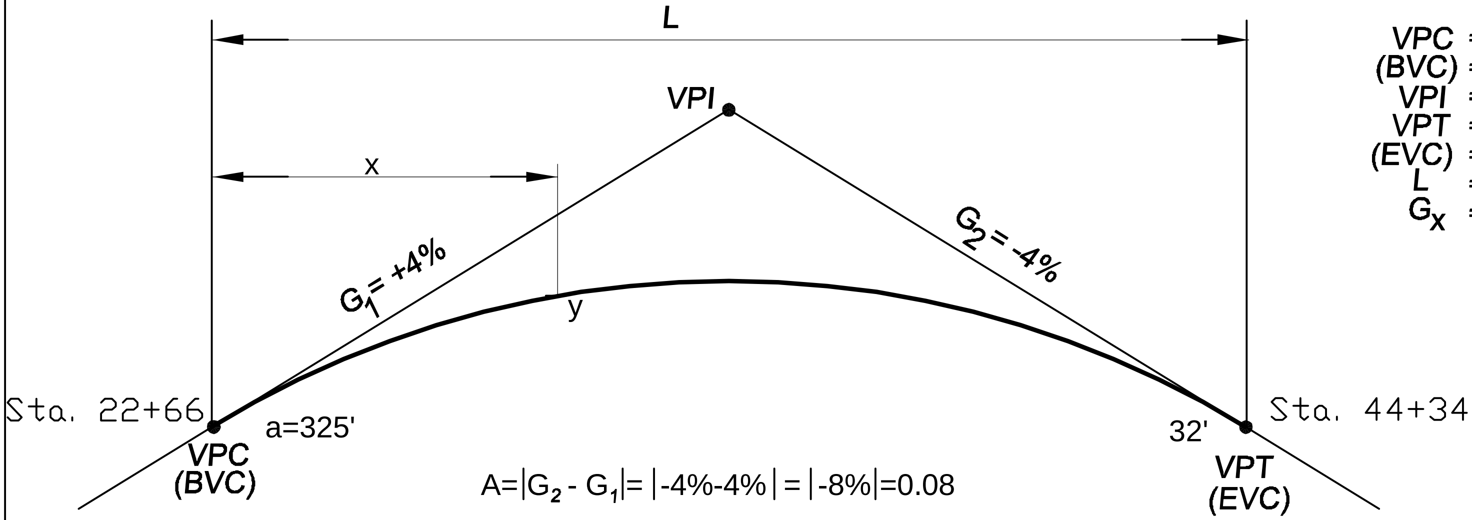
7.1

GEOMETRY OF A (CREST) VERTICAL CURVE



VPC = *Vertical Point of Curvature*
(BVC) = *Begin Vertical Curve*
VPI = *Vertical Point of Intersection*
VPT = *Vertical Point of Tangency*
(EVC) = *End Vertical Curve*
L = *Length of the curve*
G_X = *Slope*

$A = |G_2 - G_1| = |-4\% - 4\%| = |-8\%| = 0.08$

L = (44+34) - (22+66)
L = 4434-2266
L = 2168 feet

EQ. (7.5): $X_{HI} = L * \dfrac{G_1}{G_1 - G_2} = 2168 \dfrac{4\%}{4\% - (-4\%)} = 2168 \dfrac{0.04}{0.08} = 1084 \text{ feet}$

$b = G_1$

EQ. (7.4): $c = \dfrac{G_2 - G_1}{2L} = \dfrac{-0.08}{2(2168)} = -0.0000185/\text{ft}$

EQ. (7.3): $y = a + bx + cx^2$

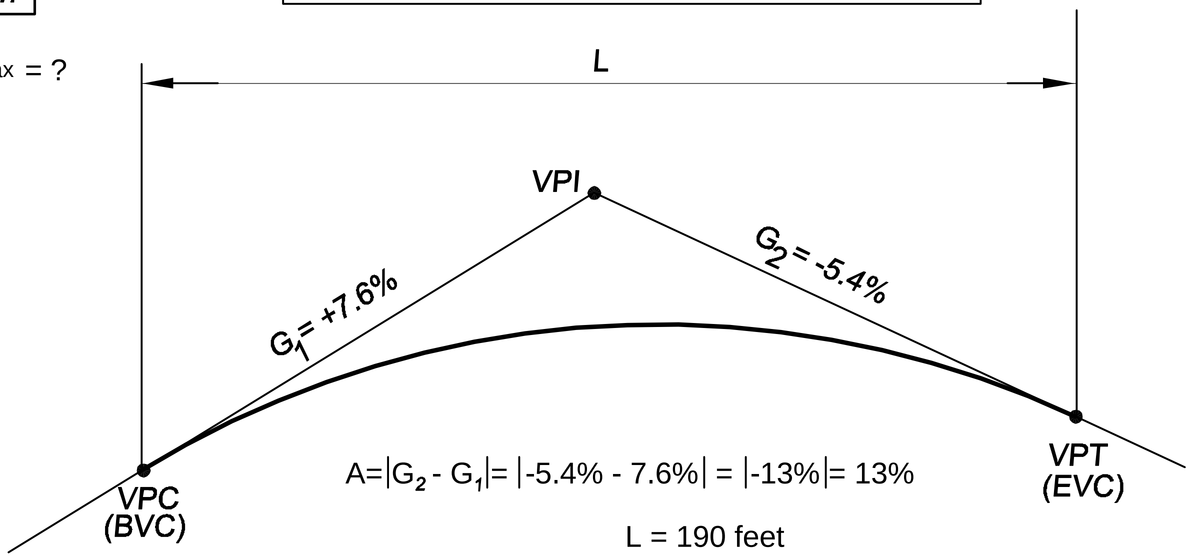
$y = 325 \text{ ft.} + 0.04(1084 \text{ ft.}) + (-0.0000185/\text{ft})(1084 \text{ ft.})^2$

$y = 325 + 43.4 - 21.7 = \underline{\underline{346.7}} \text{ ft.}$

$\boxed{7.7}$

SSD ON A CREST VERTICAL CURVE

$S_{Max} = ?$



VPC = *Vertical Point of Curvature*
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VPT = *Vertical Point of Tangency*
(EVC) = *End Vertical Curve*
L = *Length of the curve*
G_X = *Slope*

$A = |G_2 - G_1| = |-5.4\% - 7.6\%| = |-13\%| = 13\%$

L = 190 feet

Figure 7.13

$h_1 = 3.5'$
$h_2 = 2.0'$

Standard h_1 and h_2

EQUATIONS ASSUME

$S_{Max} = ?$

SSD < L

(EQ. 7.17) $$L_{Min\ 1} = \frac{A \times SSD^2}{2158}$$

$$190 = \frac{13.0 \times SSD^2}{2158}$$

$SSD_{ACTUAL\ PROVIDED} = 177.6$ feet

Table 7.4

~~S = 30mph ⇒ 200 feet = SSD~NEEDED~~~

S = 25mph ⇒ 155 feet = SSD_{NEEDED}

~~SSD > L~~

$$\cancel{L_{Min\ 2} = 2SSD - \frac{2158}{A}}$$ (EQ. 7.17)

$$\cancel{190 = 2SSD - \frac{2158}{13}}$$

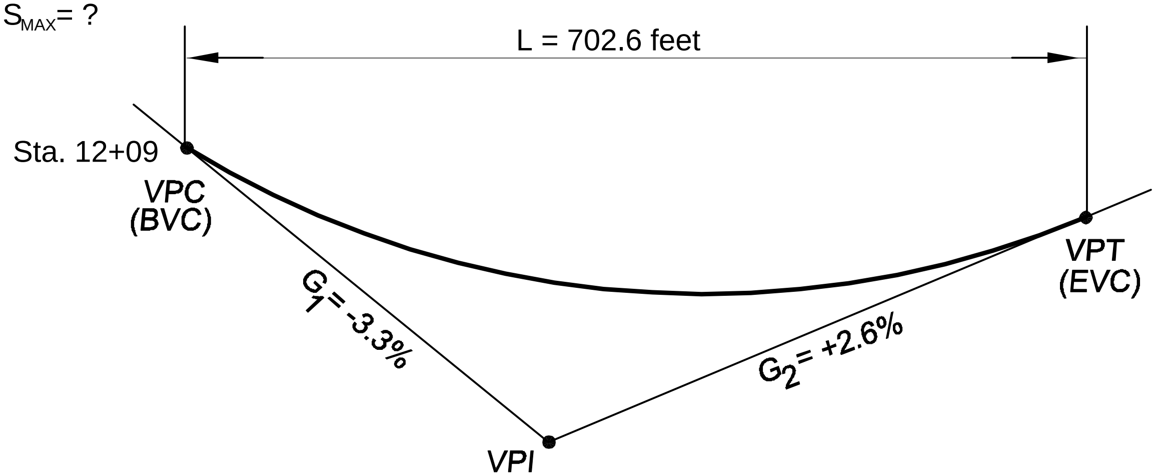
~~SSD = 178.0 feet~~

If not using Standard h_1 & h_2 then use
(EQ. 7.16) <u>not</u> (EQ. 7.17)

7.11

$S_{MAX} = ?$

SSD ON A SAG VERTICAL CURVE



VPC = *Vertical Point of Curvature*
(BVC) = *Begin Vertical Curve*
VPI = *Vertical Point of Intersection*
VPT = *Vertical Point of Tangency*
(EVC) = *End Vertical Curve*
L = *Length of the curve*
G_X = *Slope*

$$A = |G_1 - G_2| = |-3.3\% - 2.6\%| = |-5.9\%| = 5.9\%$$

$S = ?$ (SSD_{ACTUAL})

SSD < L

$$L_{Min\ 1} = \frac{|A|S^2}{200(2+0.017455S)} \quad \textit{(EQ. 7.18)}$$

S = $SSD_{ACTUAL\ PROVIDED}$

$$702.6 = \frac{5.9\,S^2}{200(2+0.017455S)}$$

$$23816.9 = \frac{S^2}{2+0.017453S}$$

$$47633.9 + 415.7S - S^2 = 0$$

$$0 = S^2 - 415.7S - 47633.9$$

$$\frac{-(-415.7) \pm \sqrt{(-415)^2 - 4(1)(-47633.9)}}{2(1)} \text{ (Quadratic Equation)}$$

$$\frac{-(-415.7) \pm \sqrt{(-415.7)^2 - 4(1)(-47633.9)}}{2(1)} = \frac{-(-415.7) \pm \sqrt{172848+190576}}{2(1)} \Rightarrow SSD_{ACTUAL\ PROVIDED} = \frac{416 \pm 603}{2} = 510,\ \cancel{-43.5}$$

Table 7.4

S = 55mph ⇒ 495 feet ✓

S = 60mph ⇒ 570 feet

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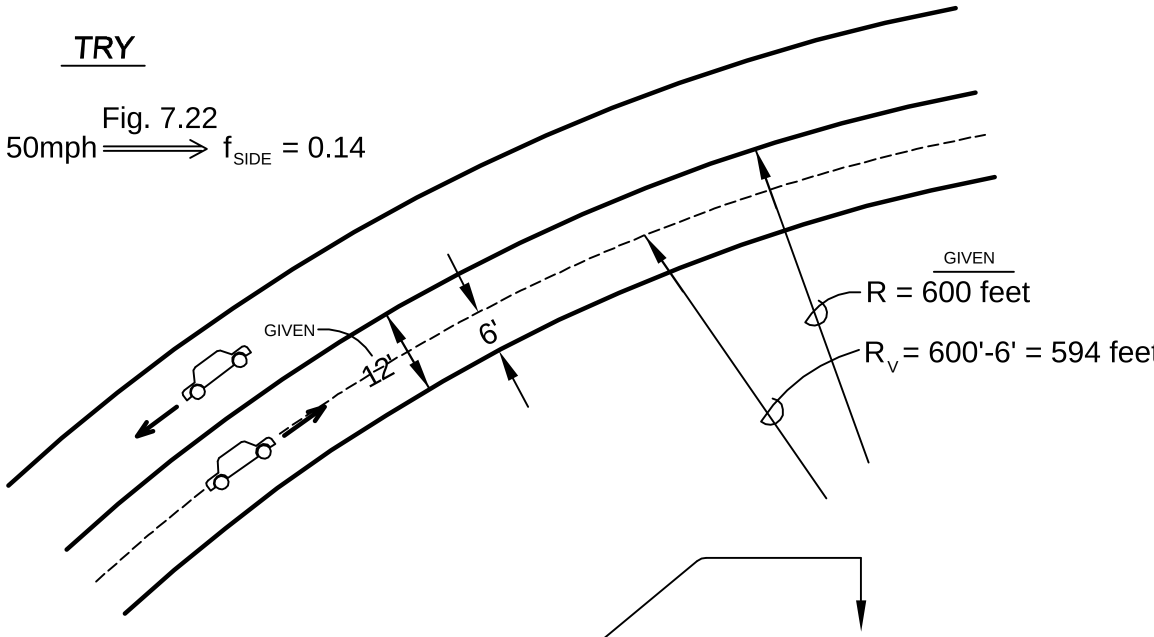
$\boxed{7.22}$

SUPERELEVATION

$S = ?$

TRY

$$S_{DESIGN} = 50mph \xRightarrow{\text{Fig. 7.22}} f_{SIDE} = 0.14$$



$$\overset{\text{ft.}}{R_V} = \frac{\overset{\text{ft/sec}}{V}{}^2}{g(e + f_{SIDE})} \qquad \textbf{\textit{EQ. (7.24)}}$$

$$594 \text{ ft} = \frac{(50mph \times 1.477)^2}{32.2 \text{ ft/sec/sec}(e + 0.14)}$$

$$3.5566 = \frac{1}{e + 0.14}$$

$$3.56e + 0.498 = 1$$

$$3.56e = 0.502$$

$$e = 0.14 \text{ ft/ft}$$

Too High "e"
(See Fig. 7.23)

TRY

$$S_{DESIGN} = 40mph \Longrightarrow f_{SIDE} = 0.15$$

$$594 \text{ ft} = \frac{(40mph \times 1.477)^2}{32.2 \text{ ft/sec/sec}(e + 0.15)}$$

$$5.56 = \frac{1}{e + 0.15}$$

$$5.56\,e + 0.833 = 1$$

$$5.56\,e = 0.167$$

$$e = 0.03 \text{ ft/ft}$$

Too Low "e"

$$\Downarrow$$

$$S_{DESIGN} = 45mph \longrightarrow 594 = \frac{(45 \times 1.477)^2}{32.2(e + 0.15)}$$

$$S_{POSTED} = S_{DESIGN} - 5 = 40mph$$

$e = 0.08$ ✓ O.K.

SSD ON A HORIZONTAL CURVE

$\boxed{7.18}$

$M_S = ?$

$T = 32+50 - 28+00 = 4+50 = 450'$

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

$450 \text{ ft} = (1650 \text{ ft}) \tan \frac{\Delta}{2}$

$\tan^{-1}(0.2727) = \frac{\Delta}{2}$

$15.25° = \frac{\Delta}{2}$

$\Delta = 30.5°$

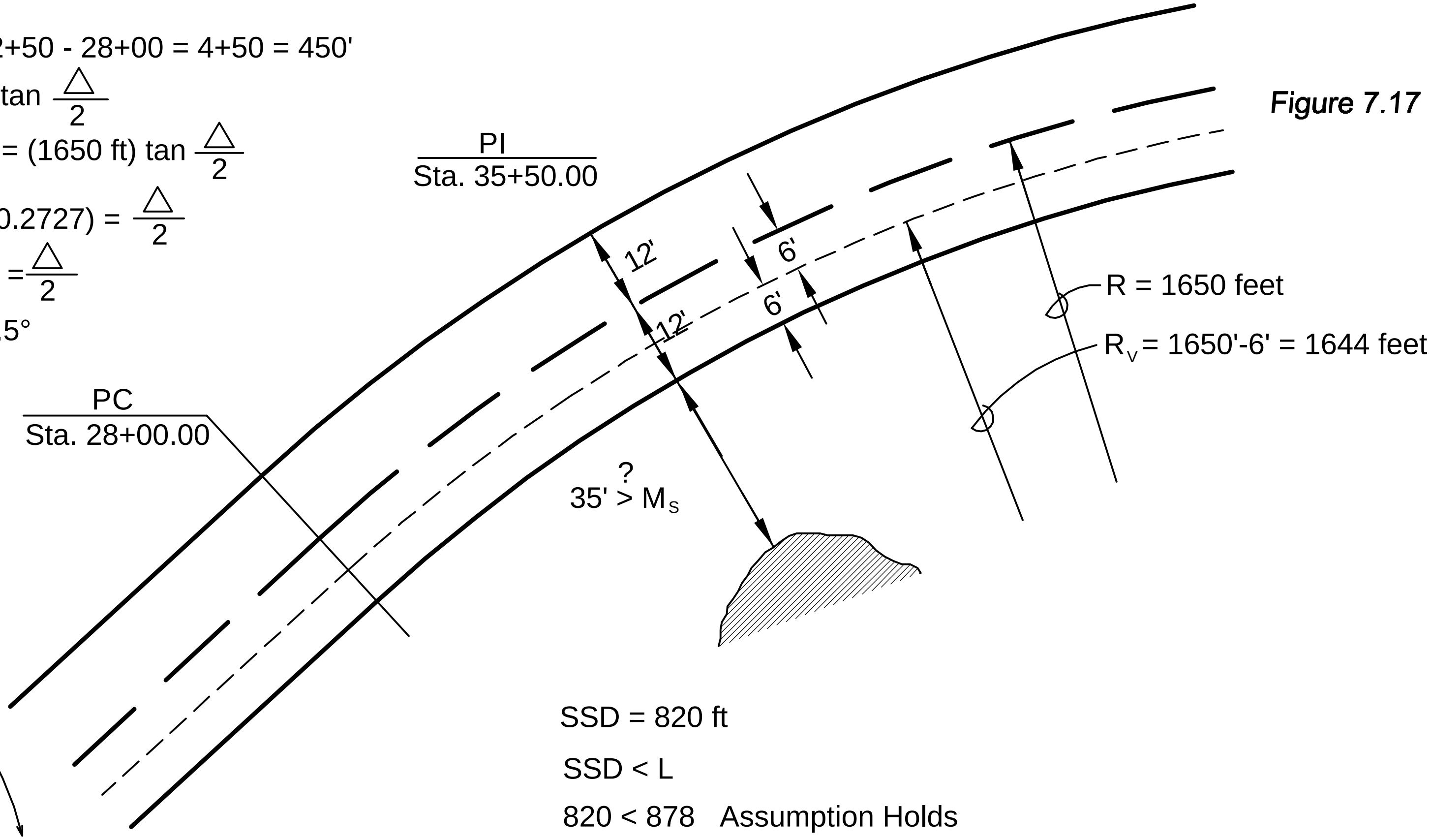


Figure 7.17

$$L = \frac{100\,\Delta}{D} = \frac{100(30.5)}{3.472} = 878 \text{ ft}$$

$$D = \frac{5729.6}{R} = \frac{5729.6}{1650} = 3.472$$

SSD = 820 ft

SSD < L

820 < 878   Assumption Holds

Assume SSD < L

$$SSD = \frac{\pi \times R_V}{90}\left(\cos^{-1}\frac{R_V - M_S}{R_V}\right)$$

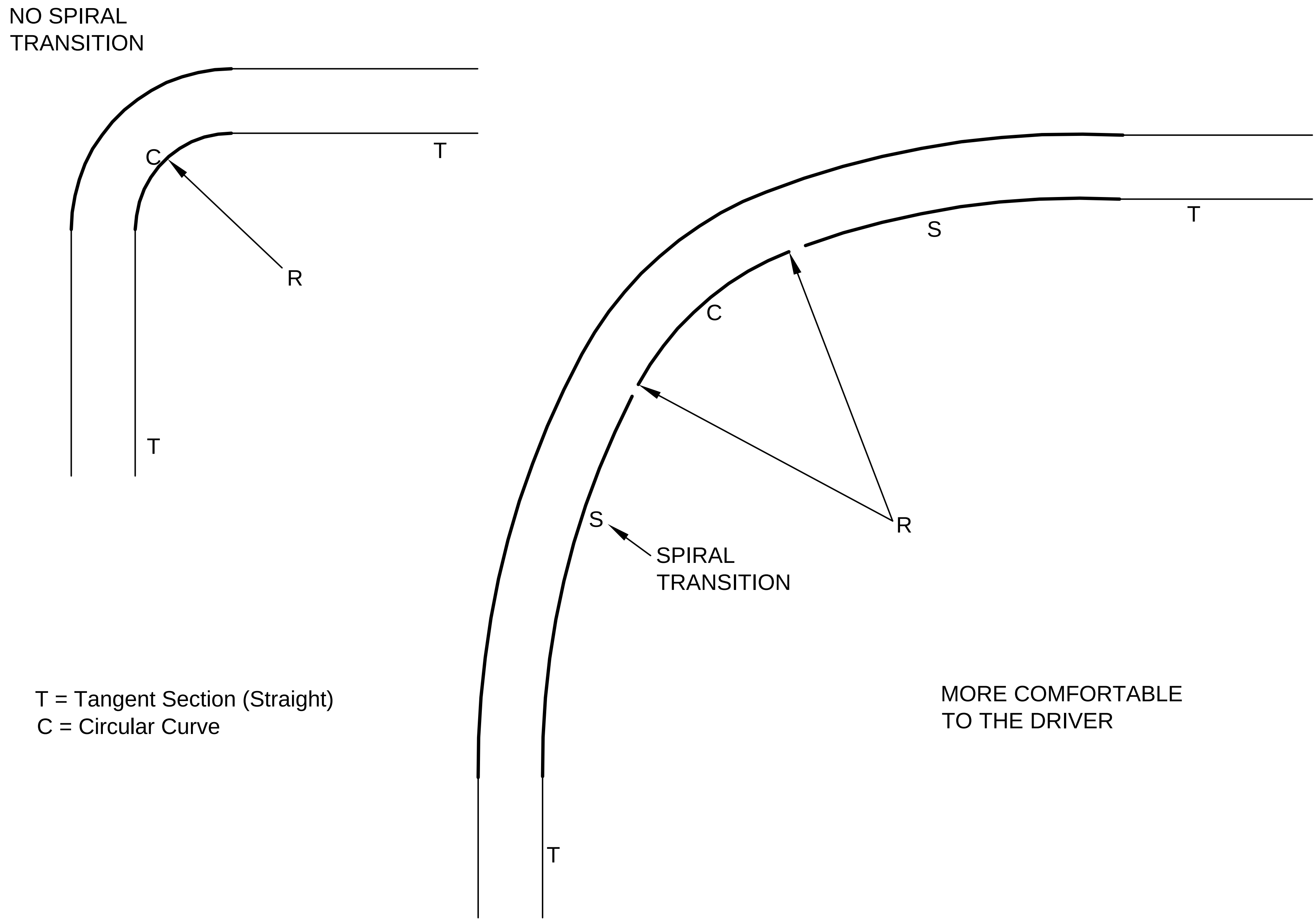
$$820 = \frac{(3.1415)(1644)}{90}\cos^{-1}\left(\frac{1644 - M_S}{1644}\right)$$

$$\cos^{-1}\left(\frac{1644 - M_S}{1644}\right) = 14.2895 \Rightarrow \frac{1644 - M_S}{1644} = 0.969 \Rightarrow M_S = \underline{\underline{50.9 \text{ ft.}}}$$

THEREFORE SET-BACK NEEDED OF:

50.9-35 = $\underline{\underline{15.9 \text{ ft.}}}$

USE OF SPIRAL CURVES



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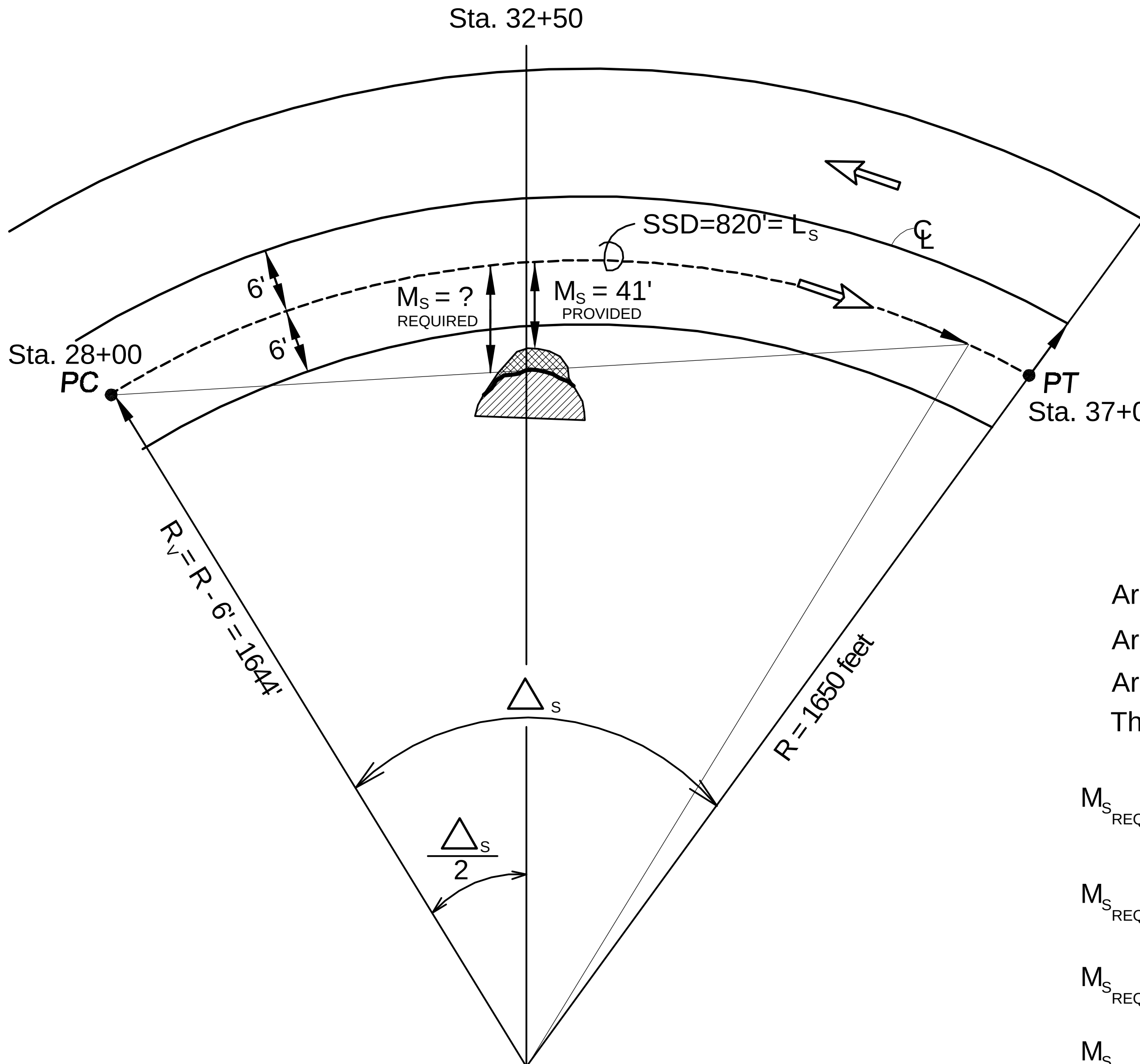
7.18

SSD ON A HORIZONTAL CURVE



Arc of Curve = 2 x [(32+50)-(28+00)]

Arc of Curve = 2 x 450' = 900 feet

Arc of Curve = 900 feet > SSD = 820 feet

Therefore, EQ. 7.20 can be used

$$M_{S_{REQUIRED}} = R_V \left(1 - \cos \frac{90 x SSD}{\pi \ x \ R_V}\right) \quad \text{(EQ. 7.20)}$$

$$M_{S_{REQUIRED}} = 1644 \left(1 - \cos \frac{90 x 820}{(3.1416)(1644)}\right)$$

$$M_{S_{REQUIRED}} = 1644(1-0.969)$$

$$M_{S_{REQUIRED}} = 50.9 \text{ feet} \rightarrow 51 \text{ feet}$$

Required Cut-Back Distance = 51'-41' = <u>10 feet</u>