	= .59375
1/8	= .125	5/8	= .625
5/32	= .15625	21/32	= .62625
3/16	= .1875	11/16	= .6875
7/32	= .21875	23/32	= .71875
1/4	= .25	3/4	= .75
9/32	= .28125	25/32	= .78125
5/16	= .3125	13/16	= .8125
11/32	= .34375	27/32	= .84375
3/8	= .375	7/8	= .875
13/32	= .40625	29/32	= .90625
7/16	= .4375	15/16	= .9375
15/32	= .46875	31/32	= .96875
1/2	= .500	1	= 1.000

▢ Rolled in Round equal in area to square section.

Method of hooking bars as recommended by A.C.I

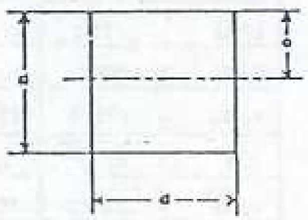


PROPERTIES OF REINF. STEEL AND STD. HOOK DIMENSIONS							
SIZE	AREA	PERIMETER	LB/FT.	P	H	X	A
1/4" ø	.049	0.785	0.167	1 1/4"	1 3/4"	7/8"	3 3/8"
3/8" ø	.110	1.178	0.376	1 7/8"	2 5/8"	1 3/8"	5"
1/2" ø	.196	1.571	0.668	2 1/2"	3 1/2"	1 3/4"	6 3/4"
1/2" □	.250	2.000	0.850	2 1/2"	3 1/2"	1 3/4"	6 3/4"
5/8" ø	.307	1.963	1.043	3 1/8"	4 3/8"	2 1/8"	8 3/8"
3/4" ø	.442	2.356	1.502	3 3/4"	5 1/4"	2 5/8"	10"
7/8" ø	.601	2.749	2.044	4 3/8"	6 1/8"	3"	11 3/4"
1" ø	.785	3.142	2.677	5"	7"	3 1/2"	13 3/8"
1" □	1.000	4.000	3.400	5"	7"	3 1/2"	13 3/8"
1 1/8" □	1.266	4.500	4.303	5 5/8"	7 7/8"	3 7/8"	15 1/8"
1 1/4" □	1.563	5.000	5.313	6 1/4"	8 3/4"	4 3/8"	16 3/4"

PROPERTIES OF GEOMETRIC SECTIONS

SQUARE

Axis of moments through center



$A = d^2$

$c = \frac{d}{2}$

$I = \frac{d^4}{12}$

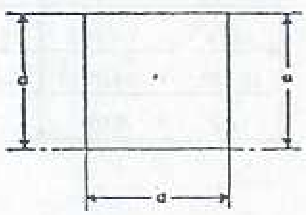
$S = \frac{d^3}{6}$

$r = \frac{d}{\sqrt{12}} = .288675\ d$

$Z = \frac{d^3}{4}$

SQUARE

Axis of moments on base



$A = d^2$

$c = d$

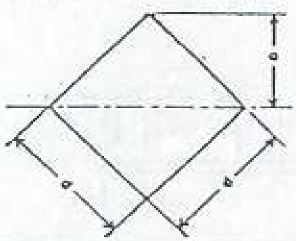
$I = \frac{d^4}{3}$

$S = \frac{d^3}{3}$

$r = \frac{d}{\sqrt{3}} = .577350\ d$

SQUARE

Axis of moments on diagonal



$A = d^2$

$c = \frac{d}{\sqrt{2}} = .707107\ d$

$I = \frac{d^4}{12}$

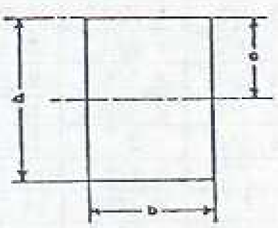
$S = \frac{d^3}{6\sqrt{2}} = .117851\ d^3$

$r = \frac{d}{\sqrt{12}} = .288675\ d$

$Z = \frac{2c^3}{3} = \frac{d^3}{3\sqrt{2}} = .235702 d^3$

RECTANGLE

Axis of moments through center



$A = bd$

$c = \frac{d}{2}$

$I = \frac{bd^3}{12}$

$S = \frac{bd^2}{6}$

$r = \frac{d}{\sqrt{12}} = .288675\ d$

$Z = \frac{bd^2}{4}$

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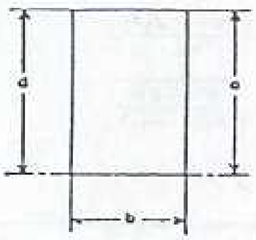
PROPERTIES OF GEOMETRIC SECTIONS

RECTANGLE

Axis of moments on base



$$A = bd$$

$$c = d$$

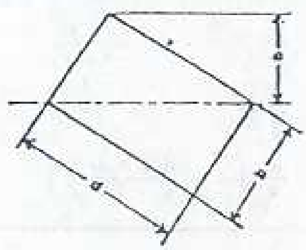
$$I = \frac{bd^3}{3}$$

$$S = \frac{bd^2}{3}$$

$$r = \frac{d}{\sqrt{3}} = .577350\ d$$

RECTANGLE

Axis of moments on diagonal



$$A = bd$$

$$c = \frac{bd}{\sqrt{b^2 + d^2}}$$

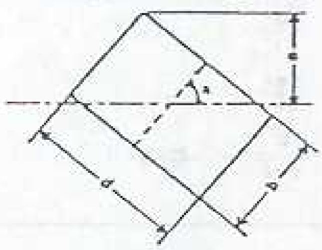
$$I = \frac{b^3d^3}{6\,(b^2 + d^2)}$$

$$S = \frac{b^2d^2}{6\sqrt{b^2 + d^2}}$$

$$= \frac{bd}{\sqrt{6\,(b^2 + d^2)}}$$

RECTANGLE

Axis of moments any line through center of gravity



$$A = bd$$

$$c = \frac{b \sin a + d \cos a}{2}$$

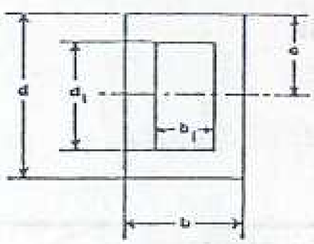
$$I = \frac{bd\,(b^2 \sin^2 a + d^2 \cos^2 a)}{12}$$

$$S = \frac{bd\,(b^2 \sin^2 a + d^2 \cos^2 a)}{6\,(b \sin a + d \cos a)}$$

$$r = \sqrt{\frac{b^2 \sin^2 a + d^2 \cos^2 a}{12}}$$

HOLLOW RECTANGLE

Axis of moments through center



$$A = bd - b_1d_1$$

$$c = \frac{d}{2}$$

$$I = \frac{bd^3 - b_1d_1^3}{12}$$

$$S = \frac{bd^3 - b_1d_1^3}{6d}$$

$$r = \sqrt{\frac{bd^3 - b_1d_1^3}{12\,A}}$$

$$Z = \frac{bd^2}{4} - \frac{b_1d_1^2}{4}$$

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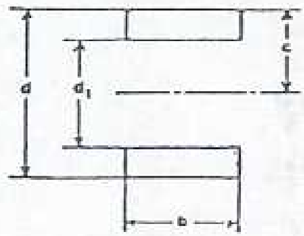
PROPERTIES OF GEOMETRIC SECTIONS

EQUAL RECTANGLES

Axis of moments through center of gravity



$$A = b(d - d_1)$$

$$c = \frac{d}{2}$$

$$I = \frac{b(d^3 - d_1^3)}{12}$$

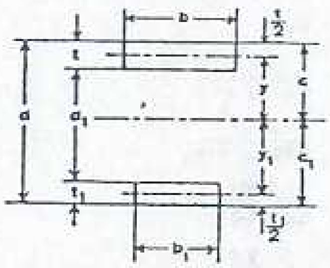
$$S = \frac{b(d^3 - d_1^3)}{6d}$$

$$r = \sqrt{\frac{d^3 - d_1^3}{12(d - d_1)}}$$

$$Z = \frac{b}{4}(d^2 - d_1^2)$$

UNEQUAL RECTANGLES

Axis of moments through center of gravity



$$A = bt + b_1t_1$$

$$c = \frac{\frac{1}{2}bt^2 + b_1t_1(d - \frac{1}{2}t_1)}{A}$$

$$I = \frac{bt^3}{12} + bty^2 + \frac{b_1t_1^3}{12} + b_1t_1y_1^2$$

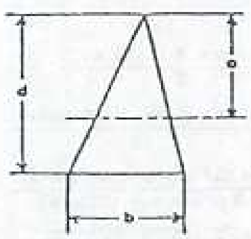
$$S = \frac{I}{c} \qquad S_1 = \frac{I}{c_1}$$

$$r = \sqrt{\frac{I}{A}}$$

$$Z = \frac{A}{2}\left[d - \left(\frac{t + t_1}{2}\right)\right]$$

TRIANGLE

Axis of moments through center of gravity



$$A = \frac{bd}{2}$$

$$c = \frac{2d}{3}$$

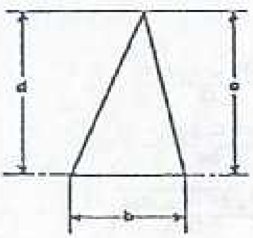
$$I = \frac{bd^3}{36}$$

$$S = \frac{bd^2}{24}$$

$$r = \frac{d}{\sqrt{18}} = .235702\ d$$

TRIANGLE

Axis of moments on base



$$A = \frac{bd}{2}$$

$$c = d$$

$$I = \frac{bd^3}{12}$$

$$S = \frac{bd^2}{12}$$

$$r = \frac{d}{\sqrt{6}} = .408248\ d$$

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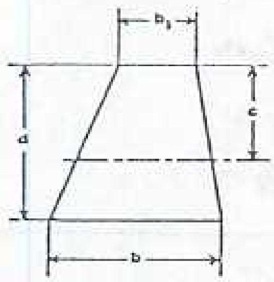
PROPERTIES OF GEOMETRIC SECTIONS

TRAPEZOID

Axis of moments through center of gravity



$$A = \frac{d(b + b_1)}{2}$$

$$c = \frac{d(2b + b_1)}{3(b + b_1)}$$

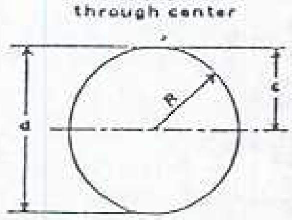
$$I = \frac{d^3 (b^2 + 4bb_1 + b_1^2)}{36 (b + b_1)}$$

$$S = \frac{d^2 (b^2 + 4bb_1 + b_1^2)}{12 (2b + b_1)}$$

$$r = \frac{d}{6(b + b_1)} \sqrt{2 (b^2 + 4bb_1 + b_1^2)}$$

CIRCLE

Axis of moments through center



$$A = \frac{\pi d^2}{4} = \pi R^2 = .785398\, d^2 = 3.141593\, R^2$$

$$c = \frac{d}{2} = R$$

$$I = \frac{\pi d^4}{64} = \frac{\pi R^4}{4} = .049087\, d^4 = .785398\, R^4$$

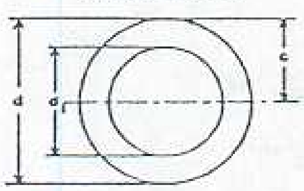
$$S = \frac{\pi d^3}{32} = \frac{\pi R^3}{4} = .098175\, d^3 = .785398\, R^3$$

$$r = \frac{d}{4} = \frac{R}{2}$$

$$Z = \frac{d^3}{6}$$

HOLLOW CIRCLE

Axis of moments through center



$$A = \frac{\pi(d^2 - d_1^2)}{4} = .785398\, (d^2 - d_1^2)$$

$$c = \frac{d}{2}$$

$$I = \frac{\pi(d^4 - d_1^4)}{64} = .049087\, (d^4 - d_1^4)$$

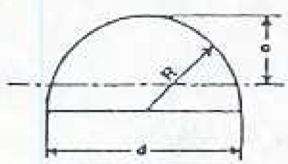
$$S = \frac{\pi(d^4 - d_1^4)}{32d} = .098175\, \frac{d^4 - d_1^4}{d}$$

$$r = \frac{\sqrt{d^2 + d_1^2}}{4}$$

$$Z = \frac{d^3}{6} - \frac{d_1^3}{6}$$

HALF CIRCLE

Axis of moments through center of gravity



$$A = \frac{\pi R^2}{2} = 1.570796\, R^2$$

$$c = R\left(1 - \frac{4}{3\pi}\right) = .575587\, R$$

$$I = R^4\left(\frac{\pi}{8} - \frac{8}{9\pi}\right) = .109757\, R^4$$

$$S = \frac{R^3}{24}\,\frac{(9\pi^2 - 64)}{(3\pi - 4)} = .190687\, R^3$$

$$r = R\,\frac{\sqrt{9\pi^2 - 64}}{6\pi} = .264336\, R$$

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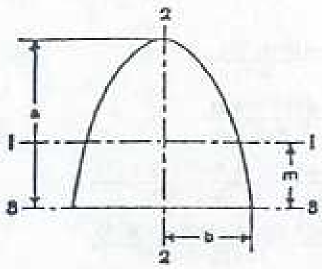
PROPERTIES OF GEOMETRIC SECTIONS

PARABOLA



$$A = \frac{4}{3}ab$$

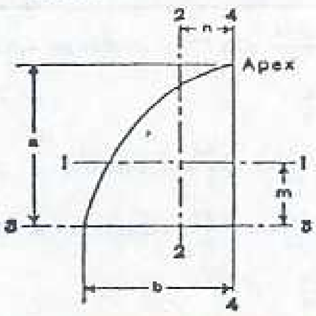
$$m = \frac{2}{5}a$$

$$I_1 = \frac{16}{175}a^3b$$

$$I_2 = \frac{4}{15}ab^3$$

$$I_3 = \frac{32}{105}a^3b$$

HALF PARABOLA



$$A = \frac{2}{3}ab$$

$$m = \frac{2}{5}a$$

$$n = \frac{3}{8}b$$

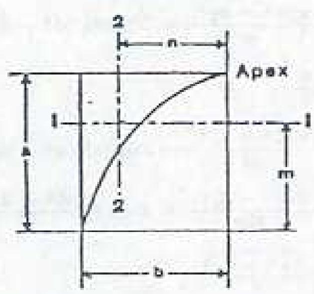
$$I_1 = \frac{8}{175}a^3b$$

$$I_2 = \frac{19}{480}ab^3$$

$$I_3 = \frac{16}{105}a^3b$$

$$I_4 = \frac{2}{15}ab^3$$

COMPLEMENT OF HALF PARABOLA



$$A = \frac{1}{3}ab$$

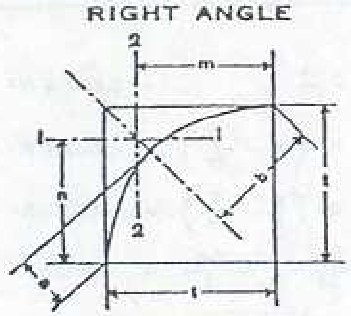
$$m = \frac{7}{10}a$$

$$n = \frac{3}{4}b$$

$$I_1 = \frac{37}{2100}a^3b$$

$$I_2 = \frac{1}{80}ab^3$$

PARABOLIC FILLET IN RIGHT ANGLE



$$a = \frac{t}{2\sqrt{2}}$$

$$b = \frac{t}{\sqrt{2}}$$

$$A = \frac{1}{6}t^2$$

$$m = n = \frac{4}{5}t$$

$$I_1 = I_2 = \frac{11}{2100}t^4$$

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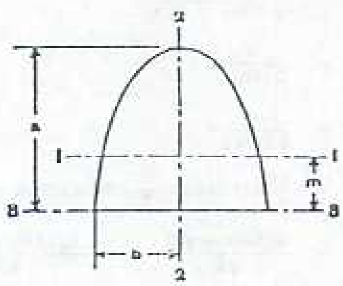
PROPERTIES OF GEOMETRIC SECTIONS

* HALF ELLIPSE



$$A = \frac{1}{2}\pi ab$$

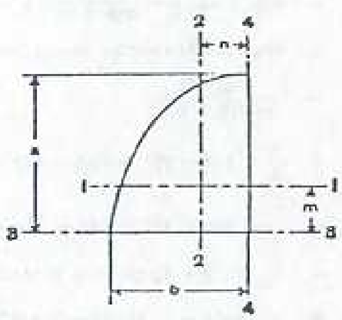
$$m = \frac{4a}{3\pi}$$

$$I_1 = a^3b\left(\frac{\pi}{8} - \frac{8}{9\pi}\right)$$

$$I_2 = \frac{1}{8}\pi ab^3$$

$$I_3 = \frac{1}{8}\pi a^3b$$

* QUARTER ELLIPSE



$$A = \frac{1}{4}\pi ab$$

$$m = \frac{4a}{3\pi}$$

$$n = \frac{4b}{3\pi}$$

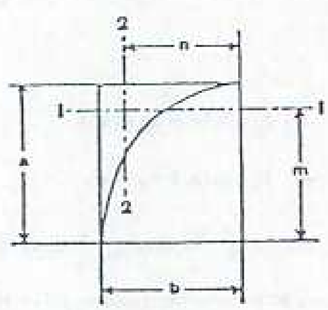
$$I_1 = a^3b\left(\frac{\pi}{16} - \frac{4}{9\pi}\right)$$

$$I_2 = ab^3\left(\frac{\pi}{16} - \frac{4}{9\pi}\right)$$

$$I_3 = \frac{1}{16}\pi a^3b$$

$$I_4 = \frac{1}{16}\pi ab^3$$

* ELLIPTIC COMPLEMENT



$$A = ab\left(1 - \frac{\pi}{4}\right)$$

$$m = \frac{a}{6\left(1 - \frac{\pi}{4}\right)}$$

$$n = \frac{b}{6\left(1 - \frac{\pi}{4}\right)}$$

$$I_1 = a^3b\left(\frac{1}{3} - \frac{\pi}{16} - \frac{1}{36\left(1 - \frac{\pi}{4}\right)}\right)$$

$$I_2 = ab^3\left(\frac{1}{3} - \frac{\pi}{16} - \frac{1}{36\left(1 - \frac{\pi}{4}\right)}\right)$$

* To obtain properties of half circle, quarter circle and circular complement substitute $a = b = R$.

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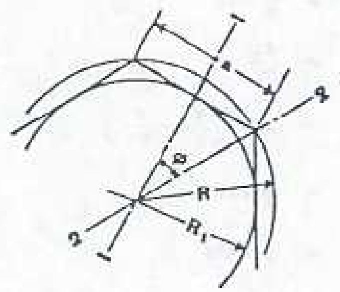
PROPERTIES OF GEOMETRIC SECTIONS AND STRUCTURAL SHAPES

REGULAR POLYGON

Axis of moments through center



n = Number of sides

$\phi = \dfrac{180°}{n}$

$a = 2\sqrt{R^2 - R_1^2}$

$R = \dfrac{a}{2 \sin \phi}$

$R_1 = \dfrac{a}{2 \tan \phi}$

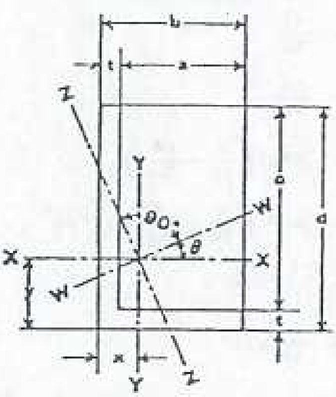
$A = \dfrac{1}{4} n a^2 \cot \phi = \dfrac{1}{2} n R^2 \sin 2\phi = n R_1^2 \tan \phi$

$I_1 = I_2 = \dfrac{A(6R^2 - a^2)}{24} = \dfrac{A(12R_1^2 + a^2)}{48}$

$r_1 = r_2 = \sqrt{\dfrac{6R^2 - a^2}{24}} = \sqrt{\dfrac{12R_1^2 + a^2}{48}}$

ANGLE

Axis of moments through center of gravity



Z-Z is axis of minimum I

$\tan 2\theta = \dfrac{2K}{I_y - I_x}$

$A = t(b + c) \quad x = \dfrac{b^2 + ct}{2(b + c)} \quad y = \dfrac{d^2 + at}{2(b + c)}$

K = Product of Inertia about X-X & Y-Y

$= \mp \dfrac{abcdt}{4(b + c)}$

$I_x = \dfrac{1}{3}\left(t(d - y)^3 + by^3 - a(y - t)^3 \right)$

$I_y = \dfrac{1}{3}\left(t(b - x)^3 + dx^3 - c(x - t)^3 \right)$

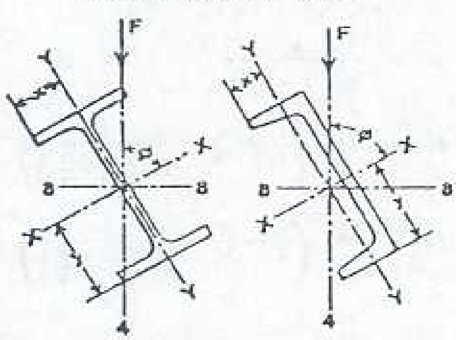
$I_z = I_x \sin^2\theta + I_y \cos^2\theta + K \sin 2\theta$

$I_w = I_x \cos^2\theta + I_y \sin^2\theta - K \sin 2\theta$

K is negative when heel of angle, with respect to c. g., is in 1st or 3rd quadrant, positive when in 2nd or 4th quadrant.

BEAMS AND CHANNELS

Transverse force oblique through center of gravity



$I_3 = I_x \sin^2\phi + I_y \cos^2\phi$

$I_4 = I_x \cos^2\phi + I_y \sin^2\phi$

$f_b = M\left(\dfrac{y}{I_x} \sin\phi + \dfrac{x}{I_y} \cos\phi \right)$

where M is bending moment due to force F.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

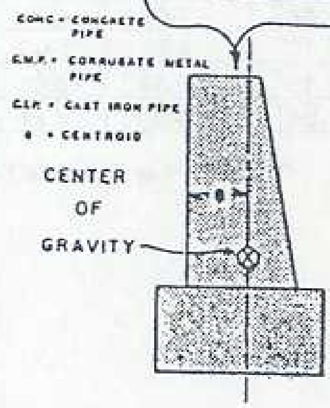
SECTION III

DRAINAGE

STANDARD ENDWALLS FOR PIPE CULVERTS

INDEX DCE-01

PIPE DIA.	CONCRETE QUANTITIES FOR ONE ENDWALL — Cu. Yds. ONE PIPE CULV'T.			TWO PIPE CULV'T.			THREE PIPE CULV'T.			FOUR PIPE CULV'T.			X-SEC. AREA	CENTR DISTA FROM FACE	STD. PIPE DEDUCT
	CONC.	C.M.P.	C. I. P.	CONC.	C.M.P.	C. I. P.	CONC.	C.M.P.	C.I.P.	CONC.	C.M.P.	C.I.P.	SQ. IN.	FACE	CU. YD.
15"	1.23	1.24	1.24	1.59	1.62	1.61	1.94	1.99	1.98	2.30	2.37	2.36	668	0.5409	0.08
18"	1.56	1.59	1.58	1.99	2.04	2.03	2.43	2.51	2.49	2.86	2.96	2.94	757.5	0.5721	0.13
21"	1.97												852	0.6033	0.16
24"	2.24	2.29	2.28	2.82	2.91	2.89	3.39	3.52	3.48	3.97	4.14	4.09	891	0.6010	0.21
27"	2.73												992	0.6322	0.26
30"	3.26	3.34	3.32	4.13	4.28	4.24	4.98	5.20	5.14	5.84	6.13	6.05	1098	0.6635	0.34
36"	4.53	4.64	4.61	5.73	5.95	5.89	6.92	7.25	7.17	8.13	8.57	8.46	1325	0.7264	0.51
42"	6.33	6.49	6.45	8.11	8.43	8.35	9.90	10.38	10.26	11.68	12.32	12.16	1632	0.7944	0.74
48"	8.15	8.38	8.32	10.40	10.85	10.74	12.64	13.34	13.17	14.89	15.82	15.59	1894.5	0.8858	1.04
54"	11.71			15.23			18.77			22.29			2406	1.0508	1.21



PIPE ARCH CULVERTS - Quantity of One Endwall

SPAN	RISE	1 PIPE	2 PIPES	3 PIPES	4 PIPES	5 PIPES	6 PIPES	7 PIPES	8 PIPES
29"	18"	1.67	2.19	2.70	3.22	3.74	4.26	4.77	5.29
36"	22"	2.21	2.88	3.54	4.21	4.87	5.54	6.20	6.87
43"	27"	2.89	3.76	4.64	5.52	6.40	7.28	8.17	9.05
50"	31"	3.68	4.81	5.93	7.05	8.18	9.30	10.43	11.55
58"	36"	4.58	6.01	7.44	8.86	10.29	11.72	13.15	14.57
65"	40"	5.54	7.28	9.02	10.77	12.51	14.25	16.00	17.74
72"	44"	7.49	9.84	12.18	14.53	16.88	19.23	21.57	23.92

STANDARD ENDWALLS FOR PIPE CULVERTS-

Quantity of One Endwall

INDEX DCE-02

PIPE DIA.	ENDWALL WITH 45° WING CONC PIPE	C.M. PIPE	C.I. PIPE	ENDWALL WITH U-TYPE WINGS CONC. PIPE INLET	CONC. PIPE OUTLET	C.M. PIPE INLET	C.M. PIPE OUTLET	C.I. PIPE INLET	C.I. PIPE OUTLET
12"				0.50	0.57	0.51	0.59	0.51	0.59
15"	0.58	0.61	0.61	0.61	0.69	0.64	0.72	0.63	0.72
18"	0.76	0.79	0.79	0.72	0.81	0.76	0.84	0.76	0.84
24"	1.03	1.08	1.08	1.03	1.13	1.08	1.18	1.08	1.18
30"	1.34	1.42	1.41	1.35	1.46	1.43	1.53	1.42	1.53
36"	1.74	1.85	1.84	1.75	1.87	1.86	1.98	1.84	1.96
42"	2.36	2.49		2.21	2.34	2.34	2.47		
48"	2.76	2.92		2.66	2.80	2.83	2.97		

U-ENDWALLS FOR PIPE CULVERTS-

Quantity of One Endwall

INDEX DCE-03

PIPE DIA.	2:1 SLOPE-w/o Baffles CONC.-c.y.	STEEL-lbs.	2:1 SLOPE-w/Baffles CONC.-c.y.	STEEL-lbs.	4:1 SLOPE CONC.-c.y.	STEEL-lbs.	6:1 SLOPE CONC.-c.y.	STEEL-lbs.
15"	0.89	49	1.61	99	1.54	95	2.19	138
18"	1.05	60	1.89	142	1.84	109	2.63	145
24"	1.48	82	2.52	193	2.53	139	3.59	227

U-ENDWALLS for PIPE CULVERTS-

Quantity for One Endwall

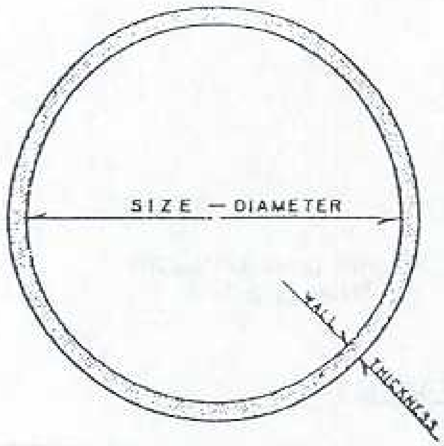
INDEX DCE-03

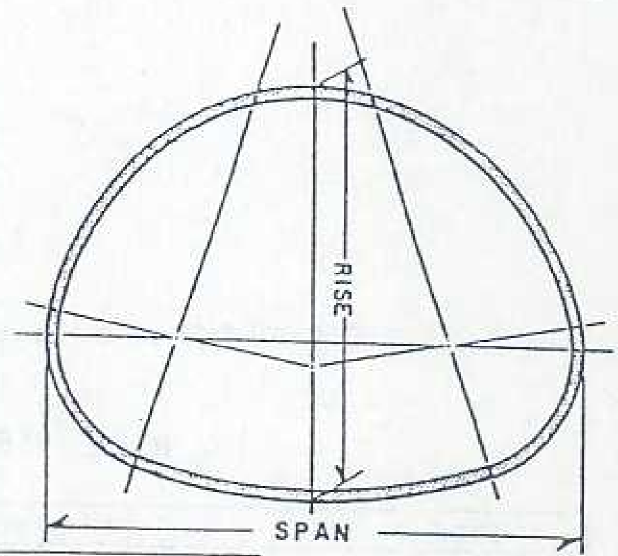
SIZE PIPE	AREA OPENING	2:1 SLOPE w/Baffles*		2:1 SLOPE w/o Baffles		4:1 SLOPE *		6:1 SLOPE *	
		CONC.-c.y.	STEEL-lbs.	CONC.-c.y.	STEEL-lbs.	CONC.-c.y.	STEEL-lbs.	CONC.-c.y.	STEEL-lbs.
15"	1.23	1.58	95	0.97	53	1.60	98	2.24	141
18"	1.77	1.85	134	1.14	64	1.91	110	2.69	146
24"	3.14	2.47	181	1.58	86	2.61	143	3.66	231
30"	4.91	3.27	223	2.00	151	3.43	238	4.88	334
36"	7.07	4.11	286	2.52	199	4.35	287	6.20	412
42"	9.62	5.06	335	3.11	240	5.40	401	7.71	572
48"	12.57	6.05	457	3.70	273	6.49	474	9.31	673
54"	15.90	7.26	556	4.49	334	7.83	563	11.19	804

* NOTE: For Construction With Baffles, See Table Below —

ADDITIONAL QUANTITIES for CONSTR. with BAFFLES

SIZE PIPE	CONCRETE cu. yd.	REINF. ST. lbs.
15"	.03	4
18"	.04	8
24"	.05	12
30"	.07	18
36"	.09	22
42"	.12	30
48"	.14	33
54"	.18	41





STANDARD PIPE PLUGS - 8" THK.			
SIZE	* WALL THICKNESS	AREA of OPENING ⌀'	PLUG VOL-c.y.
12"	2"	0.785	0.0194
15"	2 1/4"	1.227	0.0303
18"	2 1/2"	1.767	0.0436
21"	2 3/4"	2.405	0.0594
24"	3"	3.142	0.0776
27"	3 1/4"	3.976	0.0982
30"	3 1/2"	4.909	0.1212
36"	4"	7.069	0.1745
42"	4 1/2"	9.621	0.2376
48"	5"	12.566	0.3103
54"	5 1/2"	15.904	0.3927
60"	6"	19.635	0.4848
66"	6 1/2"	23.758	0.5866
72"	7"	28.274	0.6981

* Thickness are for Concrete Pipe, Class III - Wall B A.S.T.M. SPECS C-76.

PIPE ARCH CULVERT - 8" Plugs			
SPAN	RISE	AREA SQ FT.	PLUG VOL-c.y.
29"	18"	2.8471	0.0703
36"	22"	4.3197	0.1067
43"	27"	6.3323	0.1564
50"	31"	8.4539	0.2087
58"	36"	11.3883	0.2812
65"	40"	14.1808	0.3501
72"	44"	17.2788	0.4266

SEE PAGES I 57 , T.I. 59 PROGRAM NO. 1. PIPE DITCH EXCAVATION
5. FLOW IN PIPES

PIPE MEASUREMENT

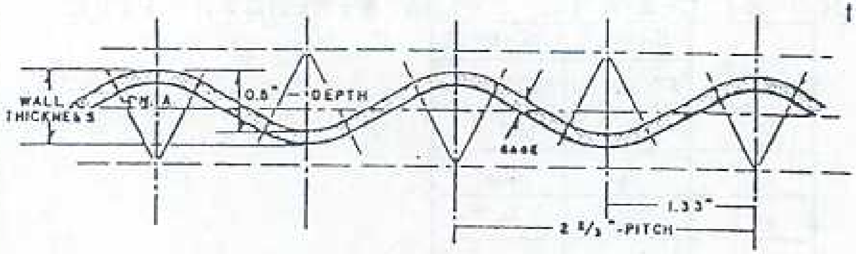
PIPE SIZES				Minimum Wall Thickness for Concrete Pipe									C. M. P. Pipe Arch GAGE of Metal D.O.T. SPECS
IN. Diam.	AREA sq. ft.	LOW-HEAD		Class III			Class IV			Class V		Low-Head or Elliptical	
		CONC. S. & D.	STEEL S. & D.	A	B	C	A	B	C	B	C		
12"	0.785	*	*	1¾"	2"	*	1¾"	2"	*	2"	*	*	*
15"	1.227	19 x 12	18 x 11	1⅞"	2¼"	*	1⅞"	2¼"	*	2¼"	*	*	*
18"	1.767	23 x 14	22 x 13	2"	2½"	*	2"	2½"	*	2½"	*	2¾"	16
21"	2.405	26 x 17	25 x 16	2¼"	2¾"	*	2¼"	2¾"	*	2¾"	*	3"	16
24"	3.142	30 x 19	29 x 18	2½"	3"	*	2½"	3"	3¼"	3"	3¼"	3¼"	14
27"	3.976	33 x 22	32 x 21	2⅝"	3¼"	*	2⅝"	3¼"	4"	3¼"	4"	3½"	14
30"	4.909	38 x 24	36 x 22	2¾"	3½"	*	2¾"	3½"	4¼"	3½"	4¼"	3¾"	14
36"	7.069	45 x 29	43 x 27	3"	4"	4¾"	*	4"	4¾"	4"	4¾"	4½"	12
42"	9.621	53 x 34	50 x 31	3½"	4½"	5¼"	*	4½"	5¼"	4½"	5¼"	5"	12
48"	12.566	60 x 38	58 x 36	4"	5"	5¾"	*	5"	5¾"	5"	5¾"	5½"	12
54"	15.904	68 x 43	65 x 40	4½"	5½"	6¼"	*	5½"	6¼"	*	6¼"	6"	12
60"	19.635	76 x 48	72 x 44	5"	6"	6¾"	*	6"	6¾"	*	6¾"	6½"	10
66"	23.758	83 x 53	*	5½"	6½"	7¼"	*	6½"	7¼"	*	7¼"	7"	*
72"	28.274	91 x 58	*	6"	7"	7¾"	*	7"	7¾"	*	7¾"	7½"	*
78"	33.183	98 x 63	*	6½"	7½"	8¼"	*	*	8¼"	*	*	8"	*
84"	38.485	106 x 68	*	7"	8"	8¾"	*	*	8¾"	*	*	8½"	*
90"	44.179	113 x 72	*	7½"	8½"	9¼"	*	*	*	*	*	9"	*
96"	50.265	121 x 77	*	8"	9"	9¾"	*	*	*	*	*	9½"	*

	Class III	Class IV	Class V
D-Load	1,350	2,000	3,000
D-Load, ult.	2,000	3,000	3,750

* No Standard - Set on each individual design

NOTE: The D.O.T. Specs call for concrete pipe meeting the requirements of Class III. Special concrete pipe shall meet the requirements of Class IV, except where the plans specifically designate Class V pipe. Standard wall used is "Type B".

– Standard Corrugated Steel Pipe Wall –



NOTE:
Pipe Diameter is measured to the <u>Inside crest</u> of corrugations.
(ARMCO Drainage Handbook)

STANDARD CORRUGATED STEEL PIPE X-Sectional Areas.															
DIA.	16 GAGE			14 GAGE			12 GAGE			10 GAGE			8 GAGE		
	METAL THICKNESS	WALL THICKNESS	X-SECTION AREA-S.F.	METAL THICKNESS	WALL THICKNESS	X-SECTION AREA-S.F.	METAL THICKNESS	WALL THICKNESS	X-SECTION AREA-S.F.	METAL THICKNESS	WALL THICKNESS	X-SECTION AREA-S.F.	METAL THICKNESS	WALL THICKNESS	X-SECTION AREA-S.F.
8"	00598	05598	0.40	00747	0.5747	0.40	0.1046	0.6046	0.40	0.1345	0.6345	0.41	0.1644	0.6644	0.41
10"	"	"	0.61	"	"	0.61	"	"	0.61	"	"	0.62	"	"	0.62
12"	"	"	0.86	"	"	0.86	"	"	0.87	"	"	0.87	"	"	0.87
15"	"	"	1.32	"	"	1.32	"	"	1.33	"	"	1.33	"	"	1.34
18"	"	"	1.88	"	"	1.88	"	"	1.89	"	"	1.89	"	"	1.90
21"	"	"	2.54	"	"	2.54	"	"	2.55	"	"	2.55	"	"	2.56
24"	"	"	3.29	"	"	3.29	"	"	3.30	"	"	3.31	"	"	3.32
27"			4.14			4.15			4.16			4.17			4.17
30"	"	"	5.09	"	"	5.10	"	"	5.11	"	"	5.12	"	"	5.13
33"			6.14			6.15			6.16			6.17			6.18
36"	"	"	7.29	"	"	7.29	"	"	7.30	"	"	7.32	"	"	7.33
42"	"	"	9.88	"	"	9.89	"	"	9.90	"	"	9.91	"	"	9.93
48"	"	"	12.86	"	"	12.87	"	"	12.88	"	"	12.90	"	"	12.91
54"	"	"	16.23	"	"	16.24	"	"	16.26	"	"	16.28	"	"	16.30
60"	"	"	20.00	"	"	20.01	"	"	20.03	"	"	20.05	"	"	20.07
66"	"	"	24.16	"	"	24.17	"	"	24.20	"	"	24.22	"	"	24.24
72"	"	"	28.72	"	"	28.73	"	"	28.75	"	"	28.77	"	"	28.80
78"	"	"	33.66	"	"	33.67	"	"	33.70	"	"	33.73	"	"	33.75
84"	"	"	39.00	"	"	39.01	"	"	39.04	"	"	39.07	"	"	39.10
90"															
96"															

VITRIFIED CLAY PIPE

Conforming to A.S.T.M. SPECIFICATIONS C-13 and C-261 for STANDARD STRENGTH PIPE, and C-200 and C-278 for EXTRA STRENGTH PIPE.

SIZE	BARREL THICKNESS	
	STANDARD	XTRA-STR.
4"	1/2"	5/8"
6"	5/8"	11/16"
8"	3/4"	7/8"
10"	7/8"	1"
12"	1"	1 3/16"
15"	1 1/4"	1 1/2"
18"	1 1/2"	1 7/8"
21"	1 3/4"	2 1/4"
24"	2"	2 1/2"
27"	2 1/4"	2 3/4"
30"	2 1/2"	3"
33"	2 5/8"	3 1/4"
36"	2 3/4"	3 1/2"

SECTION IV

GENERAL TABLES

FORMULAE FOR VOLUMETRIC CHANGE IN BIT. MATLS.

V = V /K(T-60) + 1, WHERE :
V = VOLUME AT 60 (PAY VOLUME)
T = TEMPERATURE IN DEGREES F.
V =VOLUME AS MEASURED. (HOT VOLUME)
K =COEFFICIENT OF EXPANSION (.00035)
CORRECTION FACTOR = 1/K(T-60) + 1

SAS
CORRECTION FACTORS FOR RC-3000, AC-5, AC-20, AC-30

TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR
1=1.0211	57=1.0011	113=0.9818	169=0.9633	225=0.9454	281=0.9282	337=0.9116	393=0.8956	449=0.8802
2=1.0207	58=1.0007	114=0.9815	170=0.9629	226=0.9451	282=0.9279	338=0.9113	394=0.8953	450=0.8799
3=1.0204	59=1.0004	115=0.9811	171=0.9626	227=0.9448	283=0.9276	339=0.9110	395=0.8951	451=0.8796
4=1.0200	60=1.0000	116=0.9808	172=0.9623	228=0:9445	284=0.9273	340=0.9107	396=0.8948	452=0.8794
5=1.0196	61=0.9997	117=0.9804	173=0.9620	229=0.9442	285=0.9270	341=0.9105	397=0.8945	453=0.8791
6=1.0193	62=0.9993	118=0.9801	174=0.9616	230=0.9438	286=0.9267	342=0.9102	398=0.8942	454=0.8788
7=1.0189	63=0.9990	119=0.9798	175=0.9613	231=0.9435	287=0.9264	343=0.9099	399=0.8939	455=0.8785
8=1.0185	64=0.9986	120=0.9794	176=0.9610	232=0.9432	288=0.9261	344=0.9096	400=0.8937	456=0.8783
9=1.0182	65=0.9983	121=0.9791	177=0.9607	233=0.9429	289=0.9258	345=0.9093	401=0.8934	457=0.8780
10=1.0178	66=0.9979	122=0.9788	178=0.9603	234=0.9426	290=0.9255	346=0.9090	402=0.8931	458=0.8777
11=1.0174	67=0.9976	123=0.9784	179=0.9600	235=0.9423	291=0.9252	347=0.9087	403=0.8928	459=0.8775
12=1.0171	68=0.9972	124=0.9781	180=0.9597	236=0.9420	292=0.9249	348=0.9084	404=0.8925	460=0.8772
13=1.0167	69=0.9969	125=0.9778	181=0.9594	237=0.9417	293=0.9246	349=0.9081	405=0.8923	461=0.8769
14=1.0164	70=0.9965	126=0.9774	182=0.9590	238=0.9414	294=0.9243	350=0.9079	406=0.8920	462=0.8767
15=1.0160	71=0.9962	127=0.9771	183=0.9587	239=0.9410	295=0.9240	351=0.9076	407=0.8917	463=0.8764
16=1.0156	72=0.9958	128=0.9768	184=0.9584	240=0.9407	296=0.9237	352=0.9073	408=0.8914	464=0.8761
17=1.0153	73=0.9955	129=0.9764	185=0.9581	241=0.9404	297=0.9234	353=0.9070	409=0.8911	465=0.8758
18=1.0149	74=0.9951	130=0.9761	186=0.9578	242=0.9401	298=0.9231	354=0.9067	410=0.8909	466=0.8756
19=1.0146	75=0.9948	131=0.9758	187=0.9574	243=0.9398	299=0.9228	355=0.9064	411=0.8906	467=0.8753
20=1.0142	76=0.9944	132=0.9754	188=0.9571	244=0.9395	300=0.9225	356=0.9061	412=0.8903	468=0.8750
21=1.0138	77=0.9941	133=0.9751	189=0.9568	245=0.9392	301=0.9222	357=0.9058	413=0.8900	469=0.8748
22=1.0135	78=0.9937	134=0.9748	190=0.9565	246=0.9389	302=0.9219	358=0.9056	414=0.8898	470=0.8745
23=1.0131	79=0.9934	135=0.9744	191=0.9562	247=0.9386	303=0.9216	359=0.9053	415=0.8895	471=0.8742
24=1.0128	80=0.9930	136=0.9741	192=0.9558	248=0.9383	304=0.9213	360=0.9050	416=0.8892	472=0.8740
25=1.0124	81=0.9927	137=0.9738	193=0.9555	249=0.9380	305=0.9210	361=0.9047	417=0.8889	473=0.8737
26=1.0120	82=0.9924	138=0.9734	194=0.9552	250=0.9376	306=0.9207	362=0.9044	418=0.8887	474=0.8734
27=1.0117	83=0.9920	139=0.9731	195=0.9549	251=0.9373	307=0.9204	363=0.9041	419=0.8884	475=0.8732
28=1.0113	84=0.9917	140=0.9728	196=0.9546	252=0.9370	308=0.9201	364=0.9038	420=0.8881	476=0.8729
29=1.0110	85=0.9913	141=0.9724	197=0.9542	253=0.9367	309=0.9198	365=0.9035	421=0.8878	477=0.8726
30=1.0106	86=0.9910	142=0.9721	198=0.9539	254=0.9364	310=0.9195	366=0.9033	422=0.8875	478=0.8724
31=1.0103	87=0.9906	143=0.9718	199=0.9536	255=0.9361	311=0.9192	367=0.9030	423=0.8873	479=0.8721
32=1.0099	88=0.9903	144=0.9714	200=0.9533	256=0.9358	312=0.9189	368=0.9027	424=0.8870	480=0.8718
33=1.0095	89=0.9900	145=0.9711	201=0.9530	257=0.9355	313=0.9187	369=0.9024	425=0.8867	481=0.8716
34=1.0092	90=0.9896	146=0.9708	202=0.9527	258=0.9352	314=0.9184	370=0.9021	426=0.8864	482=0.8713
35=1.0088	91=0.9893	147=0.9704	203=0.9523	259=0.9349	315=0.9181	371=0.9018	427=0.8862	483=0.8710
36=1.0085	92=0.9889	148=0.9701	204=0.9520	260=0.9346	316=0.9178	372=0.9016	428=0.8859	484=0.8708
37=1.0081	93=0.9886	149=0.9698	205=0.9517	261=0.9343	317=0.9175	373=0.9013	429=0.8856	485=0.8705
38=1.0078	94=0.9882	150=0.9695	206=0.9514	262=0.9340	318=0.9172	374=0.9010	430=0.8853	486=0.8702
39=1.0074	95=0.9879	151=0.9691	207=0.9511	263=0.9337	319=0.9169	375=0.9007	431=0.8851	487=0.8700
40=1.0070	96=0.9876	152=0.9688	208=0.9508	264=0.9334	320=0.9166	376=0.9004	432=0.8848	488=0.8697
41=1.0067	97=0.9872	153=0.9685	209=0.9504	265=0.9331	321=0.9163	377=0.9001	433=0.8845	489=0.8695
42=1.0063	98=0.9869	154=0.9681	210=0.9501	266=0.9327	322=0.9160	378=0.8998	434=0.8843	490=0.8692
43=1.0060	99=0.9865	155=0.9678	211=0.9498	267=0.9324	323=0.9157	379=0.8996	435=0.8840	491=0.8689
44=1.0056	100=0.9862	156=0.9675	212=0.9495	268=0.9321	324=0.9154	380=0.8993	436=0.8837	492=0.8687
45=1.0053	101=0.9859	157=0.9672	213=0.9492	269=0.9318	325=0.9151	381=0.8990	437=0.8834	493=0.8684
46=1.0049	102=0.9855	158=0.9668	214=0.9489	270=0.9315	326=0.9148	382=0.8987	438=0.8832	494=0.8681
47=1.0046	103=0.9852	159=0.9665	215=0.9485	271=0.9312	327=0.9145	383=0.8984	439=0.8829	495=0.8679
48=1.0042	104=0.9848	160=0.9662	216=0.9482	272=0.9309	328=0.9142	384=0.8981	440=0.8826	496=0.8676
49=1.0039	105=0.9845	161=0.9659	217=0.9479	273=0.9306	329=0.9140	385=0.8979	441=0.8823	497=0.8673
50=1.0035	106=0.9842	162=0.9655	218=0.9476	274=0.9303	330=0.9137	386=0.8976	442=0.8821	498=0.8671
51=1.0032	107=0.9838	163=0.9652	219=0.9473	275=0.9300	331=0.9134	387=0.8973	443=0.8818	499=0.8668
52=1.0028	108=0.9835	164=0.9649	220=0.9470	276=0.9297	332=0.9131	388=0.8970	444=0.8815	500=0.8666
53=1.0025	109=0.9831	165=0.9646	221=0.9467	277=0.9294	333=0.9128	389=0.8967	445=0.8813	501=0.8663
54=1.0021	110=0.9828	166=0.9642	222=0.9463	278=0.9291	334=0.9125	390=0.8965	446=0.8810	502=0.8660
55=1.0018	111=0.9825	167=0.9639	223=0.9460	279=0.9288	335=0.9122	391=0.8962	447=0.8807	503=0.8658
56=1.0014	112=0.9821	168=0.9636	224=0.9457	280=0.9285	336=0.9119	392=0.8959	448=0.8804	504=0.8655

FORMULAE FOR VOLUMETRIC CHANGE IN BIT. MATLS.

V = V /K(T-60) + 1, WHERE :
V = VOLUME AT 60 (PAY VOLUME)
T = TEMPERATURE IN DEGREES F.
V =VOLUME AS MEASURED. (HOT VOLUME)
K =COEFFICIENT OF EXPANSION (.00040)
CORRECTION FACTOR = 1/K(T-60) + 1

SAS
CORRECTION FACTORS FOR ASPHALT GRADES RC-70 AND RC-250

TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR
1=1.0242	57=1.0012	113=0.9792	169=0.9582	225=0.9381	281=0.9188	337=0.9003	393=0.8825	449=0.8654
2=1.0238	58=1.0008	114=0.9789	170=0.9579	226=0.9377	282=0.9184	338=0.8999	394=0.8821	450=0.8651
3=1.0233	59=1.0004	115=0.9785	171=0.9575	227=0.9374	283=0.9181	339=0.8996	395=0.8818	451=0.8648
4=1.0229	60=1.0000	116=0.9781	172=0.9571	228=0.9370	284=0.9178	340=0.8993	396=0.8815	452=0.8645
5=1.0225	61=0.9996	117=0.9777	173=0.9568	229=0.9367	285=0.9174	341=0.8990	397=0.8812	453=0.8642
6=1.0221	62=0.9992	118=0.9773	174=0.9564	230=0.9363	286=0.9171	342=0.8986	398=0.8809	454=0.8639
7=1.0217	63=0.9988	119=0.9769	175=0.9560	231=0.9360	287=0.9168	343=0.8983	399=0.8806	455=0.8636
8=1.0212	64=0.9984	120=0.9766	176=0.9557	232=0.9356	288=0.9164	344=0.8980	400=0.8803	456=0.8633
9=1.0208	65=0.9980	121=0.9762	177=0.9553	233=0.9353	289=0.9161	345=0.8977	401=0.8800	457=0.8630
10=1.0204	66=0.9976	122=0.9758	178=0.9549	234=0.9349	290=0.9158	346=0.8973	402=0.8797	458=0.8627
11=1.0200	67=0.9972	123=0.9754	179=0.9546	235=0.9346	291=0.9154	347=0.8970	403=0.8794	459=0.8624
12=1.0196	68=0.9968	124=0.9750	180=0.9542	236=0.9342	292=0.9151	348=0.8967	404=0.8790	460=0.8621
13=1.0192	69=0.9964	125=0.9747	181=0.9538	237=0.9339	293=0.9147	349=0.8964	405=0.8787	461=0.8618
14=1.0187	70=0.9960	126=0.9743	182=0.9535	238=0.9335	294=0.9144	350=0.8961	406=0.8784	462=0.8615
15=1.0183	71=0.9956	127=0.9739	183=0.9531	239=0.9332	295=0.9141	351=0.8957	407=0.8781	463=0.8612
16=1.0179	72=0.9952	128=0.9735	184=0.9527	240=0.9328	296=0.9137	352=0.8954	408=0.8778	464=0.8609
17=1.0175	73=0.9948	129=0.9731	185=0.9524	241=0.9325	297=0.9134	353=0.8951	409=0.8775	465=0.8606
18=1.0171	74=0.9944	130=0.9728	186=0.9520	242=0.9321	298=0.9131	354=0.8948	410=0.8772	466=0.8603
19=1.0167	75=0.9940	131=0.9724	187=0.9517	243=0.9318	299=0.9127	355=0.8945	411=0.8769	467=0.8600
20=1.0163	76=0.9936	132=0.9720	188=0.9513	244=0.9314	300=0.9124	356=0.8941	412=0.8766	468=0.8597
21=1.0158	77=0.9932	133=0.9716	189=0.9509	245=0.9311	301=0.9121	357=0.8938	413=0.8763	469=0.8594
22=1.0154	78=0.9929	134=0.9713	190=0.9506	246=0.9308	302=0.9117	358=0.8935	414=0.8760	470=0.8591
23=1.0150	79=0.9925	135=0.9709	191=0.9502	247=0.9304	303=0.9114	359=0.8932	415=0.8757	471=0.8588
24=1.0146	80=0.9921	136=0.9705	192=0.9498	248=0.9301	304=0.9111	360=0.8929	416=0.8754	472=0.8585
25=1.0142	81=0.9917	137=0.9701	193=0.9495	249=0.9297	305=0.9107	361=0.8925	417=0.8750	473=0.8582
26=1.0138	82=0.9913	138=0.9697	194=0.9491	250=0.9294	306=0.9104	362=0.8922	418=0.8747	474=0.8579
27=1.0134	83=0.9909	139=0.9694	195=0.9488	251=0.9290	307=0.9101	363=0.8919	419=0.8744	475=0.8576
28=1.0130	84=0.9905	140=0.9690	196=0.9484	252=0.9287	308=0.9098	364=0.8916	420=0.8741	476=0.8573
29=1.0126	85=0.9901	141=0.9686	197=0.9480	253=0.9283	309=0.9094	365=0.8913	421=0.8738	477=0.8570
30=1.0121	86=0.9897	142=0.9682	198=0.9477	254=0.9280	310=0.9091	366=0.8909	422=0.8735	478=0.8568
31=1.0117	87=0.9893	143=0.9679	199=0.9473	255=0.9276	311=0.9088	367=0.8906	423=0.8732	479=0.8565
32=1.0113	88=0.9889	144=0.9675	200=0.9470	256=0.9273	312=0.9084	368=0.8903	424=0.8729	480=0.8562
33=1.0109	89=0.9885	145=0.9671	201=0.9466	257=0.9270	313=0.9081	369=0.8900	425=0.8726	481=0.8559
34=1.0105	90=0.9881	146=0.9667	202=0.9463	258=0.9266	314=0.9078	370=0.8897	426=0.8723	482=0.8556
35=1.0101	91=0.9878	147=0.9664	203=0.9459	259=0.9263	315=0.9074	371=0.8894	427=0.8720	483=0.8553
36=1.0097	92=0.9874	148=0.9660	204=0.9455	260=0.9259	316=0.9071	372=0.8890	428=0.8717	484=0.8550
37=1.0093	93=0.9870	149=0.9656	205=0.9452	261=0.9256	317=0.9068	373=0.8887	429=0.8714	485=0.8547
38=1.0089	94=0.9866	150=0.9653	206=0.9448	262=0.9252	318=0.9065	374=0.8884	430=0.8711	486=0.8544
39=1.0085	95=0.9862	151=0.9649	207=0.9445	263=0.9249	319=0.9061	375=0.8881	431=0.8708	487=0.8541
40=1.0081	96=0.9858	152=0.9645	208=0.9441	264=0.9246	320=0.9058	376=0.8878	432=0.8705	488=0.8538
41=1.0077	97=0.9854	153=0.9641	209=0.9438	265=0.9242	321=0.9055	377=0.8875	433=0.8702	489=0.8535
42=1.0073	98=0.9850	154=0.9638	210=0.9434	266=0.9239	322=0.9051	378=0.8872	434=0.8699	490=0.8532
43=1.0068	99=0.9846	155=0.9634	211=0.9430	267=0.9235	323=0.9048	379=0.8868	435=0.8696	491=0.8530
44=1.0064	100=0.9843	156=0.9630	212=0.9427	268=0.9232	324=0.9045	380=0.8865	436=0.8693	492=0.8527
45=1.0060	101=0.9839	157=0.9626	213=0.9423	269=0.9228	325=0.9042	381=0.8862	437=0.8690	493=0.8524
46=1.0056	102=0.9835	158=0.9623	214=0.9420	270=0.9225	326=0.9038	382=0.8859	438=0.8687	494=0.8521
47=1.0052	103=0.9831	159=0.9619	215=0.9416	271=0.9222	327=0.9035	383=0.8856	439=0.8684	495=0.8518
48=1.0048	104=0.9827	160=0.9615	216=0.9413	272=0.9218	328=0.9032	384=0.8853	440=0.8681	496=0.8515
49=1.0044	105=0.9823	161=0.9612	217=0.9409	273=0.9215	329=0.9029	385=0.8850	441=0.8678	497=0.8512
50=1.0040	106=0.9819	162=0.9608	218=0.9406	274=0.9211	330=0.9025	386=0.8846	442=0.8675	498=0.8509
51=1.0036	107=0.9815	163=0.9604	219=0.9402	275=0.9208	331=0.9022	387=0.8843	443=0.8672	499=0.8506
52=1.0032	108=0.9812	164=0.9601	220=0.9398	276=0.9205	332=0.9019	388=0.8840	444=0.8669	500=0.8503
53=1.0028	109=0.9808	165=0.9597	221=0.9395	277=0.9201	333=0.9016	389=0.8837	445=0.8666	501=0.8501
54=1.0024	110=0.9804	166=0.9593	222=0.9391	278=0.9198	334=0.9012	390=0.8834	446=0.8663	502=0.8498
55=1.0020	111=0.9800	167=0.9590	223=0.9388	279=0.9195	335=0.9009	391=0.8831	447=0.8660	503=0.8495
56=1.0016	112=0.9796	168=0.9586	224=0.9384	280=0.9191	336=0.9006	392=0.8828	448=0.8657	504=0.8492

FORMULAE FOR VOLUMETRIC CHANGE IN BIT. MATLS.

V = V /K(T-60) + 1, WHERE :
V = VOLUME AT 60 (PAY VOLUME)
T = TEMPERATURE IN DEGREES F.
V =VOLUME AS MEASURED. (HOT VOLUME)
K =COEFFICIENT OF EXPANSION (.00025)
CORRECTION FACTOR = 1/K(T-60) + 1

CORRECTION FACTORS FOR ASPHALT GRADE RS-2

TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR	TEMP CORR
1=1.0150	57=1.0008	113=0.9869	169=0.9735	225=0.9604	281=0.9476	337=0.9352	393=0.9231	449=0.9114
2=1.0147	58=1.0005	114=0.9867	170=0.9732	226=0.9602	282=0.9474	338=0.9350	394=0.9229	450=0.9112
3=1.0145	59=1.0003	115=0.9864	171=0.9730	227=0.9599	283=0.9472	339=0.9348	395=0.9227	451=0.9110
4=1.0142	60=1.0000	116=0.9862	172=0.9728	228=0.9597	284=0.9470	340=0.9346	396=0.9225	452=0.9107
5=1.0139	61=0.9998	117=0.9860	173=0.9725	229=0.9595	285=0.9467	341=0.9344	397=0.9223	453=0.9105
6=1.0137	62=0.9995	118=0.9857	174=0.9723	230=0.9592	286=0.9465	342=0.9341	398=0.9221	454=0.9103
7=1.0134	63=0.9993	119=0.9855	175=0.9721	231=0.9590	287=0.9463	343=0.9339	399=0.9219	455=0.9101
8=1.0132	64=0.9990	120=0.9852	176=0.9718	232=0.9588	288=0.9461	344=0.9337	400=0.9217	456=0.9099
9=1.0129	65=0.9988	121=0.9850	177=0.9716	233=0.9585	289=0.9459	345=0.9335	401=0.9214	457=0.9097
10=1.0127	66=0.9985	122=0.9847	178=0.9713	234=0.9583	290=0.9456	346=0.9333	402=0.9212	458=0.9095
11=1.0124	67=0.9983	123=0.9845	179=0.9711	235=0.9581	291=0.9454	347=0.9331	403=0.9210	459=0.9093
12=1.0121	68=0.9980	124=0.9843	180=0.9709	236=0.9579	292=0.9452	348=0.9328	404=0.9208	460=0.9091
13=1.0119	69=0.9978	125=0.9840	181=0.9706	237=0.9576	293=0.9450	349=0.9326	405=0.9206	461=0.9089
14=1.0116	70=0.9975	126=0.9838	182=0.9704	238=0.9574	294=0.9447	350=0.9324	406=0.9204	462=0.9087
15=1.0114	71=0.9973	127=0.9835	183=0.9702	239=0.9572	295=0.9445	351=0.9322	407=0.9202	463=0.9085
16=1.0111	72=0.9970	128=0.9833	184=0.9699	240=0.9569	296=0.9443	352=0.9320	408=0.9200	464=0.9083
17=1.0109	73=0.9968	129=0.9830	185=0.9697	241=0.9567	297=0.9441	353=0.9317	409=0.9198	465=0.9081
18=1.0106	74=0.9965	130=0.9828	186=0.9695	242=0.9565	298=0.9438	354=0.9315	410=0.9195	466=0.9079
19=1.0104	75=0.9963	131=0.9826	187=0.9692	243=0.9563	299=0.9436	355=0.9313	411=0.9193	467=0.9076
20=1.0101	76=0.9960	132=0.9823	188=0.9690	244=0.9560	300=0.9434	356=0.9311	412=0.9191	468=0.9074
21=1.0098	77=0.9958	133=0.9821	189=0.9688	245=0.9558	301=0.9432	357=0.9309	413=0.9189	469=0.9072
22=1.0096	78=0.9955	134=0.9818	190=0.9685	246=0.9556	302=0.9430	358=0.9307	414=0.9187	470=0.9070
23=1.0093	79=0.9953	135=0.9816	191=0.9683	247=0.9553	303=0.9427	359=0.9304	415=0.9185	471=0.9068
24=1.0091	80=0.9950	136=0.9814	192=0.9681	248=0.9551	304=0.9425	360=0.9302	416=0.9183	472=0.9066
25=1.0088	81=0.9948	137=0.9811	193=0.9678	249=0.9549	305=0.9423	361=0.9300	417=0.9181	473=0.9064
26=1.0086	82=0.9945	138=0.9809	194=0.9676	250=0.9547	306=0.9421	362=0.9298	418=0.9179	474=0.9062
27=1.0083	83=0.9943	139=0.9806	195=0.9674	251=0.9544	307=0.9418	363=0.9296	419=0.9176	475=0.9060
28=1.0081	84=0.9940	140=0.9804	196=0.9671	252=0.9542	308=0.9416	364=0.9294	420=0.9174	476=0.9058
29=1.0078	85=0.9938	141=0.9802	197=0.9669	253=0.9540	309=0.9414	365=0.9292	421=0.9172	477=0.9056
30=1.0076	86=0.9935	142=0.9799	198=0.9667	254=0.9537	310=0.9412	366=0.9289	422=0.9170	478=0.9054
31=1.0073	87=0.9933	143=0.9797	199=0.9664	255=0.9535	311=0.9410	367=0.9287	423=0.9168	479=0.9052
32=1.0070	88=0.9930	144=0.9794	200=0.9662	256=0.9533	312=0.9407	368=0.9285	424=0.9166	480=0.9050
33=1.0068	89=0.9928	145=0.9792	201=0.9660	257=0.9531	313=0.9405	369=0.9283	425=0.9164	481=0.9048
34=1.0065	90=0.9926	146=0.9790	202=0.9657	258=0.9528	314=0.9403	370=0.9281	426=0.9162	482=0.9046
35=1.0063	91=0.9923	147=0.9787	203=0.9655	259=0.9526	315=0.9401	371=0.9279	427=0.9160	483=0.9044
36=1.0060	92=0.9921	148=0.9785	204=0.9653	260=0.9524	316=0.9398	372=0.9276	428=0.9158	484=0.9042
37=1.0058	93=0.9918	149=0.9782	205=0.9650	261=0.9522	317=0.9396	373=0.9274	429=0.9155	485=0.9040
38=1.0055	94=0.9916	150=0.9780	206=0.9648	262=0.9519	318=0.9394	374=0.9272	430=0.9153	486=0.9038
39=1.0053	95=0.9913	151=0.9778	207=0.9646	263=0.9517	319=0.9392	375=0.9270	431=0.9151	487=0.9035
40=1.0050	96=0.9911	152=0.9775	208=0.9643	264=0.9515	320=0.9390	376=0.9268	432=0.9149	488=0.9033
41=1.0048	97=0.9908	153=0.9773	209=0.9641	265=0.9512	321=0.9387	377=0.9266	433=0.9147	489=0.9031
42=1.0045	98=0.9906	154=0.9770	210=0.9639	266=0.9510	322=0.9385	378=0.9264	434=0.9145	490=0.9029
43=1.0043	99=0.9903	155=0.9768	211=0.9636	267=0.9508	323=0.9383	379=0.9261	435=0.9143	491=0.9027
44=1.0040	100=0.9901	156=0.9766	212=0.9634	268=0.9506	324=0.9381	380=0.9259	436=0.9141	492=0.9025
45=1.0038	101=0.9899	157=0.9763	213=0.9632	269=0.9503	325=0.9379	381=0.9257	437=0.9139	493=0.9023
46=1.0035	102=0.9896	158=0.9761	214=0.9629	270=0.9501	326=0.9376	382=0.9255	438=0.9137	494=0.9021
47=1.0033	103=0.9894	159=0.9758	215=0.9627	271=0.9499	327=0.9374	383=0.9253	439=0.9135	495=0.9019
48=1.0030	104=0.9891	160=0.9756	216=0.9625	272=0.9497	328=0.9372	384=0.9251	440=0.9132	496=0.9017
49=1.0028	105=0.9889	161=0.9754	217=0.9622	273=0.9494	329=0.9370	385=0.9249	441=0.9130	497=0.9015
50=1.0025	106=0.9886	162=0.9751	218=0.9620	274=0.9492	330=0.9368	386=0.9246	442=0.9128	498=0.9013
51=1.0023	107=0.9884	163=0.9749	219=0.9618	275=0.9490	331=0.9365	387=0.9244	443=0.9126	499=0.9011
52=1.0020	108=0.9881	164=0.9747	220=0.9615	276=0.9488	332=0.9363	388=0.9242	444=0.9124	500=0.9009
53=1.0018	109=0.9879	165=0.9744	221=0.9613	277=0.9485	333=0.9361	389=0.9240	445=0.9122	501=0.9007
54=1.0015	110=0.9877	166=0.9742	222=0.9611	278=0.9483	334=0.9359	390=0.9238	446=0.9120	502=0.9005
55=1.0013	111=0.9874	167=0.9739	223=0.9608	279=0.9481	335=0.9357	391=0.9236	447=0.9118	503=0.9003
56=1.0010	112=0.9872	168=0.9737	224=0.9606	280=0.9479	336=0.9355	392=0.9234	448=0.9116	504=0.9001

TABLES OF CONVERSION FACTORS, UNITS OF WEIGHTS AND MEASURES

Length [L]

Multiply Number of → by to Obtain ↓	Centimeters	Feet	Inches	Kilometers	Nautical miles	Meters	Mils	Miles	Millimeters	Yards
Centimeters	1	30.48	2.540	10^5	1 853 $\times 10^5$	100	2.540 $\times 10^{-3}$	1.609 $\times 10^5$	0.1	91.44
Feet	3.281 $\times 10^{-2}$	1	8 333 $\times 10^{-2}$	3281	6080.27	3.281	8.333 $\times 10^{-5}$	5280	3.281 $\times 10^{-3}$	3
Inches	0.3937	12	1	3.937 $\times 10^4$	7.296 $\times 10^4$	39.37	0.001	6.336 $\times 10^4$	3.937 $\times 10^{-2}$	36
Kilometers	10^{-5}	3.048 $\times 10^{-4}$	2.540 $\times 10^{-5}$	1	1.853	0.001	2.540 $\times 10^{-8}$	1.609	10^{-6}	9.144 $\times 10^{-4}$
Nautical miles		1.645 $\times 10^{-4}$		0.5396	1	5.396 $\times 10^{-4}$		0.8684		4.934 $\times 10^{-4}$
Meters	0.01	0.3048	2.540 $\times 10^{-2}$	1000	1853	1		1609	0.001	0.9144
Mils	393 7	1.2 $\times 10^4$	1000	3.937 $\times 10^7$		3.937 $\times 10^4$	1		39.37	3.6 $\times 10^4$
Miles	6.214 $\times 10^{-6}$	1 694 $\times 10^{-4}$	1.578 $\times 10^{-5}$	0.6214	1.1516	6.214 $\times 10^{-4}$		1	6.214 $\times 10^{-7}$	5.682 $\times 10^{-4}$
Millimeters	10	304 8	25.40	10^6		1000	2.540 $\times 10^{-2}$		1	914.4
Yards	1.094 $\times 10^{-2}$	0.3333	2 778 $\times 10^{-2}$	1094	2027	1 094	2.778 $\times 10^{-5}$	1760	1 094 $\times 10^{-3}$	1

Metric Multiples

10^6 microns = 10^3 millimeters = 10^2 centimeters = 10 decimeters = 1 meter = 10^{-1} dekameter = 10^{-2} hectometer = 10^{-3} kilometer = 10^{-4} myriameter = 10^{-6} megameter = 10^{10} Angstrom Units.

Land Measure

7.92 inches = 1 link
25 links = 1 rod = 16.5 feet = 5.5 yards (1 rod = 1 pole = 1 perch)
4 rods = 1 chain (Gunther's) = 66 feet = 22 yards = 100 links
10 chains = 1 furlong = 660 feet = 220 yards = 1000 links = 40 rods
8 furlongs = 1 mile = 5280 feet = 1760 yards = 8000 links = 320 rods = 80 chains

Ropes and Cables

2 yards = 1 fathom   120 fathoms = 1 cable's length

Nautical Measure

6080.27 feet = 1 nautical mile = 1.15156 statute miles
3 nautical miles = 1 league (U. S.)   3 statute miles = 1 league (Gr. Britain)

(NOTE. A nautical mile is the length of a minute of longitude of the earth at the equator at sea level. The British Admiralty uses the round figure of 6080 feet. The word " knot " is used to denote " nautical miles per hour.")

Miscellaneous

3 inches = 1 palm   9 inches = 1 span
4 inches = 1 hand   2 1/2 feet = 1 military pace

WEIGHTS AND MEASURES

Area $[L^2]$

Multiply Number of → by ↘ to Obtain ↓	Acres	Circular mils	Square centimeters	Square feet	Square inches	Square kilometers	Square meters	Square miles	Square millimeters	Square yards
Acres	1			2.296×10^{-5}		247.1	2.471×10^{-4}	640		2.066×10^{-4}
Circular mils		1	1.973×10^{5}	1.833×10^{8}	1.273×10^{6}		1.973×10^{9}		1973	
Square centimeters		5.067×10^{-6}	1	929.0	6.452	10^{10}	10^{4}	2.590×10^{10}	0.01	8361
Square feet	4.356×10^{4}		1.076×10^{-3}	1	6.944×10^{-3}	1.076×10^{7}	10.76	2.788×10^{7}	1.076×10^{-5}	9
Square inches	6,272,640	7.854×10^{-7}	0.1550	144	1	1.550×10^{9}	1550	4.015×10^{9}	1.550×10^{-3}	1296
Square kilometers	4.047×10^{-3}		10^{-10}	9.290×10^{-8}	6.452×10^{-10}	1	10^{-6}	2.590	10^{-12}	8.361×10^{-7}
Square meters	4047		0.0001	9.290×10^{-2}	6.452×10^{-4}	10^{6}	1	2.590×10^{6}	10^{-6}	0.8361
Square miles	1.562×10^{-3}		3.861×10^{-11}	3.587×10^{-8}		0.3861	3.861×10^{-7}	1	3.861×10^{-13}	3.228×10^{-7}
Square millimeters		5.067×10^{-4}	100	9.290×10^{4}	645.2	10^{12}	10^{6}		1	8.361×10^{5}
Square yards	4840		1.196×10^{-4}	0.1111	7.716×10^{-4}	1.196×10^{6}	1.196	3.098×10^{6}	1.196×10^{-6}	1

Land Measure

30 1/4 square yards = 1 square rod = 272 1/4 square feet
16 square rods = 1 square chain = 484 square yards = 4356 square feet
2 1/2 square chains = 1 rood = 40 square rods = 1210 square yards
4 roods = 1 acre = 10 square chains = 160 square rods
640 acres = 1 square mile = 2560 roods = 102,400 square rods
1 section of land = 1 square mile; 1 quarter section = 160 acres

Architect's Measure

100 square feet = 1 square

Circular Inch and Circular Mil

A circular inch is the area of a circle 1 inch in diameter = 0.7854 square inch
1 square inch = 1.2732 circular inches
A circular mil is the area of a circle 1 mil (or 0.001 inch) in diameter = 0.7854 square mil
1 square mil = 1.2732 circular mils
1 circular inch = 10^6 circular mils = 0.7854×10^6 square mils
1 square inch = 1.2732×10^6 circular mils = 10^6 square mils

Metric Multiples

1 square meter = 1 centiare = 10^{-2} are = 10^{-4} hectare
= 10^{-6} square kilometer = 10^{-8} square myriameter

Volume [L^3]

Multiply Number of → by to Obtain ↓	Bushels (dry)	Cubic centimeters	Cubic feet	Cubic inches	Cubic meters	Cubic yards	Gallons (liquid)	Liters	Pints (liquid)	Quarts (liquid)
Bushels (dry)	1		0.8036	4.651 $\times 10^{-4}$	28.38			2.838 $\times 10^{-2}$		
Cubic centimeters	3.524 $\times 10^{4}$	1	2.832 $\times 10^{4}$	16.39	10^{6}	7.646 $\times 10^{5}$	3785	1000	473.2	946.4
Cubic feet	1.2445	3.531 $\times 10^{-5}$	1	5.787 $\times 10^{-4}$	35.31	27	0.1337	3.531 $\times 10^{-2}$	1.671 $\times 10^{-2}$	3.342 $\times 10^{-2}$
Cubic inches	2150.4	6.102 $\times 10^{-2}$	1728	1	6.102 $\times 10^{4}$	46,656	231	61.02	28.87	57.75
Cubic meters	3.524 $\times 10^{-2}$	10^{-6}	2.832 $\times 10^{-2}$	1.639 $\times 10^{-5}$	1	0.7646	3.785 $\times 10^{-3}$	0.001	4.732 $\times 10^{-4}$	9.464 $\times 10^{-4}$
Cubic yards		1.308 $\times 10^{-6}$	3.704 $\times 10^{-2}$	2.143 $\times 10^{-5}$	1.308	1	4.951 $\times 10^{-3}$	1.308 $\times 10^{-3}$	6.189 $\times 10^{-4}$	1.238 $\times 10^{-3}$
Gallons (liquid)		2.642 $\times 10^{-4}$	7.481	4.329 $\times 10^{-3}$	264.2	202.0	1	0.2642	0.125	0.25
Liters	35.24	0.001	28.32	1.639 $\times 10^{-2}$	1000	764.6	3.785	1	0.4732	0.9464
Pints (liquid)		2.113 $\times 10^{-3}$	59.84	3.463 $\times 10^{-2}$	2113	1616	8	2.113	1	2
Quarts (liquid).....		1.057 $\times 10^{-3}$	29.92	1.732 $\times 10^{-2}$	1057	807.9	4	1.057	0.5	1

Metric Multiples

10 milliliters	= 1 centiliter	= 0.338 fluid ounce
10 centiliters	= 1 deciliter	= 0.845 liquid gill
10 deciliters	= 1 liter	= 1.0567 liquid quarts
10 liters	= 1 dekaliter	= 2.6417 liquid gallons
10 dekaliters	= 1 hectoliter	= 2.8375 U. S. bushels
10 hectoliters	= 1 kiloliter (or stere)	= 28.375 U. S. bushels

Cubic Measure

1 cord of wood = a pile cut 4 feet long, piled 4 feet high and 8 feet on the ground = 128 cubic feet

1 perch of stone = a quantity 1 1/2 feet thick, 1 foot high and 16 1/2 feet long = 24 3/4 cubic feet

(NOTE.—A perch of stone is, however, often computed differently in different localities; thus, in most if not all of the States and Territories west of the Mississippi, stonemasons figure rubble by the perch of 16 1/2 cubic feet. In Philadelphia, 22 cubic feet are called a perch. In Chicago, stone is measured by the cord of 100 cubic feet. Check should be made against local practice.)

Board Measure

In board measure, boards are assumed to be one inch in thickness. Therefore, feet board measure of a stick of square timber = length in feet × breadth in feet × thickness in inches.

WEIGHTS AND MEASURES

Linear Velocity $[LT^{-1}]$

Multiply Number of → by ↘ to Obtain ↓	Centimeters per second	Feet per minute	Feet per second	Kilometers per hour	Kilometers per minute	Knots	Meters per minute	Meters per second	Miles per hour	Miles per minute
Centimeters per second	1	0.5080	30.48	27.78	1667	51.46	1.667	100	44.70	2682
Feet per minute	1.969	1	60	54.68	3281	101.3	3.281	196.8	88	5280
Feet per second	3.281 $\times 10^{-2}$	1.667 $\times 10^{-2}$	1	0.9113	54.68	1.689	5.468 $\times 10^{-2}$	3.281	1.467	88
Kilometers per hour	0.036	1.829 $\times 10^{-2}$	1.097	1	60	1.853	0.06	3.6	1.609	96.54
Kilometers per minute	0.0006	3.048 $\times 10^{-4}$	1.829 $\times 10^{-2}$	1.667 $\times 10^{-2}$	1	3.088 $\times 10^{-2}$	0.001	0.06	2.682 $\times 10^{-2}$	1.609
Knots *	1.943 $\times 10^{-2}$	9.868 $\times 10^{-3}$	0.5921	0.5396	32.38	1	3.238 $\times 10^{-2}$	1.943	0.8684	52.10
Meters per minute	0.6	0.3048	18.29	16.67	1000	30.88	1	60	26.82	1609
Meters per second	0.01	5.080 $\times 10^{-3}$	0.3048	0.2778	16.67	0.5148	1.667 $\times 10^{-2}$	1	0.4470	26.82
Miles per hour	2.237 $\times 10^{-2}$	1.136 $\times 10^{-2}$	0.6818	0.6214	37.28	1.152	3.728 $\times 10^{-2}$	2.237	1	60
Miles per minute	3.728 $\times 10^{-4}$	1.892 $\times 10^{-4}$	1.136 $\times 10^{-2}$	1.036 $\times 10^{-2}$	0.6214	1.919 $\times 10^{-2}$	6.214 $\times 10^{-4}$	3.728 $\times 10^{-2}$	1.667 $\times 10^{-2}$	1

* Nautical miles per hour.

The Miner's Inch
(Used in Measuring Flow of Water)

An Act of the California legislature, May 23, 1901, makes the standard miner's inch 1.5 cu ft per minute, measured through any aperture or orifice.

The term Miner's Inch is more or less indefinite, for the reason that California water companies do not all use the same head above the center of the aperture, and the inch varies from 1.36 to 1.73 cu ft per minute, but the most common measurement is through an aperture 2 in. high and whatever length is required, and through a plank 1 1/4 in. thick. The lower edge of the aperture should be 2 in. above the bottom of the measuring-box, and the plank 5 in. high above the aperture, thus making a 6-in. head above the center of the stream. Each square inch of this opening represents a miner's inch, which is equal to a flow of 1.5 cu ft per minute.

WEIGHTS AND MEASURES

Mass [M] and Weight *

Multiply Number of → by to Obtain ↓	Grains	Grams	Kilograms	Milligrams	Ounces †	Pounds †	Tons (long)	Tons (metric)	Tons (short)
Grains	1	15.43	1.543×10^{4}	1.543×10^{-2}	437.5	7000			
Grams	6.481×10^{-2}	1	1000	0.001	28.35	453.6	1.016×10^{6}	10^{6}	9.072×10^{5}
Kilograms	6.481×10^{-5}	0.001	1	10^{-6}	2.835×10^{-2}	0.4536	1016	1000	907.2
Milligrams	64.81	1000	10^{6}	1	2.835×10^{4}	4.536×10^{5}	1.016×10^{9}	10^{9}	9.072×10^{8}
Ounces †	2.286×10^{-3}	3.527×10^{-2}	35.27	3.527×10^{-5}	1	16	3.584×10^{4}	3.527×10^{4}	3.2×10^{4}
Pounds †	1.429×10^{-4}	2.205×10^{-3}	2.205	2.205×10^{-6}	6.250×10^{-2}	1	2240	2205	2000
Tons (long)		9.842×10^{-7}	9.842×10^{-4}	9.842×10^{-10}	2.790×10^{-5}	4.464×10^{-4}	1	0.9842	0.8929
Tons (metric)		10^{-6}	0.001	10^{-9}	2.835×10^{-5}	4.536×10^{-4}	1.016	1	0.9072
Tons (short)		1.102×10^{-6}	1.102×10^{-3}	1.102×10^{-9}	3.125×10^{-5}	0.0005	1.120	1.102	1

* These same conversion factors apply to the *gravitational* units of force having the corresponding names. The dimensions of these units when used as gravitational units of force are MLT^{-2}; see table for *Force*.

† Avoirdupois pounds and ounces.

Metric Multiples

10^{6} micrograms = 10^{3} milligrams = 10^{2} centigrams = 10 decigrams = 1 gram = 10^{-1} dekagram = 10^{-2} hectogram = 10^{-3} kilogram = 10^{-4} myriagram = 10^{-6} megagram

Avoirdupois Weight

(Used Commercially)

27.343 grains	= 1 drachm
16 drachms	= 1 ounce (oz) = 437.5 grains
16 ounces	= 1 pound (lb) = 7000 grains
28 pounds	= 1 quarter (qr)
4 quarters	= 1 hundredweight (cwt) = 112 pounds
20 hundredweight	= 1 gross or long ton *
2000 pounds	= 1 net or short ton

(* Note.—The long ton is used by the U. S. custom-houses in collecting duties upon foreign goods. It is also used in freighting coal and selling it wholesale.)

14 pounds = 1 stone; 100 pounds = 1 quintal

Troy Weight

(Used in weighing gold or silver)

24 grains	= 1 pennyweight (dwt)
20 pennyweights	= 1 ounce (oz) = 480 grains
12 ounces	= 1 pound (lb) = 5760 grains

The grain is the same in Avoirdupois, Troy and Apothecaries' weights. A carat, for weighing diamonds = 3.086 grains = 0.200 gram. (International Standard, 1913.)

1 pound troy = .8229 pound avoirdupois
1 pound avoirdupois = 1.2153 pounds troy

Plane Angle [*No Dimensions*]

Multiply Number of → by to Obtain ↓	Degrees	Minutes	Quadrants	Radians *	Revolutions * (Circumferences)	Seconds
Degrees	1	1.667×10^{-2}	90	57.30	360	2.778×10^{-4}
Minutes	60	1	5400	3438	2.16×10^{4}	1.667×10^{-2}
Quadrants	1.111×10^{-2}	1.852×10^{-4}	1	0.6366	4	3.087×10^{-6}
Radians *	1.745×10^{-2}	2.909×10^{-4}	1.571	1	6.283	4.848×10^{-6}
Revolutions * (Circumferences)	2.778×10^{-3}	4.630×10^{-5}	0.25	0.1591	1	7.716×10^{-7}
Seconds	3600	60	3.24×10^{5}	2.063×10^{5}	1.296×10^{6}	1

* 2π radians = 1 circumference = 360 degrees by definition.

Solid Angle [*No Dimensions*]

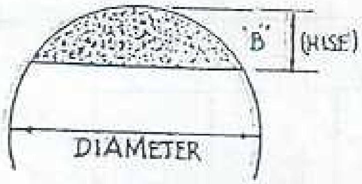
Multiply Number of → by to Obtain ↓	Hemispheres	Spheres *	Spherical right angles	Steradians †
Hemispheres	1	2	0.25	0.1592
Spheres *	0.5	1	0.125	7.958×10^{-2}
Spherical right angles	4	8	1	0.6366
Steradians †	6.283	12.57	1.571	1

* A sphere is the total solid angle about a point. † 4π steradians = 1 sphere by definition.

Time [*T*]

Multiply Number of → by to Obtain ↓	Days	Hours	Minutes	Months (average)*	Seconds	Weeks
Days	1	4.167×10^{-2}	6.944×10^{-4}	30.42	1.157×10^{-5}	7
Hours	24	1	1.667×10^{-2}	730.0	2.778×10^{-4}	168
Minutes	1440	60	1	4.380×10^{4}	1.667×10^{-2}	1.008×10^{4}
Months (average) *	3.288×10^{-2}	1.370×10^{-3}	2.283×10^{-5}	1	3.806×10^{-7}	0.2302
Seconds	8.64×10^{4}	3600	60	2.628×10^{5}	1	6.048×10^{5}
Weeks	0.1429	5.952×10^{-3}	9.921×10^{-5}	4.344	1.654×10^{-6}	1

* One common year = 365 days; one leap year = 366 days; one average month = 1/12 of a common year



AREA OF CIRCULAR SEGMENTS

FOR RATIOS OF RISE / DIAMETER

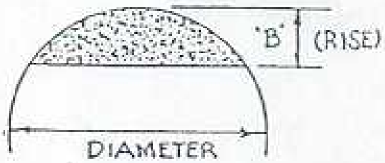
AREA = D^2 X COEFFICIENT

EXAMPLE: B = 3.75 D = 15, B/D =.250.

READ: COEFF = .153546.

AREA = $(15)^2$ X .153546 = 34.55 S.F.

B/D	COEFF	B/D	COEFF	B/D	COEFF	B/D	COEFF
.0012	.000059	.0637	.021046	.1262	.057493	.1887	.102921
.0025	.000167	.0650	.021660	.1275	.058325	.1900	.103900
.0037	.000306	.0662	.022279	.1287	.059160	.1912	.104882
.0050	.000471	.0675	.022903	.1300	.059999	.1925	.105867
.0062	.000658	.0687	.023533	.1312	.060842	.1937	.106853
.0075	.000864	.0700	.024168	.1325	.061688	.1950	.107843
.0087	.001088	.0712	.024809	.1337	.062537	.1962	.108834
.0100	.001329	.0725	.025455	.1350	.063389	.1975	.109829
.0112	.001586	.0737	.026105	.1362	.064245	.1987	.110825
.0125	.001856	.0750	.026761	.1375	.065105	.2000	.111824
.0137	.002141	.0762	.027422	.1387	.065967	.2012	.112825
.0150	.002438	.0775	.028088	.1400	.066833	.2025	.113828
.0162	.002748	.0787	.028759	.1412	.067702	.2037	.114834
.0175	.003070	.0800	.029435	.1425	.068575	.2050	.115842
.0187	.003404	.0812	.030116	.1437	.069450	.2062	.116853
.0200	.003749	.0825	.030801	.1450	.070329	.2075	.117865
.0212	.004104	.0837	.031491	.1462	.071211	.2087	.118880
.0225	.004470	.0850	.032186	.1475	.072096	.2100	.119898
.0237	.004845	.0862	.032886	.1487	.072984	.2112	.120917
.0250	.005231	.0875	.033590	.1500	.073875	.2125	.121938
.0262	.005626	.0887	.034299	.1512	.074769	.2137	.122962
.0275	.006030	.0900	.035012	.1525	.075666	.2150	.123988
.0287	.006443	.0912	.035729	.1537	.076566	.2162	.125016
.0300	.006866	.0925	.036452	.1550	.077470	.2175	.126047
.0312	.007296	.0937	.037178	.1562	.078376	.2187	.127079
.0325	.007735	.0950	.037909	.1575	.079285	.2200	.128114
.0337	.008183	.0962	.038644	.1587	.080197	.2212	.129150
.0350	.008638	.0975	.039384	.1600	.081112	.2225	.130189
.0362	.009102	.0987	.040127	.1612	.082030	.2237	.131230
.0375	.009573	.1000	.040875	.1625	.082951	.2250	.132273
.0387	.010052	.1012	.041627	.1637	.083875	.2262	.133318
.0400	.010538	.1025	.042384	.1650	.084801	.2275	.134365
.0412	.011031	.1037	.043144	.1662	.085731	.2287	.135414
.0425	.011532	.1050	.043908	.1675	.086663	.2300	.136465
.0437	.012040	.1062	.044677	.1687	.087598	.2312	.137518
.0450	.012555	.1075	.045449	.1700	.088536	.2325	.138573
.0462	.013076	.1087	.046225	.1712	.089476	.2337	.139630
.0475	.013605	.1100	.047006	.1725	.090419	.2350	.140689
.0487	.014140	.1112	.047790	.1737	.091365	.2362	.141750
.0500	.014681	.1125	.048578	.1750	.092314	.2375	.142813
.0512	.015230	.1137	.049370	.1762	.093265	.2387	.143878
.0525	.015784	.1150	.050165	.1775	.094219	.2400	.144945
.0537	.016345	.1162	.050965	.1787	.095175	.2412	.146013
.0550	.016912	.1175	.051768	.1800	.096135	.2425	.147084
.0562	.017485	.1187	.052575	.1812	.097096	.2437	.148156
.0575	.018064	.1200	.053385	.1825	.098061	.2450	.149231
.0587	.018649	.1212	.054200	.1837	.099028	.2462	.150307
.0600	.019239	.1225	.055017	.1850	.099997	.2475	.151385
.0612	.019836	.1237	.055839	.1862	.100969	.2487	.152465
.0625	.020438	.1250	.056664	.1875	.101944	.2500	.153546

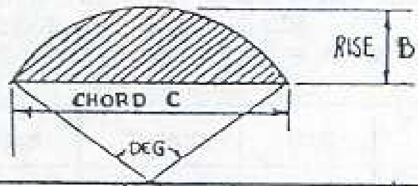


AREA OF CIRCULAR SEGMENTS

FOR RATIOS OF RISE / DIAMETER
AREA = D^2 x COEFFICIENT
EXAMPLE: B = 3.75 D = 15, B/D =.250.
READ: COEFF = .153546.
AREA = $(15)^2$ X .153546 = 34.55 S.F.

B/D	COEFF	B/D	COEFF	B/D	COEFF	B/D	COEFF
.2512	.154630	.3137	.210851	.3762	.270224	.4387	.331603
.2525	.155715	.3150	.212011	.3775	.271436	.4400	.332843
.2537	.156802	.3162	.213173	.3787	.272648	.4412	.334085
.2550	.157891	.3175	.214336	.3800	.273861	.4425	.335326
.2562	.158981	.3187	.215501	.3812	.275075	.4437	.336568
.2575	.160073	.3200	.216666	.3825	.276290	.4450	.337810
.2587	.161167	.3212	.217833	.3837	.277505	.4462	.339053
.2600	.162263	.3225	.219001	.3850	.278721	.4475	.340296
.2612	.163361	.3237	.220170	.3862	.279938	.4487	.341539
.2625	.164460	.3250	.221341	.3875	.281156	.4500	.342783
.2637	.165561	.3262	.222512	.3887	.282374	.4512	.344026
.2650	.166663	.3275	.223685	.3900	.283593	.4525	.345271
.2662	.167767	.3287	.224859	.3912	.284813	.4537	.346515
.2675	.168873	.3300	.226034	.3925	.286033	.4550	.347760
.2687	.169981	.3312	.227210	.3937	.287254	.4562	.349005
.2700	.171090	.3325	.228387	.3950	.288476	.4575	.350250
.2712	.172200	.3337	.229565	.3962	.289698	.4587	.351496
.2725	.173313	.3350	.230745	.3975	.290922	.4600	.352742
.2737	.174427	.3362	.231925	.3987	.292145	.4612	.353988
.2750	.175542	.3375	.233107	.4000	.293370	.4625	.355234
.2762	.176659	.3387	.234290	.4012	.294595	.4637	.356481
.2775	.177778	.3400	.235473	.4025	.295821	.4650	.357728
.2787	.178899	.3412	.236658	.4037	.297047	.4662	.358975
.2800	.180020	.3425	.237844	.4050	.298274	.4675	.360222
.2812	.181143	.3437	.239031	.4062	.299501	.4687	.361469
.2825	.182268	.3450	.240219	.4075	.300729	.4700	.362717
.2837	.183394	.3462	.241408	.4087	.301958	.4712	.363965
.2850	.184522	.3475	.242598	.4100	.303187	.4725	.365213
.2862	.185651	.3487	.243789	.4112	.304417	.4737	.366461
.2875	.186782	.3500	.244980	.4125	.305648	.4750	.367710
.2887	.187914	.3512	.246173	.4137	.306879	.4762	.368958
.2900	.189048	.3525	.247367	.4150	.308110	.4775	.370207
.2912	.190183	.3537	.248562	.4162	.309342	.4787	.371455
.2925	.191319	.3550	.249758	.4175	.310575	.4800	.372704
.2937	.192457	.3562	.250955	.4187	.311808	.4812	.373953
.2950	.193597	.3575	.252152	.4200	.313042	.4825	.375203
.2962	.194738	.3587	.253351	.4212	.314276	.4837	.376452
.2975	.195880	.3600	.254551	.4225	.315511	.4850	.377701
.2987	.197023	.3612	.255751	.4237	.316746	.4862	.378951
.3000	.198168	.3625	.256952	.4250	.317981	.4875	.380200
.3012	.199315	.3637	.258155	.4262	.319217	.4887	.381450
.3025	.200462	.3650	.259358	.4275	.320454	.4900	.382700
.3037	.201611	.3662	.260562	.4287	.321691	.4912	.383950
.3050	.202762	.3675	.261767	.4300	.322928	.4925	.385199
.3062	.203913	.3687	.262972	.4312	.324166	.4937	.386449
.3075	.205066	.3700	.264179	.4325	.325405	.4950	.387699
.3087	.206221	.3712	.265386	.4337	.326643	.4962	.388949
.3100	.207376	.3725	.266595	.4350	.327883	.4975	.390199
.3112	.208533	.3737	.267804	.4362	.329122	.4987	.391449
.3125	.209691	.3750	.269014	.4375	.330362	.5000	.392699

AREAS OF CIRCULAR SEGMENTS FOR RATIOS OF RISE/CHORD
(AREA = C X B X COEFFICIENT)

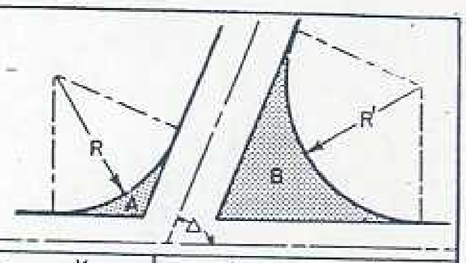


DEG	RATO	COEF	DEG	RATO	COEF	DEG	RATO	COEF	DEG	RATO	COEF
1	.0022	.6667	46	.1017	.6722	91	.2097	.6896	136	.3373	.7239
2	.0044	.6667	47	.1040	.6724	92	.2122	.6901	137	.3404	.7249
3	.0065	.6667	48	.1063	.6727	93	.2148	.6907	138	.3436	.7260
4	.0087	.6667	49	.1086	.6729	94	.2174	.6912	139	.3469	.7270
5	.0109	.6667	50	.1108	.6732	95	.2200	.6918	140	.3501	.7281
6	.0131	.6668	51	.1131	.6734	96	.2226	.6924	141	.3534	.7292
7	.0153	.6668	52	.1154	.6737	97	.2252	.6930	142	.3566	.7303
8	.0175	.6668	53	.1177	.6740	98	.2279	.6936	143	.3599	.7314
9	.0196	.6669	54	.1200	.6743	99	.2305	.6942	144	.3633	.7325
10	.0218	.6669	55	.1223	.6746	100	.2332	.6948	145	.3666	.7336
11	.0240	.6670	56	.1247	.6749	101	.2358	.6954	146	.3700	.7348
12	.0262	.6670	57	.1270	.6752	102	.2385	.6961	147	.3734	.7360
13	.0284	.6671	58	.1293	.6755	103	.2412	.6967	148	.3768	.7372
14	.0306	.6672	59	.1316	.6758	104	.2439	.6974	149	.3802	.7384
15	.0328	.6672	60	.1340	.6761	105	.2466	.6980	150	.3837	.7396
16	.0350	.6673	61	.1363	.6765	106	.2493	.6987	151	.3871	.7408
17	.0372	.6674	62	.1387	.6768	107	.2520	.6994	152	.3906	.7421
18	.0394	.6675	63	.1410	.6772	108	.2548	.7001	153	.3942	.7434
19	.0415	.6676	64	.1434	.6775	109	.2575	.7008	154	.3977	.7447
20	.0437	.6677	65	.1457	.6779	110	.2603	.7015	155	.4013	.7460
21	.0459	.6678	66	.1481	.6782	111	.2631	.7022	156	.4049	.7473
22	.0481	.6679	67	.1505	.6786	112	.2659	.7030	157	.4085	.7486
23	.0503	.6680	68	.1529	.6790	113	.2687	.7037	158	.4122	.7500
24	.0526	.6681	69	.1553	.6794	114	.2715	.7045	159	.4158	.7514
25	.0548	.6683	70	.1576	.6797	115	.2743	.7052	160	.4195	.7528
26	.0570	.6684	71	.1601	.6801	116	.2772	.7060	161	.4233	.7542
27	.0592	.6685	72	.1625	.6805	117	.2800	.7068	162	.4270	.7557
28	.0614	.6687	73	.1649	.6809	118	.2829	.7076	163	.4308	.7571
29	.0636	.6688	74	.1673	.6814	119	.2858	.7084	164	.4346	.7586
30	.0658	.6690	75	.1697	.6818	120	.2887	.7092	165	.4385	.7601
31	.0680	.6691	76	.1722	.6822	121	.2916	.7100	166	.4424	.7616
32	.0703	.6693	77	.1746	.6827	122	.2945	.7109	167	.4463	.7632
33	.0725	.6695	78	.1771	.6831	123	.2975	.7117	168	.4502	.7647
34	.0747	.6696	79	.1795	.6836	124	.3004	.7126	169	.4542	.7663
35	.0770	.6698	80	.1820	.6840	125	.3034	.7135	170	.4582	.7680
36	.0792	.6700	81	.1845	.6845	126	.3064	.7143	171	.4622	.7696
37	.0814	.6702	82	.1869	.6849	127	.3094	.7152	172	.4663	.7712
38	.0837	.6704	83	.1894	.6854	128	.3124	.7161	173	.4704	.7729
39	.0859	.6706	84	.1919	.6859	129	.3155	.7171	174	.4745	.7746
40	.0882	.6708	85	.1944	.6864	130	.3185	.7180	175	.4786	.7764
41	.0904	.6710	86	.1970	.6869	131	.3216	.7190	176	.4828	.7781
42	.0927	.6712	87	.1995	.6874	132	.3247	.7199	177	.4871	.7799
43	.0949	.6714	88	.2020	.6879	133	.3278	.7209	178	.4913	.7817
44	.0972	.6717	89	.2046	.6885	134	.3309	.7219	179	.4957	.7835
45	.0995	.6719	90	.2071	.6890	135	.3341	.7229	180	.5000	.7854

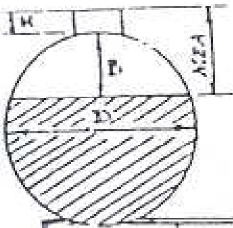
CONSTANTS FOR SPANDREL AREA CALCULATIONS

$K = \tan\frac{\Delta}{2} + \cot\frac{\Delta}{2} - \frac{\pi}{2}$

If $R = R'$ then Areas $A + B = R^2\left(\tan\frac{\Delta}{2} + \cot\frac{\Delta}{2} - \frac{\pi}{2}\right)$



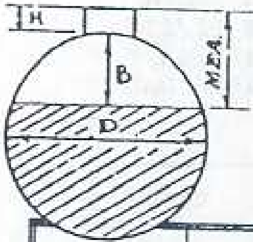
Δ	K	Δ	K	Δ	K	Δ	K	Δ	K
90°	0.4292	79° 12'	0.4653	74° 42'	0.5027	70° 12'	0.5549	67° 08'	98
89°	0.4295	06'	59	36'	37	06'	62	04'	0.6008
88°	0.4304	79°	66	30'	47	70°	75	67°	19
87° 30'	11	78° 54'	74	24'	57	69° 56'	84	66° 56'	30
87°	20	48'	80	18'	67	52'	94	52'	41
86° 30'	29	42'	88	12'	77	48'	0.5603	48'	52
86°	41	36'	95	06'	87	44'	12	44'	62
85° 30'	54	30'	0.4701	74°	98	40'	21	40'	73
85° 10'	63	24'	09	73° 54'	0.5109	36'	30	36'	85
85°	68	18'	16	48'	19	32'	40	32'	95
84° 50'	74	12'	24	42'	30	28'	49	28'	0.6106
40'	79	06'	31	36'	40	24'	58	24'	18
30'	84	78°	39	30'	51	20'	68	20'	29
20'	90	77° 54'	46	24'	62	16'	77	16'	39
10'	96	48'	54	18'	72	12'	87	12'	51
84°	0.4402	42'	62	12'	84	08'	96	08'	62
83° 50'	09	36'	69	06'	95	04'	0.5705	04'	73
40'	15	30'	78	73°	0.5206	69°	15	66°	85
30'	21	24'	86	72° 54'	17	68° 56'	24	65° 56'	96
20'	28	18'	93	48'	29	52'	34	52'	0.6208
10'	35	12'	0.4802	42'	39	48'	44	48'	19
83°	42	06'	10	36'	51	44'	54	44'	30
82° 50'	49	77°	18	30'	62	40'	63	40'	42
40'	57	76° 54'	26	24'	74	36'	73	36'	54
30'	65	48'	35	18'	86	32'	83	32'	65
20'	72	42'	44	12'	97	28'	93	28'	77
10'	80	36'	52	06'	0.5310	24'	0.5803	24'	89
82°	89	30'	60	72°	21	20'	13	20'	0.6301
81° 50'	97	24'	69	71° 54'	33	16'	22	16'	13
40'	0.4505	18'	78	48'	45	12'	33	12'	24
30'	15	12'	86	42'	58	08'	42	08'	36
20'	23	06'	95	36'	69	04'	53	04'	48
10'	32	76°	0.4904	30'	82	68°	63	65°	60
81°	41	75° 54'	13	24'	94	67° 56'	73	64° 56'	72
80° 50'	51	48'	23	18'	0.5407	52'	83	52'	83
40'	61	42'	32	12'	19	48'	94	48'	95
30'	70	36'	41	06'	32	44'	0.5903	44'	0.6408
20'	80	30'	50	71°	44	40'	14	40'	20
10'	90	24'	59	70° 54'	57	36'	24	36'	32
80°	0.4601	18'	69	48'	70	32'	35	32'	45
79° 52'	09	12'	78	42'	83	28'	45	28'	57
44'	17	06'	88	36'	96	24'	55	24'	69
36'	26	75°	97	30'	0.5509	20'	66	20'	81
28'	35	74° 54'	0.5007	24'	22	16'	76	16'	94
20'	43	48'	17	18'	35	12'	87	12'	0.6506



CYLINDERICAL TANK IN HORIZ. POSITION

VOLUME COEFF FOR RATIO OF DEPTH TO MATL / DIA.
VOL.(GAL)=K X COEFF: WHERE K=L(FT) X $D(IN)^2$ X 12/231
EXAMPLE: D=123",L=25.5,H=4;MEAS TO MATL= 104 5/16 "
B/D=.815549; COEFF=.099571,K=20041;VOL = 1996 GAL

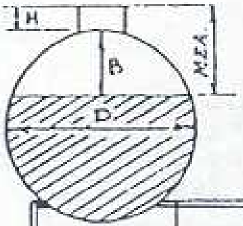
B/D	COEFF	B/D	COEFF	B/D	COEFF	B/D	COEFF
1.000	.000000	0.950	.014681	0.900	.040875	0.850	.073875
0.999	.000042	0.949	.015119	0.899	.041477	0.849	.074590
0.998	.000119	0.948	.015561	0.898	.042081	0.848	.075307
0.997	.000219	0.947	.016008	0.897	.042687	0.847	.076026
0.996	.000337	0.946	.016458	0.896	.043296	0.846	.076747
0.995	.000471	0.945	.016912	0.895	.043908	0.845	.077470
0.994	.000619	0.944	.017369	0.894	.044523	0.844	.078194
0.993	.000779	0.943	.017831	0.893	.045140	0.843	.078921
0.992	.000952	0.942	.018297	0.892	.045759	0.842	.079650
0.991	.001135	0.941	.018766	0.891	.046381	0.841	.080380
0.990	.001329	0.940	.019239	0.890	.047006	0.840	.081112
0.989	.001533	0.939	.019716	0.889	.047633	0.839	.081847
0.988	.001746	0.938	.020197	0.888	.048262	0.838	.082582
0.987	.001969	0.937	.020681	0.887	.048894	0.837	.083320
0.986	.002199	0.936	.021168	0.886	.049529	0.836	.084060
0.985	.002438	0.935	.021660	0.885	.050165	0.835	.084801
0.984	.002685	0.934	.022155	0.884	.050805	0.834	.085545
0.983	.002940	0.933	.022653	0.883	.051446	0.833	.086290
0.982	.003202	0.932	.023155	0.882	.052090	0.832	.087037
0.981	.003472	0.931	.023660	0.881	.052737	0.831	.087785
0.980	.003749	0.930	.024168	0.880	.053385	0.830	.088536
0.979	.004032	0.929	.024680	0.879	.054037	0.829	.089288
0.978	.004322	0.928	.025196	0.878	.054690	0.828	.090042
0.977	.004619	0.927	.025714	0.877	.055346	0.827	.090797
0.976	.004922	0.926	.026236	0.876	.056004	0.826	.091555
0.975	.005231	0.925	.026761	0.875	.056664	0.825	.092314
0.974	.005546	0.924	.027290	0.874	.057327	0.824	.093074
0.973	.005867	0.923	.027821	0.873	.057991	0.823	.093837
0.972	.006194	0.922	.028356	0.872	.058658	0.822	.094601
0.971	.006527	0.921	.028894	0.871	.059328	0.821	.095367
0.970	.006866	0.920	.029435	0.870	.059999	0.820	.096135
0.969	.007209	0.919	.029979	0.869	.060673	0.819	.096904
0.968	.007559	0.918	.030526	0.868	.061349	0.818	.097675
0.967	.007913	0.917	.031077	0.867	.062027	0.817	.098447
0.966	.008273	0.916	.031630	0.866	.062707	0.816	.099221
0.965	.008638	0.915	.032186	0.865	.063389	0.815	.099997
0.964	.009008	0.914	.032746	0.864	.064074	0.814	.100774
0.963	.009383	0.913	.033308	0.863	.064761	0.813	.101553
0.962	.009763	0.912	.033873	0.862	.065449	0.812	.102334
0.961	.010148	0.911	.034441	0.861	.066140	0.811	.103116
0.960	.010538	0.910	.035012	0.860	.066833	0.810	.103900
0.959	.010932	0.909	.035586	0.859	.067528	0.809	.104686
0.958	.011331	0.908	.036162	0.858	.068225	0.808	.105472
0.957	.011734	0.907	.036742	0.857	.068924	0.807	.106261
0.956	.012142	0.906	.037324	0.856	.069626	0.806	.107051
0.955	.012555	0.905	.037909	0.855	.070329	0.805	.107843
0.954	.012971	0.904	.038497	0.854	.071034	0.804	.108636
0.953	.013393	0.903	.039087	0.853	.071741	0.803	.109431
0.952	.013818	0.902	.039681	0.852	.072450	0.802	.110227
0.951	.014248	0.901	.040277	0.851	.073162	0.801	.111025



CYLINDERICAL TANK IN HORIZ. POSITION

VOLUME COEFF FOR RATIO OF DEPTH TO MATL / DIA.
VOL.(GAL)=K X COEFF: WHERE K=L(FT) X $D(IN)^2$ X 12/231
EXAMPLE: D=123",L=25.5,H=4;MEAS TO MATL= 104 5/16 "
B/D=.815549; COEFF=.099571,K=20041;VOL = 1996 GAL

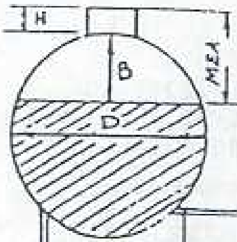
B/D	COEFF	B/D	COEFF	B/D	COEFF	B/D	COEFF
0.800	.111824	0.750	.153546	0.700	.198168	0.650	.244980
0.799	.112625	0.749	.154413	0.699	.199085	0.649	.245935
0.798	.113427	0.748	.155281	0.698	.200003	0.648	.246890
0.797	.114231	0.747	.156149	0.697	.200922	0.647	.247845
0.796	.115036	0.746	.157019	0.696	.201841	0.646	.248801
0.795	.115842	0.745	.157891	0.695	.202762	0.645	.249758
0.794	.116651	0.744	.158763	0.694	.203683	0.644	.250715
0.793	.117460	0.743	.159636	0.693	.204605	0.643	.251673
0.792	.118271	0.742	.160511	0.692	.205528	0.642	.252632
0.791	.119084	0.741	.161386	0.691	.206452	0.641	.253591
0.790	.119898	0.740	.162263	0.690	.207376	0.640	.254551
0.789	.120713	0.739	.163141	0.689	.208302	0.639	.255511
0.788	.121530	0.738	.164020	0.688	.209228	0.638	.256472
0.787	.122348	0.737	.164900	0.687	.210155	0.637	.257433
0.786	.123167	0.736	.165781	0.686	.211083	0.636	.258395
0.785	.123988	0.735	.166663	0.685	.212011	0.635	.259358
0.784	.124811	0.734	.167546	0.684	.212941	0.634	.260321
0.783	.125634	0.733	.168431	0.683	.213871	0.633	.261285
0.782	.126459	0.732	.169316	0.682	.214802	0.632	.262249
0.781	.127286	0.731	.170202	0.681	.215734	0.631	.263214
0.780	.128114	0.730	.171090	0.680	.216666	0.630	.264179
0.779	.128943	0.729	.171978	0.679	.217600	0.629	.265145
0.778	.129773	0.728	.172868	0.678	.218534	0.628	.266111
0.777	.130605	0.727	.173758	0.677	.219469	0.627	.267078
0.776	.131438	0.726	.174650	0.676	.220404	0.626	.268046
0.775	.132273	0.725	.175542	0.675	.221341	0.625	.269014
0.774	.133109	0.724	.176436	0.674	.222278	0.624	.269982
0.773	.133946	0.723	.177330	0.673	.223216	0.623	.270951
0.772	.134784	0.722	.178226	0.672	.224154	0.622	.271921
0.771	.135624	0.721	.179122	0.671	.225094	0.621	.272891
0.770	.136465	0.720	.180020	0.670	.226034	0.620	.273861
0.769	.137307	0.719	.180918	0.669	.226974	0.619	.274832
0.768	.138151	0.718	.181818	0.668	.227916	0.618	.275804
0.767	.138996	0.717	.182718	0.667	.228858	0.617	.276776
0.766	.139842	0.716	.183619	0.666	.229801	0.616	.277748
0.765	.140689	0.715	.184522	0.665	.230745	0.615	.278721
0.764	.141538	0.714	.185425	0.664	.231689	0.614	.279695
0.763	.142388	0.713	.186329	0.663	.232634	0.613	.280669
0.762	.143239	0.712	.187235	0.662	.233580	0.612	.281643
0.761	.144091	0.711	.188141	0.661	.234526	0.611	.282618
0.760	.144945	0.710	.189048	0.660	.235473	0.610	.283593
0.759	.145800	0.709	.189956	0.659	.236421	0.609	.284569
0.758	.146655	0.708	.190865	0.658	.237369	0.608	.285545
0.757	.147513	0.707	.191774	0.657	.238319	0.607	.286521
0.756	.148371	0.706	.192685	0.656	.239268	0.606	.287499
0.755	.149231	0.705	.193597	0.655	.240219	0.605	.288476
0.754	.150091	0.704	.194509	0.654	.241170	0.604	.289454
0.753	.150953	0.703	.195423	0.653	.242122	0.603	.290432
0.752	.151816	0.702	.196337	0.652	.243074	0.602	.291411
0.751	.152681	0.701	.197252	0.651	.244027	0.601	.292390



CYLINDERICAL TANK IN HORIZ. POSITION

VOLUME COEFF FOR RATIO OF DEPTH TO MATL / DIA.
VOL.(GAL)=K X COEFF: WHERE K=L(FT) X D(IN)^2 X 12/231
EXAMPLE: D=123",L=25.5,H=4;MEAS TO MATL= 104 5/16 "
B/D=.815549; COEFF=.099571,K=20041;VOL = 1996 GAL

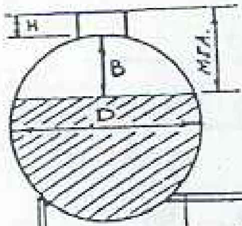
B/D	COEFF	B/D	COEFF	B/D	COEFF	B/D	COEFF
0.600	.293370	0.550	.342783	0.500	.392699	0.450	.442616
0.599	.294350	0.549	.343778	0.499	.393699	0.449	.443611
0.598	.295330	0.548	.344773	0.498	.394699	0.448	.444605
0.597	.296311	0.547	.345768	0.497	.395699	0.447	.445600
0.596	.297292	0.546	.346764	0.496	.396699	0.446	.446594
0.595	.298274	0.545	.347760	0.495	.397699	0.445	.447588
0.594	.299256	0.544	.348756	0.494	.398699	0.444	.448582
0.593	.300238	0.543	.349752	0.493	.399699	0.443	.449575
0.592	.301221	0.542	.350749	0.492	.400699	0.442	.450569
0.591	.302204	0.541	.351745	0.491	.401699	0.441	.451562
0.590	.303187	0.540	.352742	0.490	.402698	0.440	.452555
0.589	.304171	0.539	.353739	0.489	.403698	0.439	.453547
0.588	.305156	0.538	.354736	0.488	.404698	0.438	.454540
0.587	.306140	0.537	.355733	0.487	.405698	0.437	.455532
0.586	.307125	0.536	.356730	0.486	.406697	0.436	.456524
0.585	.308110	0.535	.357728	0.485	.407697	0.435	.457516
0.584	.309096	0.534	.358725	0.484	.408696	0.434	.458507
0.583	.310082	0.533	.359723	0.483	.409696	0.433	.459498
0.582	.311068	0.532	.360721	0.482	.410695	0.432	.460489
0.581	.312055	0.531	.361719	0.481	.411695	0.431	.461479
0.580	.313042	0.530	.362717	0.480	.412694	0.430	.462470
0.579	.314029	0.529	.363715	0.479	.413693	0.429	.463460
0.578	.315017	0.528	.364714	0.478	.414692	0.428	.464449
0.577	.316005	0.527	.365712	0.477	.415691	0.427	.465439
0.576	.316993	0.526	.366711	0.476	.416690	0.426	.466428
0.575	.317981	0.525	.367710	0.475	.417689	0.425	.467417
0.574	.318970	0.524	.368708	0.474	.418687	0.424	.468405
0.573	.319959	0.523	.369707	0.473	.419686	0.423	.469394
0.572	.320949	0.522	.370706	0.472	.420684	0.422	.470382
0.571	.321938	0.521	.371705	0.471	.421683	0.421	.471369
0.570	.322928	0.520	.372704	0.470	.422681	0.420	.472356
0.569	.323919	0.519	.373704	0.469	.423679	0.419	.473343
0.568	.324909	0.518	.374703	0.468	.424677	0.418	.474330
0.567	.325900	0.517	.375702	0.467	.425675	0.417	.475316
0.566	.326891	0.516	.376702	0.466	.426673	0.416	.476302
0.565	.327883	0.515	.377701	0.465	.427670	0.415	.477288
0.564	.328874	0.514	.378701	0.464	.428668	0.414	.478273
0.563	.329866	0.513	.379701	0.463	.429665	0.413	.479258
0.562	.330858	0.512	.380700	0.462	.430662	0.412	.480243
0.561	.331851	0.511	.381700	0.461	.431659	0.411	.481227
0.560	.332843	0.510	.382700	0.460	.432656	0.410	.482211
0.559	.333836	0.509	.383700	0.459	.433653	0.409	.483194
0.558	.334829	0.508	.384699	0.458	.434650	0.408	.484177
0.557	.335823	0.507	.385699	0.457	.435646	0.407	.485160
0.556	.336816	0.506	.386699	0.456	.436642	0.406	.486142
0.555	.337810	0.505	.387699	0.455	.437638	0.405	.487124
0.554	.338804	0.504	.388699	0.454	.438634	0.404	.488106
0.553	.339799	0.503	.389699	0.453	.439630	0.403	.489087
0.552	.340793	0.502	.390699	0.452	.440625	0.402	.490068
0.551	.341788	0.501	.391699	0.451	.441621	0.401	.491048



CYLINDERICAL TANK IN HORIZ. POSITION

VOLUME COEFF FOR RATIO OF DEPTH TO MATL / DIA.
VOL.(GAL)=K X COEFF: WHERE $K=L(FT) \times D(IN)^2 \times 12/231$
EXAMPLE: D=123",L=25.5,H=4;MEAS TO MATL= 104 5/16 "
B/D=.815549; COEFF=.099571,K=20041;VOL = 1996 GAL

B/D	COEFF	B/D	COEFF	B/D	COEFF	B/D	COEFF
0.400	.492028	0.350	.540418	0.300	.587230	0.250	.631852
0.399	.493008	0.349	.541371	0.299	.588146	0.249	.632717
0.398	.493987	0.348	.542324	0.298	.589061	0.248	.633582
0.397	.494966	0.347	.543277	0.297	.589975	0.247	.634445
0.396	.495944	0.346	.544228	0.296	.590889	0.246	.635307
0.395	.496922	0.345	.545179	0.295	.591801	0.245	.636168
0.394	.497900	0.344	.546130	0.294	.592713	0.244	.637027
0.393	.498877	0.343	.547080	0.293	.593624	0.243	.637885
0.392	.499853	0.342	.548029	0.292	.594534	0.242	.638743
0.391	.500829	0.341	.548977	0.291	.595442	0.241	.639599
0.390	.501805	0.340	.549925	0.290	.596350	0.240	.640453
0.389	.502780	0.339	.550872	0.289	.597258	0.239	.641307
0.388	.503755	0.338	.551818	0.288	.598164	0.238	.642159
0.387	.504730	0.337	.552764	0.287	.599069	0.237	.643010
0.386	.505704	0.336	.553709	0.286	.599973	0.236	.643860
0.385	.506677	0.335	.554653	0.285	.600876	0.235	.644709
0.384	.507650	0.334	.555597	0.284	.601779	0.234	.645556
0.383	.508622	0.333	.556540	0.283	.602680	0.233	.646402
0.382	.509594	0.332	.557482	0.282	.603581	0.232	.647247
0.381	.510566	0.331	.558424	0.281	.604480	0.231	.648091
0.380	.511537	0.330	.559364	0.280	.605379	0.230	.648933
0.379	.512507	0.329	.560305	0.279	.606276	0.229	.649774
0.378	.513477	0.328	.561244	0.278	.607173	0.228	.650614
0.377	.514447	0.327	.562182	0.277	.608068	0.227	.651452
0.376	.515416	0.326	.563120	0.276	.608963	0.226	.652289
0.375	.516385	0.325	.564057	0.275	.609856	0.225	.653125
0.374	.517352	0.324	.564994	0.274	.610749	0.224	.653960
0.373	.518320	0.323	.565929	0.273	.611640	0.223	.654793
0.372	.519287	0.322	.566864	0.272	.612531	0.222	.655625
0.371	.520253	0.321	.567798	0.271	.613420	0.221	.656455
0.370	.521219	0.320	.568732	0.270	.614309	0.220	.657284
0.369	.522185	0.319	.569664	0.269	.615196	0.219	.658112
0.368	.523149	0.318	.570596	0.268	.616082	0.218	.658939
0.367	.524114	0.317	.571527	0.267	.616968	0.217	.659764
0.366	.525077	0.316	.572457	0.266	.617852	0.216	.660588
0.365	.526040	0.315	.573387	0.265	.618735	0.215	.661410
0.364	.527003	0.314	.574315	0.264	.619617	0.214	.662231
0.363	.527965	0.313	.575243	0.263	.620498	0.213	.663050
0.362	.528926	0.312	.576170	0.262	.621378	0.212	.663869
0.361	.529887	0.311	.577096	0.261	.622257	0.211	.664685
0.360	.530848	0.310	.578022	0.260	.623135	0.210	.665501
0.359	.531807	0.309	.578946	0.259	.624012	0.209	.666315
0.358	.532766	0.308	.579870	0.258	.624887	0.208	.667127
0.357	.533725	0.307	.580793	0.257	.625762	0.207	.667938
0.356	.534683	0.306	.581715	0.256	.626635	0.206	.668748
0.355	.535640	0.305	.582636	0.255	.627508	0.205	.669556
0.354	.536597	0.304	.583557	0.254	.628379	0.204	.670362
0.353	.537553	0.303	.584476	0.253	.629249	0.203	.671168
0.352	.538509	0.302	.585395	0.252	.630118	0.202	.671971
0.351	.539463	0.301	.586313	0.251	.630985	0.201	.672774



CYLINDERICAL TANK IN HORIZ. POSITION

VOLUME COEFF FOR RATIO OF DEPTH TO MATL / DIA.
VOL.(GAL)=K X COEFF: WHERE K=L(FT) X D(IN)^2 X 12/231
EXAMPLE: D=123",L=25.5,H=4;MEAS TO MATL= 104 5/16 "
B/D=.815549; COEFF=.099571,K=20041;VOL = 1996 GAL

B/D	COEFF	B/D	COEFF	B/D	COEFF	B/D	COEFF
0.200	.673574	0.150	.711523	0.100	.744523	0.050	.770717
0.199	.674374	0.149	.712237	0.099	.745122	0.049	.771151
0.198	.675171	0.148	.712948	0.098	.745718	0.048	.771580
0.197	.675968	0.147	.713657	0.097	.746311	0.047	.772006
0.196	.676762	0.146	.714364	0.096	.746901	0.046	.772427
0.195	.677555	0.145	.715069	0.095	.747489	0.045	.772843
0.194	.678347	0.144	.715773	0.094	.748074	0.044	.773256
0.193	.679137	0.143	.716474	0.093	.748656	0.043	.773664
0.192	.679926	0.142	.717173	0.092	.749236	0.042	.774067
0.191	.680713	0.141	.717870	0.091	.749813	0.041	.774466
0.190	.681498	0.140	.718565	0.090	.750386	0.040	.774860
0.189	.682282	0.139	.719258	0.089	.750957	0.039	.775250
0.188	.683064	0.138	.719949	0.088	.751525	0.038	.775635
0.187	.683845	0.137	.720638	0.087	.752090	0.037	.776015
0.186	.684624	0.136	.721324	0.086	.752653	0.036	.776390
0.185	.685401	0.135	.722009	0.085	.753212	0.035	.776760
0.184	.686177	0.134	.722691	0.084	.753768	0.034	.777125
0.183	.686951	0.133	.723371	0.083	.754321	0.033	.777485
0.182	.687724	0.132	.724049	0.082	.754872	0.032	.777839
0.181	.688494	0.131	.724725	0.081	.755419	0.031	.778189
0.180	.689264	0.130	.725399	0.080	.755963	0.030	.778533
0.179	.690031	0.129	.726070	0.079	.756504	0.029	.778871
0.178	.690797	0.128	.726740	0.078	.757042	0.028	.779204
0.177	.691561	0.127	.727407	0.077	.757577	0.027	.779531
0.176	.692324	0.126	.728072	0.076	.758108	0.026	.779852
0.175	.693084	0.125	.728734	0.075	.758637	0.025	.780167
0.174	.693844	0.124	.729394	0.074	.759162	0.024	.780477
0.173	.694601	0.123	.730053	0.073	.759684	0.023	.780780
0.172	.695357	0.122	.730708	0.072	.760202	0.022	.781076
0.171	.696110	0.121	.731362	0.071	.760718	0.021	.781366
0.170	.696863	0.120	.732013	0.070	.761230	0.020	.781650
0.169	.697613	0.119	.732661	0.069	.761738	0.019	.781926
0.168	.698362	0.118	.733308	0.068	.762244	0.018	.782196
0.167	.699108	0.117	.733952	0.067	.762745	0.017	.782458
0.166	.699854	0.116	.734594	0.066	.763244	0.016	.782713
0.165	.700597	0.115	.735233	0.065	.763738	0.015	.782960
0.164	.701338	0.114	.735870	0.064	.764230	0.014	.783199
0.163	.702078	0.113	.736504	0.063	.764717	0.013	.783430
0.162	.702816	0.112	.737136	0.062	.765202	0.012	.783652
0.161	.703552	0.111	.737766	0.061	.765682	0.011	.783865
0.160	.704286	0.110	.738393	0.060	.766159	0.010	.784069
0.159	.705018	0.109	.739017	0.059	.766632	0.009	.784263
0.158	.705749	0.108	.739639	0.058	.767101	0.008	.784446
0.157	.706477	0.107	.740259	0.057	.767567	0.007	.784619
0.156	.707204	0.106	.740876	0.056	.768029	0.006	.784780
0.155	.707928	0.105	.741490	0.055	.768487	0.005	.784927
0.154	.708651	0.104	.742102	0.054	.768941	0.004	.785061
0.153	.709372	0.103	.742711	0.053	.769391	0.003	.785179
0.152	.710091	0.102	.743318	0.052	.769837	0.002	.785279
0.151	.710808	0.101	.743922	0.051	.770279	0.001	.785356

INCHES AND FRACTIONS TO DECIMALS OF A FOOT

0	.0000	**3**	.2500	**6**	.5000	**9**	.7500
1/16	.0052	1/16	.2552	1/16	.5052	1/16	.7552
1/8	.0104	1/8	.2604	1/8	.5104	1/8	.7604
3/16	.0156	3/16	.2656	3/16	.5156	3/16	.7656
1/4	.0208	1/4	.2708	1/4	.5208	1/4	.7708
5/16	.0260	5/16	.2760	5/16	.5260	5/16	.7760
3/8	.0312	3/8	.2812	3/8	.5312	3/8	.7812
7/16	.0365	7/16	.2865	7/16	.5365	7/16	.7865
1/2	.0417	1/2	.2917	1/2	.5417	1/2	.7917
9/16	.0469	9/16	.2969	9/16	.5469	9/16	.7969
5/8	.0521	5/8	.3021	5/8	.5521	5/8	.8021
11/16	.0573	11/16	.3073	11/16	.5573	11/16	.8073
3/4	.0625	3/4	.3125	3/4	.5625	3/4	.8125
13/16	.0677	13/16	.3177	13/16	.5677	13/16	.8177
7/8	.0729	7/8	.3229	7/8	.5729	7/8	.8229
15/16	.0781	15/16	.3281	15/16	.5781	15/16	.8281
1	.0833	**4**	.3333	**7**	.5833	**10**	.8333
1/16	.0885	1/16	.3385	1/16	.5885	1/16	.8385
1/8	.0937	1/8	.3437	1/8	.5937	1/8	.8437
3/16	.0990	3/16	.3490	3/16	.5990	3/16	.8490
1/4	.1042	1/4	.3542	1/4	.6042	1/4	.8542
5/16	.1094	5/16	.3594	5/16	.6094	5/16	.8594
3/8	.1146	3/8	.3646	3/8	.6146	3/8	.8646
7/16	.1198	7/16	.3698	7/16	.6198	7/16	.8698
1/2	.1250	1/2	.3750	1/2	.6250	1/2	.8750
9/16	.1302	9/16	.3802	9/16	.6302	9/16	.8802
5/8	.1354	5/8	.3854	5/8	.6354	5/8	.8854
11/16	.1406	11/16	.3906	11/16	.6406	11/16	.8906
3/4	.1458	3/4	.3958	3/4	.6458	3/4	.8958
13/16	.1510	13/16	.4010	13/16	.6510	13/16	.9010
7/8	.1562	7/8	.4062	7/8	.6562	7/8	.9062
15/16	.1615	15/16	.4115	15/16	.6615	15/16	.9115
2	.1667	**5**	.4167	**8**	.6667	**11**	.9167
1/16	.1719	1/16	.4219	1/16	.6719	1/16	.9219
1/8	.1771	1/8	.4271	1/8	.6771	1/8	.9271
3/16	.1823	3/16	.4323	3/16	.6823	3/16	.9323
1/4	.1875	1/4	.4375	1/4	.6875	1/4	.9375
5/16	.1927	5/16	.4427	5/16	.6927	5/16	.9427
3/8	.1979	3/8	.4479	3/8	.6979	3/8	.9479
7/16	.2031	7/16	.4531	7/16	.7031	7/16	.9531
1/2	.2083	1/2	.4583	1/2	.7083	1/2	.9583
9/16	.2135	9/16	.4635	9/16	.7135	9/16	.9635
5/8	.2187	5/8	.4687	5/8	.7187	5/8	.9687
11/16	.2240	11/16	.4740	11/16	.7240	11/16	.9740
3/4	.2292	3/4	.4792	3/4	.7292	3/4	.9792
13/16	.2344	13/16	.4844	13/16	.7344	13/16	.9844
7/8	.2396	7/8	.4896	7/8	.7396	7/8	.9896
15/16	.2448	15/16	.4948	15/16	.7448	15/16	.9948