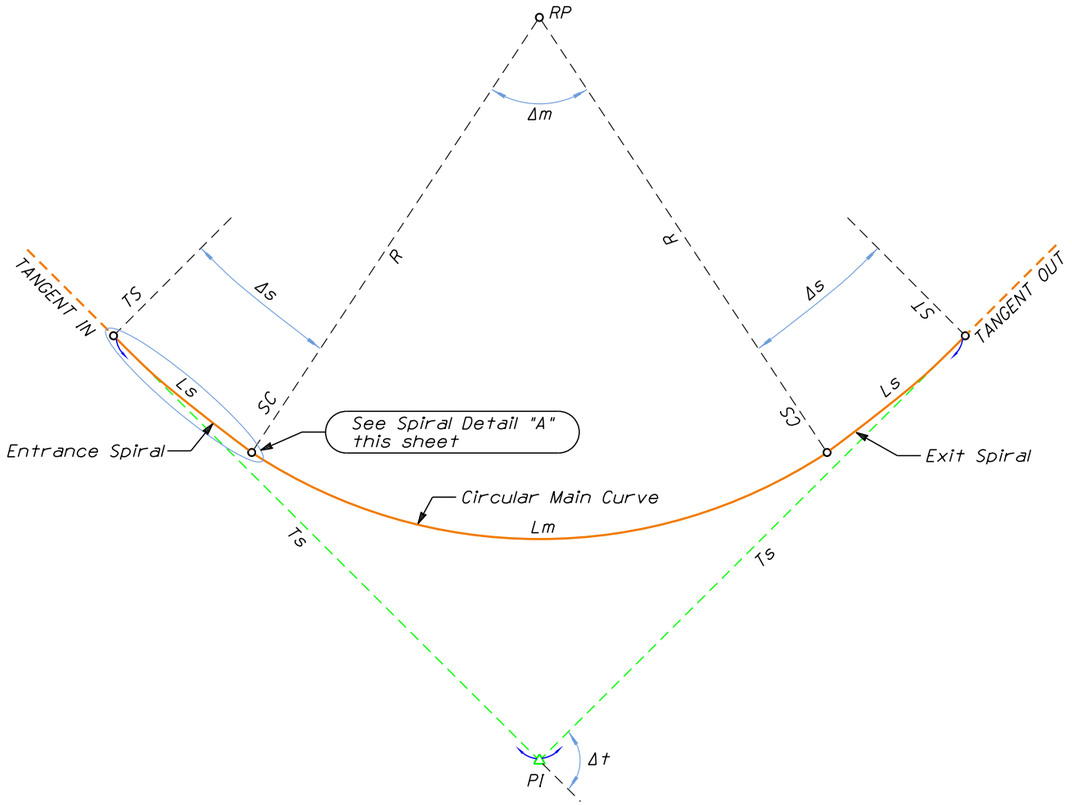
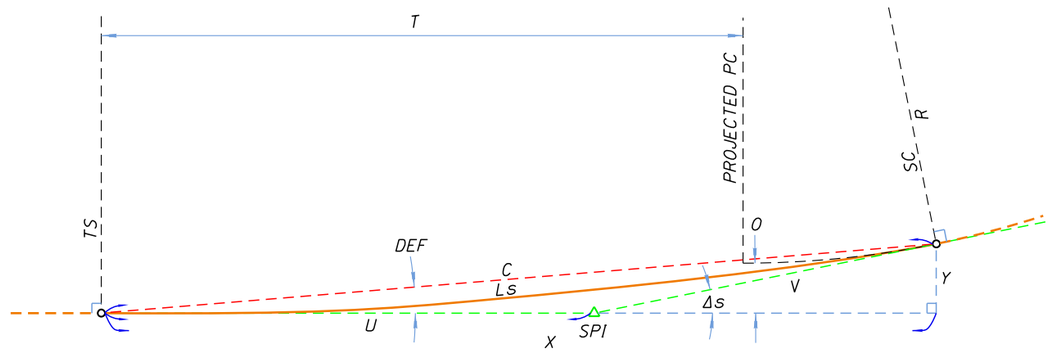
FULL TRANSITION SPIRAL CURVE



TYPICAL HIGHWAY SPIRAL-MAIN-SPIRAL CURVE
Not to scale



SPIRAL DETAIL "A"
Not to scale

Highway Spiral Curve where Δs < 16°

FORMULAS

R = 5729.57795 / D
a = (D * 100) / Ls
O = 0.0727 * a * ((Ls / 100)^3)
T = (Ls / 2) - (0.000127 * a^2 * (Ls / 100)^5)
Ts = (Tan(Δt / 2) * (R + O)) + T
C = Ls - (0.00034 * a^2 * (Ls / 100)^5)
DEF = (a * Ls^2) / 60000
Δs = 0.005 * D * Ls
U = C * Sin(Δs * 2 / 3) / Sin(Δs)
V = C * Sin(Δs * 1 / 3)/ Sin(Δs)
Δm = Δt - Δs - Δs
Lm = (Δm * R * pi) / 180
X = C * Cos(DEF)
Y = C * Sin(DEF)

SC(Sta) = TS(Sta) + Ls
CS(Sta) = SC(Sta) + Lm
ST(Sta) = CS(Sta) + Ls
PI(Sta) = TS(Sta) + Ts

EXAMPLE

Given: Δt = 36°29'16"; D = 2°00'00"; Ls = 200'; TS(Sta) = 2180+84.70

R = 5729.57795 / 2.0000° = 2864.78898
a = (2.0000° * 100) / 200 = 1.00
O = 0.0727 * 1 * ((200 / 100)^3) = 0.58160
T = (200 / 2) - (0.000127 * 1^2 * (200 / 100)^5) = 99.99594
Ts = (Tan(36.48777777° / 2) * (2864.78898 + 0.58160)) + 99.99594 = 1044.51462
C = 200 - (0.00034 * 1^2 * (200 / 100)^5) = 199.98912
DEF = (1 * 200^2) / 60000 = 0.666667° or 0°40'00"
Δs = 0.005 * 2.0000° * 200 = 2.0000° or 2°00'00"
U = 199.98912 * Sin(2.0000° * 2 / 3) / Sin(2.0000°) = 133.34112
V = 199.98912 * Sin(2.0000° * 1 / 3) / Sin(2.0000°) = 66.67508
Δm = 36°29'16" - 2°00'00" - 2°00'00" = 32°29'16" or 32.48777777°
Lm = (32.48777777° * 2864.78898 * 3.141592654) / 180 = 1624.38889
X = 199.98912 * Cos(0.666667°) = 199.97558
Y = 199.98912 * Sin(0.666667°) = 2.32693

SC(Sta) = 2180+84.70 + 200 = 2182+84.70
CS(Sta) = 2182+84.70 + 1624.39 = 2199+09.09
ST(Sta) = 2199+09.09 + 200 = 2201+09.09
PI(Sta) = 2180+84.70 + 1044.51 = 2191+29.21

DEFINITIONS

Δt = Total Delta Deflection
D = Degree of Curvature
Ls = Length of Spiral
TS(Sta) = Tangent to Spiral
R = Radius
a = Rate of change per 100'
O = Radial Offset
T = Projected curve P.C.
Ts = Tangent Length
C = Spiral Chord
DEF = Deflection angle at TS(Sta)
Δs = Spiral Delta
U = Distance to Spiral PI
V = Distance to SC(Sta)
Δm = Main Curve - Delta
Lm = Main Curve - Length
X = Distance along X axis
Y = Distance along Y axis
SC(Sta) = Spiral to Curve
CS(Sta) = Curve to Spiral
ST(Sta) = Spiral to Tangent
PI(Sta) = Point of Intersection
RP = Radius Point of Main Curve
SPI = Spiral Point of Intersection
POS = Point on Spiral

FULL TRANSITION SPIRAL CURVE
EQUAL ENTRANCE & EXIT SPIRALS

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Date: Jun 2011
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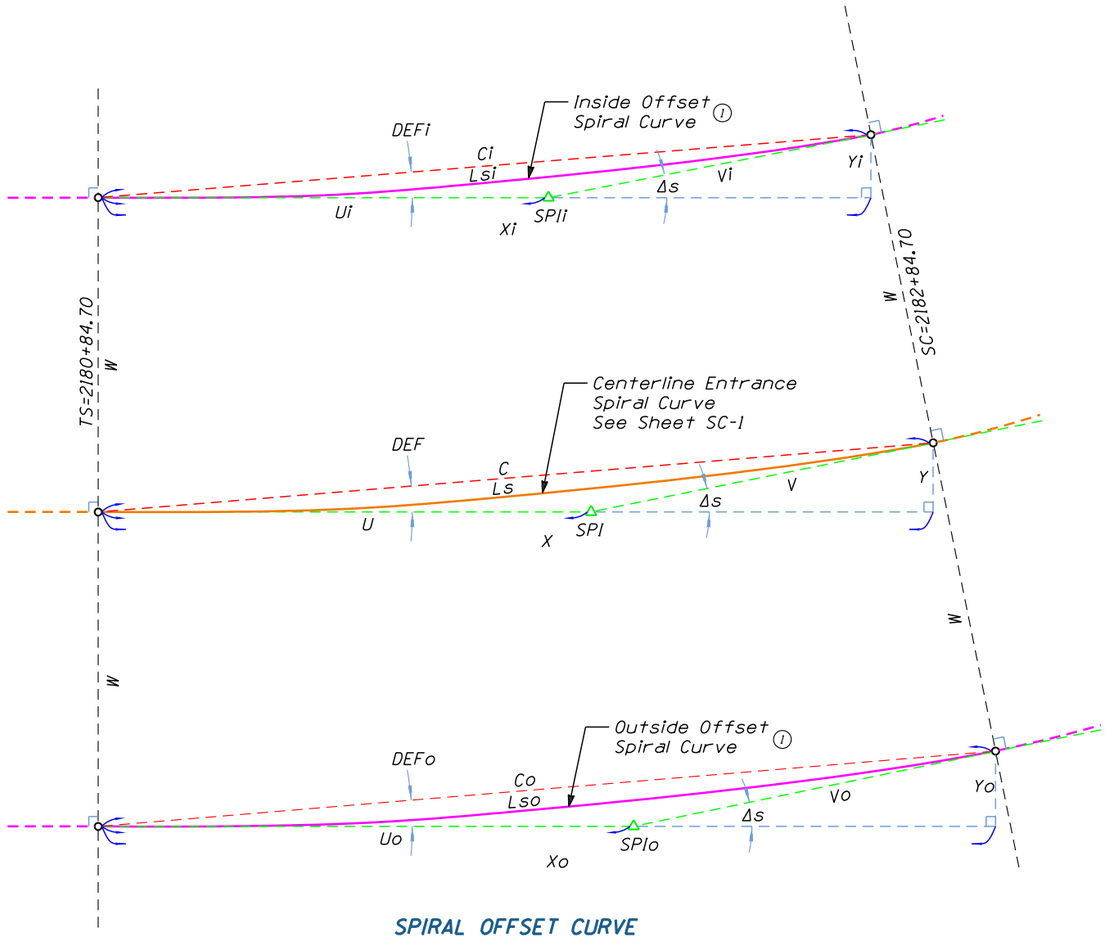
Project No.: ADOT Spiral
Project Manager: Jim Crume

SC-1
Sht: 1 of 7

Default [Model]
C:\Project Files\spiral\SC sheets\SC-1.dgn

SPIRAL OFFSET CURVE



SPIRAL OFFSET CURVE
Not to scale

FORMULAS

INSIDE OFFSET SPIRAL	OUTSIDE OFFSET SPIRAL
Xi = X - (Sin(Δs) * W)	Xo = X + (Sin(Δs) * W)
Yi = Y - W + (Cos(Δs) * W)	Yo = Y + W - (Cos(Δs) * W)
Ci = $\sqrt{(Xi^2 + Yi^2)}$	Co = $\sqrt{(Xo^2 + Yo^2)}$
Vi = Yi / Sin(Δs)	Vo = Yo / Sin(Δs)
Ui = Xi - (Yi / Tan(Δs))	Uo = Xo - (Yo / Tan(Δs))
Lsi = Ci * Ls / C	Lso = Co * Ls / C
DEFi = ArcTan(Yi / Xi)	DEFo = ArcTan(Yo / Xo)
Ri = R - W	Ro = R + W
Di = 5729.57795 / Ri	Do = 5729.57795 / Ro
ai = Di * 100 / Lsi	ao = Do * 100 / Lso

Alternate formula's for Spiral Lengths as published in "Route Location and Design" by Thomas Felix Hickerson (1967)
Lsi = Ls - (0.017453 * W * Δs) and Lso = Ls + (0.017453 * W * Δs)

EXAMPLE

Given: Δs = 2°00'00"; Ls = 200; C = 199.98912'; R = 2864.78898 (From SC-1)
X = 199.97558; Y = 2.32693; W = 100'

INSIDE OFFSET SPIRAL
Xi = 199.97558 - (Sin(2.0000°) * 100) = 196.48563
Yi = 2.32693 - 100 + (Cos(2.0000°) * 100) = 2.26601
Ci = $\sqrt{(196.48563^2 + 2.26601^2)}$ = 196.49870
Vi = 2.26601 / Sin(2.0000°) = 64.92959
Ui = 196.48563 - (2.26601 / Tan(2.0000°)) = 131.59559
Lsi = 196.49870 * 200 / 199.98912 = 196.50939
DEFi = ArcTan(2.26601 / 196.48563) = 0.66075° or 00°39'39"
Ri = 2864.78898 - 100 = 2764.78898
Di = 5729.57795 / 2764.78898 = 2.07234° or 2°04'20"
ai = 2.07234 * 100 / 196.50939 = 1.05458

OUTSIDE OFFSET SPIRAL
Xo = 199.97558 + (Sin(2.0000°) * 100) = 203.46553
Yo = 2.32693 + 100 - (Cos(2.0000°) * 100) = 2.38785
Co = $\sqrt{(203.46553^2 + 2.38785^2)}$ = 203.47954
Vo = 2.38785 / Sin(2.0000°) = 68.42076
Uo = 203.46553 - (2.38785 / Tan(2.0000°)) = 135.08645
Lso = 203.47954 * 200 / 199.98912 = 203.49061
DEFo = ArcTan(2.38785 / 203.46553) = 0.67239° or 00°40'21"
Ro = 2864.78898 + 100 = 2964.78898
Do = 5729.57795 / 2964.78898 = 1.93254° or 1°55'57"
ao = 1.93254 * 100 / 203.49061 = 0.94969

DEFINITIONS

W = Offset distance
Xi / Xo = Distance along X axis
Yi / Yo = Distance along Y axis
Ci / Co = Offset Spiral Chord
Vi / Vo = Distance to SC(Sta)
Ui / Uo = Distance to Offset Spiral PI
DEFi / DEFo = Offset Spiral Deflection angle
Lsi / Lso = Offset Spiral Length
SPIi / SPIo = Offset Spiral PI

See SC-1 for additional definitions

① Offset Spiral Curve characteristics vary slightly from the centerline spiral. The formula's on this sheet are dependent upon the centerline spiral as described on sheet SC-1.

SPIRAL OFFSET CURVE TABLE

	W	a	D	R	Length	Delta	DEF	Chord	X	Y	U	V
INSIDE	100	1.05463	2°04'20"	2764.789	196.509	2°00'00"	00°39'39"	196.499	196.486	2.266	131.596	64.930
	50	1.02678	2°02'08"	2914.789	198.255	2°00'00"	00°39'49"	198.244	198.231	2.296	132.468	65.802
CENTERLINE	0	1.00000	2°00'00"	2864.789	200.00	2°00'00"	00°40'00"	199.989	199.976	2.326	133.341	66.675
OUTSIDE	50	0.97440	1°57'57"	2914.789	201.745	2°00'00"	00°40'10"	201.734	201.721	2.357	134.214	67.548
	100	0.94975	1°55'57"	2964.789	203.491	2°00'00"	00°40'21"	203.480	203.466	2.388	135.087	68.421

SPIRAL OFFSET CURVE

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SC-2
Sht: 2 of 7

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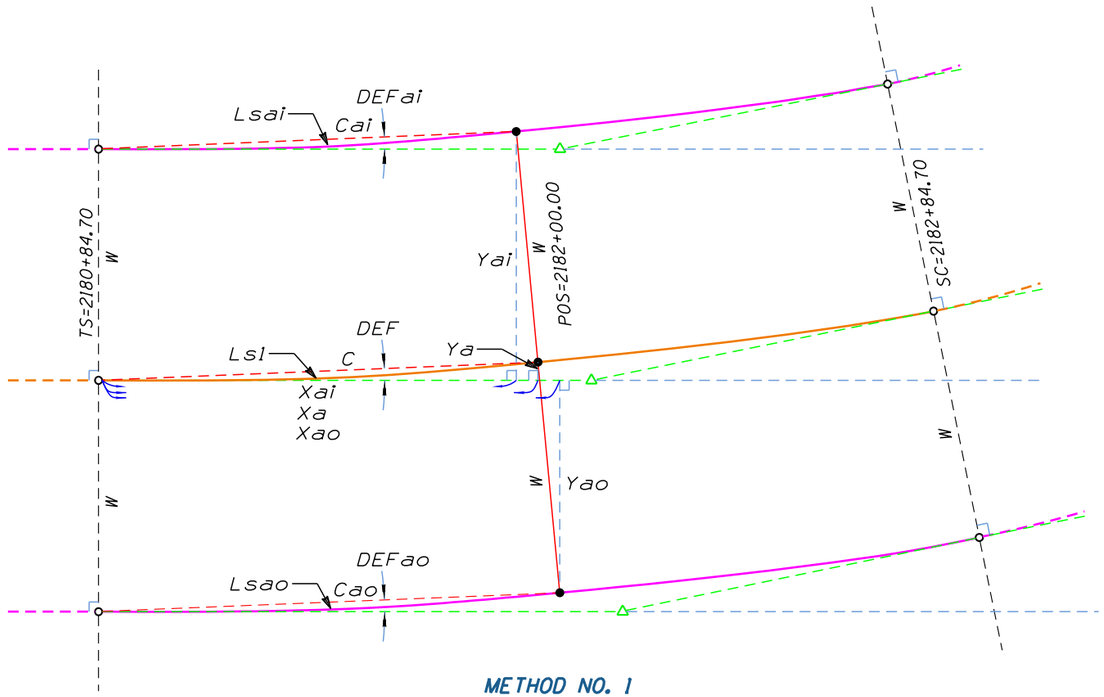
POINTS ON SPIRAL OFFSET CURVE



METHOD NO. 1
Not to scale

FORMULAS

$C = Lsl - (0.00034 * a^2 * (Lsl / 100)^5)$; $Lsi = POS - TS$
$DEF = (a * Lsl^2) / 60000$

$Xa = C * Cos(DEF)$
$Ya = C * Sin(DEF)$
$Xai = Xa - (Sin(DEF * 3) * W)$
$Yai = Ya + (Cos(DEF * 3) * W)$
$Xao = Xa + (Sin(DEF * 3) * W)$
$Yao = Ya - (Cos(DEF * 3) * W)$

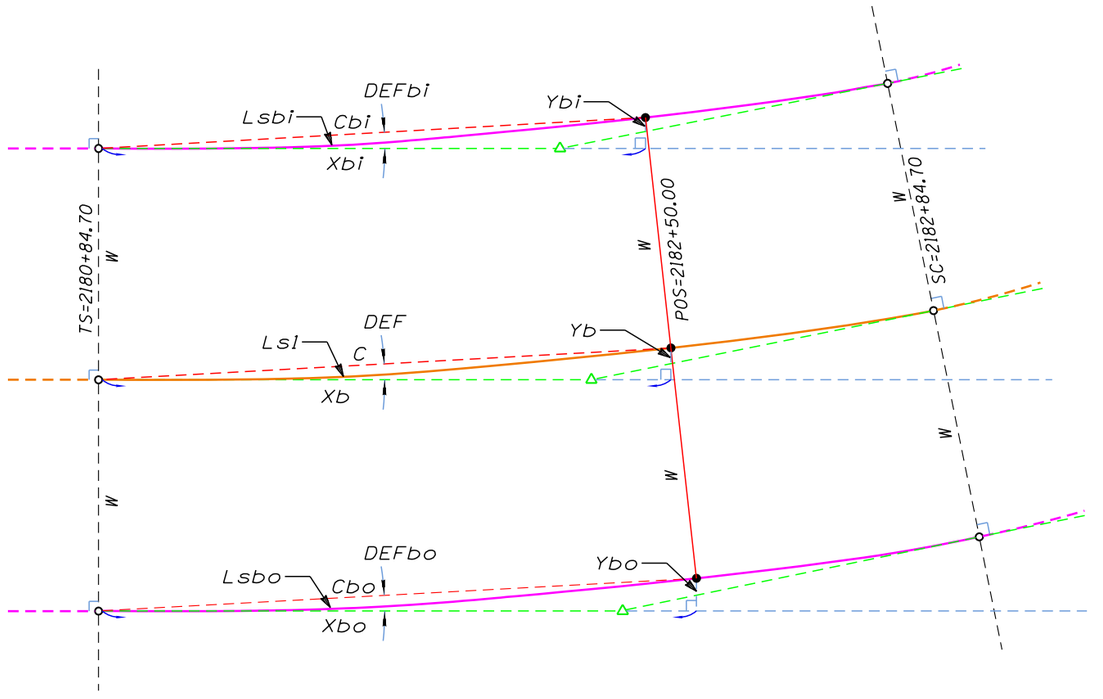
$Cai = \sqrt{Xai^2 + (Yai - W)^2}$
$Lsai = Cai * Lsi / C$
$DEFai = ArcTan((Yai - W) / Xai)$
$Cao = \sqrt{Xao^2 + (Yao + W)^2}$
$Lsao = Cao * Lsi / C$
$DEFao = ArcTan((Yao + W) / Xao)$

EXAMPLE

Given: a = 1 TS = 2180+84.70 (From SC-1) POS = 2182+00.00 W = 100'

$Lsi = 2182+00.00 - 2180+84.70 = 115.30'$
$C = 115.30 - (0.00034 * 1^2 * (115.30 / 100)^5) = 115.29931$
$DEF = (1 * 115.30^2) / 60000 = 0.22157° \text{ or } 0°13'18"$

$Xa = 115.29931 * Cos(0.22157) = 115.29845$
$Ya = 115.29931 * Sin(0.22157) = 0.44588$
$Xai = 115.29845 - (Sin(0.22157 * 3) * 100) = 114.13834$
$Yai = 0.44588 + (Cos(0.22157 * 3) * 100) = 100.43915$
$Cai = \sqrt{114.13834^2 + (100.43915 - 100)^2} = 114.13918$
$Lsai = 114.13918 * 115.30 / 115.29931 = 114.13986$
$DEFai = ArcTan((100.43915 - 100) / 114.13834 = 0.22045° \text{ or } 0°13'14"$
$Xao = 115.29845 + (Sin(0.22157 * 3) * 100) = 116.45856$
$Yao = 0.44588 - (Cos(0.22157 * 3) * 100) = -99.54739$
$Cao = \sqrt{116.45856^2 + (-99.54739 + 100)^2} = 116.45944$
$Lsao = 116.45944 * 115.30 / 115.29931 = 116.46014$
$DEFao = ArcTan((-99.54739 + 100) / 116.45856) = 0.22268° \text{ or } 0°13'22"$



METHOD NO. 2
Not to scale

FORMULAS

$C = Lsl - (0.00034 * a^2 * (Lsl / 100)^5)$; $Lsi = POS - TS$
$DEF = (a * Lsl^2) / 60000$

$Xb = C * Cos(DEF)$
$Yb = C * Sin(DEF)$
$Xbi = Xb - (Sin(DEF * 3) * W)$
$Ybi = Yb + (Cos(DEF * 3) * W) - W$
$Xbo = Xb + (Sin(DEF * 3) * W)$
$Ybo = Yb + W - (Cos(DEF * 3) * W)$

$Cbi = \sqrt{Xbi^2 + Ybi^2}$
$Lsbi = Cbi * Lsi / C$
$DEFbi = ArcTan(Ybi / Xbi)$
$Cbo = \sqrt{Xbo^2 + Ybo^2}$
$Lsbo = Cbo * Lsi / C$
$DEFbo = ArcTan(Ybo / Xbo)$

EXAMPLE

Given: a = 1 TS = 2180+84.70 (From SC-1) POS = 2182+50.00 W = 100'

$Lsi = 2182+50.00 - 2180+84.70 = 165.30'$
$C = 165.30 - (0.00034 * 1^2 * (165.30 / 100)^5) = 165.29580$
$DEF = (1 * 165.30^2) / 60000 = 0.45540° \text{ or } 0°27'19"$

$Xb = 165.29580 * Cos(0.45540) = 165.29058$
$Yb = 165.29580 * Sin(0.45540) = 1.31380$
$Xbi = 165.29058 - (Sin(0.45540 * 3) * 100) = 162.90634$
$Ybi = 1.31380 + (Cos(0.45540 * 3) * 100) - 100 = 1.28537$
$Cbi = \sqrt{162.90634^2 + 1.28537^2} = 162.91141$
$Lsbi = 162.91141 * 165.30 / 165.29580 = 162.91555$
$DEFbi = ArcTan(1.28537 / 162.90634) = 0.45207 ° \text{ or } 0°27'07"$
$Xbo = 165.29058 + (Sin(0.45540 * 3) * 100) = 167.67482$
$Ybo = 1.31380 + 100 - (Cos(0.45540 * 3) * 100) = 1.34223$
$Cbo = \sqrt{167.67482^2 + 1.34223^2} = 167.68019$
$Lsbo = 167.67882 * 165.30 / 165.29580 = 167.68308$
$DEFbo = ArcTan(1.34223 / 167.67482) = 0.45864° \text{ or } 0°27'31"$

POINTS ON SPIRAL OFFSET CURVE

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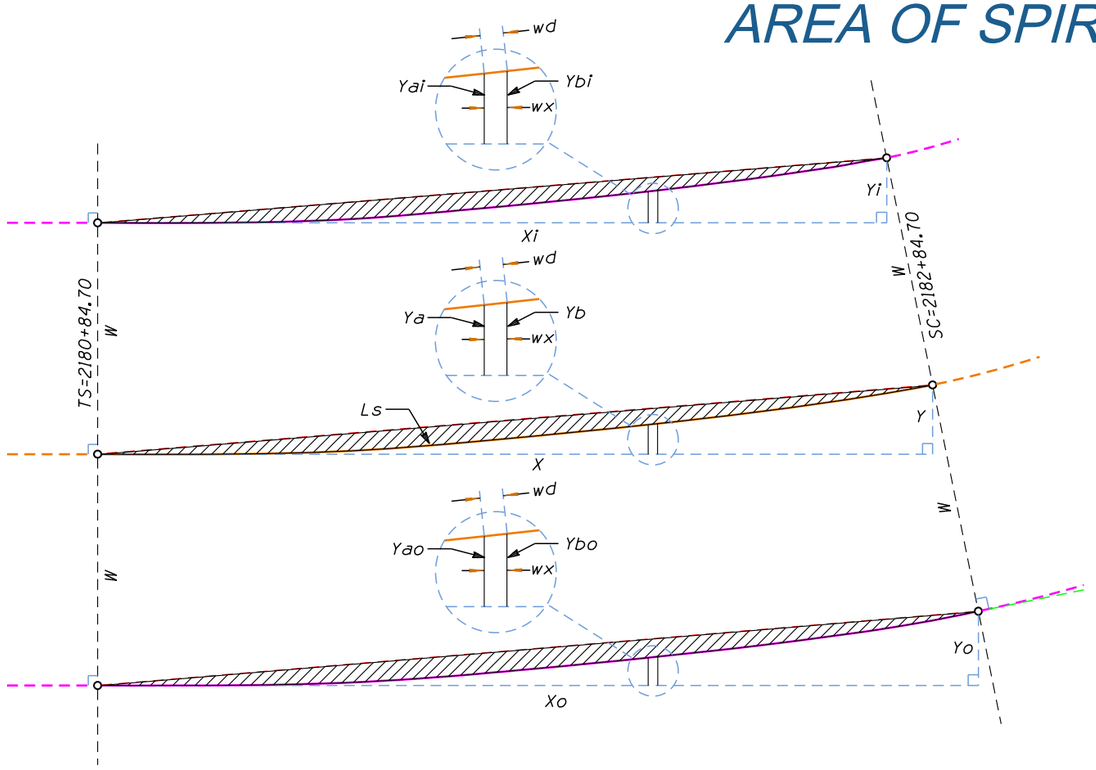
SC-3
Sht: 3 of 7

AREA OF SPIRAL CHORD



AREA OF SPIRAL CHORD
Not to scale

Chord Area

FORMULAS

Given: a = 1, Ls = 200 (From SC-1); W = 100',
Lsi = 196.50939, Xi = 196.48563, Yi = 2.26601 (From SC-2)
wd = 1 (Interval distance) (Area precision is based upon wd)
wx (Segment width)

$$\text{Chord Area} = (Xi * Yi / 2) - \sum_{Ls1=wd}^{Ls} (Yai + Ybi) / 2 * wx$$

Step 1:
Xi * Yi / 2 = 196.48563 * 2.26601 / 2 = 222.61920Φ

Step 2
Summation: $\sum_{Ls1=wd}^{Ls} (Yai + Ybi) / 2 * wx$
Start Lsl = wd: DefYa = a * Lsl² / 60000; DefYb = a * (Lsl + wd)² / 60000
Yai = (Lsl - (0.00034 * a² * (Lsl / 100)⁵)) * Sin(DefYa) +
((Cos(DefYa * 3) * W) - W)
Ybi = ((Lsl + wd) - (0.00034 * a² * ((Lsl + wd) / 100)⁵)) * Sin(DefYb) +
((Cos(DefYb * 3) * W) - W)
wx = $\sqrt{(wd * Lsi / Ls)^2 - (Ybi - Yai)^2}$
Segment Area = (Yai + Ybi) / 2 * wx
Lsl = Lsl + wd
Repeat until Lsl = Ls
Area below spiral curve = 111.88952Φ

Step 3:
Chord Area = 222.61920Φ - 111.88952Φ = 110.72968Φ

INSIDE SPIRAL

FORMULAS

Given: a = 1, Ls = 200, X = 199.97558, Y = 2.32693 (From SC-1)
wd = 1 (Interval distance) (Area precision is based upon the value of wd)
wx (Segment width)

$$\text{Chord Area} = (X * Y / 2) - \sum_{Ls1=wd}^{Ls} (Ya + Yb) / 2 * wx$$

Step 1:
X * Y / 2 = 199.97558 * 2.32693 / 2 = 232.66459Φ

Step 2
Summation: $\sum_{Ls1=wd}^{Ls} (Ya + Yb) / 2 * wx$
Start Lsl = wd: Ya = (Lsl - (0.00034 * a² * (Lsl / 100)⁵)) * Sin(a * Lsl² / 60000)
Yb = ((Lsl + wd) - (0.00034 * a² * ((Lsl + wd) / 100)⁵)) * Sin(a * (Lsl + wd)² /60000)
wx = $\sqrt{wd^2 - (Yb - Ya)^2}$
Segment Area = (Ya + Yb) / 2 * wx
Lsl = Lsl + wd
Repeat until Lsl = Ls
Area below spiral curve = 116.31862Φ

Step 3
Chord Area = 232.66459Φ - 116.31862Φ = 116.34597Φ

CENTERLINE SPIRAL

FORMULAS

Given: a = 1, Ls = 200 (From SC-1); W = 100',
Lso = 203.49061, Xo = 203.46553, Yo = 2.38785 (From SC-2)
wd = 1 (Interval distance) (Area precision is based upon wd)
wx (Segment width)

$$\text{Chord Area} = (Xo * Yo / 2) - \sum_{Ls1=wd}^{Ls} (Yao + Ybo) / 2 * wx$$

Step 1:
Xo * Yo / 2 = 203.46553 * 2.38785 / 2 = 242.92258Φ

Step 2
Summation: $\sum_{Ls1=wd}^{Ls} (Yao + Ybo) / 2 * wx$
Start Lsl = wd: DefYa = a * Lsl² / 60000; DefYb = a * (Lsl + wd)² / 60000
Yao = (Lsl - (0.00034 * a² * (Lsl / 100)⁵)) * Sin(DefYa) +
(W - (Cos(DefYa * 3) * W))
Ybo = ((Lsl + wd) - (0.00034 * a² * ((Lsl + wd) / 100)⁵)) * Sin(DefYb) +
(W - (Cos(DefYb * 3) * W))
wx = $\sqrt{(wd * Lso / Ls)^2 - (Ybo - Yao)^2}$
Segment Area = (Yao + Ybo) / 2 * wx
Lsl = Lsl + wd
Repeat until Lsl = Ls
Area below spiral curve = 120.82001Φ

Step 3:
Chord Area = 242.92258Φ - 120.82001Φ = 122.10257Φ

OUTSIDE SPIRAL

AREA OF SPIRAL CHORD

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SC-4
Sht: 4 of 7

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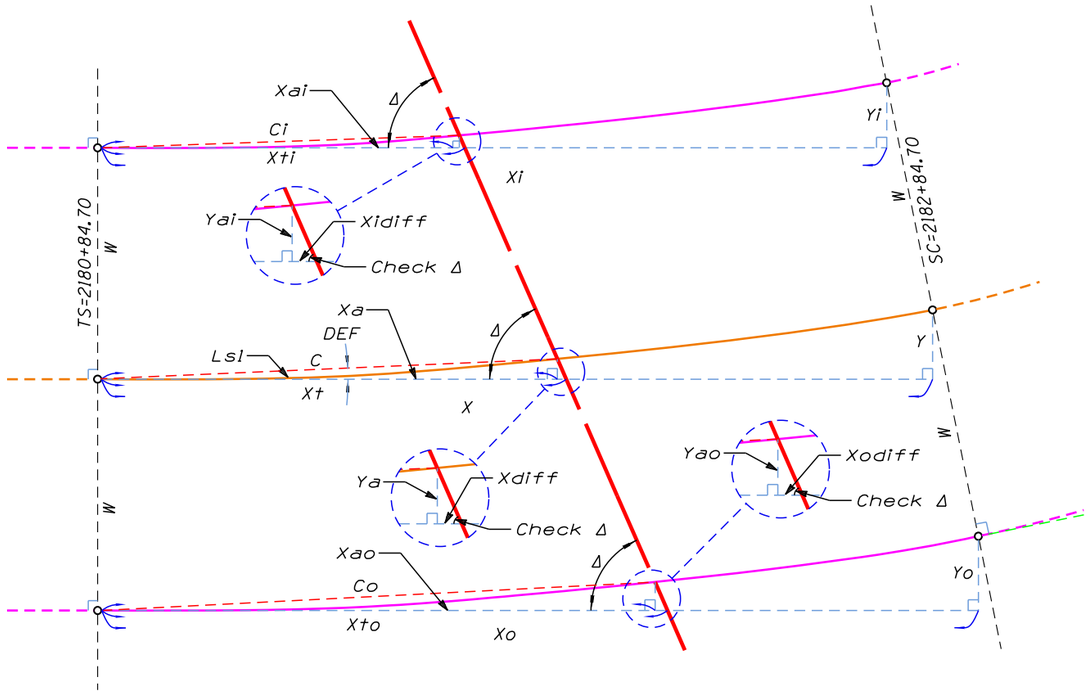
SPIRAL CURVE - LINE INTERSECTION



INTERSECTION
Not to scale

FORMULAS

Given: a = 1.00, Δ = 66°20'20", Xti = 76.43, W = 100.00

$C = Lsl - (0.00034 * a^2 * (Lsl / 100)^5)$
$DEF = (a * Lsl^2) / 60000$
$Xa = C * Cos(DEF)$
$Ya = C * Sin(DEF)$
$Xai = Xa - (Sin(DEF * 3) * W)$
$Yai = Ya + (Cos(DEF * 3) * W) - W$
$Xidiff = Xti - Xai$
$Check\ \Delta = ArcTan(Yai / Xidiff)$

Solution
Lsl = 76.88876
C = 76.88867
DEF = 0.09853°
Xa = 76.88855
Ya = 0.13223
Xai = 76.37264
Yai = 0.13089
Xidiff = 0.05736
Check Δ = 66.3389°

Starting value needs to be larger than Xti in order to find a solution.

Begin Iteration
Starting values: Lsl = 100', Tolerance = 0.0001

$C = 100 - (0.00034 * 1^2 * (100 / 100)^5) = 99.99966$
$DEF = (1 * 100^2) / 60000 = 0.166667°$ or 0°10'00"
$Xa = 99.99966 * Cos(0.166667) = 99.99924$
$Ya = 99.99966 * Sin(0.166667) = 0.29089$
$Xai = 99.99924 - (Sin(0.166667 * 3) * 100.00) = 99.12658$
$Yai = 0.29089 + (Cos(0.166667 * 3) * 100.00) - 100.00 = 0.28708$
$Xidiff = 76.43 - 99.12658 = -22.69658$
$Check\ \Delta = ArcTan(0.28708 / -22.69658) = -0.72467°$ or -0°43'28.8"

Δ - Check Δ = 66.33889 - 0.72467 = 65.61422 (If <= Tolerance then solution found) If no solution found then Lsl = Lsl - Tolerance.
Repeat iteration with new Lsl until solution is found.
The solution is best found by utilizing a computer program to run the iterations.

Note:
Rounding error will occur based upon the number of decimal places used.

INSIDE SPIRAL INTERSECTION

FORMULAS

Given: a = 1.00, Δ = 66°20'20", Xt = 120.25

$C = Lsl - (0.00034 * a^2 * (Lsl / 100)^5)$
$DEF = (a * Lsl^2) / 60000$
$Xa = C * Cos(DEF)$
$Ya = C * Sin(DEF)$
$Xdiff = Xt - Xa$
$Check\ \Delta = ArcTan(Ya / Xdiff)$

Solution
Lsl = 120.03149
C = 120.03064
DEF = 0.240126°
Xa = 120.02959
Ya = 0.50305
Xdiff = 0.22041
Check Δ = 66.338883°

Starting value needs to be larger than Xt in order to find a solution.

Begin Iteration
Starting values: Lsl = 200', Tolerance = 0.0001

$C = 200 - (0.00034 * 1^2 * (200 / 100)^5) = 199.98912$
$DEF = (1 * 200^2) / 60000 = 0.666667°$ or 0°40'00"
$Xa = 199.98912 * Cos(0.666667) = 199.97558$
$Ya = 199.98912 * Sin(0.666667) = 2.32693$
$Xdiff = 120.25 - 199.98912 = -79.73912$
$Check\ \Delta = ArcTan(2.32693 / -79.73912) = -1.671519°$ or -1°40'17.5"

Δ - Check Δ = 66.33889 - 1.671519 = 64.667371 (If <= Tolerance then solution found)
If no solution found then Lsl = Lsl - Tolerance.
Repeat iteration with new Lsl until solution found.

The solution is best found by utilizing a computer program to run the iterations.

Note:
Rounding error will occur based upon the number of decimal places used.

CENTERLINE SPIRAL INTERSECTION

FORMULAS

Given: a = 1.00, Δ = 66°20'20", Xto = 164.07, W = 100.00

$C = Lsl - (0.00034 * a^2 * (Lsl / 100)^5)$
$DEF = (a * Lsl^2) / 60000$
$Xa = C * Cos(DEF)$
$Ya = C * Sin(DEF)$
$Xao = Xa + (Sin(DEF * 3) * W)$
$Yao = Ya + W - (Cos(DEF * 3) * W)$
$Xodiff = Xto - Xao$
$Check\ \Delta = ArcTan(Yao / Xodiff)$

Solution
Lsl = 161.26329
C = 161.25958
DEF = 0.43343°
Xa = 161.25497
Ya = 1.21988
Xao = 163.52421
Yao = 1.24563
Xodiff = 0.54579
Check Δ = 66.33881°

Starting value needs to be larger than Xto in order to find a solution.

Begin Iteration
Starting values: Lsl = 180', Tolerance = 0.0001

$C = 180 - (0.00034 * 1^2 * (180 / 100)^5) = 179.99358$
$DEF = (1 * 180^2) / 60000 = 0.54000°$ or 0°32'24"
$Xa = 179.99358 * Cos(0.54000) = 179.98559$
$Ya = 179.99358 * Sin(0.54000) = 1.69637$
$Xao = 179.98559 + (Sin(0.54000 * 3) * 100.00) = 182.81264$
$Yao = 1.69637 + 100.00 - (Cos(0.54000 * 3) * 100.00) = 1.73634$
$Xodiff = 164.07 - 182.81264 = -18.74264$
$Check\ \Delta = ArcTan(1.73634 / -18.74264) = -5.29284°$ or -5°17'34.2"

Δ - Check Δ = 66.33889 - 5.29284 = 61.04605 (If <= Tolerance then solution found) If no solution found then Lsl = Lsl - Tolerance.
Repeat iteration with new Lsl until solution is found.
The solution is best found by utilizing a computer program to run the iterations.

Note:
Rounding error will occur based upon the number of decimal places used.

OUTSIDE SPIRAL INTERSECTION

SPIRAL CURVE - LINE INTERSECTION

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Date	Project Sur.
Jun 2011	Jim Crume
Project No.	Project Manager
ADOT Spiral	Jim Crume

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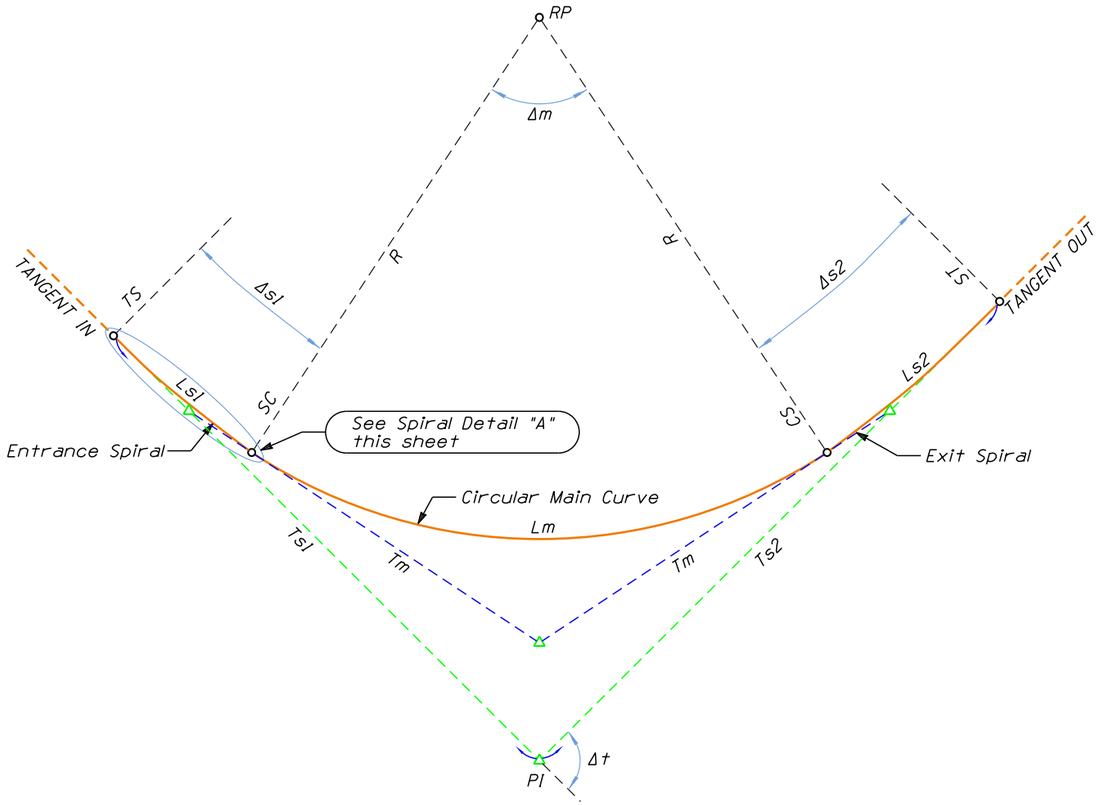
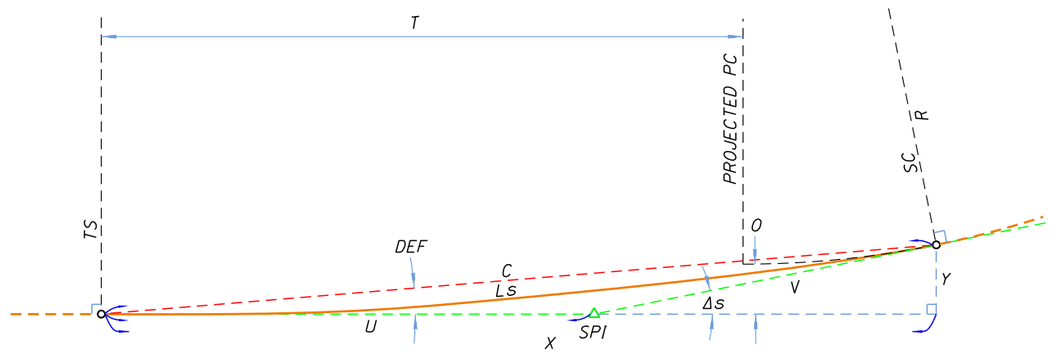
FULL TRANSITION UNEQUAL SPIRAL CURVES



TYPICAL HIGHWAY SPIRAL-MAIN-SPIRAL CURVE
Not to scale



SPIRAL DETAIL "A"
Not to scale

Highway Spiral Curve where Δs < 16°

FORMULAS

See SC-1 for spiral formulas

$\Delta m = \Delta t - \Delta s1 - \Delta s2$
$Xa = Cos(\Delta s1) * (V1 + Tm)$
$Ya = Sin(\Delta s1) * (V1 + Tm)$
$Xb = Cos(\Delta m + \Delta s1) * (V2 + Tm)$
$Yb = Sin(\Delta m + \Delta s1) * (V2 + Tm)$
$Xc = (Ya + Yb) / Tan(\Delta t)$
$Ts1 = Xa + Xb - Xc + U1$
$Ts2 = \sqrt{Xc^2 + (Ya + Yb)^2} + U2$

EXAMPLE

Given: Δt = 36°29'16"; D = 2°00'00"; Ls1 = 200'; Ls2 = 300'; TS(Sta) = 2180+84.70

Entrance Spiral (Ls1)

a = (2.0000° * 100) / 200 = 1.00
O = 0.0727 * 1 * ((200 / 100)^3) = 0.58160
T = (200 / 2) - (0.000127 * 1^2 * (200 / 100)^5) = 99.99594
C = 200 - (0.00034 * 1^2 * (200 / 100)^5) = 199.98912
DEF = (1 * 200^2) / 60000 = 0.666667° or 0°40'00"
Δs = 0.005 * 2.0000° * 200 = 2.0000° or 2°00'00"
U = 199.98912 * Sin(2.0000° * 2 / 3) / Sin(2.0000°) = 133.34112
V = 199.98912 * Sin(2.0000° * 1 / 3) / Sin(2.0000°) = 66.67508
X = 199.98912 * Cos(0.666667°) = 199.97558
Y = 199.98912 * Sin(0.666667°) = 2.32693

Main Curve

R = 5729.57795 / 2.0000° = 2864.78898
Δm = 36°29'16" - 2°00'00" - 3°00'00" = 31°29'16" or 31.48778°
Lm = (31.48778° * 2864.78898 * 3.141592654) / 180 = 1574.38900
Tm = 2864.78898 * Tan(31.48778 / 2) = 807.62426

SC(Sta) = 2180+84.70 + 200 = 2182+84.70
CS(Sta) = 2182+84.70 + 1574.39 = 2198+59.09
ST(Sta) = 2198+54.92 + 300 = 2201+59.09
PI(Sta) = 2180+84.70 + 1045.74 = 2191+30.44

Exit Spiral (Ls2)

a = (2.0000° * 100) / 300 = 0.66667
O = 0.0727 * 0.66667 * ((300 / 100)^3) = 1.30860
T = (300 / 2) - (0.000127 * 0.66667^2 * (300 / 100)^5) = 149.98628
C = 300 - (0.00034 * 0.66667^2 * (300 / 100)^5) = 299.96328
DEF = (0.66667 * 300^2) / 60000 = 1.000° or 01°00'00"
Δs = 0.005 * 2.0000° * 300 = 3.000° or 3°00'00"
U = 299.96328 * Sin(3.000° * 2 / 3) / Sin(3.000°) = 200.02630
V = 299.96328 * Sin(3.000° * 1 / 3) / Sin(3.000°) = 100.02838
X = 299.96328 * Cos(1.000°) = 299.91759
Y = 299.96328 * Sin(1.000°) = 5.23508

Tangents

Xa = Cos(2.000) * (66.67508 + 807.62426) = 873.76674
Ya = Sin(2.000) * (66.67508 + 807.62426) = 30.51261
Xb = Cos(31.48778 + 2.000) * (100.02838 + 807.62426) = 756.98550
Yb = Sin(31.48778 + 2.000) * (100.02838 + 807.62426) = 500.80562
Xc = (30.51261 + 500.80562) / Tan(36.48778) = 718.35575
Ts1 = 873.76674 + 756.98550 - 718.35575 + 133.34112 = 1045.73711
Ts2 = $\sqrt{718.35575^2 + (30.51261 + 500.80562)^2}$ + 200.02630 = 1093.52171

FULL TRANSITION SPIRAL CURVE
UNEQUAL ENTRANCE & EXIT SPIRALS

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Date: Jun 2011
Project Sur.: Jim Crume
Project No.: ADOT Spiral
Project Manager: Jim Crume

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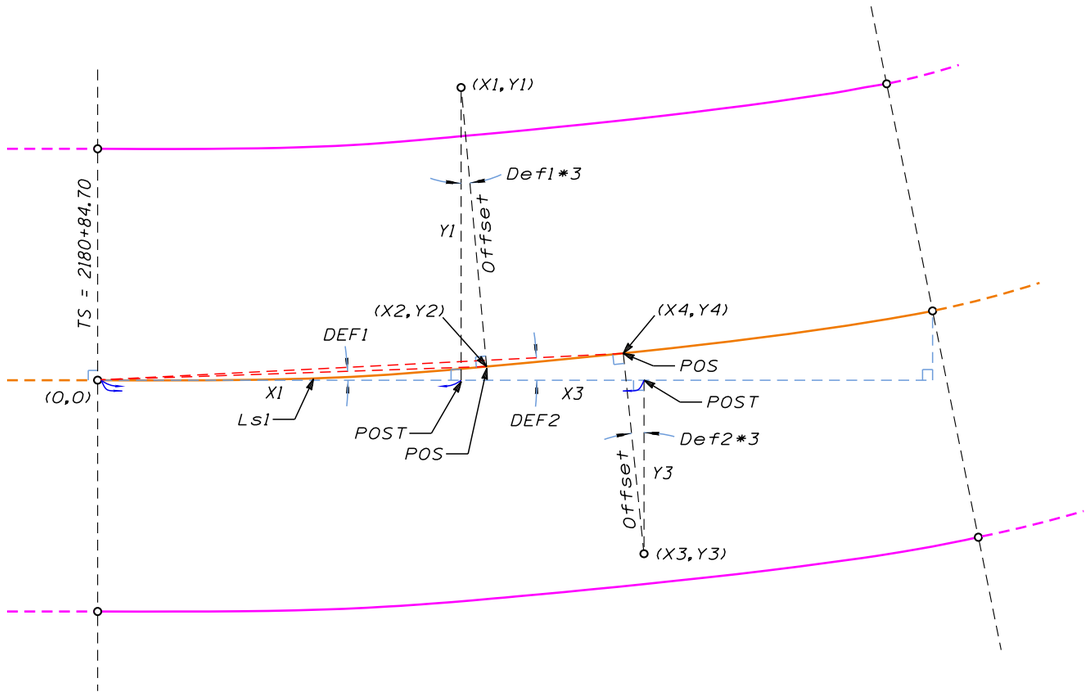
SPIRAL CURVE - STATION - OFFSET



STATION - OFFSET
Not to scale

FORMULAS

Given: TS(Sta) = 2180+84.70; X = 0, Y = 0; X1 = 94.500, Y1 = 110.400;
Ls = 200'; D = 2°00'00"; a = 1.000

P.O.S.T.
Sta = TS + X1; Offset = Y1

P.O.S.
Begin Iteration
Starting values: Ls1 = 200', Tolerance = 0.0001

$C = Ls1 - (0.00034 * a^2 * (Ls1 / 100)^5)$
$DEF1 = (a * Ls1^2) / 60000$
$X2 = C * Cos(DEF1)$
$Y2 = C * Sin(DEF1)$

$Xdiff = X2 - X1$
$Ydiff = Y2 - Y1$
$Check\ \Delta = ArcTan(Xdiff / Ydiff)$

If Def1 * 3 = Check Δ then solution found
If no solution found then Ls1 = Ls1 - Tolerance.
Repeat iteration with new Ls1 until solution found.

$Sta = TS + Ls1$
$Offset = \sqrt{Xdiff^2 + Ydiff^2}$

Solution
2180+84.70 + 94.50 =
2181+79.20 (P.O.S.T.)
110.40 LT

Ls1 = 95.37476 C = 95.37479
DEF1 = 0.15161° or 00°09'05.8"
X2 = 95.37446
Y2 = 0.25236

Xdiff = 0.87446
Ydiff = -110.14764

0.45482 - 0.45486 = -0.00004
less than 0.0001 (Tolerance)
Solution found

2180+84.70 + 95.37 =
2181+80.07 (P.O.S.)

$\sqrt{0.87446^2 + (-110.14764)^2}$
= 110.15 (Offset LT)

OFFSET - LEFT SIDE

FORMULAS

Given: TS(Sta) = 2180+84.70; X = 0, Y = 0; X1 = 94.500, Y1 = 110.400; X3 = 125.400, Y3 = -80.500
Ls = 200'; D = 2°00'00"; a = 1.000

P.O.S.T.
Sta = TS + X1 and TS + X3; Offset = Y1 and Y3

P.O.S.
Begin Iteration
Starting values: Ls1 = 200', Tolerance = 0.0001

$C = Ls1 - (0.00034 * a^2 * (Ls1 / 100)^5)$
$DEF1\ or\ DEF2 = (a * Ls1^2) / 60000$
$X2\ or\ X4 = C * Cos(DEF1\ or\ DEF2)$
$Y2\ or\ Y4 = C * Sin(DEF1\ or\ DEF2)$

$Xdiff = X2 - X1\ or\ X4 - X3$
$Ydiff = Y2 - Y1\ or\ Y4 - Y3$
$Check\ \Delta = ArcTan(Xdiff / Ydiff)$

If Def1 * 3 or Def2 * 3 = Check Δ then solution found
If no solution found then Ls1 = Ls1 - Tolerance.
Repeat iteration with new Ls1 until solution found.

The solution is best found by utilizing a computer program to run the iterations.

$Sta = TS + Ls1;\ \ Offset = \sqrt{Xdiff^2 + Ydiff^2}$

CENTERLINE SPIRAL STATION-OFFSET

FORMULAS

Given: TS(Sta) = 2180+84.70; X = 0, Y = 0; X3 = 125.400, Y3 = -80.500;
Ls = 200'; D = 2°00'00"; a = 1.000

P.O.S.T.
Sta = TS + X3; Offset = Y3

P.O.S.
Begin Iteration
Starting values: Ls1 = 200', Tolerance = 0.0001

$C = Ls1 - (0.00034 * a^2 * (Ls1 / 100)^5)$
$DEF2 = (a * Ls1^2) / 60000$
$X4 = C * Cos(DEF2)$
$Y4 = C * Sin(DEF2)$

$Xdiff = X4 - X3$
$Ydiff = Y4 - Y3$
$Check\ \Delta = ArcTan(Xdiff / Ydiff)$

If Def2 * 3 = Check Δ then solution found
If no solution found then Ls1 = Ls1 - Tolerance.
Repeat iteration with new Ls1 until solution found.

$Sta = TS + Ls1$
$Offset = \sqrt{Xdiff^2 + Ydiff^2}$

Solution
2180+84.70 + 125.400 =
2182+10.10 (P.O.S.T.)
80.50 RT

Ls1 = 124.31152 C = 124.30807
DEF2 = 0.25754° or 00°15'27.1"
X4 = 124.30682
Y4 = 0.55877

Xdiff = -1.09318
Ydiff = 81.05877

0.77263 - 0.77266 = -0.00004
less than 0.0001 (Tolerance)
Solution found

2180+84.70 + 124.31 =
2182+09.01 (P.O.S.)

$\sqrt{(-1.09318)^2 + 81.05877^2}$
= 81.07 (Offset RT)

OFFSET - RIGHT SIDE

SPIRAL CURVE - STATION - OFFSET

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Project No. ADOT Spiral | Project Manager Jim Crume

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