ENGINEER MANUAL

EM 1110-3-152
April 1984

ENGINEERING AND DESIGN

RAILROADS

MOBILIZATION CONSTRUCTION

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
OFFICE OF THE CHIEF OF ENGINEERS

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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314

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Engineer Manual
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Engineering and Design
RAILROADS
Mobilization Construction

1. Purpose. This manual provides guidance for the design and construction of railroad facilities at U.S. Army mobilization installations.

2. Applicability. This manual is applicable to all field operating activities having mobilization construction responsibilities.

3. Discussion. Criteria and standards presented herein apply to construction considered crucial to a mobilization effort. These requirements may be altered when necessary to satisfy special conditions on the basis of good engineering practice consistent with the nature of the construction. Design and construction of mobilization facilities must be completed within 180 days from the date notice to proceed is given with the projected life expectancy of five years. Hence, rapid construction of a facility should be reflected in its design. Time-consuming methods and procedures, normally preferred over quicker methods for better quality, should be de-emphasized. Lesser grade materials should be substituted for higher grade materials when the lesser grade materials would provide satisfactory service and when use of higher grade materials would extend construction time. Work items not immediately necessary for the adequate functioning of the facility should be deferred until such time as they can be completed without delaying the mobilization effort.

FOR THE COMMANDER:

PAUL F. KAVANAUGH
Colonel, Corps of Engineers
Chief of Staff

DEPARTMENT OF THE ARMY
U. S. Army Corps of Engineers
Washington, D.C. 20134

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CHAPTER 1

GENERAL

1-1. Purpose and scope. This manual provides guidance for design and construction of railroad facilities at Army mobilization installations.

1-2. Basis of design. The AREA Manual for Railway Engineering forms the basis for design. For work not specifically covered in this manual, the recommended practice of AREA or of the serving railroad will be used.

1-3. Description.

a. Railroad connections. Railroad connections include the turnouts from the serving railroad and all track to their right-of-way line.

b. Auxiliary tracks. Auxiliary tracks used by the serving railroad include passing sidings, setout or interchange tracks, and wyes.

c. Access line. Where the project is not adjacent to the serving railroad, the access line is the track between right-of-way of the serving railroad and the facilities to be served.

d. Tracks for delivery of construction materials. Delivery tracks for construction materials should be provided by the contractor or serving railroad unless the tracks later become a part of the project trackage. The construction of project trackage during the early phases of project construction will expedite delivery of construction materials for other phases of the project.

e. Project trackage. Project trackage includes all tracks, other than those listed above, within the project.

1-4. Design procedure. Maximum curvatures and grades will not exceed those discussed in chapter 3.

1-5. State regulations. Design will conform with regulations of state commissions and regulatory bodies for public highway crossings.

CHAPTER 2

TRACK DESIGN

2-1. Track layouts. Track layouts should allow the movement to be continuous from the interchange yard through the classification yard to the delivery tracks. Each interchange or receiving track should hold the maximum single delivery. The length of classification tracks is determined by the average number of cars in each classification.

2-2. Rail.

a. Function. The function of railroad rail is to provide a smooth, hard rolling surface for railroad rolling stock; to transmit the loading of the rolling stock wheels to the ties; to provide beam strength and stiffness to minimize deflections due to the passage of railroad rolling stock; and to resist lateral loads of railroad rolling stock to maintain gage (distance between the rails).

b. Length. The standard length of rail is 39 feet. Rails are also available in 33 and 78 foot lengths.

c. Type. Rail can be new or relayer (used). New rail is preferred for new construction. However, relayer rail in good condition can be used in many instances especially when new rail may be scarce.

(1) New rail. Two types of new rail are recommended for use: 90-pound ARA-A or 115-pound AREA. The heavier section will be used for main lines and access tracks where rail traffic is heavy and design train speeds are more than 40 miles per hour. Ninety-pound ARA-A sections will be used for yard, industrial, and storage sidings and running and access tracks which do not justify 115-pound rail. If either of the above rail weights are not available, heavier rail sections may be substituted, using the 90-pound and 115-pound sections as minimum weights for the services described above.

(2) Relayer rail. The selection of relayer rail will be based on the predicted rail traffic and design train speed. Relayer rail 115-pound or heavier in good condition may be substituted for new 115-pound rail for tracks bearing heavy rail traffic or tracks with design train speeds in excess of 40 miles per hour if new rail is not available for that service. For service where new 90-pound ARA-A rail is specified, 85-pound or heavier relayer sections may be substituted provided the relayer rail is in good condition. Relayer rail will be of the same section throughout the project for each service listed in paragraph 2-2c(1). Rail sections will be drilled for 6-hole, 36-inch AREA angle bars except that rail sections below 115-pound may be drilled for 4-hole, 24-inch AREA angle bars, or other 24-inch angle bars appropriate for the selected rail section. Drilling patterns will

be the same for all rail of the same section. If both new and relayer rail are used, provide for the preferential use of new rail on main lines, access tracks and running tracks. New and relayer rail should not be intermixed. If possible, each separate track should be laid with either all-new or all-relayer rails.

d. Continuous welded rail. This type of construction should not be considered for use on an Army railroad unless the line under construction is to become part of a continuing transportation system.

2-3. Wood ties. The functions of ties are to secure the two lines of rail in the transverse direction, to interact with the ballast to anchor the track against lateral, longitudinal and vertical movement, and to distribute the wheel load from the rails to the ballast. Railway track ties most widely used are made of treated wood, usually oak, gum, pine, or fir. Ties made from hardwood trees are preferable but other wood ties may be used if necessary. Ties should consist of heartwood since this part of the tree has more desirable characteristics for railroad ties. Tie life depends on the species of wood, treatment, mechanical protection, severity of usage, and climate. Hardwood ties should be provided with antisplitting devices in each end to maintain the structural integrity of the ties. Wood crossties should be prebored for spikes and adzed prior to treatment since cutting or drilling of the wood after treatment will expose untreated surfaces to decay. Seven inch by 9 inch by 8-foot 6-inch crossties are recommended for most Army applications.

2-4. Rail accessories.

a. Joint bars. Joint bars are used to join abutting rail sections together. These bars can be headfree or head contact type. Headfree bars fit into the upper fillet between the web and head of the rails. Joint bars can also be short-toe, long-toe, or toeless. The toe refers to the lower joint bar flange which makes contact with the rail.

b. Compromise joint bars. Compromise joint bars will be used where rail of different sections are connected. The bars will conform to the section and drilling pattern of each rail at the connection. The offset at surface or gage side alinement will not exceed 1/8 inch. Compromise joints will not be located on open deck trestles or bridges, or within the limits of switch ties.

c. Expansion openings. Temperature can severely affect rail construction, so corrective measures must be taken. When laying rails, temperature will be measured by applying a thermometer to the base of the rail in the shade. Shims are used to provide openings for expansion between the ends of rails.

d. Tie plates. Tie plates are used between rail and tie to reduce tie abrasion and to maintain rail gage. Tie plates are used on permanent construction. On low-speed temporary work, they are only required on bridges, trestles, tunnels, through turnouts and crossovers, and on all curves of 3 degrees or more.

e. Rail anchors. Train traffic and thermal expansion have a tendency to move rail lengthwise. Therefore, rail anchors are used to restrain this movement. Traffic essentially can be in one direction or it can be in two directions. As rail creepage is in the direction of traffic, the necessity of anchors is greater with one-way traffic than with two-way traffic using the same track. Normally, for most kinds of ballast, eight forward anchors and two backup anchors are required per 39 foot rail length for one direction traffic. For two-way traffic, eight anchors for each direction, or a total of 16, are required.

f. Rail braces. If tie plates are not used, four braces per rail length are applied to curves 1 degree to 6 degrees; six per rail length for curves 6 degrees to 10 degrees; and every other tie on some curves of 10 degrees and over. When tie plates are used, braces are not necessary on curves under 12 degrees and should be applied to every fourth tie on curves 12 degrees and over.

g. Spikes. Size 6- by 5/8-inch spikes are normally used for all ties. New track spikes will be used for both new and relayer rail.

2-5. Ballast. Ballast forms the foundation part of track construction. The minimum depth of ballast under the ties should be 8 inches. Procedures for determination of ballast thickness are contained in AREA Manual for Railway Engineering. Prepared ballast (stone, gravel, or slag) is preferred to other ballast materials. Transportation problems discourage shipment over great distances, so materials found locally should be investigated for use. Subballast with a minimum depth of 6 inches will be used where roadbed is difficult to drain. The roadbed will be wide enough to provide 18-inch shoulders beyond the toe of ballast. In the selection of roadbed width, provide for: (a) the extra width required for the ballast section on curves with superelevation and (b) subballast (if required). Typical AREA ballast sections are shown on Standard Mobilization Drawing No. XEC-009.

2-6. Railroad layout data. The tables in appendix A, with figures and formulas, provide solutions to problems in railroad track layouts typical for Army installations. Main objectives are minimum track construction and curvature where road power can be safely operated. Computations are based on standard No. 8 turnout with tangents through switch points and frogs to prevent bunching of curvature near turnouts. The dimensions in the tables may be used in planning, revision of existing layouts, and layouts on the ground. The formulas determine essential dimensions for other curvature or track spacing not in the tables. All radii are to the center line of tracks.

CHAPTER 3

GEOMETRIC DESIGN

3-1. Curvature.

a. The curvature will be limited to preclude any requirement for superelevation in excess of 5-1/2 inches at the design train speed. Curves of less than 1 degree 30 minutes will be avoided for tracks where design speed requires the use of superelevation.

b. Where the design train speed is less than 20 miles per hour, the maximum degree of curvature should, in most cases, be limited to curvature of the turnout being used. With the standard No. 8 turnout this curvature will be 11 degrees 46 minutes 44 seconds (nearly 12 degrees). In congested areas where sharp curves cannot be avoided, the curvature will not exceed 15 degrees.

c. Standard gage will be used on all curves up to 8 degrees and then widened 1/8 of an inch for each increment of 2 degrees to a maximum of 4 feet 9-1/2 inches.

3-2. Superelevation. Superelevation will not be used on curves where the speed is less than 20 miles per hour except when required by the serving railroad. Superelevation will be provided on access or main running tracks where the speed is 20 miles per hour or more. Table 3-1 gives some practical superelevations in inches which may be provided where the speed justifies their use. The low rail will hold the grade of the track. The superelevation figures shown in table 3-1 were derived from the following equation:

$$E = CDV^2$$

where:

E = superelevation, inches
C = constant with following values:
  C = 0.0005 for 1-degree 30-minute curve
  C = 0.0004 for 3 degrees and above
D = actual degree of curve
V = Maximum speed, miles per hour

Table 3-1. Superelevation in Inches

Degree	Speed in Miles Per Hour					
	45	40	35	30	25	20
1 deg 30 min	1-1/2	1-1/4	1			
2 deg 00 min	1-3/4	1-1/4	1			
2 deg 30 min	2	1-1/2	1-1/4			
3 deg 00 min	2-1/2	2	1-1/2	1		
3 deg 30 min	3	2-1/2	2	1-1/4		
4 deg 00 min	3-1/4	2-1/2	2	1-1/2	1	
4 deg 30 min	3-1/2	3	2-1/2	1-1/2	1	
5 deg 00 min	4	3-1/4	2-1/2	1-3/4	1-1/4	
5 deg 30 min	4-1/2	3-1/2	2-1/2	2	1-1/4	1
6 deg 00 min	5	4	3	2-1/4	1-1/2	1
6 deg 30 min	5-1/4	4-1/4	3-1/4	2-1/4	1-1/2	1
7 deg 00 min	5-1/2	4-1/2	3-1/2	2-1/2	1-3/4	1

A spiral easement will be used where superelevation is required. The minimum length of the spiral will be derived from the following formula:

$$L = 1.17EV$$

where:

L = spiral length, feet (minimum length)
E = superelevation, inches
V = Maximum train speed, miles per hour

3-3. Grades. The maximum grade on access lines will be determined by the tonnage handled in one train unit. Reduction of the ruling grade will depend on the initial cost of construction compared with the savings in cost of operation. Usually the grades on all tracks can be kept well below 2 percent. In some cases, light train units and rough terrain may require some grades over 2 percent. Grades should not exceed 3 percent. Grades in the body (parallel tracks of a yard upon which cars are placed or stored) or yards and on standing tracks will not exceed 0.4 percent except at warehouses or storehouses, where the grade can be 0.5 percent.

a. Compensating grades for curvature. Maximum grades on access lines will be compensated 0.04 percent per degree of curvature. Compensation will also be applied when heavy traffic or large tonnage units will be handled.

b. Vertical curves. Usually, a vertical curve will be needed to provide a smooth transition between grades. Vertical curves will not be shorter than the length established by the formula and rates of grade change outlined below:

$$L = \frac{G_1 - G_2}{R} \times 100$$

where:

L = minimum length of vertical curve, feet
G_1 and G_2 = gradients in feet per 100 feet, with the proper algebraic sign for each
R = rate of change of grade per 100 feet

(1) Access or running tracks. Vertical curves will connect all grades where the algebraic difference in gradient exceeds 0.15 percent in sags and 0.3 percent on summits. Using the formula shown above, the minimum length vertical curve will be based on a rate of grade change per 100 feet of 0.15 (R = 0.15) on sags and 0.30 (R = 0.30) on summits.

(2) Spurs and sidings. Vertical curves will connect all grades where the algebraic difference in gradient exceeds 0.35 percent. Using the formula shown above, the minimum length vertical curve will be based on a rate of grade change per 100 feet of 0.40 percent (R = 0.40).

c. Stub-end tracks. If practicable, grades on stub-end tracks should have a slight descending grade from the switch.

d. Derails. Provide for the protection of main line, access, and running tracks by the use of derails on tracks which descend toward switches.

3-4. Clearances. Clearances for tangent track will not be less than those listed below. Side clearances will be measured horizontally from the center line of tracks. Side clearances on the outside of curves will be increased 1 inch for each degree of track curvature over that shown for tangent track. Side clearances on the inside of curves will be increased 1 inch for each degree of track curvature and also 3-1/2 times the amount of superelevation of the high rail.

a. Overhead wires.

- Open supply wires, arc wires, and service drops

0 to 750 volts	27 feet
750 to 15,000 volts	28 feet
Exceeding 15,000 volts	30 feet

- Guys, messenger, communication, span, and lightning protection wires and all voltage of effectively grounded continuous-metal sheath cables	27 feet
- Trolley wires	22 feet

b. Miscellaneous overhead obstructions.

- Other than wires and building entrances	22 feet
- Building entrance (including engine-houses)	18 feet

c. Side clearances.

- Buildings (other than for delivery)	8 feet 6 inches
- Buildings, without platforms (where delivery is required)	8 feet
- Canopies over platform, 16 feet or less (delivery to platform required)	8 feet
- Freight platforms to 4 feet (maximum) (or 5 feet 9 inches if there is an 8-foot clearance on other side of the track)	6 feet 2 inches
- Refrigerator car platforms, 3 feet 3 inches or less or 5 feet 9 inches if there is an 8-foot clearance on other side of track)	6 feet 2 inches
- Refrigerator car platforms, between 3 feet 3 inches and 4 feet	8 feet
- Low platforms, 8 inches or less	5 feet
- Engine-house entrances	6 feet 6 inches

- Building entrances (other than engine-house) 8 feet

d. Track centers. Yard tracks will be a minimum of 13 feet center to center, and when parallel to a main track or running track, will be not less than 15 feet from such track. Ladder tracks will be not less than 15 feet from any parallel track and will be not less than 18 feet when such parallel track is another ladder track. Tracks in pairs for operation of locomotive cranes will be not less than 18 feet on centers.

e. Safety requirements. Overhead clearances less than 22 feet will be protected by warning signs and telltales or by standards of the serving railroad or local state laws. No overhead clearance will be less than 18 feet. All overhead clearances less than 22 feet will be included in operating contracts made with the serving railroad or others. Side clearances for immovable obstructions, such as buildings, canopies, platforms, poles, etc., other than railroad track appurtenances, which are less than 8 feet 6 inches from the center line of track, will be protected by appropriate close-clearance signs.

CHAPTER 4

DRAINAGE

4-1. Requirements. Size, strength, and design of all drainage facilities will conform to EM 1110-3-136. The following requirements will also apply.

4-2. Side drainage ditches. The minimum grade for side drainage ditches will be 0.2 percent, so that the design storm will produce channel velocities of 2 feet to 2.5 fps. Paving, riprap, or erosion checks may be required if the grade produces eroding velocities. The lower ends should diverge from the toe of embankment and be extended sufficiently to prevent erosion.

4-3. Intercepting ditches. Intercepting ditches will be used to prevent water from coming over the top of the cut and to prevent erosion of the slopes. The grade of intercepting ditches will be not less than 0.3 percent. The ends should diverge from the toe of the slope to prevent erosion of adjoining embankments. A paved gutter, or pipe, will be required to carry the flow from the intercepting ditch to the drainage ditch.

4-4. Culverts. Culverts under the track will be corrugated metal, reinforced concrete, or cast iron pipe.

4-5. Lateral drains. Lateral subsurface drains will be installed to conduct springs or ground water from the roadbed to the longitudinal pipe drains or open ditches.

4-6. Pipe drains. Pipe drains, parallel to the track, will be installed in wet or narrow cuts where side ditches cannot be maintained. Inlets will be designed to carry off surface water. The size of pipe will be a minimum diameter of 6 inches.

CHAPTER 5

MISCELLANEOUS

5-1. Turnouts. Normally, No. 8 turnouts will be installed. Larger or smaller turnouts may be installed only if required by unusual local conditions. The track layouts for various conditions, using No. 8 turnouts (8-foot 3-inch theoretical heel distance), are described in appendix A. No. 8 self-guarded frogs will be installed at Army installations within the United States when the design train speed does not exceed 30 miles per hour. Switch stand will be placed, if possible, on the turnout side of the track; however, in double-track territory, the stand will be placed on the right-hand side of the track, whenever possible. The switch stand will be of a standard low-type construction. Normally, reflector switch lamps only will be provided as switch stand targets. Colored reflector switch lamps with day target discs will be used only at important turnouts subject to considerable traffic. Illuminated switch lamps will not be provided except as required by the serving railroad or specific safety regulation.

5-2. Crossing frogs. Crossing frogs are costly to install and maintain. Therefore, their use should be avoided whenever practicable. When required, crossing frogs will conform to AREA trackwork plans.

5-3. Structures. Structures, as discussed herein, carry the weight of moving equipment on railroad tracks. The design and specifications of the serving railroad or the AREA Manual for Railway Engineering, modified where necessary, may be used. In order to provide for the standard interchange car, design strength will not be less than that required for Coopers E-80 loading; however, the design strength could be stronger if conditions warrant.

5-4. Track scales. Railroad track scales will not be provided for depots or troop-housing areas. They will be provided at other installations only if necessary from both an operating and economical standpoint.

5-5. Guardrails. Two inner guardrails will be installed on all single track bridges and trestles. Each guardrail will be 11 inches from the traffic rail and will extend at least 30 feet beyond each end of the bridge or trestle. One guardrail will be placed on each track of double-track bridges or trestles.

5-6. Highway-railway grade crossing. The grade crossing of a highway will be suitable for the volume of highway traffic and train traffic and appropriate for the physical characteristics of the site. Typical railroad crossing design can be found in the AREA Manual for Railway Engineering.

a. Drainage. Each crossing will have adequate drainage. Underdrainage will be installed if side drainage does not prevent formation of water pockets.

b. Width of crossing. Crossing pavements and/or timbers on roads or driveways in warehouses, storage or industrial areas, and on all roads with curbs will extend at least 2 feet on each side of the approach highway pavement. Crossing pavements and/or timbers on primary or secondary roads without curbs will extend through the full width of roadway including shoulders.

c. Crossing approaches. Approaches to the track will be on a smooth grade with no abrupt breaks so that vehicles with low road clearance may pass over the crossing without touching the rail or surface.

d. Rails. Rails will be laid to eliminate joints within the crossing with the nearest joint not less than 6 feet from the crossing. Where necessary, long or welded rails will be used. Rails will be double spiked, and the track solidly tamped to uniform surface.

e. Flangeway widths. Flangeways 2-1/2 inches minimum width will be provided on tangent track or on curves of 8 degrees or less, and 2-3/4 inches minimum width on curves of more than 8 degrees.

f. Signs and signals. The type of crossing protection will be determined by the physical characteristics of the crossing, density, and type of highway and rail traffic.

g. Public crossings. Public crossings, drainage, signs, crossing protection, and approaches not located within a project will conform to the requirements of the state or municipality and the recommendations of the AREA. The installation of any mechanical protecting device required by public regulation will be covered by an agreement with the highway agency.

5-7. Grounding. Railroad spur tracks or tracks for unloading or filling tank cars with aircraft or automotive fuels will be located not less than 65 feet from the center line of other tracks and not less than 100 feet from the shell of an aboveground tank or from an existing building or future building not considered a part of the tank farm. This restriction is for blast distance. Should site conditions dictate distances less than those stated above, waiver must be obtained from the using service. Grounding will be provided at 100-foot intervals, or major fractions thereof, for effectively discharging electrical potentials generated by static and lightning before these charges are permitted to accumulate to the point of discharge across an air gap causing a source of ignition of hazardous mixtures. Grounding will include bonding between rail sections, installation of ground electrodes, connections between ground electrodes and rails, and interconnection of spur track with building grounding systems where they are within 25 feet of each other.

a. Electrodes. Ground electrodes normally will consist of 8-foot-long by 3/4-inch-diameter copper-clad steel rods or 1-inch-diameter zinc-coated steel pipe. Electrodes will be driven vertically to a depth sufficient to have the top not less than 12 inches below the roadbed surface at the ballast toe on one side of the track. Where the roadbed is rocky, preventing full length installation of the ground electrodes, not less than 15 feet of No. 1/0 American Wire Gage (AWG) bare stranded copper wire will be laid in a trench and covered with not less than 6 inches of material arranged to remain in place, unless other provisions are required by the using service.

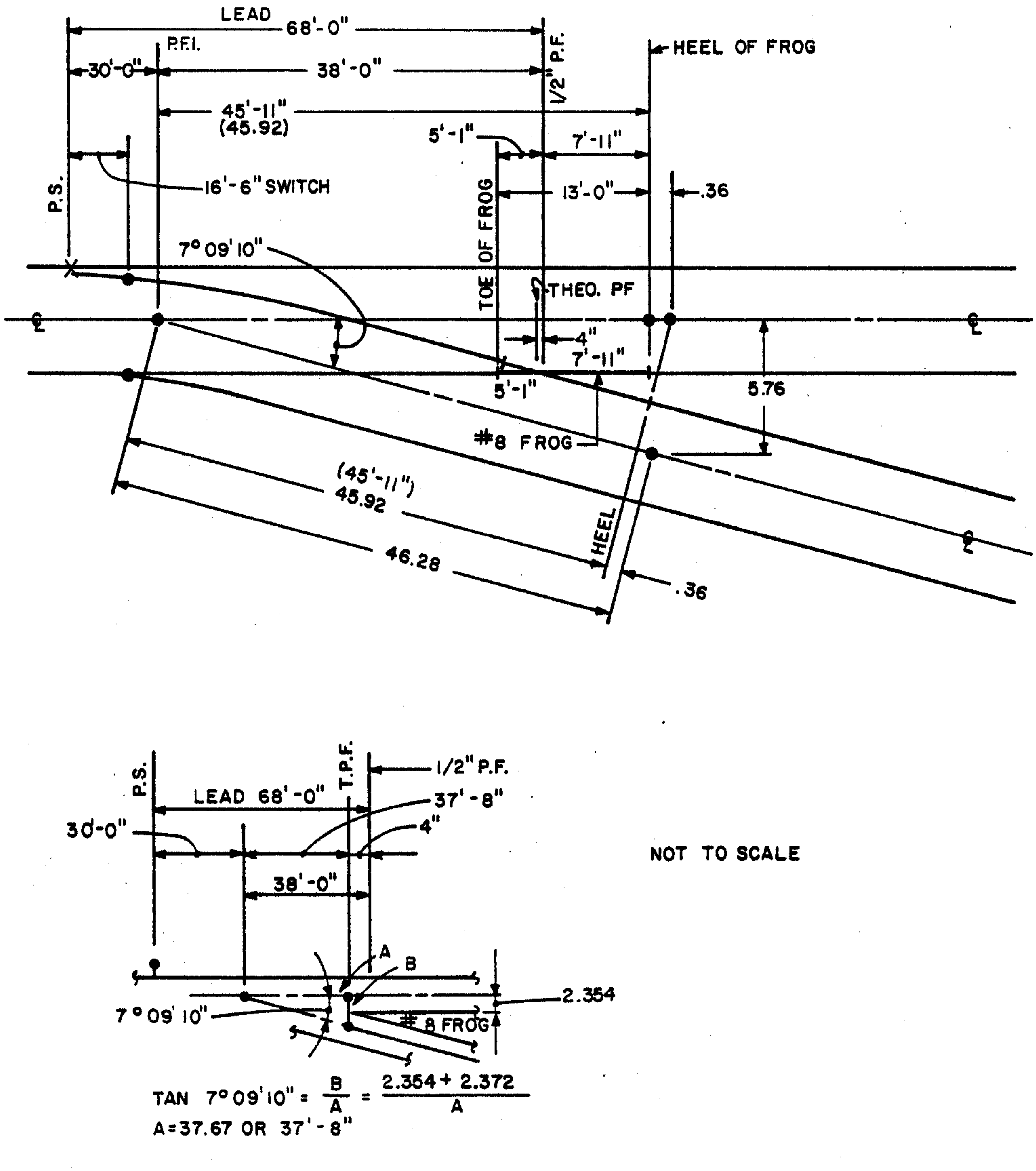
b. Ground connections and bonding. Rail sections will be bonded together with not less than No. 1/0 AWG (3/8-inch diameter) bare stranded copper conductor, and the sections terminating beyond the 100-foot distance will be electrically insulated from the remaining rails. Conductors between rails and ground electrodes, and interconnections between grounding systems will be of No. 2 AWG bare stranded copper installed not less than 12 inches below the roadbed surface. Connections will be of the bolted, thermochemical, or other approved permanent type. Bolted connectors will be of the pressure bar type having no rotating parts coming in direct contact with conductors.

APPENDIX A

RAILROAD LAYOUT DATA

The tables and figures listed below are based on the use of: (a) 4-foot 8-1/2 inch gage, (b) No. 8 frog, 13 feet long, theoretical heel distance of 8 feet 3 inches, and (c) 68-foot lead distance. If other types of turnouts are used, mathematical calculations will be necessary in lieu of these tables and figures.

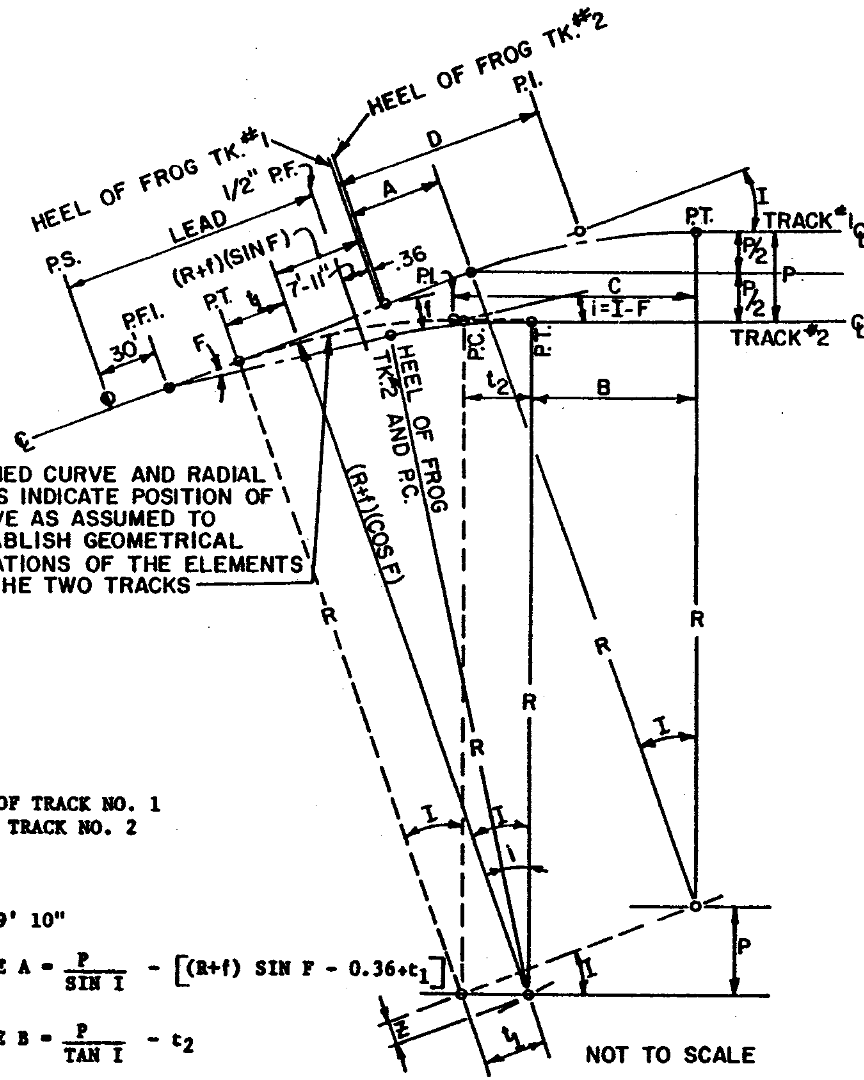
- Figure A-1 shows basic layout data for No. 8 turnouts and components.
- Figures A-2 and A-2(a) (with tables A-1 through A-6) show dimensions for minimum trackage in layouts where parallel tracks at various centers are reached over curved entrance tracks.
- Figure A-3 shows spacing of frogs in crossovers between parallel tracks in which the crossover track is on reversed curves with sufficient tangent between curves to adjust the locomotive wheel base.
- Figure A-4 (with table A-7) shows essential dimensions for ladder and yard tracks where the ladder must be on a curve. In the table, all curvature is taken up in the turnout leads, the distance between frogs being the chord distance subtended by the frog angle. The formula on figure A-4 can be used for any combination of ladder curvature and turnout spacing.
- Figure A-5 shows essential dimensions for two types of railroad yard ladders.
- Table A-8 is a tabulation of material required for 1,000 feet of track.



U. S. Army Corps of Engineers

FIGURE A-1. BASIC DATA FOR STANDARD NO. 8 TURNOUT GAGE 4 FEET 8 1/2 INCHES; FROG LENGTH 13 FEET

U. S. Army Corps of Engineers



FORMULA AND PROCUEDURE FOR DETERMINING THE MOST ECONOMICAL YET SATISFACTORY LAYOUT FOR CURVED ENTRANCE TRACKS TO FACILITIES WHERE BOTH TRACKS HAVE THE SAME DEGREE OF CURVATURE OR CURVATURE OF TRACK NO. 2 IS OF GREATER RADIUS THAN TRACK NO. 1. TABLES A-1 THROUGH A-6 RELATE TO THIS FIGURE.

CASE I

RADIUS OF TRACK NO. 1 SAME AS TRACK NO. 2

F = 7° 09' 10"

DISTANCE A = $\frac{P}{\text{SIN I}} - \left[(R+f)\ \text{SIN F} - 0.36 + t_1\right]$

DISTANCE B = $\frac{P}{\text{TAN I}} - t_2$

DISTANCE C = TANG. DISTANCE TK. NO. 2+B

DISTANCE D = TANG. DISTANCE TK. NO. 1+A

KNOWN FACTORS ARE:

F = FROG ANGLE (NO. 8 USED HERE HAVING AN ANGLE OF 7° -09' -10" AND A THEORETICAL HEEL DISTANCE OF 8' - 3")

LEAD = DISTANCE FROM 1/2" POINT OF FROG TO P.S.= L

R = RADIUS OF CURVES OF TRACKS

P = CENTER TO CENTER OF TRACKS

REQUIRED:

I = CENTRAL ANGLE OF TRACK NO. I

i = CENTRAL ANGLE OF TRACK NO. 2 = 1-F

f = 5.76 FOR NO. 8 FROG 8'-3" THEORETICAL HEEL DISTANCE.

Z = $\left[(R+f)\ \text{COS F}\right] - R$

= 0.0 FOR 7° - 50' CURVE

= 1.2526 FOR 10° CURVE

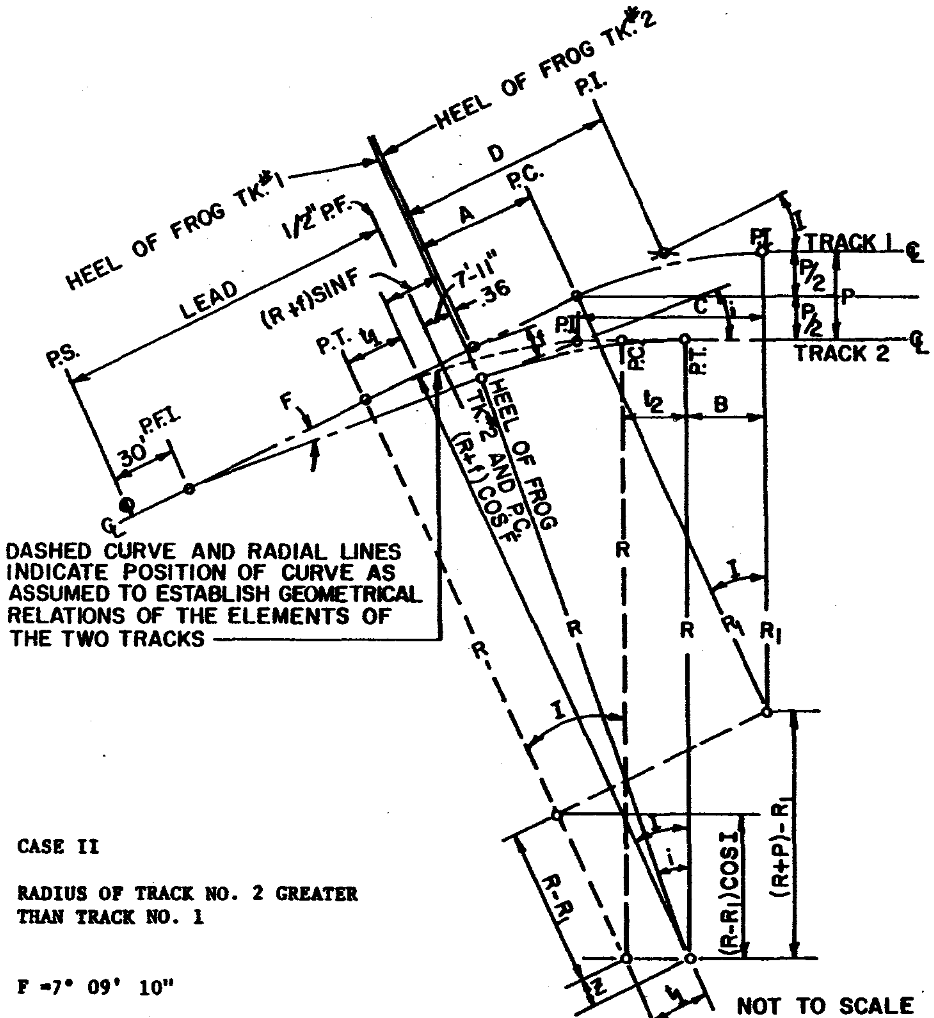
= 1,9947 FOR 12° CURVE

= 2.5244 FOR 14° CURVE

t_2 = TANGENTIAL CORRECTION $\frac{Z}{\text{SIN I}}$

t_1 = TANGENTIAL CORRECTION $\frac{Z}{\text{TAN I}}$

FIGURE A-2 RAILROAD LAYOUT DATA



CASE II

RADIUS OF TRACK NO. 2 GREATER THAN TRACK NO. 1

$F = 7° \ 09' \ 10''$

DISTANCE A = $\dfrac{[(R+P)-R_1] - [(R-R_1)\cos I]}{\sin I} - [(R+f)\sin F - 0.36 + t_1]$

DISTANCE B = $\dfrac{[(R+P)-R_1] - [(R-R_1)\cos I]}{\sin I}\ [\cos I\ (R-R_1)\sin I - t_2]$

DISTANCE C = TANG DISTANCE TK. NO. 2+B

DISTANCE D = TANG DISTANCE TK. NO. 1+A

FORMULA AND PROCEDURE FOR DETERMINING THE MOST ECONOMICAL YET SATISFACTORY LAYOUT FOR CURVED ENTRANCE TRACKS TO FACILITIES WHERE BOTH TRACKS HAVE THE SAME DEGREE OF CURVATURE OR CURVATURE OF TRACK NO. 2 IS OF GREATER RADIUS THAN TRACK NO. 1. TABLES A-1 THROUGH A-6 RELATE TO THIS FIGURE.

KNOWN FACTORS ARE:

F = FROG ANGLE (NO. 8 USED HERE HAVING AN ANGLE OF 7° - 09' - 10" AND A THEORETICAL HEEL DISTANCE OF 8' - 3")

LEAD = DISTANCE FROM 1/2" POINT OF FROG TO P.S. = L

R = RADIUS OF CURVES OF TRACKS

P = CENTER TO CENTER OF TRACKS

REQUIRED:

I = CENTRAL ANGLE OF TRACK NO. 1

i = CENTRAL ANGLE OF TRACK NO. 2 = I-F

f = 5.76 FOR NO. 8 FROG 8'-3" THEORETICAL HEEL DISTANCE

z = $[(R+F)\cos F] - R$

= 0.0 FOR 7°-50' CURVE

= 1.2526 FOR 10° CURVE

= 1.9947 FOR 12° CURVE

= 2.5244 FOR 14° CURVE

t_2 = TANGENTIAL CORRECTION $\dfrac{z}{\sin I}$

t_1 = TANGENTIAL CORRECTION $\dfrac{z}{\tan I}$

FIGURE A-2a RAILROAD LAYOUT DATA

Table A-1. Minimum Track and Operating Movement

Case I - Reference Figure A-2

R = 573.69', D = 10°, Turnouts No. 8

P. ft.	I. degrees	Track No. 1		Track No. 2		Total-ft.		Total track ft
		A-ft.	L-ft.	B-ft.	L-ft.	Track 1	Track 2	
13	8°38′	6.57	86.33	77.28	14.80	92.90	92.08	184.98
14	8°58′	10.16	89.60	80.75	18.07	99.76	98.82	198.58
15	9°16′	13.61	92.75	84.08	21.22	106.36	105.30	211.66
16	9°35′	16.93	95.80	87.28	24.27	112.73	111.55	224.28
17	9°53′	20.13	98.75	90.35	27.22	118.88	117.57	236.45
18	10°10′	23.25	101.62	93.32	30.09	124.87	123.41	248.28
19	10°26′	26.25	104.41	96.19	32.88	130.66	129.07	259.73
20	10°43′	29.17	107.14	98.97	35.61	136.31	134.58	270.89
21	10°59′	32.03	109.79	101.67	38.26	141.82	139.93	281.75
22	11°14′	34.79	112.38	104.30	40.85	147.17	145.15	292.32
23	11°29′	37.50	114.91	106.85	43.38	152.41	150.23	302.64
24	11°44′	40.14	117.39	109.33	45.86	157.53	155.19	312.72
25	11°59′	42.73	119.83	111.76	48.30	162.56	160.06	322.62
26	12°13′	45.26	122.21	114.13	50.68	167.47	164.81	332.28
27	12°27′	47.74	124.54	116.44	53.01	172.28	169.45	341.73
28	12°41′	50.16	126.84	118.70	55.31	177.00	174.01	351.01
29	12°55′	52.55	129.09	120.92	57.56	181.64	178.48	360.12
30	13°08′	54.90	131.31	123.09	59.78	186.21	182.87	369.08
31	13°21′	57.20	133.49	125.22	61.96	190.69	187.18	377.87
32	13°34′	59.47	135.64	127.30	64.11	195.11	191.41	386.52
33	13°46′	61.69	137.75	129.35	66.22	199.44	195.57	395.01
34	13°59′	63.89	139.83	131.35	68.30	203.72	199.65	403.37
35	14°11′	66.05	141.88	133.33	70.35	207.93	203.68	411.61
36	14°23′	68.18	143.91	135.27	72.38	212.09	207.65	419.74
37	14°35′	70.28	145.90	137.17	74.37	216.18	211.54	427.72
38	14°47′	72.36	147.87	139.05	76.34	220.23	215.39	435.62
39	14°59′	74.40	149.81	140.89	78.28	224.21	219.17	443.38
40	15°10′	76.41	151.73	142.72	80.20	228.14	222.92	451.06
45	16°06′	86.14	161.00	151.39	89.47	247.14	240.86	488.00
50	16°59′	95.35	169.83	159.49	98.30	265.18	257.79	522.97
55	17°49′	104.11	178.12	167.09	106.59	282.23	273.68	555.91
60	18°37′	112.49	186.11	174.25	114.58	298.60	288.83	587.43
65	19°23′	120.55	193.78	181.03	122.25	314.33	303.28	617.61
70	20°07′	128.31	201.17	187.49	129.64	329.48	317.13	646.61
75	20°50′	135.83	208.31	193.60	136.78	344.14	330.48	674.52
80	21°31′	143.10	215.22	199.45	143.69	358.32	343.14	701.46

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Table A-2. Minimum Track and Operating Movement
Case I - Reference Figure A-2
R = 478.34', D = 12°, Turnouts No. 8

P. ft.	I. degrees	Track No. 1		Track No. 2		Total-ft.		Total track ft.
		A-ft.	L-ft.	B-ft.	L-ft.	Track 1	Track 2	
13	9°27'	7.23	78.80	65.91	19.19	86.03	85.10	171.13
14	9°49'	10.68	81.78	69.23	22.17	92.46	91.40	183.86
15	10°10'	14.00	84.66	72.40	25.05	98.66	97.45	196.11
16	10°30'	17.17	87.45	75.43	27.84	104.62	103.27	207.89
17	10°49'	20.22	90.14	78.34	30.53	110.36	108.87	219.23
18	11°08'	23.17	92.79	81.15	33.18	115.96	114.33	230.29
19	11°26'	26.03	95.32	83.85	35.71	121.35	119.56	240.91
20	11°44'	28.81	97.80	86.46	38.19	126.61	124.65	251.26
21	12°02'	31.49	100.23	89.00	40.62	131.72	129.62	261.34
22	12°19'	34.12	102.59	91.45	42.98	136.71	134.43	271.14
23	12°35'	36.66	104.91	93.84	45.30	141.57	139.14	280.81
24	12°52'	39.17	107.18	96.16	47.57	146.35	143.73	290.08
25	13°08'	41.61	109.39	98.42	49.78	151.00	148.20	299.20
26	13°23'	43.98	111.57	100.63	51.96	155.55	152.59	308.14
27	13°39'	46.32	113.71	102.76	54.10	160.03	156.86	316.89
28	13°54'	48.61	115.80	104.87	56.19	164.41	161.06	325.47
29	14°09'	50.85	117.86	106.92	58.25	168.71	165.17	333.88
30	14°23'	53.04	119.89	108.93	60.28	172.93	169.21	342.14
31	14°38'	55.21	121.88	110.89	62.27	177.09	173.16	350.25
32	14°52'	57.34	123.84	112.82	64.23	181.18	177.05	358.23
33	15°06'	59.43	125.77	114.70	66.16	185.20	180.86	366.06
34	15°19'	61.48	127.68	116.55	68.07	189.16	184.62	373.78
35	15°33'	63.50	129.55	118.37	69.94	193.05	188.31	381.36
36	15°46'	65.50	131.40	120.15	71.79	196.90	191.94	388.84
37	15°59'	67.46	133.22	121.90	73.61	200.68	195.51	396.19
38	16°12'	69.39	135.03	123.62	75.42	204.42	199.04	403.46
39	16°25'	71.31	136.80	125.31	77.19	208.11	202.50	410.61
40	16°38'	73.19	138.56	126.98	78.95	211.75	205.93	417.68
45	17°39'	82.28	147.03	134.91	87.42	229.31	222.33	451.64
50	18°36'	90.86	155.05	142.27	95.44	245.91	237.71	483.62
55	19°31'	99.03	162.69	149.15	103.08	261.72	252.23	513.95
60	20°24'	106.85	170.00	155.61	110.39	276.85	266.00	542.85
65	21°15'	114.35	177.09	161.71	117.47	291.44	279.18	570.62
70	22°03'	121.59	183.75	167.48	124.14	305.34	291.62	596.96
75	22°50'	128.57	190.32	172.94	130.91	319.09	303.85	622.94
80	23°36'	135.35	196.65	178.15	137.04	332.00	315.19	647.19

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Table A-3. Minimum Track and Operating Movement

Case I - Reference Figure A-2

R = 410.28', D = 14°, Turnouts No. 8

P. ft.	I. degrees	Track No. 1		Track No. 2		Total-ft.		Total track ft.
		A-ft.	L-ft.	B-ft.	L-ft.	Track 1	Track 2	
13	10°13′	7.87	72.95	57.92	21.86	80.82	79.78	160.60
14	10°36′	11.16	75.71	61.13	24.62	86.87	85.75	172.62
15	10°58′	14.35	78.37	64.11	27.28	92.72	91.39	184.11
16	11°20′	17.38	80.95	66.99	29.86	98.33	96.85	195.18
17	11°41′	20.30	83.45	69.75	32.36	103.75	102.11	205.86
18	12°01′	23.12	85.88	72.40	34.79	109.00	107.19	216.19
19	12°22′	25.83	88.24	74.95	37.15	114.07	112.10	226.17
20	12°41′	28.48	90.54	77.42	39.45	119.02	116.87	235.89
21	12°59′	31.04	92.79	79.80	41.70	123.83	121.50	245.33
22	13°18′	33.53	94.98	82.11	43.89	128.51	126.00	254.51
23	13°36′	35.95	97.14	84.39	46.05	133.09	130.44	263.53
24	13°53′	38.31	99.23	86.53	48.14	137.54	134.67	272.21
25	14°11′	40.62	101.28	88.64	50.19	141.90	138.83	280.73
26	14°28′	42.88	103.30	90.71	52.21	146.18	142.92	239.10
27	14°44′	45.08	105.28	92.71	54.19	150.36	146.90	297.26
28	15°01′	47.25	107.22	94.67	56.13	154.47	150.80	305.27
29	15°17′	49.37	109.13	96.59	58.04	158.50	154.63	313.13
30	15°32′	51.45	111.01	98.46	59.92	162.46	158.38	320.84
31	15°48′	53.49	112.85	100.28	61.76	166.34	162.04	328.38
32	16°03′	55.50	114.67	102.07	63.58	170.17	165.65	335.82
33	16°18′	57.47	116.46	103.83	65.37	173.93	169.20	343.13
34	16°33′	59.41	118.22	105.54	67.13	177.63	171.67	350.30
35	16°48′	61.32	119.96	107.23	68.87	181.28	176.10	357.38
36	17°02′	63.20	121.67	108.88	70.58	184.87	179.46	364.33
37	17°16′	65.06	123.36	110.50	72.27	188.42	182.77	371.19
38	17°30′	66.89	125.04	112.09	73.95	191.93	186.04	377.97
39	17°44′	68.69	126.69	113.65	75.60	195.38	189.25	384.63
40	17°58′	70.47	128.31	115.19	77.22	198.78	192.41	391.19
45	19°04′	79.03	136.16	122.50	85.07	215.19	207.57	422.76
50	20°06′	87.12	143.61	129.25	92.52	230.73	221.77	452.50
55	21°06′	94.81	150.69	135.55	99.60	245.50	235.15	480.65
60	22°03′	102.17	157.48	141.43	106.39	259.65	247.82	507.47
65	22°58′	109.23	163.99	146.97	112.90	273.22	259.87	533.09
70	23°50′	116.05	170.27	152.18	119.18	286.32	271.36	557.68
75	24°41′	122.63	176.34	157.11	125.25	298.97	282.36	581.33
80	25°31′	129.07	182.22	161.78	131.13	311.29	292.91	604.20

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Table A-4. Minimum Track and Operating Movement

Case II - Reference Figure A-2a

$R = 573.69'$, $R_1 = 478.34'$, $D = 10°$, $D_1 = 12°$, Turnouts No. 8

P. ft.	I. degrees	Track No. 1		Track No. 2		Total-ft.		Total track ft.
		A-ft.	L-ft.	B-ft.	L-ft.	Track 1	Track 2	
13	9°27′	7.71	78.80	62.55	23.03	86.51	85.58	172.09
14	9°49′	11.29	81.78	65.40	26.61	93.07	92.01	185.08
15	10°10′	14.74	84.66	68.13	30.06	99.40	98.19	197.59
16	10°30′	18.05	87.45	70.75	33.41	105.50	104.16	209.66
17	10°49′	21.26	90.14	73.27	36.65	111.40	109.92	221.32
18	11°08′	24.36	92.79	75.69	39.79	117.15	115.48	232.63
19	11°26′	27.38	95.32	78.04	42.83	122.70	120.87	243.57
20	11°44′	30.30	97.80	80.31	45.83	128.10	126.14	254.24
21	12°02′	33.15	100.23	82.51	48.74	133.38	131.25	264.63
22	12°19′	35.94	102.59	84.66	51.58	138.53	136.24	274.77
23	12°35′	38.64	104.91	86.72	54.36	143.55	141.08	284.63
24	12°52′	41.29	107.18	88.75	57.08	148.47	145.83	294.30
25	13°08′	43.89	109.39	90.72	59.74	153.28	150.46	303.74
26	13°23′	46.43	111.57	92.63	62.35	158.00	154.98	312.98
27	13°39′	48.91	113.71	94.51	64.92	162.62	159.43	322.05
28	13°54′	51.36	115.80	96.34	67.43	167.16	163.77	330.93
29	14°09′	53.75	117.86	98.12	69.91	171.61	168.03	339.64
30	14°23′	56.11	119.89	99.87	72.34	176.00	172.21	348.21
31	14°38′	58.42	121.88	101.60	74.73	180.30	176.33	356.63
32	14°52′	60.70	123.84	103.28	77.08	184.54	180.36	364.90
33	15°06′	62.94	125.77	104.92	79.40	188.71	184.32	373.03
34	15°19′	65.14	127.68	106.54	81.68	192.82	188.22	381.04
35	15°33′	67.31	129.55	108.12	83.93	196.86	192.05	388.91
36	15°46′	69.45	131.40	109.68	86.15	200.85	195.83	396.68
37	15°59′	71.57	133.22	111.21	88.34	204.79	199.55	404.34
38	16°12′	73.65	135.03	112.70	90.50	208.68	203.20	411.88
39	16°25′	75.71	136.80	114.18	92.63	212.51	206.81	419.32
40	16°38′	77.74	138.56	115.64	94.74	216.30	210.38	426.68
45	17°39′	87.54	147.03	122.56	104.90	234.57	227.46	462.03
50	18°36′	96.82	155.05	128.97	114.53	251.87	243.50	495.37
55	19°31′	105.67	162.69	134.97	123.70	268.36	258.67	527.03
60	20°24′	114.13	170.00	140.59	132.47	284.13	273.06	557.19
65	21°15′	122.28	177.02	145.83	140.89	299.30	286.77	586.07
70	22°03′	130.13	183.75	150.87	149.01	313.88	299.88	613.76
75	22°50′	137.73	190.32	155.59	156.86	328.05	312.45	640.50
80	23°36′	145.10	196.65	160.08	164.45	341.75	324.53	666.28

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Table A-5. Minimum Track and Operating Movement

Case II - Reference Figure A-2a

R = 478.34', R_1 = 410.28', D = 12°, D_1 = 14°, Turnouts No. 8

P. ft.	I. degrees	Track No. 1		Track No. 2		Total-ft.		Total track ft.
		A-ft.	L-ft.	B-ft.	L-ft.	Track 1	Track 2	
13	10°13′	8.41	72.95	54.83	25.50	81.36	80.33	161.69
14	10°36′	11.85	75.71	57.66	28.72	87.56	86.38	173.94
15	10°58′	15.14	78.37	60.35	31.83	93.51	92.18	185.69
16	11°20′	18.30	80.95	62.93	34.84	99.25	97.77	197.02
17	11°41′	21.35	83.45	65.40	37.75	104.80	103.15	207.95
18	12°01′	24.30	85.88	67.77	40.59	110.18	108.36	218.54
19	12°22′	27.15	88.24	70.06	43.34	115.39	113.40	228.79
20	12°41′	29.91	90.54	72.27	46.03	120.45	118.30	238.75
21	12°59′	32.61	92.79	74.41	48.65	125.40	123.06	248.46
22	13°18′	35.23	94.98	76.48	51.21	130.21	127.69	257.90
23	13°36′	37.78	97.14	78.49	53.71	134.92	132.20	267.12
24	13°53′	40.27	99.23	80.44	56.16	139.50	136.60	276.10
25	14°11′	42.71	101.28	82.34	58.56	143.99	140.90	284.89
26	14°28′	45.10	103.30	84.19	60.90	148.40	145.09	293.49
27	14°44′	47.43	105.28	85.99	63.22	152.71	149.21	301.92
28	15°01′	49.72	107.22	87.75	65.45	156.94	153.20	310.14
29	15°17′	51.97	109.13	89.47	67.71	161.10	157.18	318.28
30	15°32′	54.17	111.01	91.15	69.90	165.18	161.05	326.23
31	15°48′	56.33	112.85	92.79	72.06	169.18	164.85	334.03
32	16°03′	58.47	114.67	94.39	74.18	173.14	168.57	341.71
33	16°18′	60.56	116.46	95.96	76.26	177.02	172.22	349.24
34	16°33′	62.62	118.22	97.50	78.31	180.84	175.82	356.66
35	16°48′	64.65	119.96	99.01	80.35	184.61	179.36	363.97
36	17°02′	66.65	121.67	100.49	82.35	188.32	182.84	371.16
37	17°16′	68.63	123.36	101.96	84.32	191.99	186.28	378.27
38	17°30′	70.57	125.04	103.37	86.27	195.61	189.64	385.25
39	17°44′	72.49	126.69	104.77	88.19	199.18	192.96	392.14
40	17°58′	74.39	128.31	106.15	90.09	202.70	196.24	398.94
45	19°04′	83.52	136.16	112.69	99.25	219.68	211.94	431.62
50	20°06′	92.16	143.61	118.73	107.93	235.77	226.66	462.43
55	21°06′	100.39	150.69	124.34	116.20	251.08	240.54	491.62
60	22°03′	108.26	157.48	129.59	124.12	265.74	253.71	519.45
65	22°58′	115.82	163.99	134.50	131.72	279.81	266.22	546.03
70	23°50′	123.14	170.27	139.13	139.04	293.41	278.17	571.58
75	24°41′	130.20	176.34	143.49	146.12	306.54	289.61	596.15
80	25°31′	137.06	182.22	147.61	152.98	319.28	300.59	619.87

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Table A-6. Minimum Track and Operating Movement

Case II - Reference Figure A-2a

$R = 573.69'$, $R_1 = 410.28'$, $D = 10°$, $D_1 = 14°$, Turnouts No. 8

P. ft.	I. degrees	Track No. 1		Track No. 2		Total-ft.		Total track ft.
		A-ft.	L-ft.	B-ft.	L-ft.	Track 1	Track 2	
13	10°13′	9.18	72.95	50.49	30.60	82.13	81.09	163.22
14	10°36′	12.79	75.71	52.85	34.46	88.50	87.31	175.81
15	10°58′	16.25	78.37	55.09	38.19	94.62	93.28	187.90
16	11°20′	19.59	80.95	57.24	41.80	100.54	99.04	199.58
17	11°41′	22.82	83.45	59.31	45.30	106.27	104.61	210.88
18	12°01′	25.95	85.88	61.29	48.70	111.83	109.99	221.82
19	12°22′	28.98	88.24	63.21	52.01	117.22	115.22	232.44
20	12°41′	31.93	90.54	65.06	55.23	122.47	120.29	242.76
21	12°59′	34.81	92.79	66.86	58.38	127.60	125.24	252.84
22	13°18′	37.61	94.98	68.59	61.45	132.59	130.04	262.63
23	13°36′	40.34	97.14	70.28	64.45	137.47	134.73	272.20
24	13°53′	43.02	99.23	71.92	67.39	142.25	139.31	281.56
25	14°11′	45.63	101.28	73.51	70.26	146.91	143.77	290.68
26	14°28′	48.20	103.30	75.06	73.09	151.50	148.15	299.65
27	14°44′	50.71	105.28	76.58	75.86	155.99	152.44	308.43
28	15°01′	53.17	107.22	78.05	78.58	160.39	156.63	317.02
29	15°17′	55.60	109.13	79.50	81.25	164.73	160.75	325.48
30	15°32′	57.98	111.01	80.90	83.88	168.99	164.78	333.77
31	15°48′	60.31	112.85	82.28	86.47	173.16	168.75	341.91
32	16°03′	62.62	114.67	83.63	89.01	177.29	172.64	349.93
33	16°18′	64.88	116.46	84.95	91.52	181.34	176.47	357.81
34	16°33′	67.11	118.22	86.24	93.99	185.33	180.23	365.56
35	16°48′	69.31	119.96	87.51	96.42	189.27	183.93	373.20
36	17°02′	71.48	121.67	88.74	98.82	193.15	187.56	380.71
37	17°16′	73.62	123.36	89.97	101.19	196.98	191.16	388.14
38	17°30′	75.73	125.04	91.16	103.52	200.77	194.68	395.45
39	17°44′	77.81	126.69	92.33	105.83	204.50	198.16	402.66
40	17°58′	79.87	128.31	93.48	108.11	208.18	201.59	409.77
45	19°04′	89.80	136.16	98.95	119.10	225.96	218.05	444.01
50	20°06′	99.22	143.61	103.98	129.52	242.83	233.50	476.33
55	21°06′	108.19	150.69	108.65	139.44	258.88	248.09	506.97
60	22°03′	116.79	157.48	112.99	148.94	274.27	261.93	536.20
65	22°58′	125.07	163.99	117.04	158.06	289.06	275.10	564.16
70	23°50′	133.07	170.27	120.84	166.85	303.34	287.69	591.03
75	24°41′	140.81	176.34	124.40	175.35	317.15	299.75	616.90
80	25°31′	148.33	182.22	127.74	183.58	330.55	311.32	641.87

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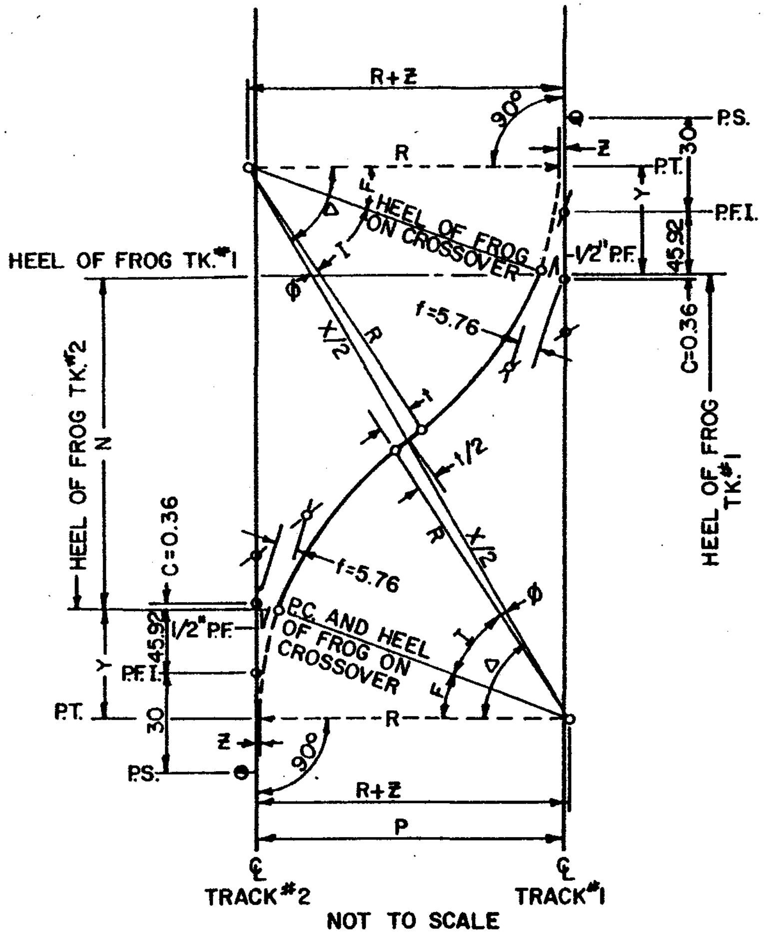


FORMULA AND PROCEDURE FOR THE DESIGN AND LAYOUT FOR A CROSSOVER BETWEEN PARALLEL TRACKS WHEN A PREDETERMINED LENGTH OF TANGENT (t) BETWEEN CURVES IS ADOPTED AND (P) IS GREATER THAN 16 FEET IN THE FIGURE AND FORMULA, KNOWN DIMENSIONS AND CHARACTERISTICS PERTAINING TO NO. 8 FROG ARE USED.

KNOWN FACTORS ARE:

F = FROG ANGLE 7° 09' 10" FOR NO. 8

R = RADIUS OF CURVES

P = DISTANCE BETWEEN TRACKS

C = 0.36 = $\frac{45.92}{\cos F}$ – 45.92 FOR NO. 8

f = 5.76 FOR NO. 8 FROG, 8'-3" THEORETICAL HEEL DIST.

t = LENGTH OF TANGENT BETWEEN CURVES.

Z = $[(R+f)\cos F] - R$

Z = 0.00 FOR 7° -50' CURVE

= 1.2526 FOR 10° CURVE

= 1.9947 FOR 12° CURVE

= 2.5244 FOR 14° CURVE

SIN 7° 09' 10" = .1245155

COS 7° 09' 10" = .99221766

TAN 7° 09' 10" = .12549213

REQUIRED:

I = INTERSECTION ANGLES

N = DISTANCE BETWEEN HEELS OF FROGS

$$\tan \phi = \frac{t/2}{R}$$

$$X = \frac{2R}{\cos \phi}$$

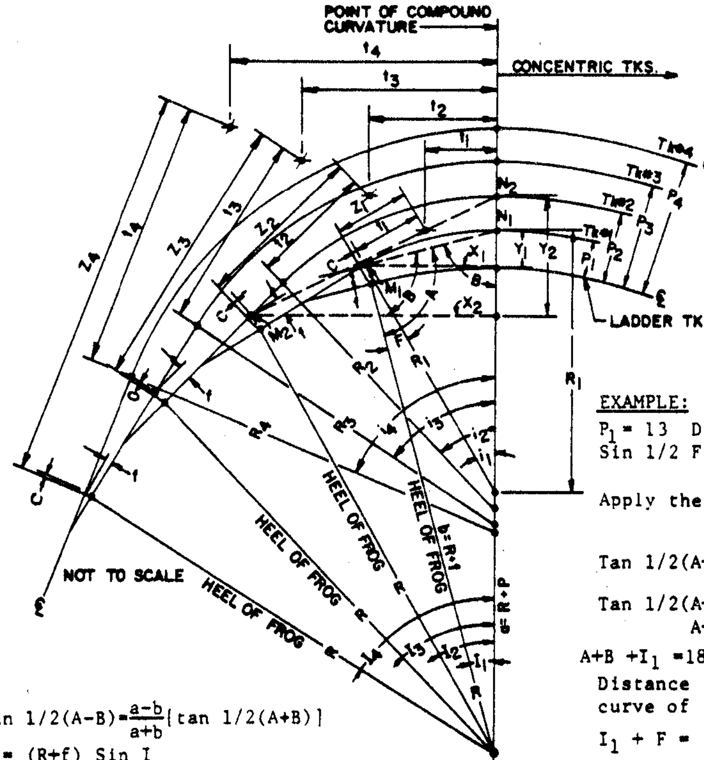
$$\cos \Delta = \frac{2(R+Z)-P}{X}$$

$$I = \Delta - (F+\phi)$$

$$Y = [(R+f)\sin F] - C$$

$$N = X \sin \Delta - 2Y$$

FIGURE A-3 CROSSOVER BETWEEN PARALLEL TRACKS



Formula for designing and laying out a series of concentric yard tracks from a curved ladder track.

Table A-7 was developed based on curved ladders in which the distance between frogs subtends one frog angle. The table is also based on the use of No. 8 frogs having a theoretical heel distance of 8'-3".

$\tan 1/2(A-B) = \frac{a-b}{a+b}[\tan 1/2(A+B)]$

$X = (R+f) \sin I$

$Y_1 = (R+P_1)-[(R+f) \cos I_1]$

$Z = \frac{Y_1}{\sin i_1} + C$

t_1 = tangent distance for yard tracks $= X_1 - \frac{Y_1}{\tan 1/2\ i_1}$

R_1 = Radius of curve for yard tracks No. 1 $= \frac{t_1}{\tan 1/2\ i_1}$

GIVEN:

Distance between frogs

F = Frog Angle = 7°09'10"

Sine	7°09'10"	=.124515
Cos	7°09'10"	=.992217
Tan	7°09'10"	=.12549
Sine	3°34'35"	=.062379
Tan	3°34'35"	=.06250

R = Radius of equivalent curve of ladder track

$P_{1,2,3}$ = Distances from centerline of ladder to consecutive yard tracks

f = Distance between centers of ladder and yard tracks measured at right angles to the ladder track at the heel of frog. f = 5.7621 for No. 8 frog.

C = Distance between the heel of frog, along the centerline of a yard track, and a point where yard track centerline is intersected by a radial line through the heel of frog of the ladder track. C = 0.36014 for No. 8 frog having a theoretical heel distance of 8'-3".

REQUIRED:

Values of I,i,t,R and tangent back of heel of frog for all yard tracks.

Solution for track No. 1

Let a = R+P, b = R+f, A-B = F

EXAMPLE:

$P_1 = 13$ Distance between frogs = 100 feet No. 8 frog

Sin 1/2 Frog Angle $= \frac{50}{R}$ $R = \frac{50}{\sin 3°34'35"} = 801.55$

Apply the tangent formula: $\frac{a-b}{a+b} = \frac{\tan 1/2(A-B)}{\tan 1/2(A+B)}$

$\tan 1/2(A+B) = (.0625)\ \frac{(801.55+13) + (801.55+5.7)}{(801.55+13) - (801.55+5.7)}$

$\tan 1/2(A+B) = 14.01$

$A+B = 171°50'$

$A+B+I_1 = 180°$ $I_1 = 180° - (A+B) = 180° - (171°50') = 8°10'$

Distance from heel of frog to P.C.C. along equivalent curve of ladder track $= L_1 = 114.25$

$I_1 + F = i_1 = 15°19'10"$

$R_1 = \frac{(R+f) \sin I_1}{\sin i_1} = \frac{(810.55+5.7621)(.14205)}{.26419} = 434.07$

$R_1 = \frac{t_1}{\tan 1/2}$

$t_1 = R_1 (\tan i_1/2) = (434.07)(\tan 7°39'35") = 58.37$

$X_1 = (R+f)(\sin I_1) = (801.55+5.7621)(.142053) = 114.68$

$Y_1 = (R+P)-[(R+f)(\cos I_1)]$

$= (801.55+13)-[(801.55+5.76)(\cos 8°10')]$

$= (814.55)-[(807.312)(.989859)] = 15.42$

$Z = \frac{Y_1}{\sin i_1} + C = \frac{15.42}{\sin 15°19'10"} + .36014 = 58.72$

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FIGURE A-4. LAYOUTS FOR YARD TRACKS

Table A-7. Railroad Yard Ladders Parallel to Tracks on Curves - Reference Figure A-4

Frog spacing ft.	Yard ladder				Yard track No. 1				Tan. back of heel	Yard track No. 2				Tan. back of heel
	Curvature	Heel of frog to P. C. C.			I_1	L_1	R_1-ft.	t_1-ft.		I_2	L_2	R_2-ft.	t_2-ft.	
		I	R-ft.	Dist-ft.										
79	9° 8′	10°18′	633.49	113.69	10°18′	17°27′	381.00	58.46	0.36	17°27′	24°36′	381.68	83.22	36.40
80	8°56′	10°10′	641.49	113.72	10°10′	17°19′	383.78	58.45	.36	17°19′	24°28′	386.16	83.75	36.30
81	8°50′	10° 3′	649.50	113.75	10° 3′	17°12′	386.54	58.45	.36	17°12′	24°21′	390.66	84.29	36.20
82	8°43′	9°55′	657.50	113.78	9°55′	17° 5′	389.27	58.44	.36	17° 5′	24°14′	395.18	84.83	36.10
83	8°37′	9°48′	665.50	113.81	9°48′	16°58′	391.98	58.44	.36	16°58′	24°07′	399.71	85.37	35.99
84	8°31′	9°42′	673.50	113.84	9°42′	16°51′	394.66	58.44	.36	16°51′	24° 0′	404.26	85.93	35.86
85	8°25′	9°35′	681.51	113.86	9°35′	16°44′	397.29	58.43	.36	16°44′	23°53′	408.78	86.47	35.74
86	8°19′	9°28′	689.51	113.89	9°28′	16°38′	399.92	58.43	.36	16°38′	23°47′	413.34	87.02	35.62
87	8°13′	9°22′	697.51	113.91	9°22′	16°31′	402.52	58.43	.36	16°31′	23°40′	417.92	87.58	35.48
88	8° 8′	9°16′	705.51	113.94	9°16′	16°26′	405.09	58.42	.36	16°25′	23°34′	422.49	88.13	35.35
89	8° 2′	9°10′	713.52	113.96	9°10′	16°19′	407.64	58.42	.36	16°19′	23°28′	427.09	88.70	35.20
90	7°57′	9° 4′	721.52	113.99	9° 4′	16°13′	410.16	58.42	.36	16°13′	23°22′	431.76	89.26	35.05
91	7°52′	8°58′	729.52	114.00	8°58′	16° 7′	412.64	58.41	.36	16° 7′	23°16′	436.29	89.82	34.90
92	7°46′	8°52′	737.53	114.03	8°52′	16° 1′	415.13	58.41	.36	16° 1′	23°10′	440.93	90.39	34.75
93	7°41′	8°46′	745.53	114.06	8°46′	15°55′	417.59	58.41	.36	15°56′	23° 5′	445.56	90.97	34.58
94	7°37′	8°41′	753.53	114.08	8°41′	15°50′	420.01	58.41	.36	15°50′	22°59′	450.23	91.54	34.42
95	7°32′	8°35′	761.53	114.10	8°35′	15°44′	422.41	58.40	.36	15°45′	22°54′	454.88	92.12	34.24
96	7°27′	8°30′	769.54	114.12	8°30′	15°39′	424.80	58.40	.36	15°39′	22°48′	459.55	92.70	34.06
97	7°22′	8°25′	777.54	114.14	8°25′	15°34′	427.16	58.40	.36	15°34′	22°43′	464.24	93.28	33.89
98	7°18′	8°20′	785.54	114.16	8°20′	15°29′	429.50	58.39	.36	15°29′	22°38′	468.93	93.86	33.71
99	7°14′	8°15′	793.54	114.18	8°15′	15°24′	431.81	58.39	.36	15°24′	22°33′	473.63	94.45	33.51
100	7° 9′	8°10′	801.55	114.20	8°10′	15°19′	434.11	58.39	.36	15°19′	22°28′	478.34	95.04	33.32
101	7° 5′	8° 5′	809.55	114.22	8° 5′	15°14′	436.39	58.39	.36	15°15′	22°24′	483.07	95.63	33.13
102	7° 1′	8° 1′	817.55	114.24	8° 1′	15°10′	438.63	58.38	.36	15°10′	22°19′	487.79	96.21	32.94
103	6°57′	7°56′	825.55	114.26	7°56′	15° 5′	440.87	58.38	.36	15° 5′	22°14′	492.55	96.81	32.73
104	6°53′	7°52′	833.56	114.28	7°52′	15° 1′	443.07	58.38	.36	15° 1′	22°10′	497.29	97.40	32.53

Table A-7 (Continued). Railroad Yard Ladders Parallel to Tracks on Curves - Reference Figure A-4

Frog spacing ft.	Yard Track No. 3				Tan. back of heel	Yard Track No. 4				Tan. back of heel
	I_3	I_4	R_3-ft.	t_3-ft.		I_4	I_5	R_4-ft.	t_4-ft.	
79	24°36′	31°45′	417.11	118.63	55.11	31°45′	38°54′	454.60	160.56	65.76
80	24°28′	31°37′	422.76	119.73	54.91	31°38′	38°47′	460.87	162.20	65.46
81	24°21′	31°30′	428.38	120.83	54.69	31°30′	38°39′	467.17	163.85	65.14
82	24°14′	31 23′	434.01	121.93	54.46	31°23′	38°32′	473.48	165.51	64.81
83	24° 7′	31°16′	439.67	123.03	54.23	31°16′	38°25′	479.82	167.18	64.48
84	24° 0′	31° 9′	445.35	124.14	53.99	31° 9′	38°18′	486.16	168.85	64.13
85	23°53′	31° 2′	451.02	125.25	53.73	31° 2′	38°12′	492.51	170.51	63.79
86	23°47′	30°56′	456.73	126.37	53.48	30°56′	38° 5′	498.90	172.19	63.43
87	23°40′	30°49′	462.46	127.49	53.21	30°49′	37°58′	505.29	173.87	63.07
88	23°34′	30°43′	468.20	128.61	52.95	30°43′	37°52′	511.70	175.55	62.71
89	23°28′	30°37′	473.95	129.73	52.68	30°37′	37°46′	518.12	177.24	62.33
90	23°22′	30°31′	479.73	130.86	52.39	30°31′	37°40′	524.56	178.94	61.94
91	23°16′	30°25′	485.49	131.99	52.11	30°25′	37°34′	531.00	180.62	61.56
92	23°10′	30°19′	491.30	133.13	51.82	30°20′	37°29′	537.48	182.33	61.16
93	23° 5′	30°14′	497.13	134.28	51.51	30°14′	37°23′	543.98	184.04	60.75
94	22°59′	30° 8′	502.96	135.42	51.21	30° 8′	37°17′	550.46	185.74	60.36
95	22°54′	30° 3′	508.80	136.57	50.90	30° 3′	37°12′	556.96	187.45	59.95
96	22°49′	29°58′	514.66	137.72	50.58	29°58′	37° 7′	563.48	189.16	59.53
97	22°43′	29°52′	520.54	138.87	50.27	29°53′	37° 2′	570.02	190.88	59.11
98	22°38′	29°47′	526.43	140.03	49.94	29°48′	36°57′	576.56	192.60	58.68
99	22°33′	29°42′	532.33	141.18	49.61	29°43′	36°52′	583.12	194.32	58.25
100	22°28′	29°37′	538.25	142.34	49.27	29°38′	36°47′	589.69	196.05	57.81
101	22°24′	29°33′	544.18	143.51	48.94	29°33′	36°42′	596.28	197.78	57.37
102	22°19′	29°28′	550.12	144.67	48.60	29°28′	36°37′	602.87	199.51	56.92
103	22°14′	29°23′	556.08	145.84	48.25	29°24′	36°33′	609.48	201.25	56.47
104	22°10′	29°19′	562.04	147.02	47.89	29°19′	36°28′	616.09	202.98	56.02

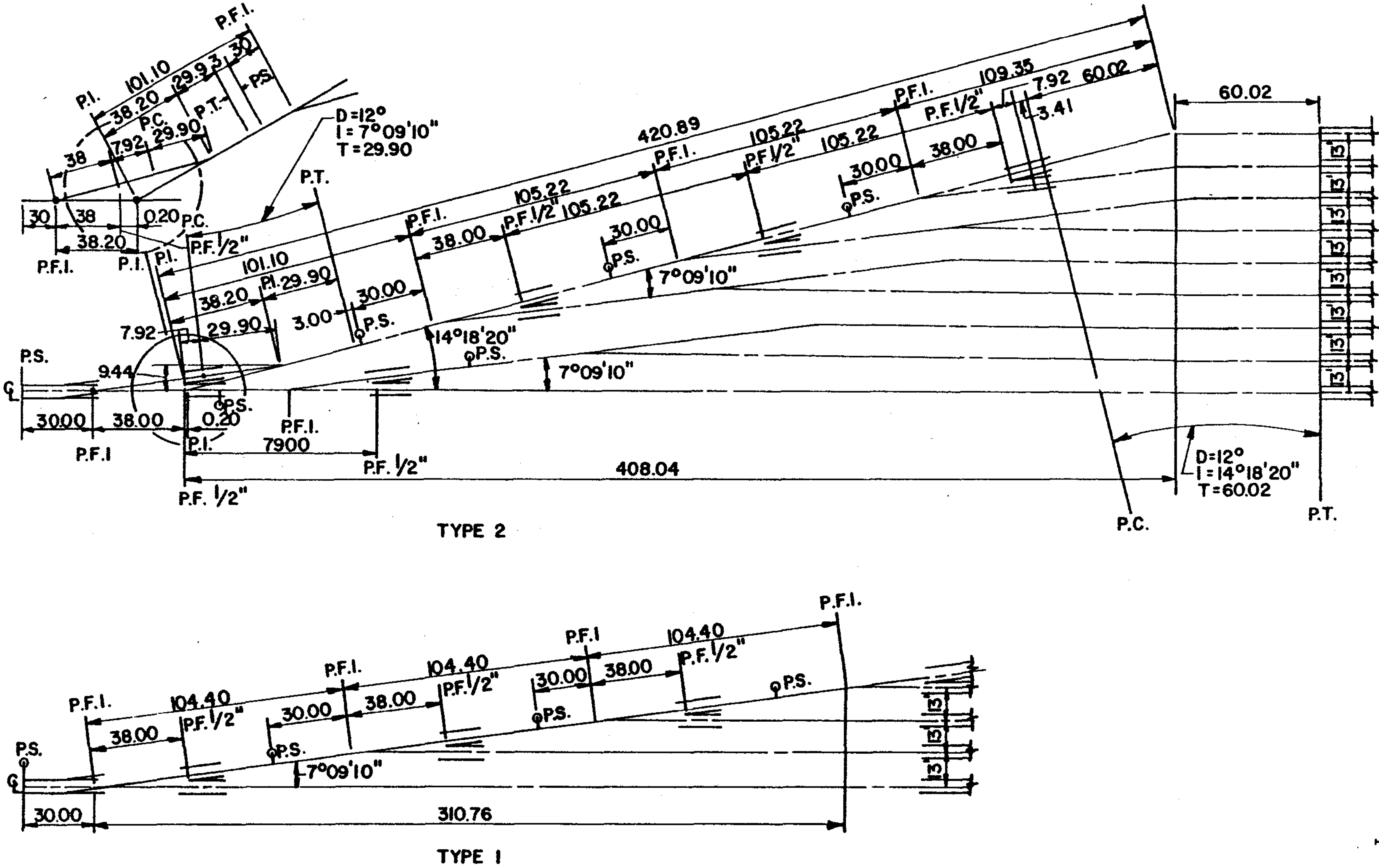

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FIGURE A-5. RAILROAD YARD LADDERS

Table A-8. Material Required for 1,000 Feet of Track

Material	Rail Section (39-Foot) 90 ARA-A	Rail Section (39-Foot) 115 RE
Rail weight, long tons	26.78	28.97
Joint bars		
No. of pairs	51.28	51.28
Weight, net tons	1.64	1.91
Ties		
No. per rail - 20	512	512
No. per rail - 21	538	538
No. per rail - 22	564	564
No. per rail - 23	589	589
No. per rail - 24	615	615
Tie Plates, net tons		
No. of ties - 512	5.78	6.86
No. of ties - 538	6.07	7.20
No. of ties - 564	6.36	7.55
No. of ties - 589	6.64	7.89
No. of ties - 615	6.94	8.23
Spikes (4 per tie) 200-pound kegs		
No. of ties - 512	8.4	8.4
No. of ties - 538	8.9	8.9
No. of ties - 564	9.3	9.3
No. of ties - 589	9.7	9.7
No. of ties - 615	10.1	10.1
Track bolts, 200-pound kegs		
Size - 1 × 5-1/2, inches	2.3	--
Size - 1 × 6, inches	--	2.4
Spring washers, pounds (approximately)	37.0	37.0
Ballast (8 inches under tie), cubic yards		
Single track	490	490
Double track	940	940

NOTES: No allowance is made in joint bars, bolts, and washers for short rail.
Spike quantities are based on 6- by 5.8-inches spikes. On curves increase quantities 50 percent
Bolts and nuts are generally shipped in same container.
Ballast is for tangent track with 15 percent allowance for shrinkage.

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APPENDIX B

REFERENCES

Government Publications.

EM 1110-3-136 Drainage and Erosion Control.

Nongovernment Publications.

American Railway Engineering Association (AREA), 2000 L Street NW, Washington, DC 20036

Manual for Railway Engineering, (Fixed Properties) (Current to July 31, 1982) (Supplement 1982-83).