ENGLISH

ALIGNMENT GUIDE

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November, 2003

APPENDIX J
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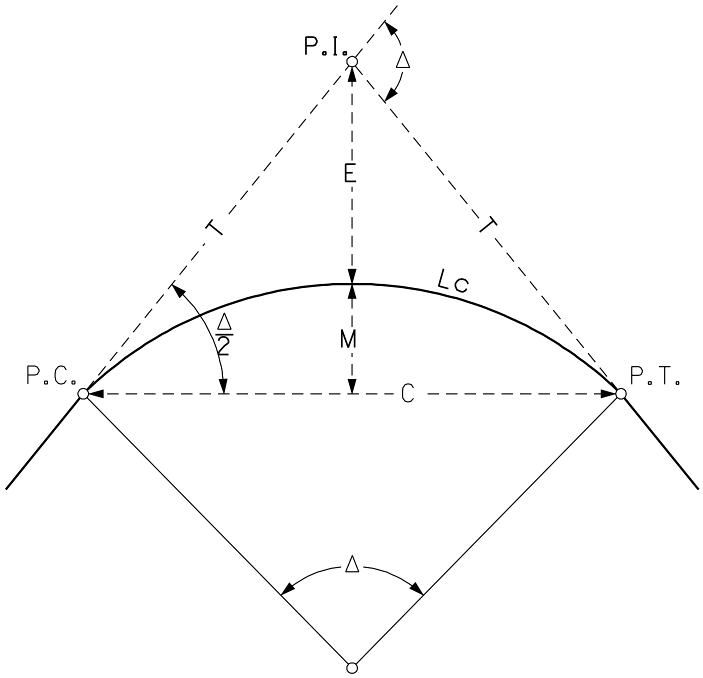
CIRCULAR CURVE DEFINITIONS



A circular curve is based on the arc definition using the degree as it's parameter designation.

P.C. = Beginning of curve.

P.I. = Point of intersection of the tangents.

P.T. = End of curve.

Δ = Deflection angle of the tangents at the P.I..

D = Degree of Curvature

T = Tangent distance from P.I. to P.C. or P.I. to P.T.

Lc = Length of curve from P.C. to P.T.

E = External distance from the P.I. to midpoint of curve.

M = Middle Ordinate distance from midpoint of chord to midpoint of curve.

C = Chord length from P.C. to P.T.

$$T = R \tan \frac{\Delta}{2}$$

$$Lc = \frac{\pi R \Delta}{180}$$

$$E = \left(R \div \cos \frac{\Delta}{2}\right) - R$$

$$M = R - \left(R \cos \frac{\Delta}{2}\right)$$

$$C = 2R \sin \text{deflection} = 2R \sin \frac{\Delta}{2}$$

$$\text{Deflection per foot of arc} = \frac{90}{\pi R}$$

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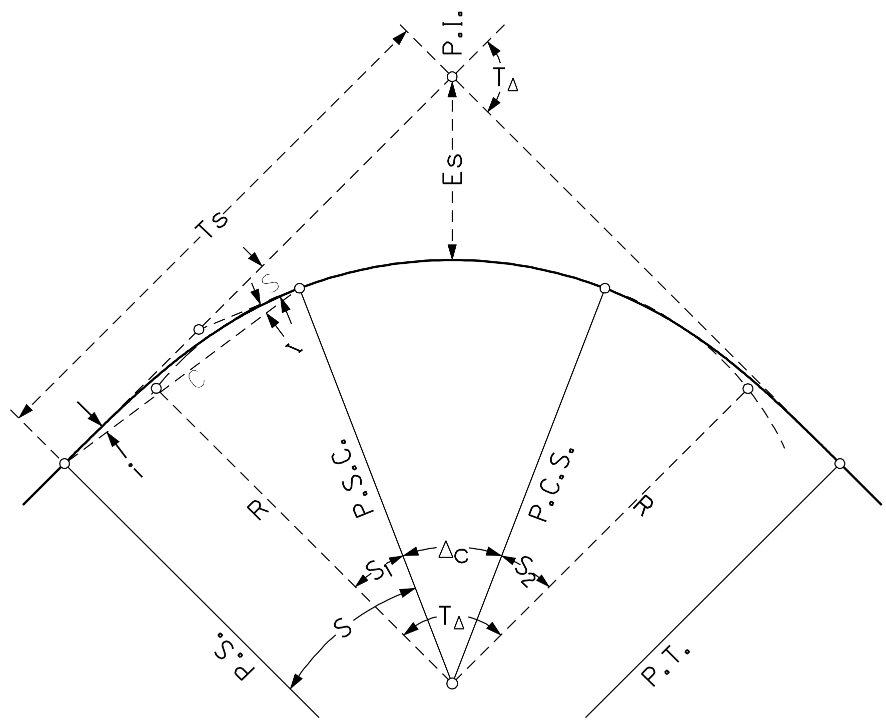
SPIRAL CURVE DEFINITIONS



T_Δ = Deflection angle of the tangents at the P.I.

$\Delta c = T_\Delta - (S_1 + S_2)$ = Central angle of circular curve.

S = The central angle of the whole spiral.

I = The angle from any point on the spiral between the tangent at that point and the chord from that point to the P.S.

i = The angle between the tangent at the P.S. and the chord from the P.S. to any point on the spiral or the deflection angle to any any point on the spiral.

Ts = The semi-tangent distance of the spiraled curve; distance from the P.I. to the P.S. or P.I. to P.T.

Es = External distance, shortest distance from P.I. to the curve assembly.

C = The chord from the P.S. to the P.S.C. or P.C.S. to P.T.

D = The degree of the central circular curve.

Ls = The length of the spiral from the P.S. to the P.S.C. or P.C.S. to P.T.

ℓ = The length of the spiral from the P.S. or P.T. to any given point on the spiral.

a - The rate of increase in degree of curve per station along the spiral (= D/Ls).

d = The degree of curve at any given point on the spiral.

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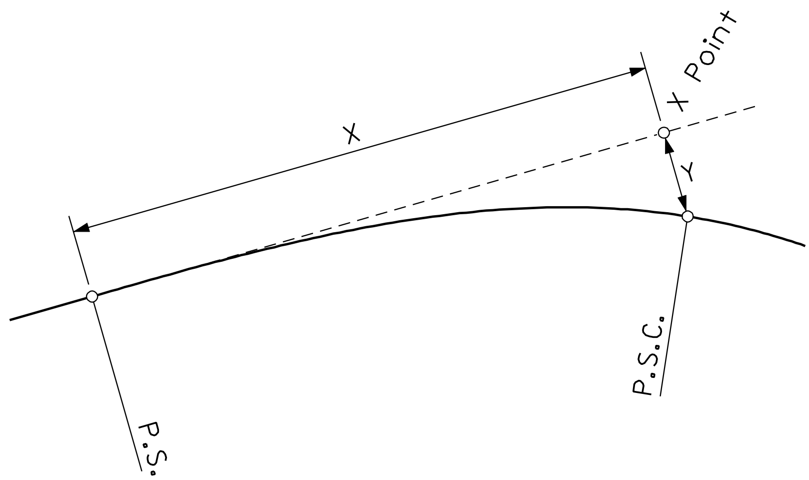
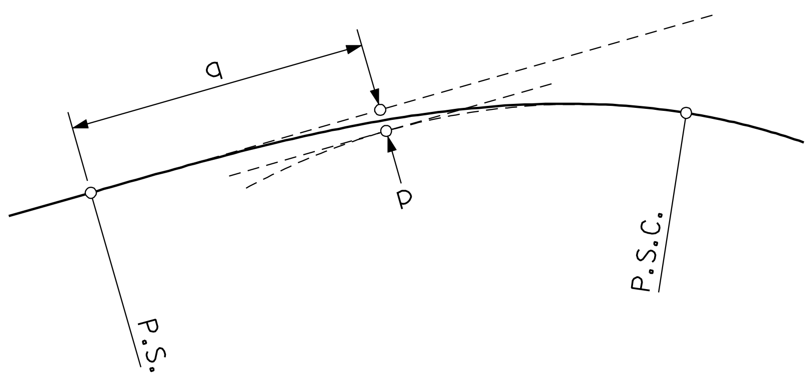


X = The distance from the P.S. to a point on the tangent perpendicular to the P.S.C.

Y = Tangent offset to the spiral at the P.S.C. from semi-tangent.

X Point = Point on the semi-tangent at X distance from the P.S. or P.T. Intersection of X and Y distances.



p = The offset from the semi-tangent to the point where the tangent to the circular curve (produced backward or forward) becomes parallel to the semi-tangent.

q = The distance measured along the semi-tangent from P.S. or P.T. to a point where the tangent to the circular curve (produced backward or forward) becomes parallel to the semi-tangent.

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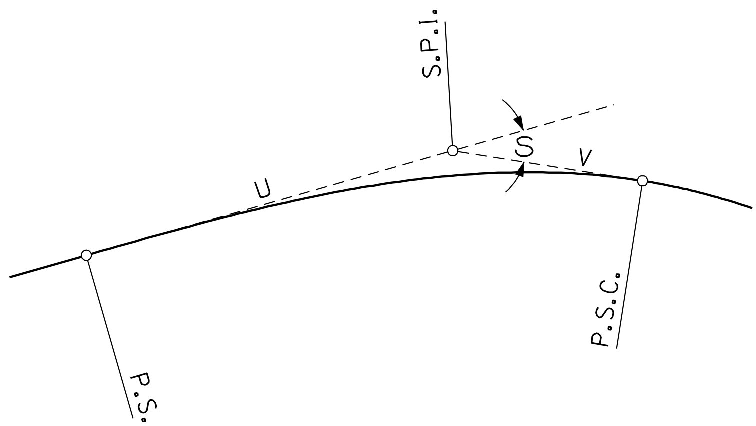

S.P.I. = Intersection of spiral tangents.

U = The distance on the tangent from the P.S. to the intersection with a tangent through the P.S.C.; the longer spiral tangent.

V = The distance on the tangent through the P.S.C. from the P.S.C. to the intersection with the tangent through the P.S.; the shorter spiral tangent.

S = The central angle of the spiral from the P.S. to any given point on the spiral.

NOTATION

P.I. = Point of intersection of tangents.

P.S. = Point of change from spiral to tangent.

P.S.C. = Point of change from spiral to circular curve.

P.C.S. = Point of change from circular curve to spiral.

P.T. = Point of change from spiral to tangent.

P.R.S. = Point of reversing spirals.

P.S.S. = Point of change from spiral to spiral.

P.O.S. = Point on spiral.

P.O.C. = Point on circular curve.

P.O.S.T. = Point on semi-tangent.

P.O.T. = Point on tangent.

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BASIC FORMULAS

Spiral Definition

The Standard Highway Spiral is a curve whose degree varies directly with its length, beginning at infinity at the P.S. and reaching a degree of curve equal to the circular curve at the P.S.C.

π = 3.1415926536

1 Radian = 57.295779513°

a = [(100)(D)/Ls]

D = [(a)(Ls)/100] = [(200)(S)/Ls]

Ls = (100)(D)/a = (200)(S)/D

S = Spiral Angle in Degrees

S = (D)(Ls)/200 = (a)(Ls^2)/20,000 = (D^2)/(2)(a)

R = 5729.5779513/D = (5729.5779513)(Ls)/(200)(S) = (28.647889757)(Ls)/S

$$\frac{X}{Ls} = \Sigma\left(\frac{\theta 2^{n-2}}{(2n-2)\,!\,(4n-3)\,(-1)^{n+1}}\right)$$

$$\frac{Y}{Ls} = \Sigma\left(\frac{\theta 2^{n-1}}{(2n-1)\,!\,(4n-1)\,(-1)^{n+1}}\right)$$

Following is the expanded form for values to n = 8 ("n" is not equal to 0)

θ = S in Radians

$$X = Ls\ \left(1 - \frac{\theta^2}{10} + \frac{\theta^4}{216} - \frac{\theta^6}{9360} + \frac{\theta^8}{685{,}440} - \frac{\theta^{10}}{76{,}204{,}800} + \frac{\theta^{12}}{11{,}975{,}040{,}000} - \frac{\theta^{14}}{2{,}528{,}170{,}444{,}800}\right)$$

Note: Designations of X and Y have been reversed to match most software. The ODOT Standard Highway Spiral Book values for X and Y are still accurate, just reversed.

$$Y = Ls\ \left(\frac{\theta}{3} - \frac{\theta^3}{42} + \frac{\theta^5}{1320} - \frac{\theta^7}{75{,}600} + \frac{\theta^9}{6{,}894{,}720} - \frac{\theta^{11}}{918{,}086{,}400} + \frac{\theta^{13}}{168{,}129{,}561{,}600} - \frac{\theta^{15}}{40{,}537{,}905{,}408{,}000} - - -\right)$$

$$\text{Tan } i = \frac{Y}{X}$$

$$I = S - i$$

$$q = X - R \sin S = X - \frac{28.647\ 889\ 757\ Ls}{S} \sin S$$

$$p = Y - R\ (1 - \text{Cos } S) = Y - \frac{28.647\ 889\ 757\ Ls}{S} (1 - \text{Cos } S)$$

$$U = X - \frac{Y}{\tan S}$$

$$V = \frac{Y}{\sin S}$$

$$C = \sqrt{X^2 + Y^2}$$

$$Ts = q + (R + p) \tan \frac{T\Delta}{2}$$

$$Es = \frac{R + p}{\text{Cos} \frac{T\Delta}{2}} - R$$

$$Lc = \text{Length of circular curve} = \frac{\pi R \Delta c}{180} = \frac{\pi R (T_\Delta - S_1 - S_2)}{180}$$

Note: Designations of X and Y have been reversed to match most software. The ODOT Standard Highway Spiral Book values for X and Y are still accurate, just reversed.

STANDARD SPIRAL DATA

All curves of one degree or sharper shall be spiraled, using an approximation of the Talbot Spiral based on the arc definition for radius of the curve. The standard length for spirals shall be as follows:

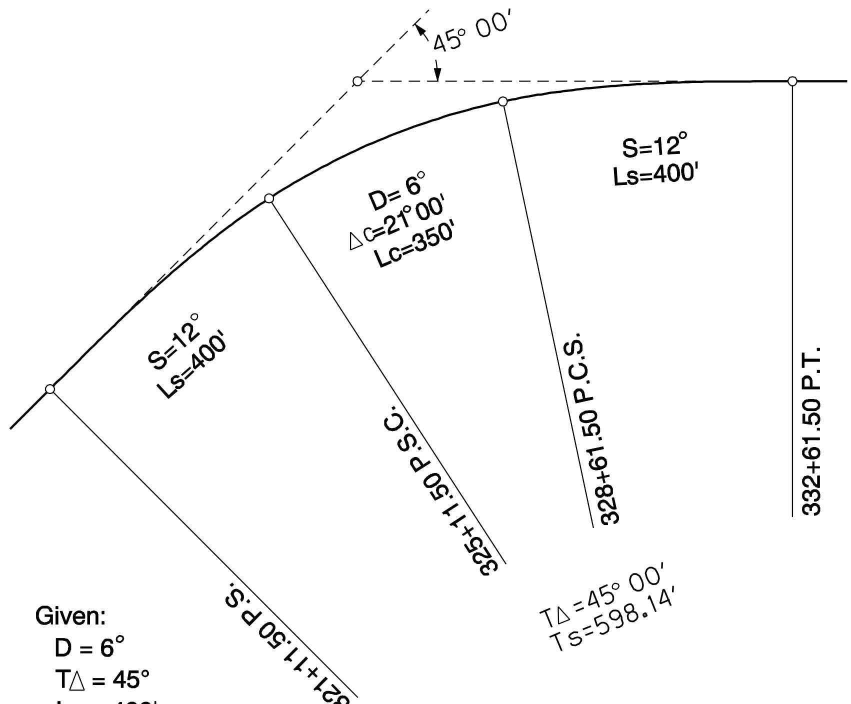
DEGREE	"a" value	Length
1° 00'	0.25	400'
1° 30'	0.40	375'
2° 00'	0.50	400'
2° 30'	0.50	500'
3° 00'	0.60	500'
3° 30'	0.70	500'
4° 00'	0.80	500'
5° 00'	1.0	500'
6° 00'	1 1/3	450'
7° 00'	1.75	400'
8° 00'	2.00	400'
10° 00'	2.50	400'
12° 00'	3.00	400'
14° 00'	4.00	350'
16° 00'	5.00	320'
18° 00'	6.00	300'
20° 00'	8.00	250'
24° 00'	10.0	240'
30° 00'	15.0	240'
36° 00'	18.0	240'

Any deviation from the standard as set forth shall be approved by the Roadway Engineering Manager.

TYPICAL SPIRAL CURVE SOLUTIONS

EXAMPLE I

TYPICAL SOLUTION OF SPIRAL ELEMENTS AND DEFLECTION ANGLES
(Curve with spirals of equal length)



Given:

- D = 6°
- TΔ = 45°
- L_S = 400'
- Station of P.S. = 321 + 11.50

Find:

Elements of spiral and main curve and to determine deflection angles from P.S. to points on the spiral.

Solution:

$$a = (100)(D)/Ls = 600/400 = 1.5$$

$$S = (D)(Ls)/200 = (6)(400')/200 = 12° 00'$$

$$i = \text{ArcTan}\,\frac{Y}{X} = 4° 26' 36''$$

$$Ts = q + (R+p)\,\text{Tan}\,\frac{T_\Delta}{2} = 598.14'$$

From Formula

X = 398.25'
Y = 27.84'
C = 399.22'
U = 267.28'
V = 133.89'
p = 6.97'
q = 119.71'

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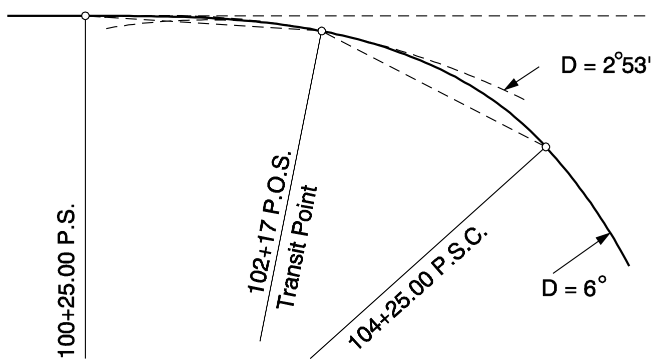
EXAMPLE II

INTERMEDIATE SETUP ON SPIRAL WITH DEFLECTIONS



Given:

S = 12° 00'
D = 6°
a = 1.5
Ls = 400'
P.S. = 100 + 25.00
P.S.C. = 104 + 25.00

Find:

Assume it is necessary to make intermediate setup at station 102 + 17

Solution:

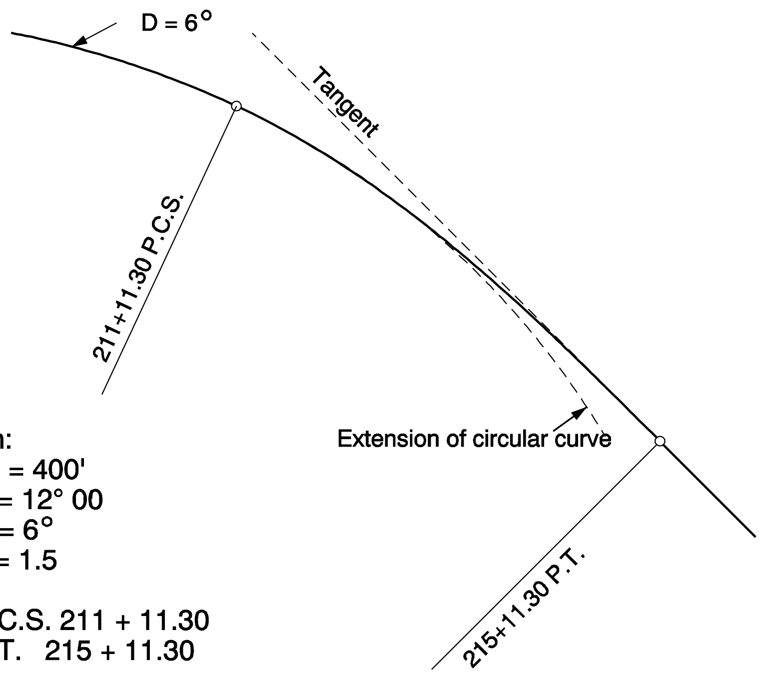
RULE: A spiral deviates from the circular curve common to it at any point at the same rate as it deviates from the tangent at the P.S. Therefore, at any point on the spiral the deflection angle from the tangent at that point to any other point on the spiral is equal to the deflection angle for a circular curve of the same radius as the spiral at the intermediate setup plus or minus the deflection from tangent at the P.S. to a point at an equivalent distance from the P. S. thus:

* Degree of curve at point of intermediate setup Sta. 102+17 $= \dfrac{(a)(\ell)}{100} = \dfrac{(1.5)(192)}{100} = 2°\ 52'\ 48''$

	Simple Curve Deflection		Spiral Deflection		Deflection (Instr. at Sta. 102+17)
P.S. 100 + 25.0	2°45'54"	-	0°55'18"	=	1°50'36"
+ 50	2°24'18"	-	0°41'48"	=	1°42'30"
101 + 00	1°41'12"	-	0°20'30"	=	1°20'36"
+ 50	0°57'54"	-	0°06'42"	=	0°51'12"
102 + 00	0°14'42"	-	0°00'24"	=	0°14'21"
Transit Pt. + 17	0°00'00"	-	0°00'00"	=	0°00'00"
+ 50	0°28'30"	+	0°01'36"	=	0°30'06"
103 + 00	1°11'42"	+	0°10'18"	=	1°22'00"
+ 50	1°54'54"	+	0°26'30"	=	2°21'24"
104 + 00	2°38'06"	+	0°50'12"	=	3°28'18"
P.S.C. 104 + 25.0	2°59'42"	+	1°04'54"	=	4°04'36"

EXAMPLE III

DEFLECTIONS TO SPIRAL FROM P.S.C. OR P.C.S.



Given:
- Ls = 400'
- S = 12° 00
- D = 6°
- a = 1.5

P.C.S. 211 + 11.30
P.T. 215 + 11.30

Find:

Deflections angles from the tangent to the curve at P.C.S.

Solution:

To back the spiral in from P.C.S.:

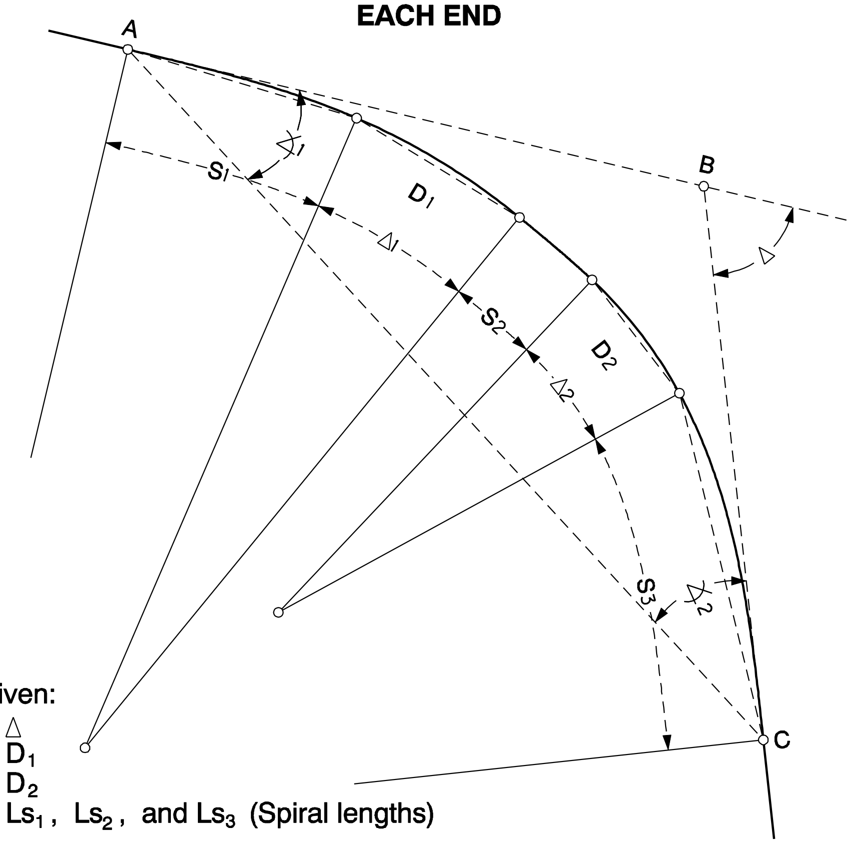
RULE: A spiral curve and a circular curve which coincide at any point (as at the P.C.S.) deviate from each other at the same rate as the spiral does from the tangent at the P.S.

Therefore, to obtain deflection angles from the tangent to the curve at the P.C.S. to the spiral, compute deflection angles to the circular curve and subtract therefrom the deflection angles to the spiral at corresponding distances from the P.S.

STATION	Simple Curve Deflection (D = 6º)	—	Spiral Deflection	=	Deflections (Instrument Setup at P.C.S.)
P.C.S.211+11.30	0º00'00"	—	0º00'00"	=	0º00'00"
211+50	1º09'42"	—	0º02'12"	=	1º07'30"
211+75	1º57'42"	—	0º06'06"	=	1º48'36"
212+00	2º39'42"	—	0º11'48"	=	2º27'54"
212+35	3º42'42"	—	0º23'00"	=	3º19'42"
212+80	5º03'42"	—	0º42'42"	=	4º21'00"
213+20	6º15'42"	—	1º05'18"	=	5º10'24"
213+50	7º09'42"	—	1º25'30"	=	5º44'12"
214+00	8º39'42"	—	2º05'00"	=	6º34'42"
214+50	10º09'42"	—	2º52'06"	=	7º17'36"
215+00	11º39'42"	—	3º46'36"	=	7º53'06"
P.T. 215+11.30	12º00'00"	—	4º00'00"		8º00'00"

EXAMPLE IV

FITTING A SPIRAL BETWEEN TWO PARTS OF A COMPOUND CURVE WITH SPIRAL TRANSITIONS AT EACH END



Given:

Δ
D_1
D_2
Ls_1, Ls_2, and Ls_3 (Spiral lengths)

Find:

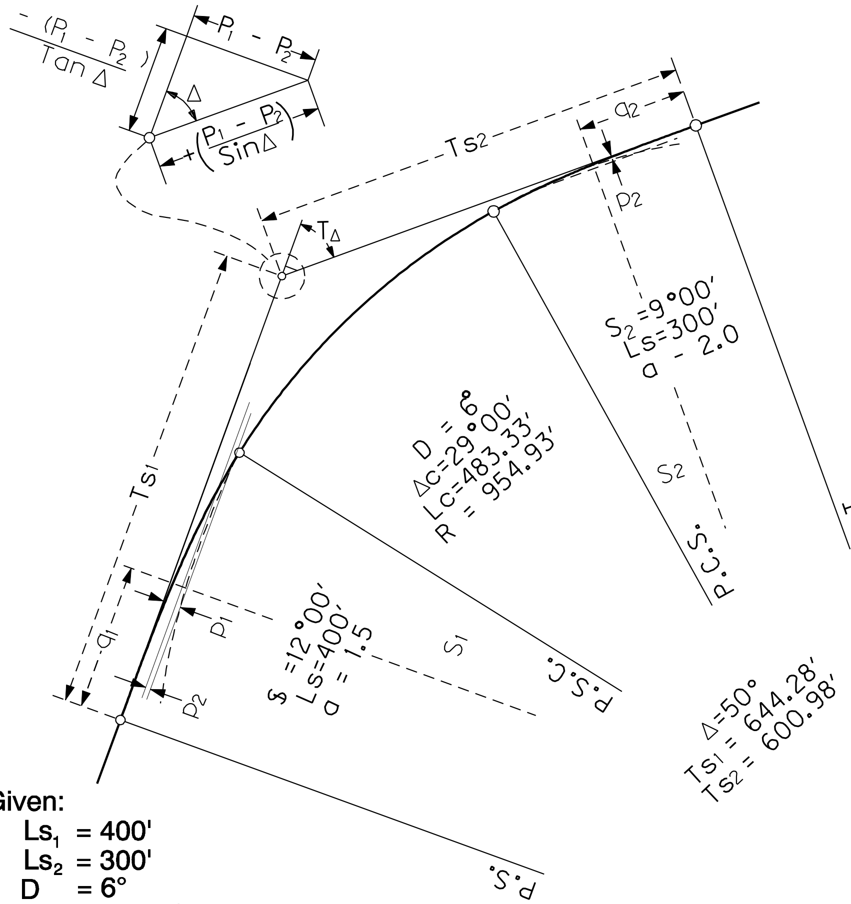
Semi-tangents

Solution:

(1) Ascertain Δ_1 (by assumption or measurement).
(2) Then $\Delta_2 = \Delta - \Delta_1 - S_1, - S_2, - S_3$.
(3) Find long chords for circular curves and spirals.
(4) Figure bearings for chords.
(5) Compute coordinates for point C.
(6) Compute length and bearing of long chord A - C.
(7) Then $\measuredangle_2 = \Delta - \measuredangle_1$:
(8) Solve triangle ABC for semi-tangents AB and BC. (Three angles and one side known).
(9) Spiral S_2 may be used to connect curves D_1 and D_2 by choosing that portion of the spiral having curvature intermediate between the radius of the two circular curves: thus if D = 3° and D_2 = 10° the connecting spiral will have a varied radius from 3° to 10° omitting the portion of the spiral below 3°. Deflection angles from P.C.S. or P.S.C. may be computed in the same manner as an intermediate setup on the spiral (see Example II).

EXAMPLE V

COMPUTING SEMI-TANGENTS FOR CURVES WITH SPIRALS OF UNEQUAL LENGTH



Given:

Ls_1 = 400'
Ls_2 = 300'
D = 6°
R = 954.93'
Δ = 50° 00'

Find: Semi-tangents (Ts_1 and Ts_2) and external (Es_1 or Es_2).

Solution:

To compute semi-tangents ascertain the spiral elements.

Then

$$Ts_1 = q_1 + (R + p_2)\ \text{Tan}\ \frac{T\Delta}{2} - \frac{p_1 - p_2}{\text{Tan}\ T\ \Delta} \qquad Ts_2 = q_2 + (R + p_2)\ \text{Tan}\ \frac{T_\Delta}{2} + \frac{p_1 - p_2}{\text{Sin}\ T_\Delta}$$

Es_1 and Es_2 formulas are valid only if S_1 and S_2 are equal to or less than ½ Δ.

$$Es_1 = \sqrt{(Ts_1 - q_1)^2 + (R + p_1)^2} - R \qquad Es_2 = \sqrt{(Ts_2 - q_2)^2 + (R + p_2)^2} - R$$

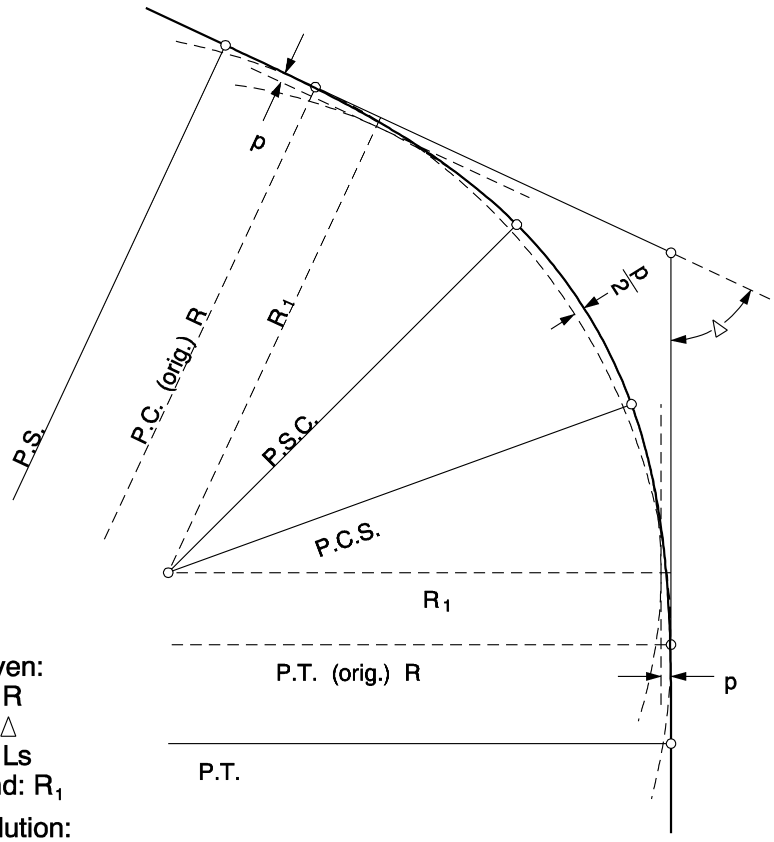
$$Ts_1 = 199.71' + (954.93' + 3.92') \times 0.466\,307\,7 - \frac{(6.97' - 3.92')}{1.191\,754} = 644.28'$$

$$Ts_2 = 149.88' + (954.93' + 3.92') \times 0.466\,307\,7 + \frac{(6.97' - 3.92')}{0.766\,044} = 600.98'$$

Rule: Ls_1 = Longer spiral

EXAMPLE VI

FITTING EXISTING CIRCULAR CURVE ALIGNMENT WITH SPIRALED CURVES REQUIRING A MINIMUM SHIFT OF ALIGNMENT



Given:
 R
 Δ
 Ls
Find: R_1

Solution:

To retain present tangents and fit spiraled alignment with least possible shift of circular curve.

The new curve will be sharper and it should lay outside of the old curve at the vertex, and the distance between the vertexes of the two curves should be equal to half the spiral

offsets, $\frac{p}{2}$

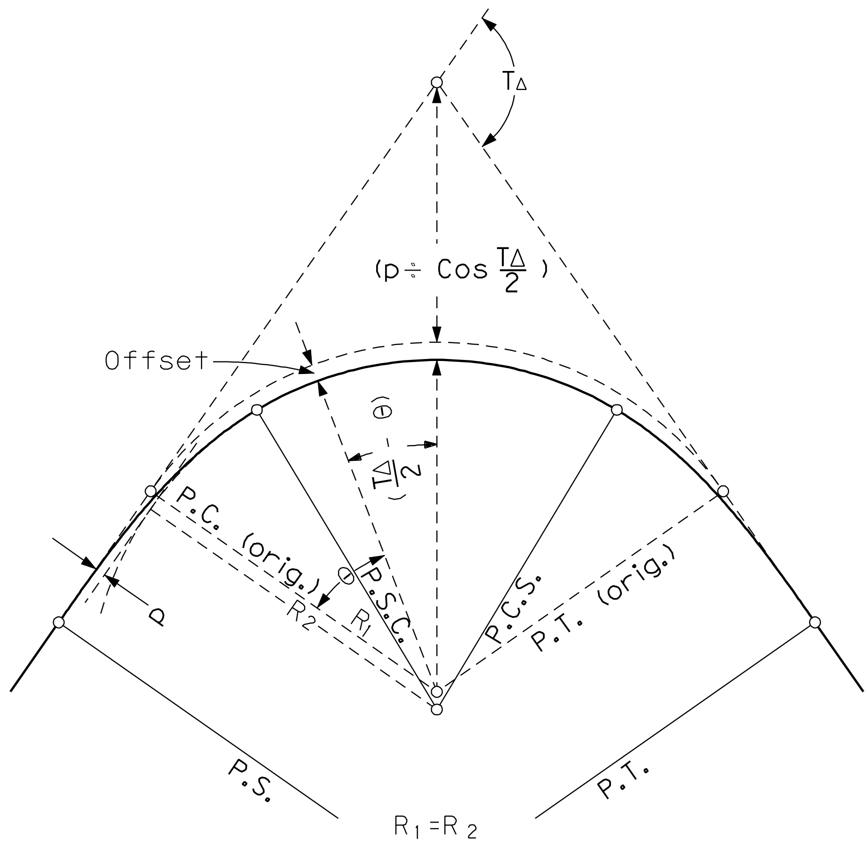
$$\text{Then } R_1 = R - \frac{p + \frac{p}{2}\cos\frac{\Delta}{2}}{1 - \cos\frac{\Delta}{2}}$$

In solving this equation, first assume a value for "p" slighty greater than the value of "p" for a radius of curve equal to the original curve. Base the assumption on an estimate of the new curve radius required.

Then revise the value of "p" to fit alignment.

EXAMPLE VII

OFFSETS FROM CIRCULAR CURVE ALIGNMENT TO SPIRALED ALIGNMENT USING SAME RADIUS OF CURVE AND ORIGINAL TANGENTS



In fitting spiraled alignment to existing circular curve alignment, while retaining the same degree of main curve and the original tangents, it will be found that the new main curve will not be concentric with nor parallel to the original curve. The offset varies from a value of "p" as shown on the sketch to a value of ($p \div \text{Cos}\ T_\Delta \div 2$) at the vertex. Between the point where the value of "p" applies to the P.S.C., the offsets from the original alignment to the new alignment may be found by obtaining the X coordinate to the point in question on the spiral and making correction for the offset to the original circular curve where that is necessary. Beyond the P.S.C. the following approximate formula will give values of the offset sufficiently close for practical purposes.

$$\text{Offset} = p \div \text{Cos}\frac{T_\Delta}{2}\left[\cos\left(\frac{T_\Delta}{2} - \theta\right)\right] \quad \text{Approximately}$$

Where θ = angle from the P.C. or P.T. of original circular curve to the point desired.

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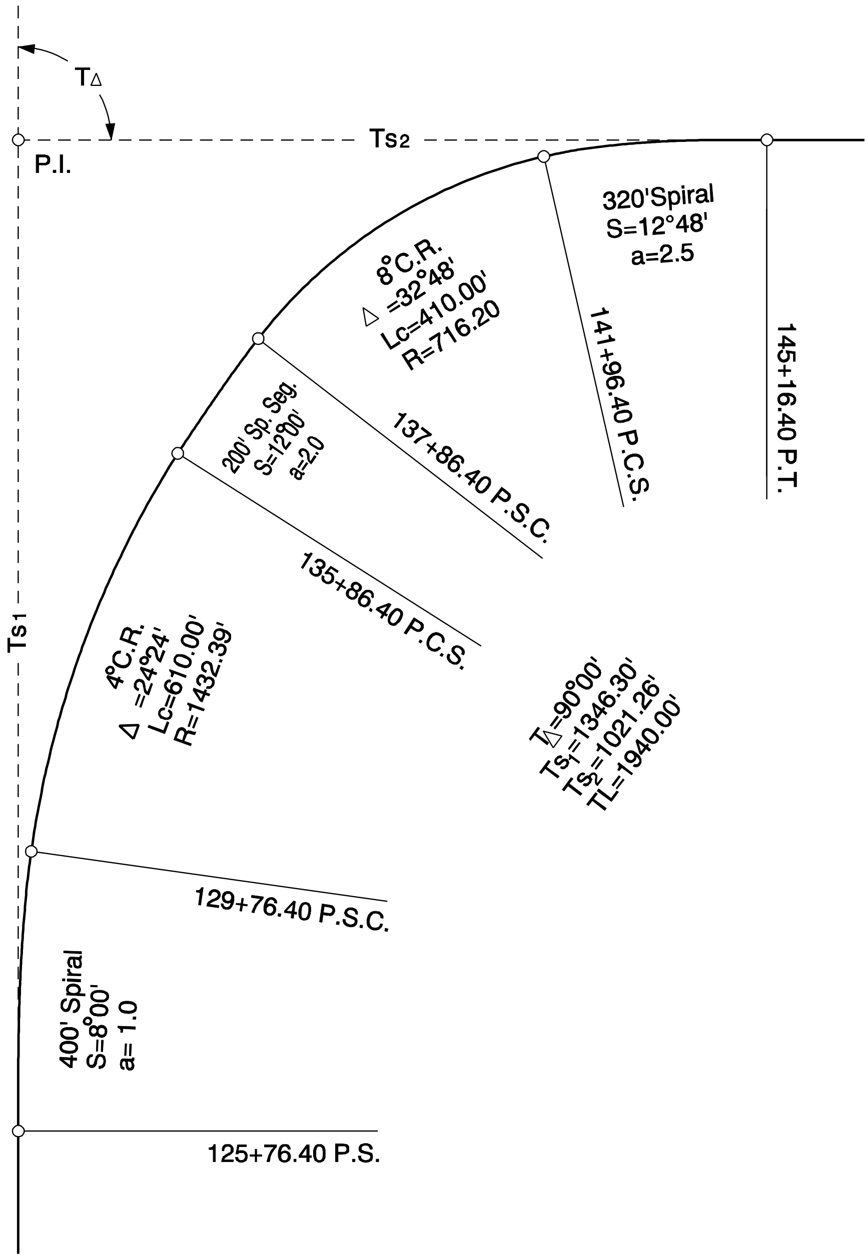
EXAMPLE VIII

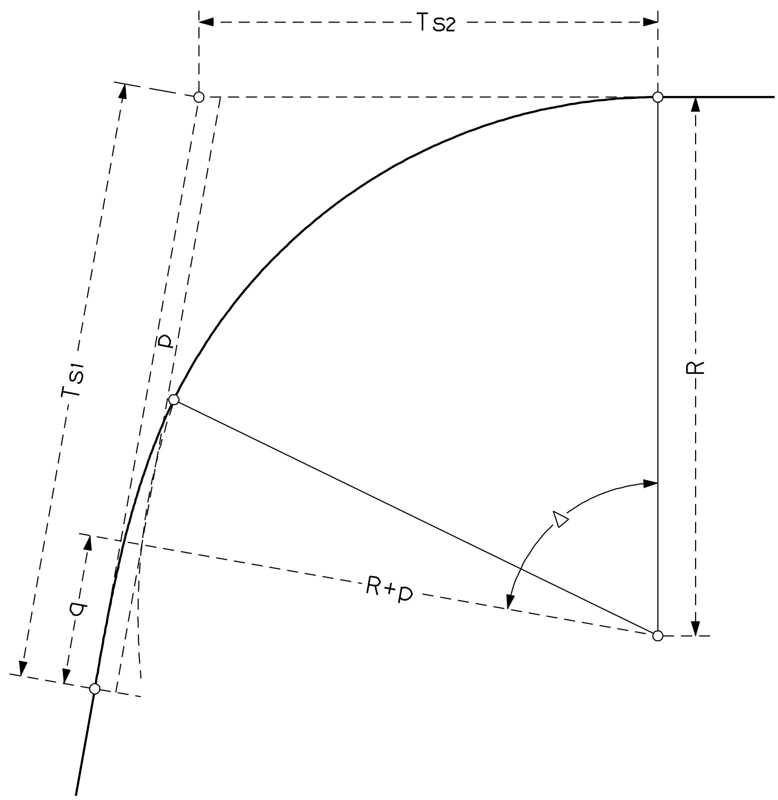
STANDARD METHOD OF SHOWING ALIGNMENT ON MAPS



Show stationing to the nearest hundredth of a foot. Show angles and bearings to the nearest second. When calculating the "S" angle, carry at least four places so coordinates are accurate to three places.

EXAMPLE IX

METHOD OF COMPUTING SEMI-TANGENTS OF CURVE WITH SPIRAL AT ONE END ONLY



Given:
Δ, R, p. and q.

Find:
Semi-Tangents.

Solution:

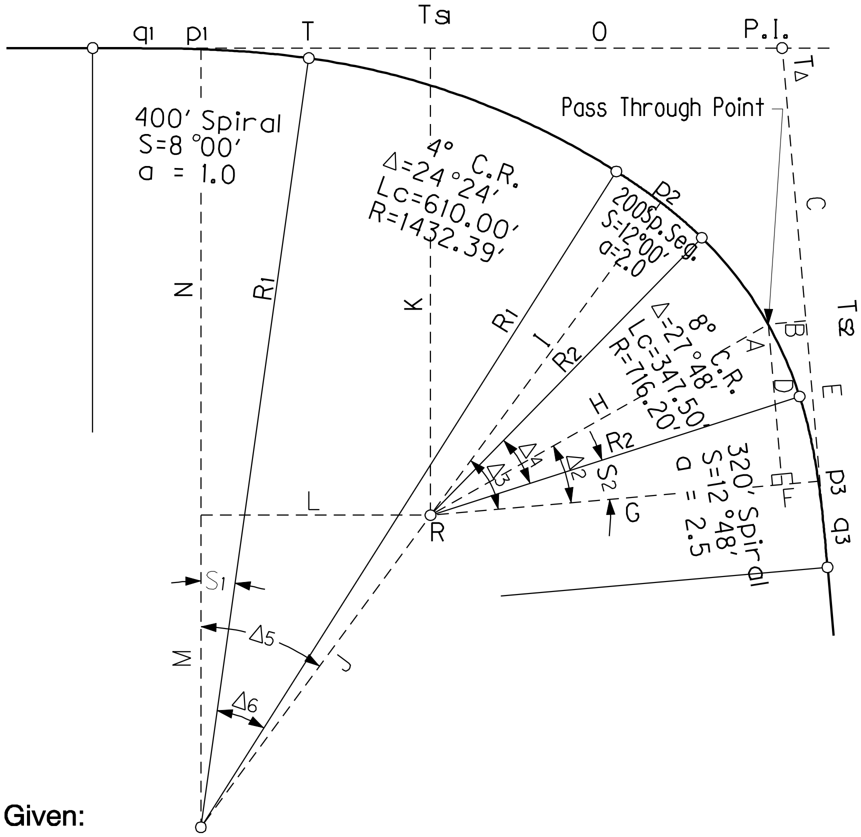
$$Ts_1 = \frac{R - (R + p)\ \text{Cos}\,\Delta}{\text{Sin}\ \Delta} + q$$

$$Ts_2 = \frac{(R + p) - (R\ \text{cos}\,\Delta)}{\text{Sin}\ \Delta}$$

When Δ is over 90°, the cosine function has a negative value.

EXAMPLE X

FITTING COMPOUND CURVE WITH THREE SPIRALS



Given:

With a fixed pass through point or a given or assumed semi-tangent (Ts_2), known P.I., $T\Delta$, R_1 and R_2, spiral lengths.

Find:

Ts_2 (for fixed point) or Ts_1 (for known Ts_2)

Solution: FIXED PASS THROUGH POINT

Calculate C and B along and perpendicular to the Ts semi-tangent tangent Then ....

$B = F$, $G = (R_2 + p_3) - F$, $H = R_2$, $\cos\Delta_2 = \frac{G}{H}$, $D = H \sin\Delta_2$,
$E = D$ and $Ts_2 = C + E + p_3$

GIVEN OR ASSUMED SEMI-TANGENT (Ts_2)

Calculate coordinates for the radius point of " R_2 " from Ts_2.
Calculate O and K along and perpendicular to the Ts_1, semi-tangent.
'p_2' is the perpendicular distance between R_1 and R_2, when tangent to each other. Then $I = R_2 + p_2$.
$J = R_1 - I$, $K = N$, $M = (R_1 + p_1) - N$, $\cos\Delta_5 = \frac{M}{J}$, $L = J \sin\Delta_5$,
$T = L$, $\Delta_6 = \Delta_5 - (S_1 + \Delta$ for D_1 for ½ length of intermediate spiral), $\Delta_3 = T\Delta - \Delta_5$, $\Delta_4 = \Delta_3 - (S_3 + \Delta$ for R_2 for ½ length of intermediate spiral) $Ts_1 = O + T + q_1$; the use of ½ the length of the intermediate spiral is a close approximation of the true answer.

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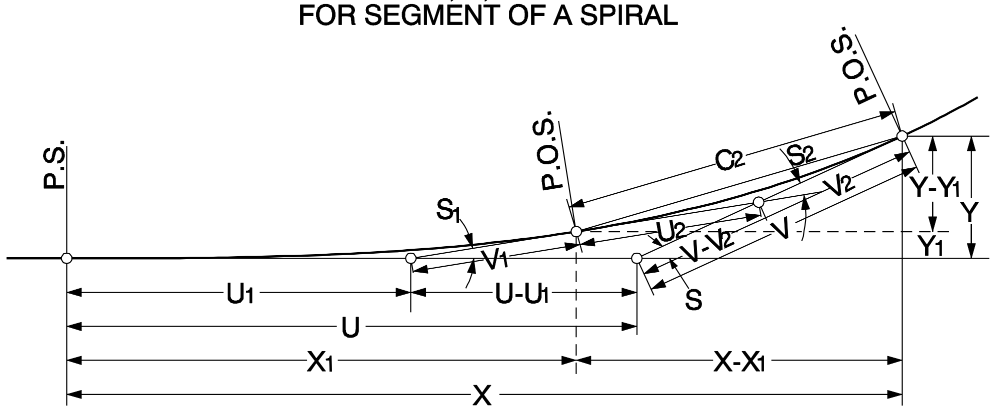
EXAMPLE XI

DETERMINING U, V, AND C DISTANCES FOR SEGMENT OF A SPIRAL



Given:

200' spiral segment, a=1.0, connecting 3° curve to 5° curve.

Find:

S, U, C, and V distances for that spiral segment.

Solution:

The given spiral segment is that portion of the Standard Highway Spiral , a=1.0, between the P.O.S. at Ls = 300' and the P.O.S. at Ls = 500'. In the solution of the given problem S,U,V, X, and Y are values for L = 500', S_1, U_1, V_1, X_1, and Y_1 are values for L = 300' m and S_2, U_2, C_2 and V_2 are the values to be found for the given spiral segment.

Ls = 500', S = 12° 30' , U = 334.17', V = 167.43', Y = 36.24'
X = 497.63'

Ls = 300', S_1 = 4° 30' , U_1= 200.06', V_1= 100.06', Y_1= 7.85'
X_1 = 299.81'

$$S_2 = S - S_1 \qquad V_2 = V - \frac{(U - U_1)\text{Sin } S_1}{\text{Sin } S_2}$$

$$U_2 = \frac{(U - U_1)\text{ Sin } S}{\text{Sin } S_2} - V_1 \qquad C_2 = \sqrt{(X_1 - X)^2 + (Y_1 - Y)^2}$$

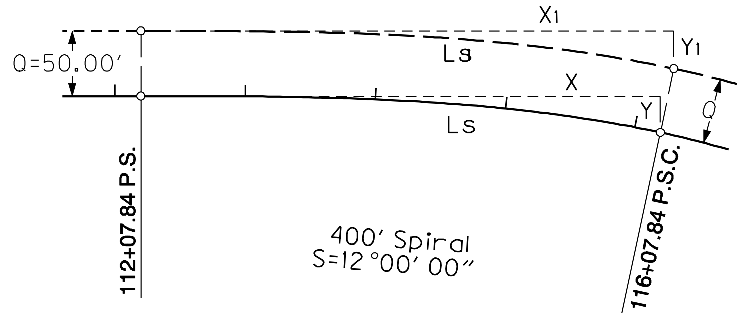
$$S_2 = 12°\,30' - 4°\,30' = 8°\,00'$$

$$U_2 = \frac{(334.17' - 200.06')\text{ Sin } 12°\,30'}{\text{Sin } 8°\,00'} - 100.06' = 108.506'$$

$$V_2 = 167.43' - \frac{(334.17' - 200.06')\text{ Sin } 4°\,30'}{\text{Sin } 8°\,00'} = 91.83'$$

$$C_2 = \sqrt{(36.24' - 7.85')^2 + (497.63' - 299.81')^2} = 199.847'$$

EXAMPLE XII
COMPUTING OFFSET SPIRALS



NOTE: The offset spiral is not related to the Standard Highway Spiral. Therefore use the following method.

Given:

$Ls = 400'$
$a = 1.5$
$S = 12° 00' 00"$
$Q = 50.00'$ (Outside offset)

Find:

Offset spiral.

Solution:

θ = S (in radians) for the base spiral = $\frac{S}{57.29578}$

Q = Offset in feet

$Ls_1 = Ls \pm Q(\theta)$ (+) for outside offset

$X_1 = X \pm Q \sin S$ (-) for inside offset

$Y_1 = Y \pm Q(1 - \cos S)$ Use (+) for outside offset

To compute the spiral offset as it would be run in the field; setting stakes at right angles to and "Q" offset from the corresponding stations on the base spiral with transit setup at the P.S. or P.T. of the offset spiral:

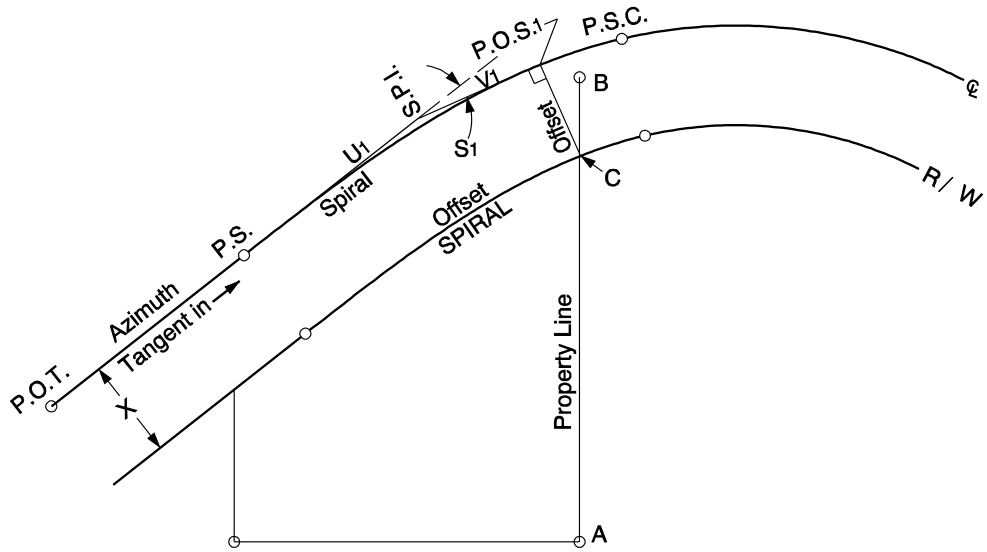
(1) Find the S angle for each station.
(2) Determine length of the offset spiral, Ls_1, from P.S. or P.T. to each station.
(3) Using S angles found in step 1, determine the corresponding X and Y values for each station of the base spiral.
(4) Determine the X_1 and Y_1 values for the offset spiral.
(5) Determine the offset spiral deflections from $\tan i = \frac{Y_1}{X_1}$
(6) Calculate chords using formula in example XI.

TABULATION OF RESULTS FOR ABOVE DATA

STATION	Ls	S	L1	Y	X	Y1	X1	i1	C1
112+07.84 P.S.	0.00	0°00'00"	0.00	0.00	0.00	0.00	0.00	0°00'00"	0.00
112+50	42.16	0°08'00"	42.28	0.03	42.16	0.03	42.28	0°02'24"	42.28
113+00	92.16	0°38'13"	92.72	0.34	92.16	.034	92.72	0°12'36"	50.44
113+50	142.16	1°30'57"	143.48	1.25	142.15	1.27	143..47	0°30'36"	50.76
114+00	192.16	2°46'10"	194.58	3.10	192.12	3.16	194.54	0°55'48"	51.10
114+50	242.16	4°23'53"	246.00	6.20	242..01	6.35	245.84	1°28'48"	51.39
115+00	292.16	6°24'07"	297.75	10.88	291.79	11.19	297.36	2°09'18"	51.75
115+50	342.16	8°46'50"	349.82	17.45	341.35	18.04	348.98	2°57'30"	52.07
116+00	392.16	11°32'03"	402.23	26.25	390.57	27.26	400.57	3°53'36"	52.41
116+07.84 P.S.C.	400.00	12°00'00"	410.47	27.84	398.25	28.93	408.65	4°03'00"	8.24

EXAMPLE XIII

SOLUTION OF OFFSET SPIRAL INTERSECTING WITH PROPERTY LINE



Given:

Centerline geometry, offset value, coordinate of P.O.T. on tangent in, azimuth of tangent in, coords of point A and B or coords of A or B and azimuth to the other. "Lg" is a generic value representing the guess length of spiral to offset point.

Find:

Coordinate of intersect point C.

Solution:

This problem has no direct solution. It can be solved by iteration. This is not as difficult as it seems.
Begin at the P.S. of the spiral and guess an "Lg" length. Using the "Lg" and the "a" value generate "U_1" and "V_1" and "S " values for trial solution. The solution is to coordinate from the P.S. to the S.P.I. to the P.S.C. of the P.O.S. along the spiral. Next coordinate a point "C" from the P.O.S.$_1$ 90° off the tangent between the S.P.I. and P.O.S. out the offset distance "X". Finally inverse between point "C" and point "A" and determine the azimuth of point "C" to "A". Compare this azimuth to the azimuth between point "B" to "A". When azimuths are identical you have solved for the intersect.

ALGORITHM FOR ITERATION

Lg_1 = $Guess_1$ = Length of spiral for Trial #1
Lg_2 = $Guess_2$ = Length of spiral for Trial #2
Ls_3 = ? = Projected length from linear regression

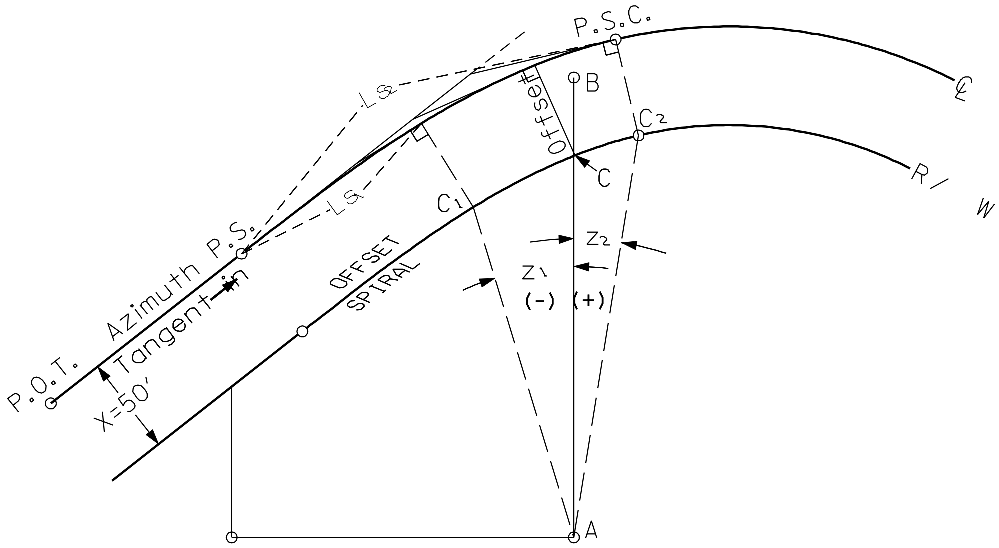
"Equation" is all calculations to produce difference in azimuths (d_1 , d_2).

Solve "equation" using Lg_1 - result is z_1
Solve "equation" using Lg_2 - result is z_2

Given Lg_1 , z_1 , Lg_2 , z_2 , compute Ls_3:

$$Ls_3 = Lg_2 - (z_2 \, (Lg_1 - Lg_2) / (z_1 - z_2))$$

APPENDIX J
ENGLISH ALIGNMENT GUIDE



Given:

Centerline geometry, D - 8, Spiral 400', offset 50', coordinate of P.O.T. on tangent in, azimuth of tangent in, coords of point "A" and "B" or coords of (A or B) and azimuth to the other.

Find:

Coordinate of intersect point C.

Solution:

Lg_1 = $Guess_1$ = 300' Lg_2 = $Guess_2$ = 400'

Calculate "z_1" by assuming a "Ls_1" length and computing for "U_1", "V_1" and "S_1". Turn a 90° and "X" distance from "V_1" tangent at point on spiral to offset spiral. Inverse between point "C_1" and "A" for azimuth. Take the difference between "C" to "A" and "B" to "A" and this is angle z_1. Repeat steps for z_2.

Note:

To reduce the number of iterations select "Lg_1" and "Lg_2" as close as possible to point "C". Keep in mind the positive and negative "z" values.

Ls_3 = 400' - (8.9151 (300' - 400') / (-3.3458- 8.9151) = 327.28839'

Ls_3 = 327.28839' - (0.299(400' - 327.28839') / (8.9151- 0.299) = 324.76512'

Ls_3 = 324.76512' - (-0.0276(327.28839' - 324.76512') / (0.299 - (- 0.0276)) = 324.97835'

Ls_3 = 324.97835' - (0.0001 (324.76512' - 324.97835') / (-0.0276 - (0.0001)) = 324.97758'

In this example the L_3 starts to repeat itself to significant figures, & it is solved.

Flow Diagram for "Lg" in Ls_3 equation

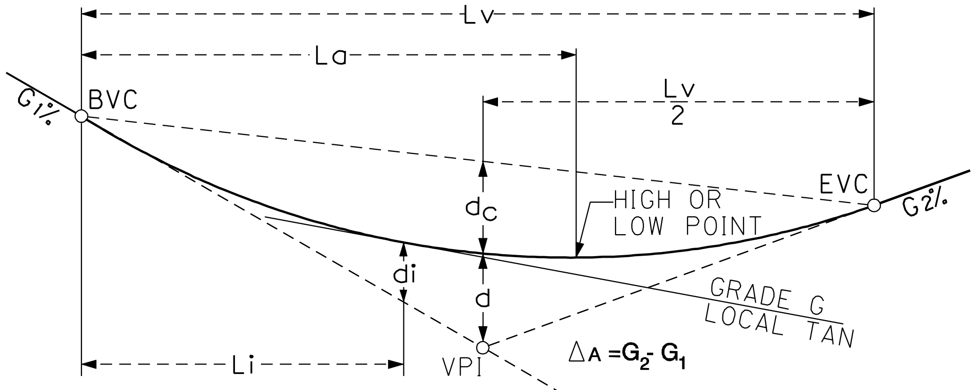
Lg_1 Lg_2 Ls_3

Lg_1 Lg_2 Ls_3 Lg_2 becomes new Lg_1, and Ls_3 becomes, new Lg_2.

Lg_1 Lg_2 Ls_3

APPENDIX J
ENGLISH ALIGNMENT GUIDE

VERTICAL CURVE
SYMMETRICAL
PARABOLIC



L_i - Distance from beginning point of vertical curve to any point along the curve.

G_1, G_2 = Tangent grades in percent, positive for ascending forward, negative for decending forward.
K = Ls/$\triangle_A$ - feet to affect a 1% change in grade.
$\triangle_A$ = algebraic difference in grades, percent.
Lv = Length of vertical curve in feet, measured horizontally.
d = Vertical offset from the vertex (called PI) to the middle of curve.
d_i= Vertical offset from a tangent to the vertical curve vary as the square of the distance from the PC.
d_c= Vertical offset from the chord to the vertical curve.

$$\triangle_A = G_2 - G_1 \qquad K = \frac{Lv}{\triangle_A}$$

$$d = d_c = \frac{\triangle_A\, Lv}{800} = \frac{K\, \triangle_A^2}{800}$$

$$d_i = \frac{L_i^2}{\left(\frac{Lv}{2}\right)^2} \quad d = \frac{\triangle_A\, L_i^2}{200\, Lv} = \frac{L_i^2}{200\, K}$$

$$G = G_1 - \frac{L_i}{K} \qquad L_a = G_1\, K$$

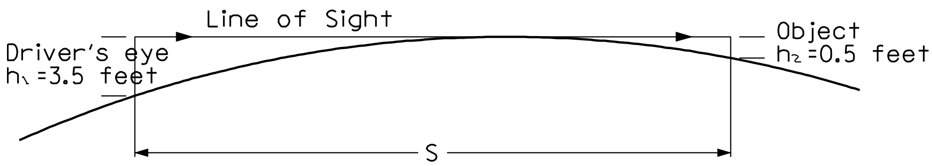
Note: Distances Lv, d, d_c, L_a, L_i, d_i, are in feet.
Grades G_1, G_2, $\triangle_A$, G are in percent.

APPENDIX J
ENGLISH ALIGNMENT GUIDE

VERTICAL CURVE

CREST CURVATURE

Design Speed (V) mph	25	30	35	40	45	50	55	60	65	70
Design (K)	19	31	47	70	98	136	185	245	313	401

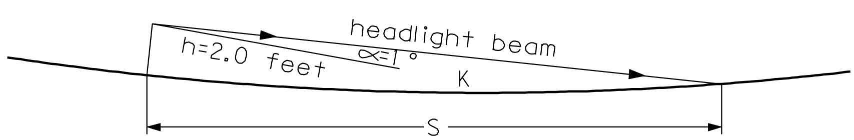


$$K = \frac{S^2}{200\ h_1\ (1 + \sqrt{h_2 / h_1})^2}$$

Stopping Sight Distance (S) is derived from this formula:
S = 1.47Vt + (1.075)(V /a)
where:
t = brake reaction time, 2.5 seconds;
V = design speed, mph;
a = deceleration rate - 11.2 ft/s^2

SAG CURVATURE

Design Speed (V) mph	25	30	35	40	45	50	55	60	65	70
Design (K)	26	37	50	64	79	96	116	136	157	181



Where the length of curve exceeds the stopping sight distance, K is given.

S Less Than or Equal to Lv $\quad K = \frac{S^2}{200\ (h + S\ \tan\alpha)}$

Where the stopping sight distance exceeds the curve length, K is given.

S > Lv $\quad K = \frac{2S}{\Delta A} - \frac{200\ h_1}{\Delta A^2}(1 + \sqrt{h_2 / h_1})^2$ where:
A = Algebraic Difference in Grades

Minimum sag vertical curvature for comfort critera, illumination may be required.

$$L = \frac{AV^2}{46.5}$$
where:
A = Algebraic Difference in Grades