Railway Alignment Design and Geometry

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Topics

- Horizontal and Vertical geometry
- Clearances
- Turnout design
- Structures and loading

REES 2010

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Railroad vs. Highway – Passenger Vehicles

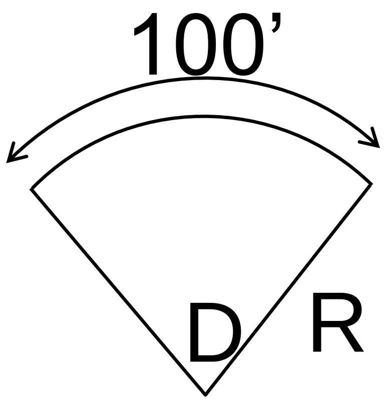
	Passenger Car	Light rail vehicle
Top speed (mph)	65+	65
Weight (tons)	1.4	53.5
Power to weight ratio (hp/ton)	150	9.3
Length (ft)	15	92 (articulated)
# of passengers	5	160
Propulsion method	Gasoline engine	Electric (or diesel-electric)

Railroad vs. Highway – Freight

	Semi-trailer Truck	Freight (Unit) Train
Top speed (mph)	55+	40+
Weight (tons)	40	18,000
Power to weight ratio (hp/ton)	12.5	0.73
Length (ft)	65	7,000
# of power units	1	1-4
# of trailing units	1	Up to 125
Propulsion method	Diesel engine	Diesel-electric

Horizontal Geometry – Degree of Curve

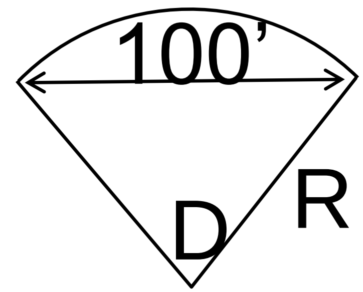
- Arc (Roadway and LRT)
  - Angle measured along the length of a section of curve subtended by a 100’ **arc**



D/360 = 100/2(pi)R

- 1-deg curve, R= 5729.58’
- 7-deg curve, R=818.51’

- Chord (Railroad)
  - Angle measured along the length of a section of curve subtended by a 100’ **chord**



R = 50/sin(D/2)

- 1-deg curve, R=5729.65’
- 7-deg curve, R=819.02’

Curve length difference

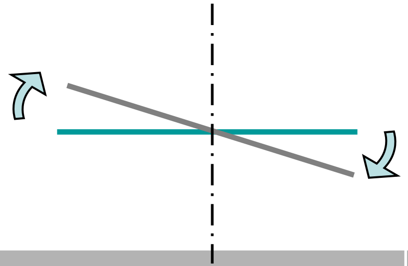
Railway D 100 ft chord	Radius (feet)	Equiv. Hwy D 100 ft arc	Arc length (ft) of a 100 ft chord	% of error longer
1° 00’	5,729.65	0° 59’ 59.95”	100.0013	0.0013 %
3° 00’	1,910.08	2° 59’ 58.77”	100.0114	0.0114 %
6° 00’	955.37	5° 59’ 50.13”	100.0457	0.0457 %
9° 00’	637.27	8° 59’ 26.70”	100.1029	0.1029 %
12° 00’	478.34	11° 58’ 41.09”	100.1830	0.1830 %
16° 00’	359.26	15° 56’ 53.03”	100.3257	0.3257 %
20° 00’	287.94	19° 53’ 55.02”	100.5095	0.5095 %
30° 00’	193.19	29° 39’ 30.52”	101.1515	1.1515 %
40° 00’	146.19	39° 11’ 33.44”	102.0600	2.0600 %
60° 00’	100.00	57° 17’ 44.81”	104.7198	4.7198 %
80° 00’	77.79	73° 39’ 28.92”	108.6100	8.6100 %

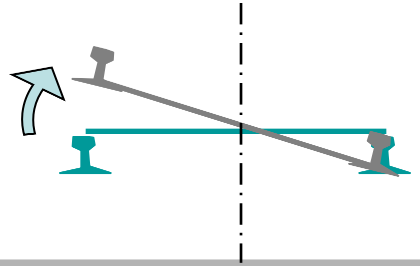
Watch out for LONG and SHARP curves

Horizontal Geometry – Curves

	Highway	Railroad
Criteria	- Design speed	-Design speed -Allowable superelevation
Typical values	Freeway: - 60 mph, R=1,340, D=4.28 - 70 mph, R=2,050, D=2.79	Main lines: -High speed: R > 5,729, D<1 -Typical: R >2,865, D<2 -Low speed: R>1,433, D<4 Industrial facilities: - R>764, D<7.5

Horizontal Geometry – Superelevation



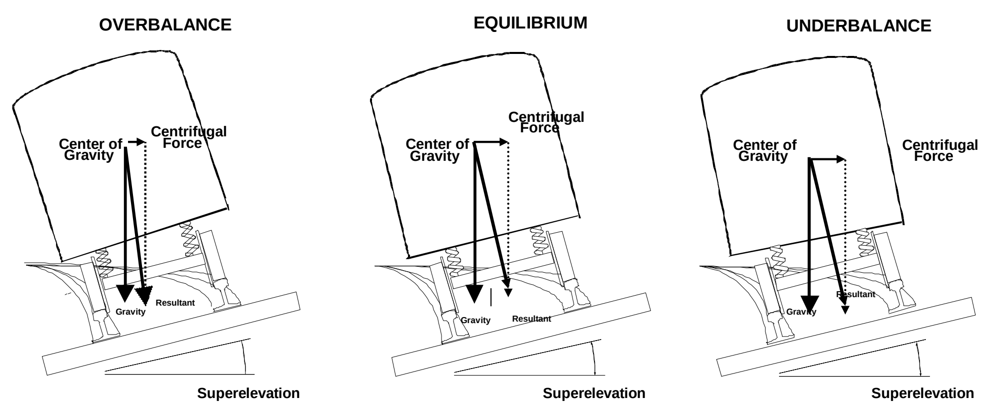


	Highway	Railroad
Expressed by…	"e" expressed as cross-slope in percent	"E" is inches of elevation difference between "high rail" (outside) and "low rail" (inside)
Function of…	Vehicle speed, curve radius and tire side friction $(0.01e + f) / (1 – 0.01ef) = V^2/15R$	Function of design speed, degree of curve $E = 0.0007V^2D – Eu$ Where Eu is unbalance (1-2" typical)
Max. values	6-8%	Freight: 6-7" Light Rail: 6"
Rotation point	Centerline	"Inside rail"
Transition	Runoff (2/3 on tangent, 1/3 in curve)	Spiral

7

Unbalanced Elevation

- Different maximum allowed speeds for different trains on the same track:
  - passenger, express freight, general freight
- Actual elevation on track to balance head and flange wear of both rails



$$V_{\max} = \sqrt{\frac{E_a + 3}{0.0007D}}$$

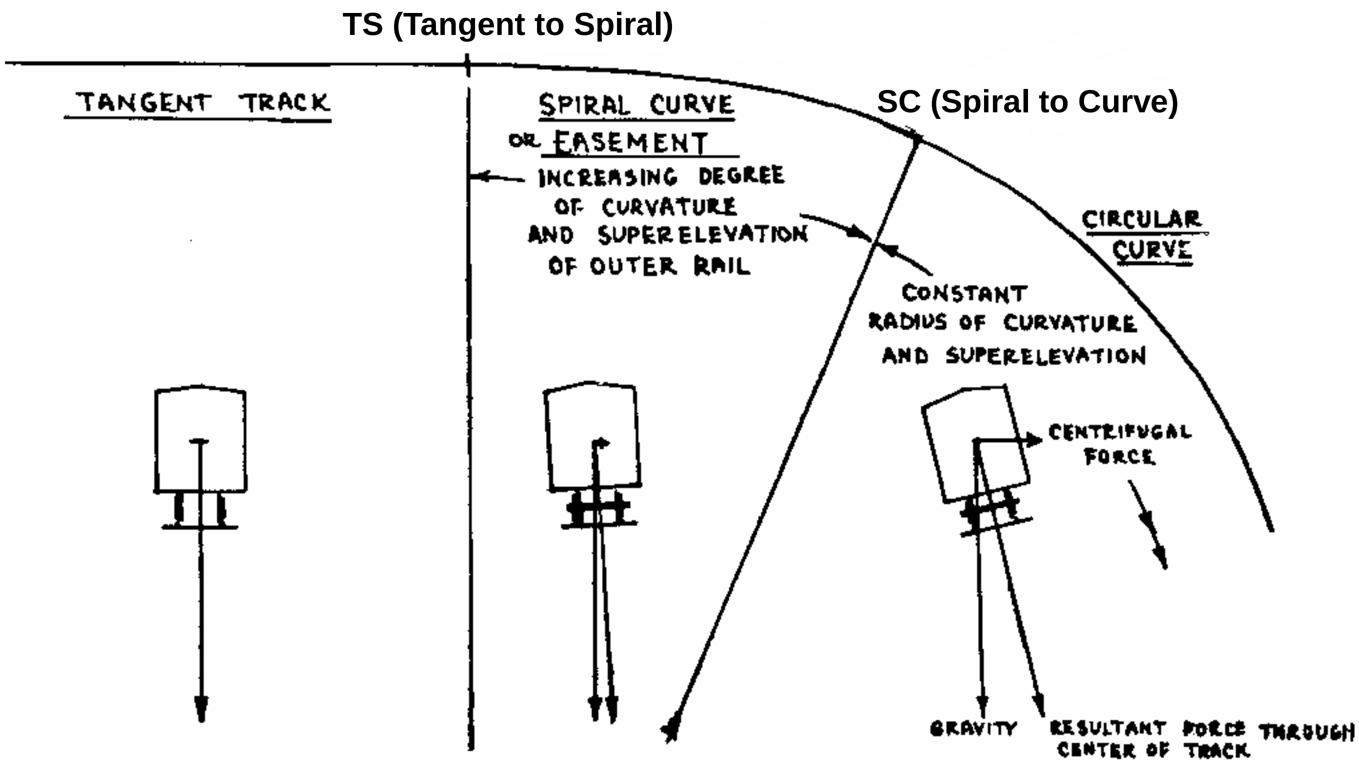
Amount of Underbalance

$V_{\max}$ = Maximum allowable operating speed (mph).

E_a = Average elevation of the outside rail (inches).

D = Degree of curvature (degrees).

Spiral Transition Curves



Railways use the higher length of two formulae:

- To limit unbalanced lateral acceleration acting on passengers to 0.03 g per second:

  $L = 1.63\ E_u\ V$ E_u = unbalanced elevation (in.)

- To limit track twist to 1 inch in 62 feet:

  $L = 62\ E_a$ 9 E_a = actual elevation (in.)

Superelevation Tables

2511

DEGREE OF CURVE — EQUILIBRIUM ELEVATION MINUS 1 ½" OR 2 ½" BASED ON SPEED

INCHES SUBTRACTED	SPEED IN MILES PER HOUR	0°-10'	0°-20'	0°-30'	0°-40'	0°-50'	1°-00'	1°-15'	1°-30'	1°-45'	2°-00'	2°-15'	2°-30'	2°-45'	3°-00'	3°-15'	3°-30'	3°-45'
1½"	10							½	½	½	½	½	½	½	½	½	½	½
1½"	20						½	½	½	½	½	½	½	½	½	½	½	½
1½"	25					½	½	½	½	½	½	½	½	½	½	½	½	½
1½"	30				½	½	½	½	½	½	½	½	½	½	½	½	¾	¾
1½"	35			½	½	½	½	½	½	½	½	½	¾	¾	1	1¼	1½	1¾
1½"	40		½	½	½	½	½	½	½	½	¾	1	1¼	1½	1¾	2¼	2½	2¾
1½"	45	½	½	½	½	½	½	½	¾	1	1¼	1¾	2	2½	2¾	3	3½	3¾
1½"	50	½	½	½	½	½	½	¾	1¼	1½	2	2½	3	3¼	3¾	4¼		
1½"	55	½	½	½	½	½	½	1¼	1¾	2¼	2¾	3¼	3¾	4¼	4¾			
1½"	60	½	½	½	½	½	1	1¾	2¼	3	3½	4¼	4¾					
2½"	65	½	½	½	½	½	½	1¼	2	2¾	3½	4¼	5					
2½"	70	½	½	½	½	½	1	1¾	2¾	3½	4¼							

INCHES SUBTRACTED	SPEED IN MILES PER HOUR	4°-00'	4°-30'	5°-00'	5°-30'	6°-00'	6°-30'	7°-00'	8°-00'	9°-00'	10°-00'	11°-00'	12°-00'	14°-00'	16°-00'	18°-00'	20°-00'
1½"	10	½	½	½	½	½	½	½	½	½	½	½	½	½	½	½	½
1½"	20	½	½	½	½	½	½	½	¾	1	1¼	1½	1¾	2½	3	3½	4
1½"	25	½	½	¾	1	1	1¼	1½	2	2½	2¾	3¼	3¾	4½			
1½"	30	1	1¼	1¾	2	2¼	2½	3	3½	4¼							
1½"	35	2	2½	2¾	3¼	3½	4	4½									
1½"	40	3	3½	4	4½												
1½"	45	4¼															

THE REGIONAL ENGINEER- TRACK WILL USE THIS TABLE TO DETERMINE SUPERELEVATION AND ENTER INTO SCREEN OECV.

FIELD PERSONNEL ARE TO USE SCREEN OECV TO FIND THE SUPERELEVATION REQUIRED FOR A SPECIFIC CURVE.

LIMITS ON SUPERELEVATION FOUND ON THIS PAGE MUST BE OBSERVED.

TABLE BASED ON EQUILIBRIUM ELEVATION MINUS AN UNBALANCE BASED ON SPEED AS FOLLOWS AND ADJUSTED TO NEAREST ¼".
1 ½" UNBALANCED FOR SPEEDS UP TO AND INCLUDING 60 MPH
2 ½" UNBALANCED FOR SPEEDS OF 65 AND 70 MPH

NOTE - $E = 0.0007V^2D$
WHERE E = EQUILIBRIUM ELEVATION IN INCHES

LIMITS ON SUPERELEVATION

1. 5" MAXIMUM SUPERELEVATION ON ANY CURVE.
2. 4 ½" SUPERELEVATION ON CURVES GREATER THAN 3 - 00' WHEN REQUIRED TO MAINTAIN MAXIMUM AUTHORIZED SPEED.
3. 4" SUPERELEVATION ON NON-SIGNALED BRANCH LINES HAVING A MAXIMUM AUTHORIZED SPEED OF 30 MPH OR LESS.
4. 4" SUPERELEVATION ON GRADES WHERE FREIGHT TRAINS REGULARLY OPERATE BELOW 25 MPH.
5. CURVES SHALL BE REGULARLY EXAMINED FOR PREMATURE OR ACCELERATED WEAR ON THE HIGH OR LOW RAIL. A REQUEST FOR A DEVIATION FROM THE STANDARD SUPERELEVATION MUST BE SUBMITTED ON FORM "ELEVATION CHANGE REQUEST" TO CHIEF ENGINEER, MAINTENANCE OF WAY FOR CONCURRENCE.

MINIMUM LENGTH OF SPIRAL

MAXIMUM AUTHORIZED SPEED IN MPH	MINIMUM SPIRAL LENGTH PER ½ INCH OF SUPERELEVATION
NEW CONSTRUCTION AND EXISTING TRACKS WHERE PRACTICAL.	
UP TO 50	31 FEET
55 TO 60	39 FEET
70 TO 80	50 FEET
85 AND 90	55 FEET
EXISTING TRACKS	
UP TO 50	31 FEET
55 TO 80	39 FEET
85 AND UP	50 FEET

CSX TRANSPORTATION

SUPERELEVATION OF CURVES

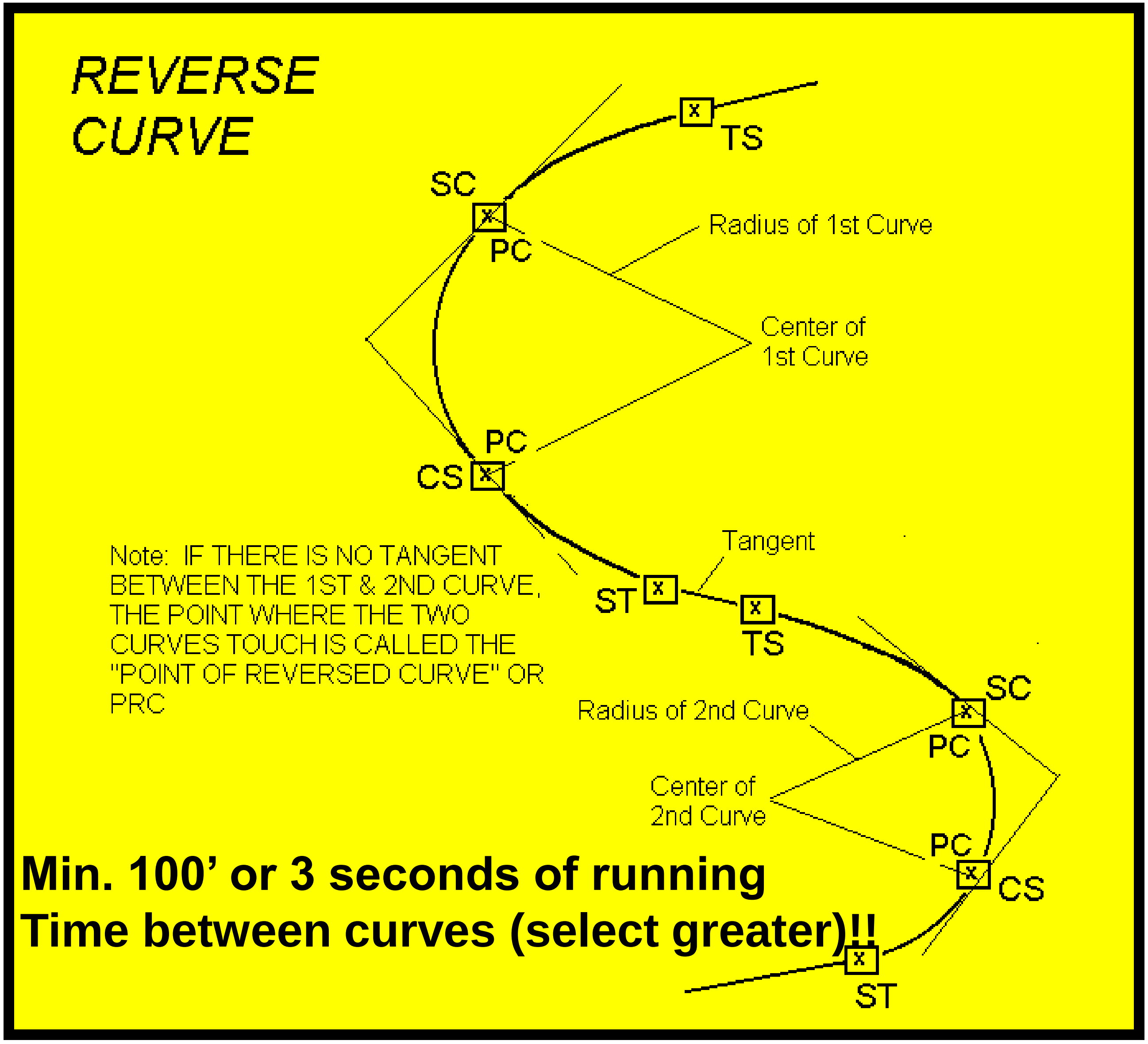
REVIEWED - GENERAL MANAGER ENGINEERING STANDARDS & INDUSTRIAL ENGINEERING

APPROVED - CHIEF ENGINEER MAINTENANCE OF WAY

PREPARED BY, D. N. WITT

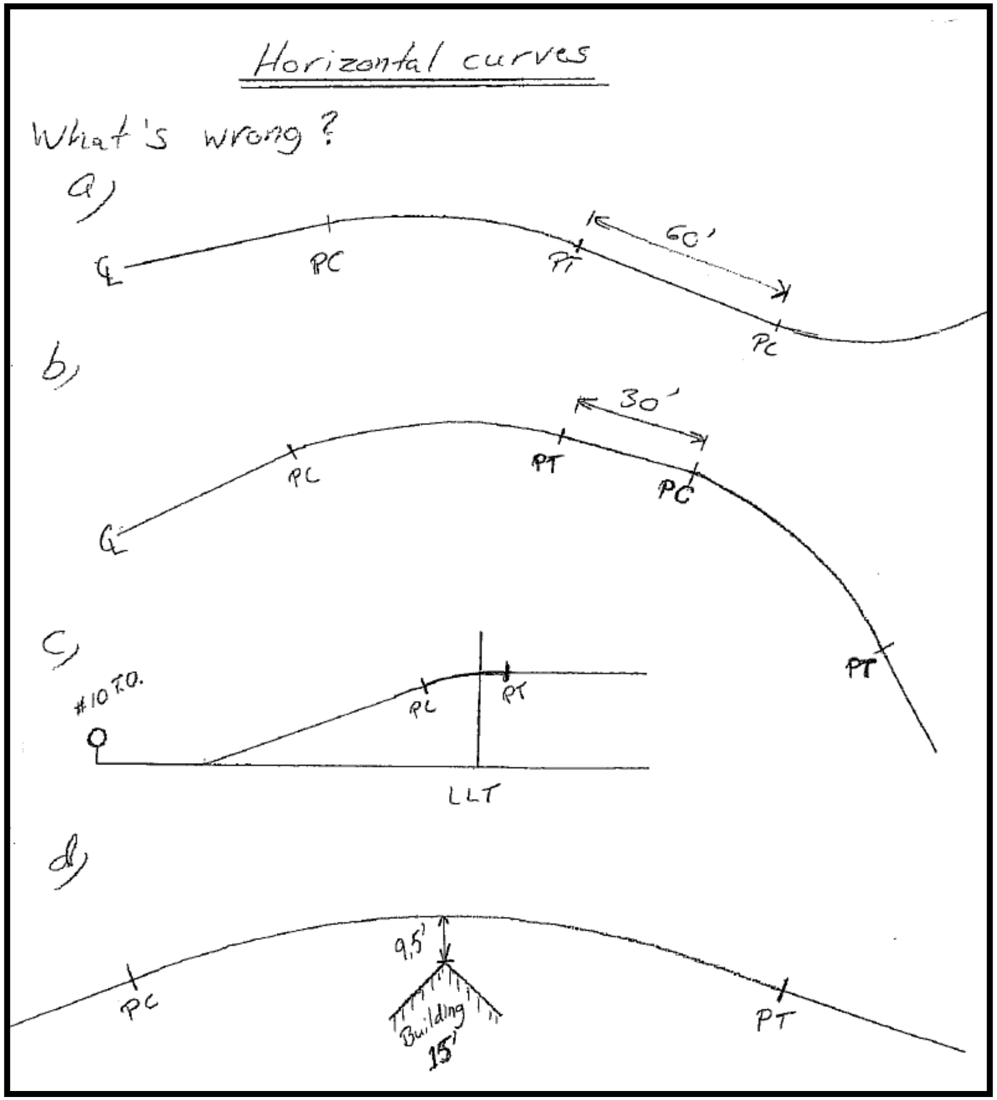
ISSUED, MARCH 24, 1997
REVISED, NOVEMBER 25, 2002

Avoid Reversed Curves



Critical Issues with Horizontal Curves

a) Too short tangent between reversed curves
b) "Broken back" curve
c) Curve within turnout
d) Additional horizontal clearance required



Vertical Geometry - Grades

Rail – rarely exceeds 1%
(2-2.5% for industry lines)

Highway –
4% common
6% on ramps
Up to 8% on
county roads

LRT – maximum 4 to 6%
Up to 10% for short sections

Design Grade for Railways

- Ideal maximum for railway grade:
  - Trains can roll safely down 0.3% grade without wasting energy on brakes
  - <0.1% for tracks for extensive storage
- Railway vertical curves – old formula:

  L = D / R

  D = algebraic difference of grade (ft. per 100-ft. station)

  R = rate of change per 100-ft. station

  - 0.05 ft. per station for crest on main track
  - 0.10 ft. per station for sag on main track
  - Secondary line may be twice those for main line

New Shorter Vertical Curves

- Old railway formula developed in 1880's for "hook and pin" couplers in those days
- Present day couplers can accommodate shorter vertical curves
- New formula developed in recent years:

  $L = 2.15\, V^2\, D / A$

  V = train speed in mph

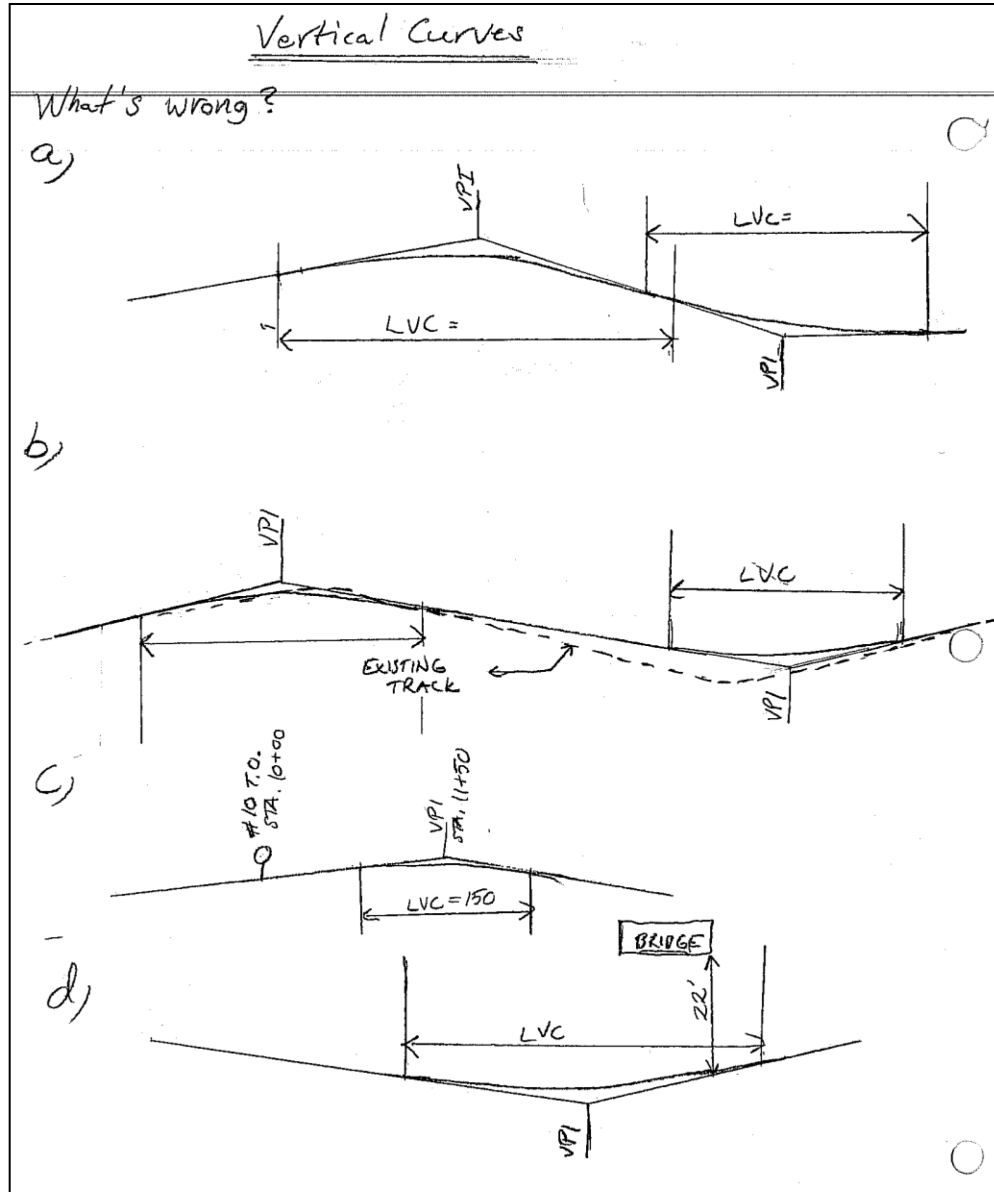
  D = algebraic difference of grade in decimal

  A = vertical acceleration in ft./sec^2

  0.1 ft./ sec^2 for freight, 0.6 ft./ sec^2 for passenger or transit

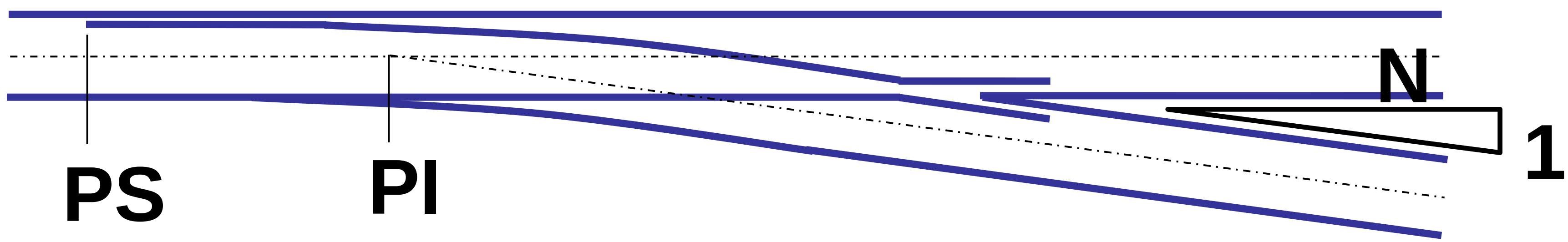
Critical issues with Vertical Curves

a) Overlapping vertical curves
b) Avoid lowering existing tracks
c) No vertical curves within turnouts
d) Provide additional clearance in sag curves
e) No vertical curves within horizontal spirals



Railroad Turnouts

- Allows diverging from one track to another
- Identified by "frog number"

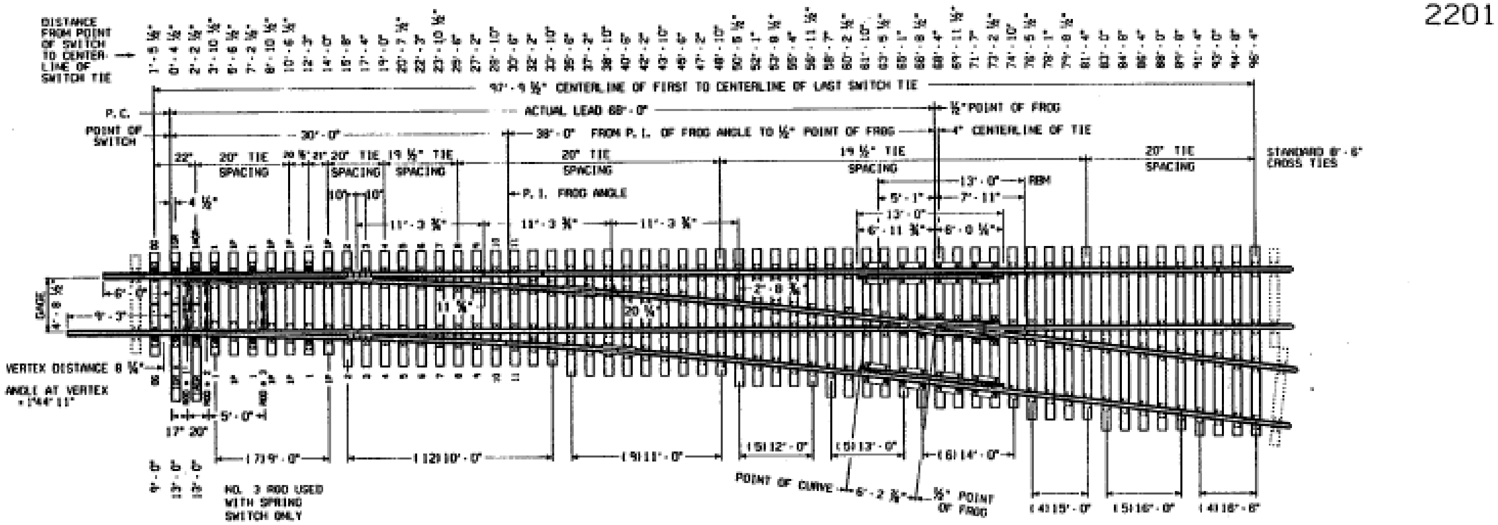


- Typical frog numbers:
  - Mainline No.20 or 24
  - Sidings No.15
  - Yards and Industry No. 11
- Diverging turnout speed ~ 2 x N

#8 RH Turnout

Diagram: Number 8 Turnout and Crossover (2201)

2201



LENGTH OF HEAD BLOCK TIES
13'-0" FOR HAND OPERATED
14'-0" FOR HAND OPERATED WITH CIRCUIT CONTROLLER
14'-0" FOR MACHINE OPERATED
16'-0" FOR SPRING SWITCH

VERTICAL SWITCH RODS SHOWN USE HORIZONTAL RODS AND ADJUSTABLE SIDE JAW CLIPS WITH HAND OPERATED SWITCHES

PLAN OF
RIGHT HAND SWITCH

SWITCH PLATES AND TIE LAYOUT ARRANGED FOR HAND OPERATED SWITCH

WORKMANSHIP AND MATERIALS, INCLUDING BEVELING AND HARDENING RAIL ENDS, SHALL BE PER CURRENT AREA SPECIFICATIONS

SINCE THE ALLOWABLE VARIATION IN STANDARD LENGTHS OF RAILS, FROGS AND SWITCH POINTS IS GREATER THAN THE NORMAL EXPANSION GAPS AT RAIL JOINTS AND THICKNESS OF FIBRE END POST IN INSULATED JOINTS, NO ALLOWANCE HAS BEEN MADE FOR EXPANSION GAPS AND FIBRE END POSTS IN COMPUTING LENGTHS OF RAIL SHOWN.

FOR STRAIGHT AND CURVED CLOSURE RAILS, AND STRAIGHT AND CURVED LEAD RAILS, SEE DRAWINGS 2306 & 2307. IF LONG RAIL SWITCH POINTS ARE USED, SEE DRAWING 2307.

SWITCH HAS ADJUSTABLE PANDROL BOLTLESS BRACES PER DWG. 2317.

RBM FROG USES MILL SEATED PLATES AND WELDED STOP PLATES PER DRAWING 2409.

ALL TIES TO WHICH AN ANCHOR CAN BE APPLIED WILL BE BOX ANCHORED ON BOTH THE THROUGH TRACK AND DIVERGING TRACK, AND FOR A DISTANCE OF 234 FEET IN EACH DIRECTION. DO NOT PLACE ANCHORS WHERE THEY MAY INTERFERE WITH MOVING PARTS.

BILL OF TRACK MATERIAL	
QUANTITY	DESCRIPTION
1	NO. 8 RAILBOUND MANGANESE STEEL FROG, COMPLETE, PER DRAWING 2401.
2	GUARD RAILS, COMPLETE, WITH A 7'-0" MINIMUM STRAIGHT GUARDING FACE FOR USE WITH RBM FROG.
1	39'-0" STRAIGHT STOCK RAIL PER DRAWING 2307
1	39'-0" BENT STOCK RAIL, PER DRAWING 2307
1	16'-6" STRAIGHT SPLIT SWITCH, COMPLETE, WITH UNIFORM RISERS, PER DRAWINGS 2302, 2307, 2310 2311, 2314, 2315, 2316, & 2317
118	TIE PLATES
8	KEGS, TRACK SPIKES, 100 POUND KEGS
10	JOINTS, COMPLETE
2	INSULATED JOINTS, COMPLETE IF REQUIRED
256	ANCHORS
12	PANDROL CLIPS, REGULAR
26	SCREW SPIKES

TURNOUT DATA		
		RBM
FROG	NUMBER	8
FROG	TOTAL LENGTH	13'-0"
FROG	TOE LENGTH	5'-1"
FROG	HEEL LENGTH	7'-11"
FROG	TOE SPREAD	7 ⅝"
FROG	HEEL SPREAD	12 ⅜"
FROG	ANGLE	7°-9'-10"
SWITCH	LENGTH OF SWITCH POINT	16'-6"
SWITCH	HEEL SPREAD	6 ¼"
SWITCH	SWITCH ANGLE	1°-44'-11"
SWITCH	THICKNESS OF POINT	¼"
SWITCH	VERTEX DISTANCE	8 ¾"
ACTUAL LEAD		68'-0"
RADIUS OF CENTERLINE		462.73
DEGREE OF CURVE		12°-24'-23"
½" PT. TO PT. OF CURVE		6'-2 ⅜"
STRAIGHT CLOSURE LENGTH		46'-5"
CURVED CLOSURE LENGTH		46'-7 ⅞"

BILL OF SWITCH TIES			
LENGTH	TURNOUT ONLY	CROSSOVER 14'-0"	CROSSOVER 15'-0"
9'-0"	8	16	16
10'-0"	12	24	24
11'-0"	9	18	18
12'-0"	5	10	10
13'-0"*	7	14	14
14'-0"	6	18	12
14'-0" (Dapped)*	0	0	0
15'-0"	4	8	8
16'-0"	5	0	9
16'-6"	4	0	0
TOTAL NO.	60	108	113
BOARD MEAS.	3043	6594	7044.5

ALL SWITCH TIES ARE 7" X 9"

* ADJUST THE NUMBER OF 13'-0" TIES IF LAYOUT REQUIRES THE USE OF 14'-0", 14'-0" DAPPED, OR 16'-0" HEAD BLOCK TIES.

CSX TRANSPORTATION

NUMBER 8 TURNOUT AND CROSSOVER
RAILBOUND MANGANESE FROG
FOR 115RE, 122CB, 132RE, AND 136RE RAIL

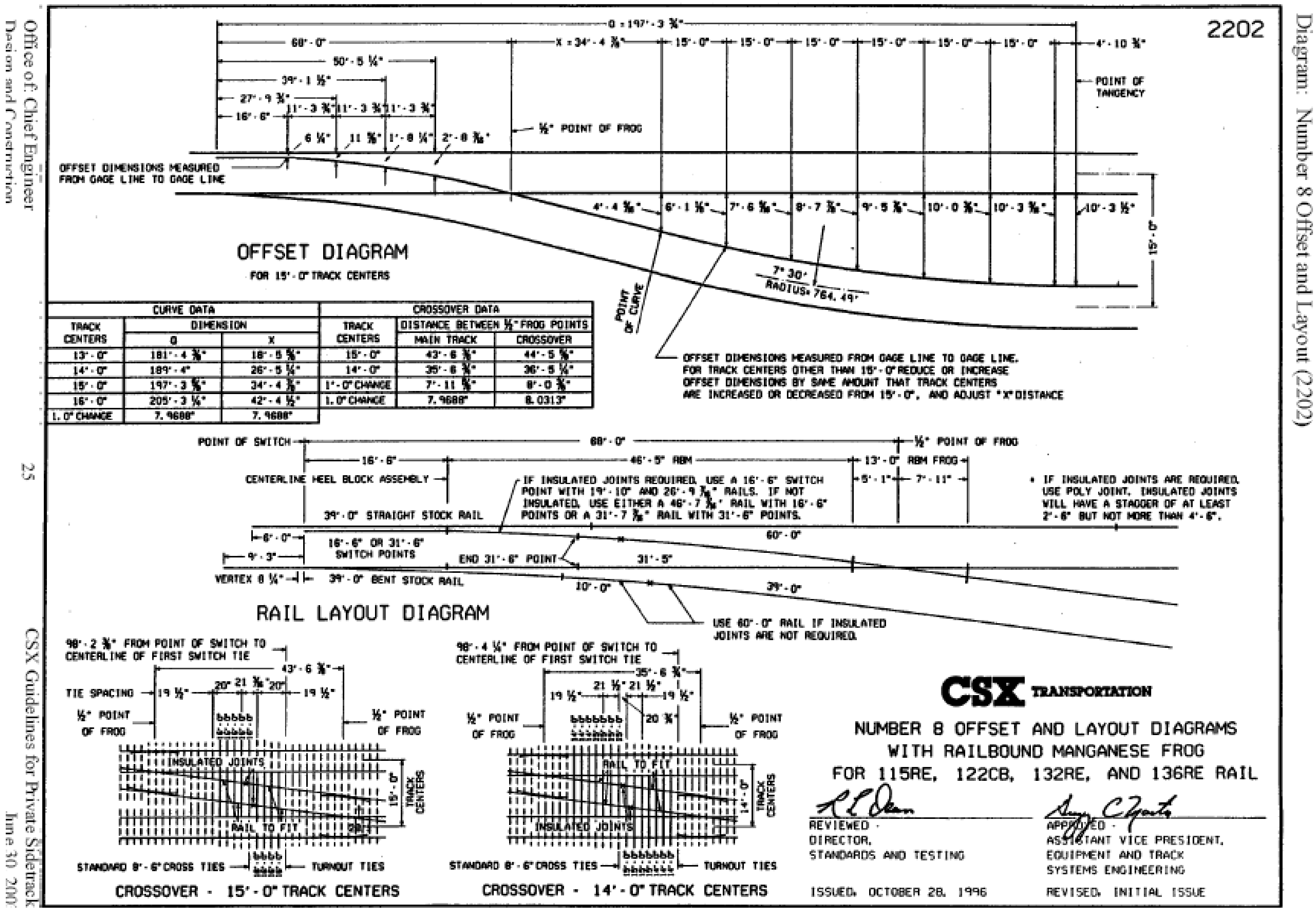
REVIEWED -
DIRECTOR,
STANDARDS AND TESTING

APPROVED -
ASSISTANT VICE PRESIDENT,
EQUIPMENT AND TRACK
SYSTEMS ENGINEERING

ISSUED: JUNE 14, 1996

REVISED:

#8 – Offsets & layout



CURVE DATA

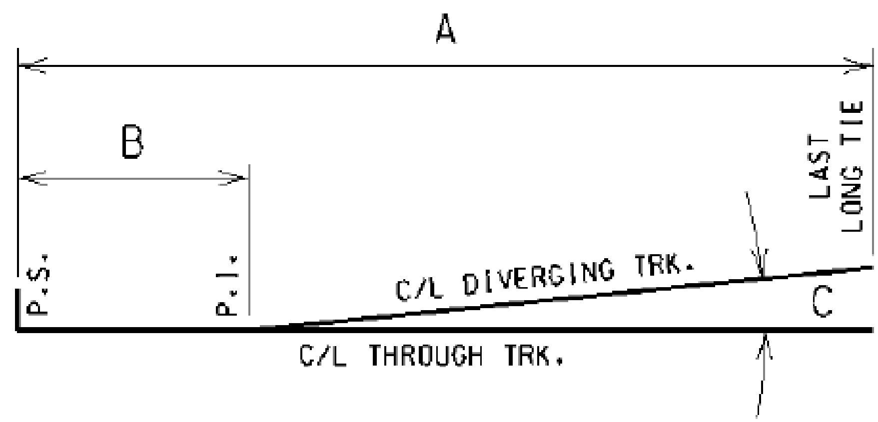
TRACK CENTERS	DIMENSION Q	DIMENSION X
13'-0"	181'-4 ⅜"	18'-5 ⅝"
14'-0"	189'-4"	26'-5 ¼"
15'-0"	197'-3 ⅝"	34'-4 ⅜"
16'-0"	205'-3 ¼"	42'-4 ½"
1.0" CHANGE	7.9688"	7.9688"

CROSSOVER DATA

TRACK CENTERS	DISTANCE BETWEEN ½" FROG POINTS: MAIN TRACK	DISTANCE BETWEEN ½" FROG POINTS: CROSSOVER
15'-0"	43'-6 ⅜"	44'-5 ⅝"
14'-0"	35'-6 ⅜"	36'-5 ¼"
1'-0" CHANGE	7'-11 ⅝"	8'-0 ⅜"
1.0" CHANGE	7.9688"	8.0313"

Designing a Turnout in Plans

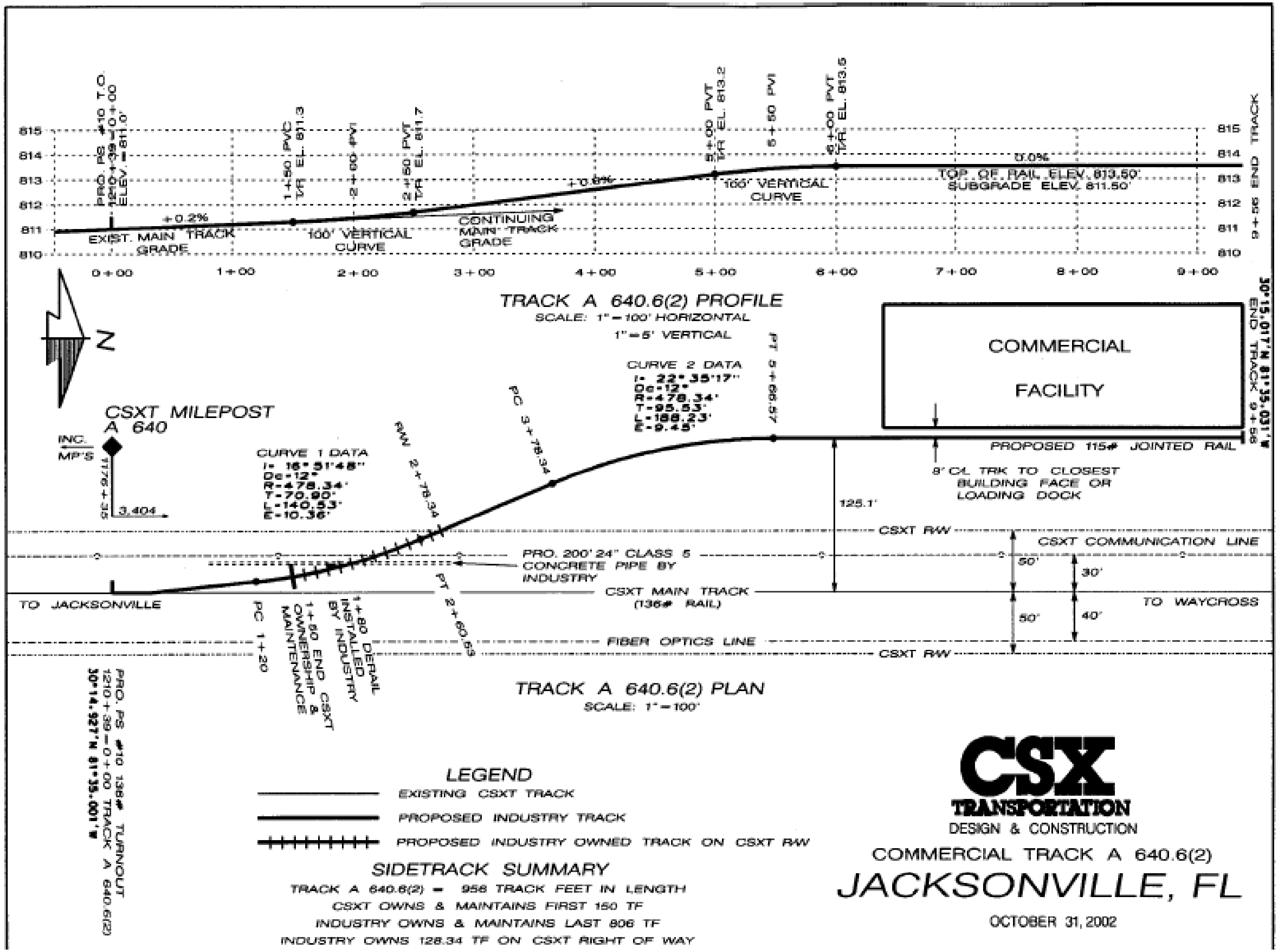
- Need to know:
  - PS to PI length (B)
  - Angle (C)
  - PS to LLT (A)
- Draw centerline of each track
- Good to mark PS & LLT
  - No curves and/or adjacent turnouts between PS and LLT



T.O.	A	B	C
#8	97′	30.00′	7°09′10″
#10	116′	31.25′	5°43′29″

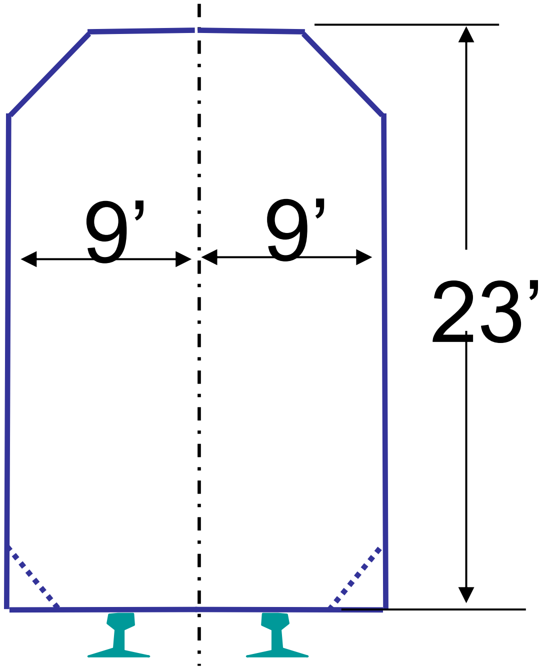
Legend:
PS = Point of Switch
PI = Point of intersection
LLT = Last long tie
Angle C = Turnout angle

Basic Plan Sheet for Track Design



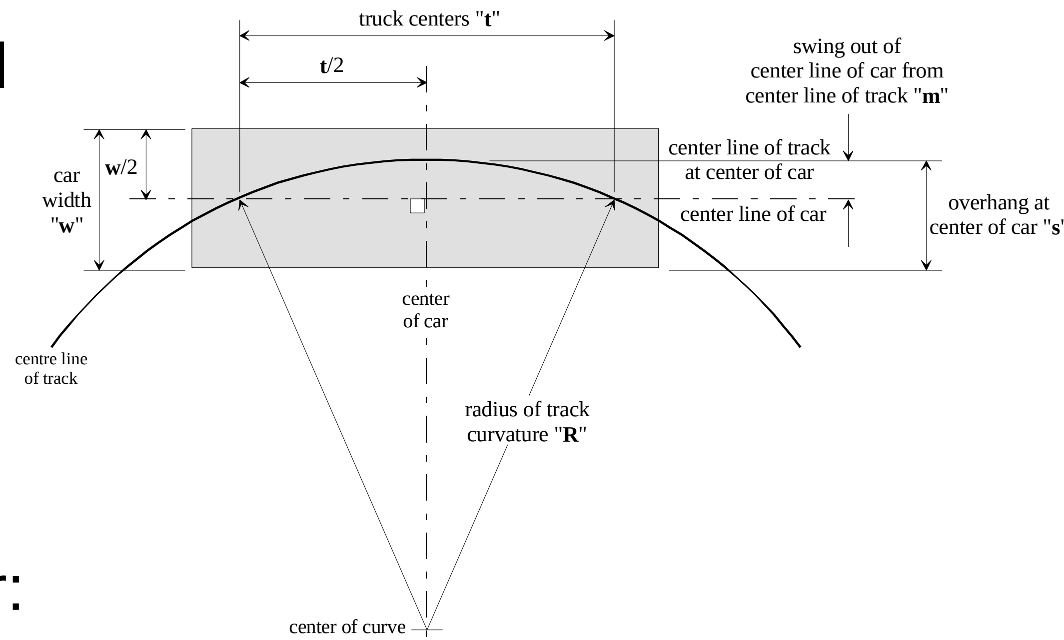
Track Clearances

- Specific clearances necessary for safe operations
- Size of car clearance envelope is based on dimensions of:
  - Locomotives
  - Cars
  - Potential large loads
- Requirements set by several agencies

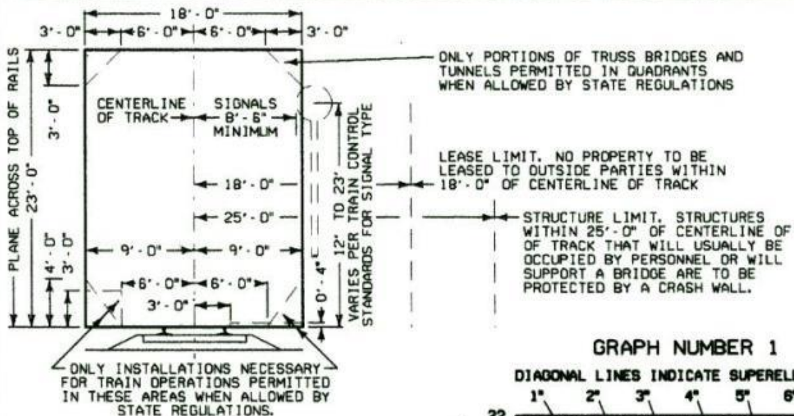


Horizontal Clearance

- Constant on tangent track
- Additional clearance:
  - In curves for car end swing and car overhang
  - In superelevated tracks to provide room for cant
- Use clearance chart (next page) to define horizontal clearance for:
  - Main track
  - 5.5 degree curve
  - 2 inch superelevation
  - 10 feet high object

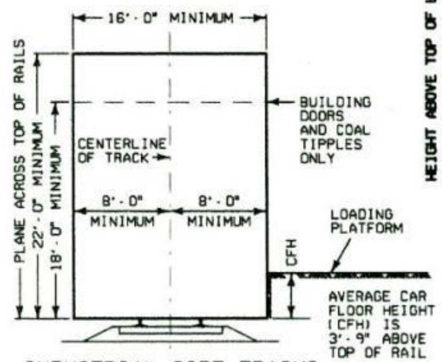


Clearance Chart



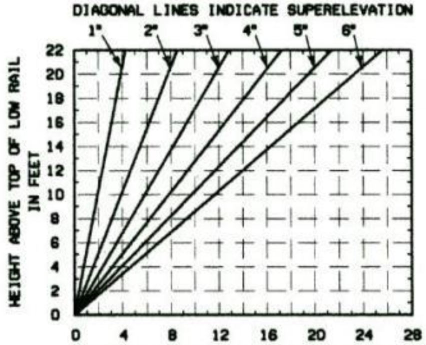
GENERAL

MAIN TRACKS, YARD TRACKS AND SIDINGS



INDUSTRIAL SIDE TRACKS

GRAPH NUMBER 1



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1. STANDARD CLEARANCES ARE TO BE USED FOR ALL NEW CONSTRUCTION WHERE THERE ARE NO LEGAL REQUIREMENTS THAT DICTATE GREATER CLEARANCES.
2. CLEARANCES FOR RECONSTRUCTION, REHABILITATION AND ALTERATION WORK ARE DEPENDENT ON EXISTING PHYSICAL CONDITIONS. WHERE POSSIBLE, THEY WILL BE IMPROVED TO COMPLY WITH THE STANDARD CLEARANCES.
3. STATE OR CANADIAN CLEARANCE LAWS MUST NOT BE VIOLATED. LEGAL REQUIRMENTS MAY BE MODIFIED ONLY BY THE GOVERNMENTAL BODY THAT ISSUED THEM.
4. STANDARD CLEARANCE MAY BE MODIFIED ONLY IF APPROVED BY THE CHIEF ENGINEER D & C.
5. STANDARD CLEARANCE DIAGRAMS SHOWN ARE FOR TANGENT TRACK AND INCREASES MUST BE BE PROVIDED FOR THE EFFECTS OF CURVATURE AND SUPERELEVATION.
   A. ADDITIONAL CLEARANCE DUE TO CURVATURE.
      WHEN A FIXED OBSTRUCTION IS LOCATED ADJACENT TO A CURVED TRACK, THE HORIZONTAL CLEARANCE WILL BE INCREASED 1 ½ INCHES PER DEGREE OF CURVATURE ON BOTH SIDES OF THE TRACK CENTERLINE PER TABLE 1. EXCEPTION: FLORIDA REQUIRES 2 INCHES PER DEGREE.
   B. ADDITIONAL CLEARANCE DUE TO SUPERELEVATION.
      WHEN A FIXED OBSTRUCTION IS LOCATED ADJACENT TO A SUPERELEVATED TRACK, THE HORIZONTAL CLEARANCE ON THE LOW RAIL SIDE OF THE TRACK WILL BE INCREASED TO ALLOW FOR TILT. THE MINIMUM INCREASE IS SHOWN ON GRAPH NO. 1.
   C. ADDITIONAL CLEARANCE DUE TO CURVATURE AND SUPERELEVATION.
      WHEN A FIXED OBSTRUCTION IS LOCATED ADJACENT TO A CURVED AND SUPERELEVATED TRACK, THE HORIZONTAL CLEARANCE INCREASE WILL BE THE SUM OF THE INCREASES OBTAINED USING 5.A AND 5.B ABOVE. EXCEPTION: CANADA REQUIRES A MINIMUM OF 2 INCHES PER DEGREE.
   D. ADDITIONAL CLEARANCE ON TANGENT TRACKS.
      WHEN A FIXED OBSTRUCTION IS ADJACENT TO TANGENT TRACK BUT THE TRACK IS CURVED WITHIN 80 FEET OF THE OBSTRUCTION, THE HORIZONTAL CLEARANCE WILL BE INCREASED AS FOLLOWS:

DISTANCE FROM OBSTRUCTION TO CURVED TRACK - FEET	INCREASED HORIZONTAL CLEARANCE
0 TO 20	100% OF PARAGRAPH 5.C
21 TO 40	75% OF PARAGRAPH 5.C
41 TO 60	50% OF PARAGRAPH 5.C
61 TO 80	25% OF PARAGRAPH 5.C

6. VERTICAL CLEARANCE ON SUPERELEVATED TRACK IS MEASURED FROM THE TOP OF THE HIGH RAIL.

CSX TRANSPORTATION

CLEARANCE DIAGRAMS

SIGNED	SIGNED
REVIEWED - DIRECTOR, STANDARDS AND TESTING	APPROVED - ASSISTANT VICE PRESIDENT, EQUIPMENT AND TRACK SYSTEMS ENGINEERING
ISSUED: JULY 19, 1996	REVISED: INITIAL ISSUE

TABLE NUMBER 1

ADDITIONAL CLEARANCE REQUIRED DUE TO CURVATURE - IN INCHES

DEGREE OF CURVE	1	2	3	4	5	6	7	8	9	10	11	12
ALL LOCATIONS EXCEPT FLORIDA	1 ½	3	4 ½	6	7 ½	9	10 ½	12	13 ½	15	16 ½	18
IN THE STATE OF FLORIDA	2	4	6	8	10	12	14	16	18	20	22	24

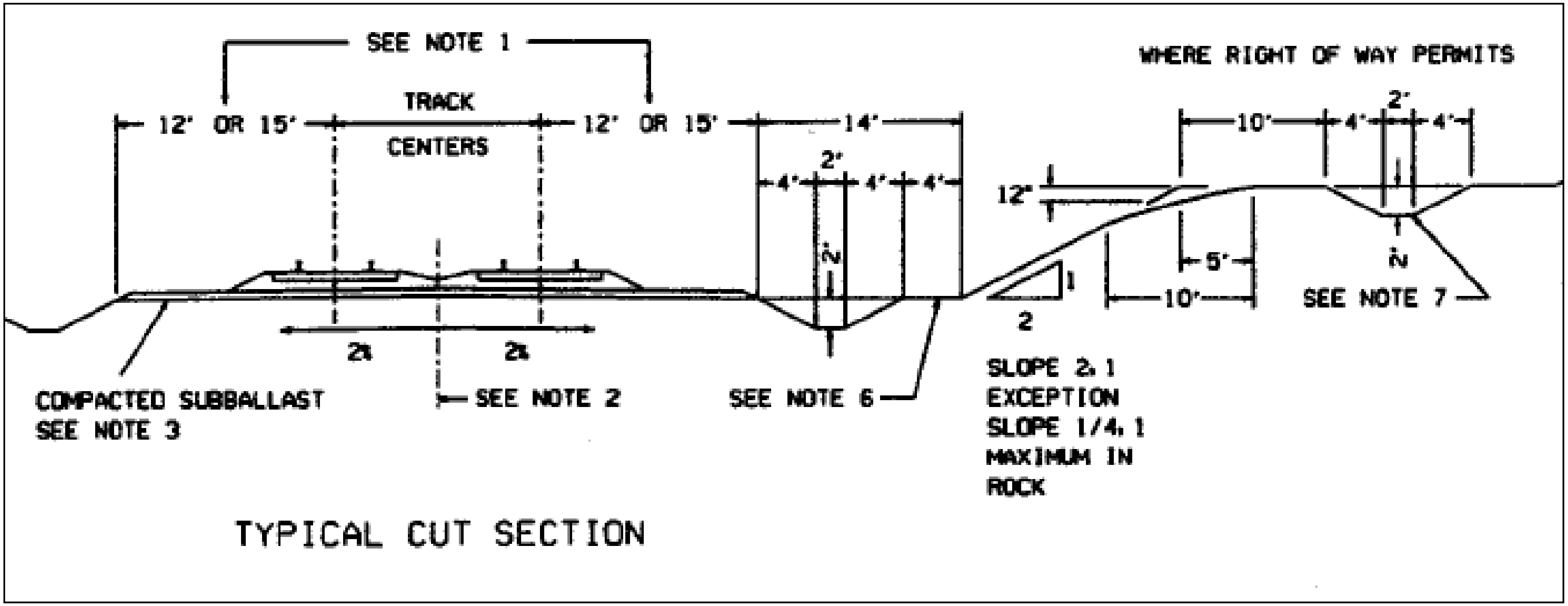
Vertical Clearance

- Constant on tangent track
- Additional clearance:
  - In sag vertical curves
  - In superelevated tracks
  - For specialized equipment (double-deck cars)
  - To provide threshold for future track maintenance and equipment changes

Typical Section - Railroad

- Subgrade top width of 24’ to 30’ for single track

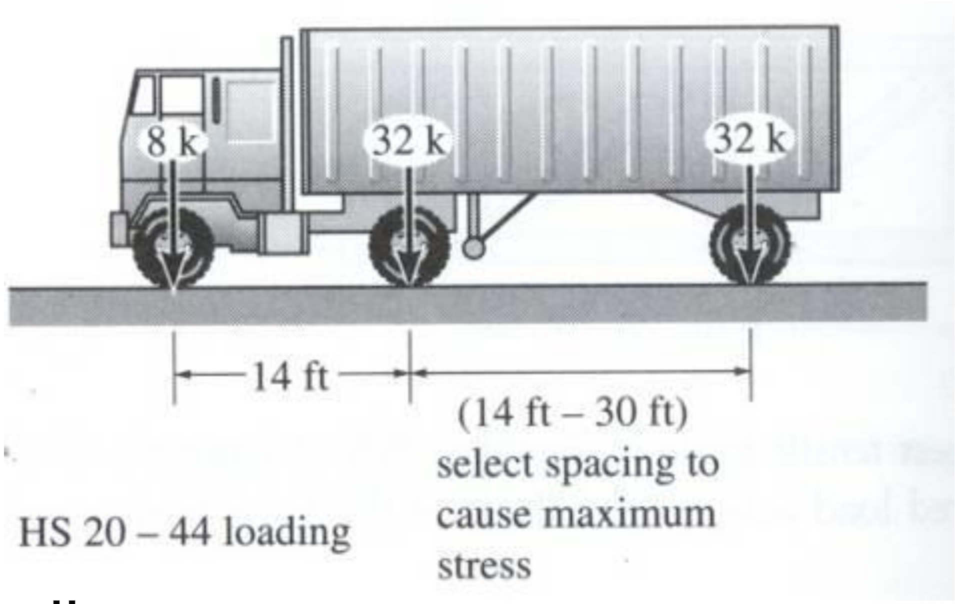
Typical section - multiple tracks



- Track centerlines minimum 13' apart
- Roadbed sloped to drain
- Sometimes wider shoulders for maintenance purposes

Bridge Loading - Highway

- HS-20 truck loading

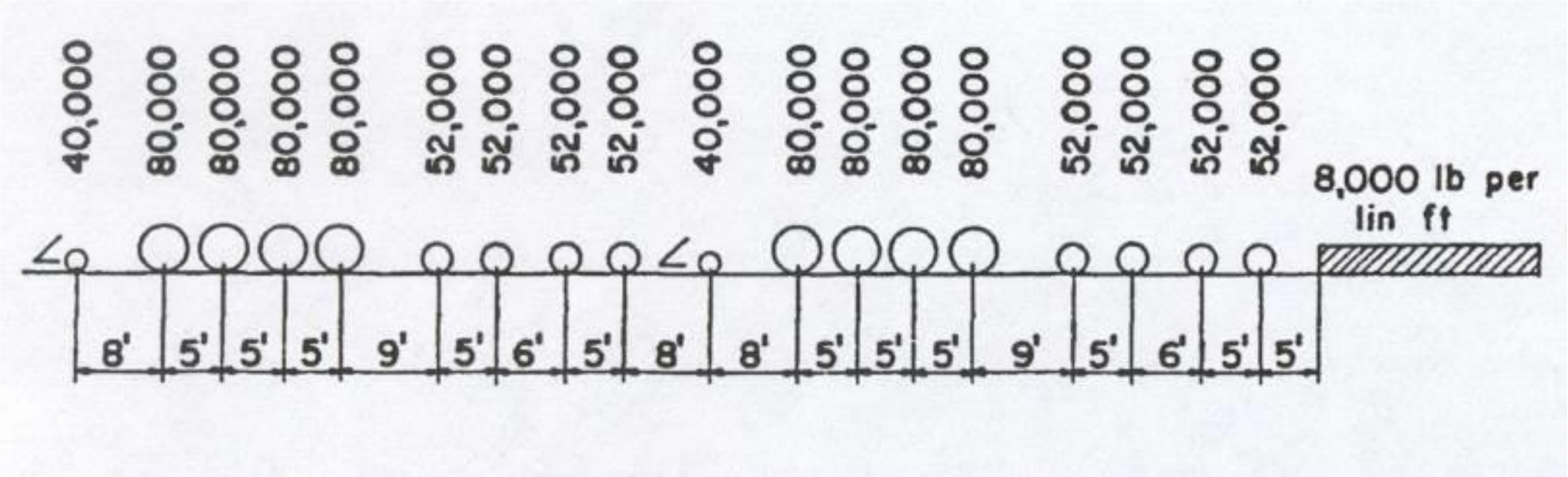


- Impact Loading

$$I = 50 / (L + 125) \text{ but } I < 0.3$$

Bridge Loading - Railroad

- Cooper E-80 railroad loading



- Developed in 1890s
- “80” refers to 80kip driving axle load on steam locomotive

Bridge Loading – Railroad (cont.)

- Impact Loading
  - The following percentages of Live Load, applied at the top of rail and added to the axle loads (E-80 Loading)

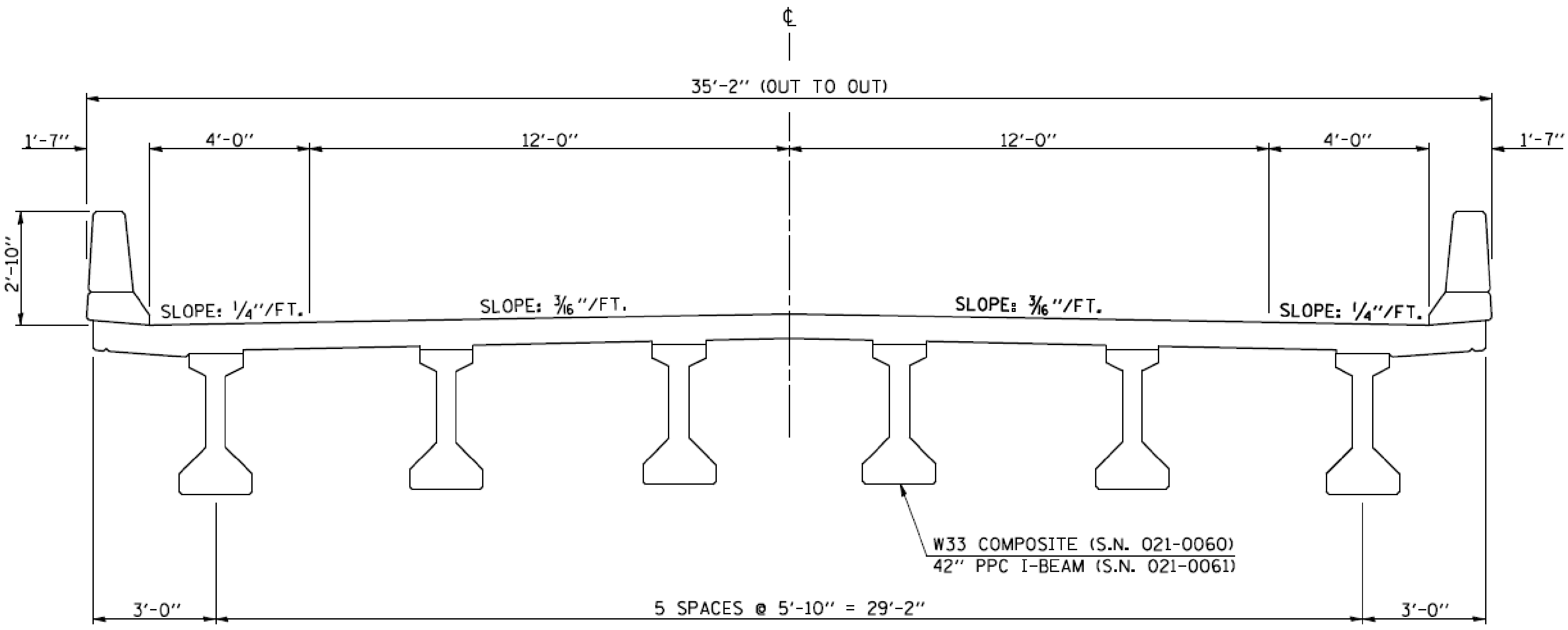
$$\text{For } L \leq 14 \text{ ft:} \quad I = 60$$

$$\text{For } 14 \text{ ft} < L \leq 127 \text{ ft:} \quad I = 225/\sqrt{L}$$

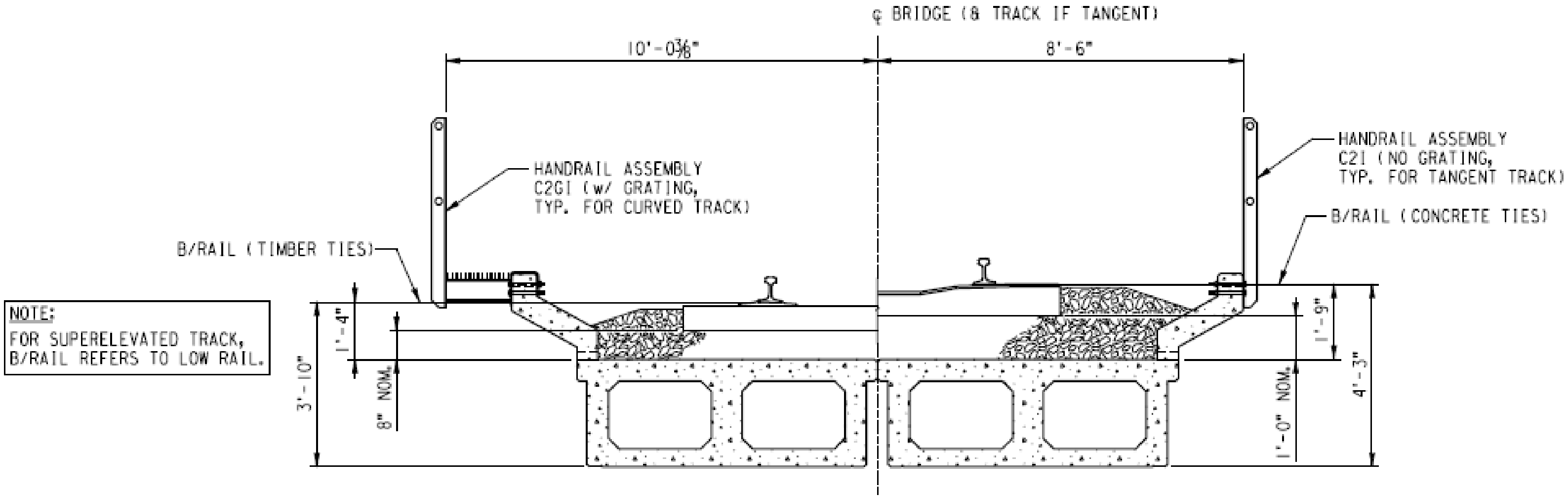
$$\text{For } L > 127 \text{ ft:} \quad I = 20$$

L = Span Length in ft

Typical Section – Roadway Superstructure

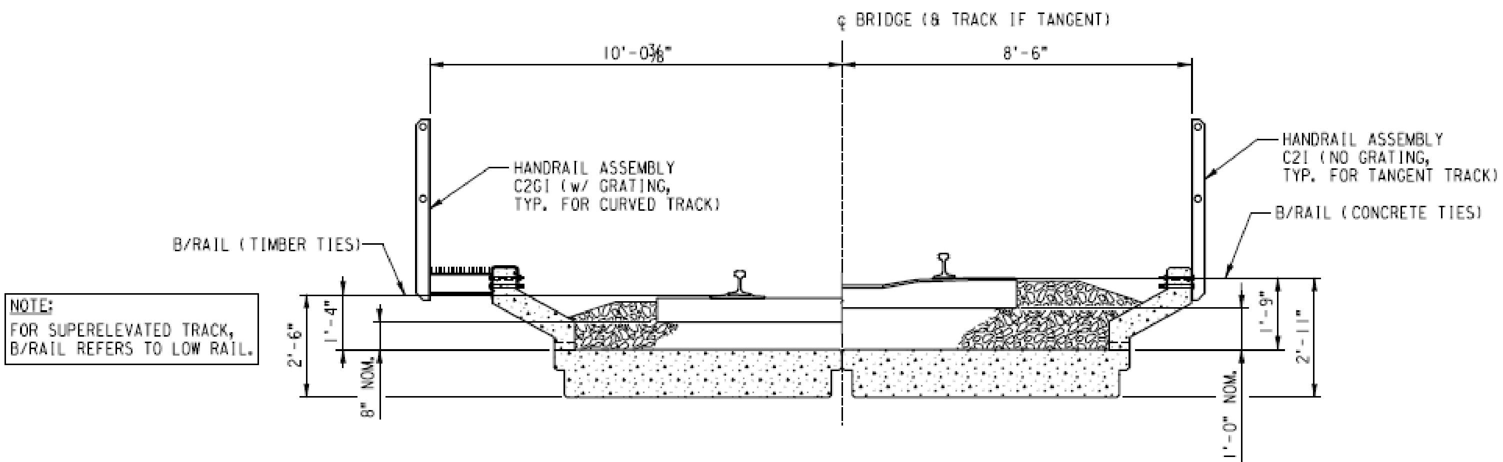


Typical Section – Railroad Concrete Superstructure



TYPICAL SECTION WITH TRACK

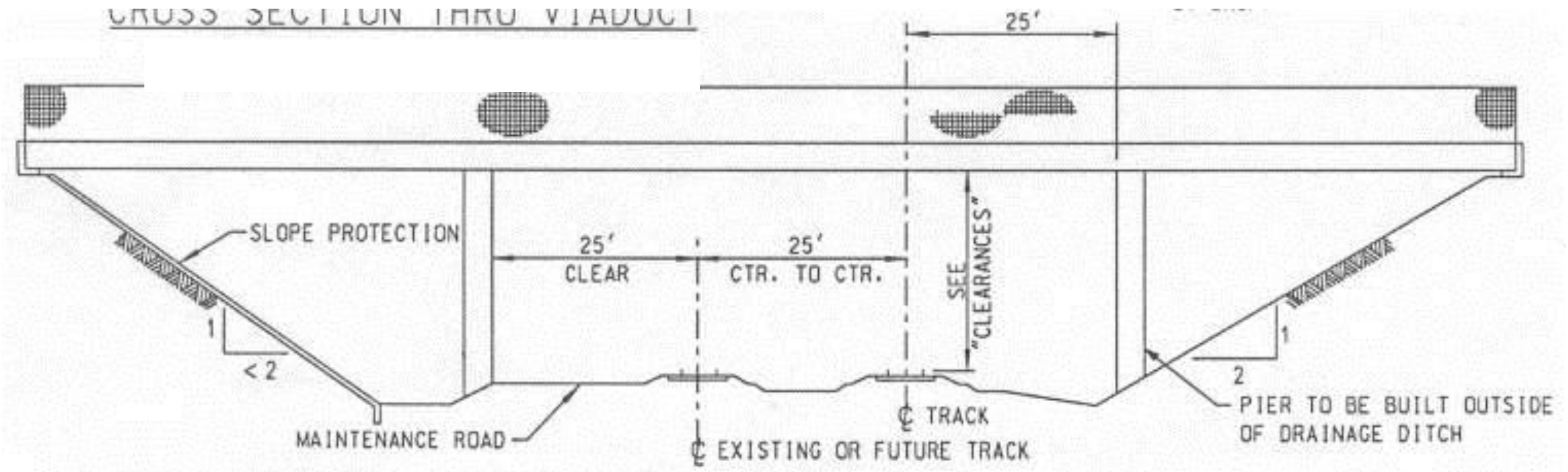
SCALE: ⅜"=1'-0"



TYPICAL SECTION WITH TRACK

SCALE: ⅜"=1'-0"

Grade Separations – Road over Rail



- 23' vertical clearance, plus future track raise
- Allow for maintenance road and future second track
- Collision protection for piers within 25' of rail centerline
- Do not drain roadway on to tracks!
- Other details vary by specific railroad

Grade Separations – Rail over Road

- Steel preferred structure type as it can be repaired
- Concrete bridges - “sacrificial beam” or “crash beam”
- Depth of structure increases rapidly with span length under railroad loading
  - Decreases clearance or increase required railroad fill
  - Need to minimize skew and span lengths

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