MAINTENANCE OF TRACKAGE

ARMY TM-5-627
NAVY MO-103
AIR FORCE AFM 91-33

DEPARTMENTS OF THE ARMY,
THE NAVY AND THE AIR FORCE

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Chapter 1.
INTRODUCTION

Section 1. GENERAL

1-1. Purpose

This manual prescribes the policy, criteria, and procedures for inspecting, maintaining, and repairing trackage at military installations. It establishes maintenance standards for railroad and crane trackage systems and provides guidance for the selection, use, and installation of railroad materials and equipment and track components that will perform satisfactorily.

1-2. Scope

This manual is a guide to maintenance of railroad trackage at military installations. Repair, modification, and minor construction procedures are presented within the limitation of maintenance personnel responsibilities. The maintenance standards prescribed have been established to protect Government property, with an economical and effective expenditure of maintenance funds commensurate with the functional requirements and the planned future use of the facilities. The publication furnishes guidance for the maintenance forces in the field who will do the work and is designed for use in the performance of their work.

1-3. Related Publications

The use of the systems and procedures described in this publication, by personnel who have the responsibility for specifications, requisitions, procurement, inspection, storage, issue, application, and safety, should assure uniform, economical, and satisfactory truck maintenance and repair. When information in this publication varies from that contained in the latest issue of Federal or Military Specifications, the(se) Specification(s) shall apply. Appendix A lists pertinent regulations, manuals, and other significant publications referenced throughout the text. In case of doubt, advice concerning any procedure may be obtained from the addresses listed below. Also recommendations or suggestions for modification, or additional information and instructions that will improve the publication and motivate its use, are invited and should be submitted through these channels:

1-3.1. HQDA (DAEN-MPO-B) WASH. DC 20314.

1-3.2. Department of the Navy, Naval Facilities Engineering Command (100), 200 Stovall St., Alexandria, VA 22332, or from its Geographic Engineering Field Division (102).

1-3.3. Department of the Air Force Directorate of Engineering and Services, ATTN: AF/LEE, WASH DC 20330.

1-4. Application

A majority of this manual deals with railroad trackage; however, most information also applies to crane trackage. Where there is a major difference in procedure, trackage will be divided into the following three trackage systems and each discussed separatelv.

1-4.1. Railroad Trackage. Railroad trackage applies to all track systems used by engines, cars, or locomotive cranes including narrow gage systems.

1-4.2. Ground-Level Crane Trackage. Ground-level crane trackage applies to tracks for all weight-handling equipment that operates on the major working level of an activity. This includes but is not limited to trackage systems for portal, gantry, hammerhead, tower, and the ground-level rail for semi-gantry cranes.

1-4.3. Elevated Crane Trackage. Elevated crane trackage applies to all trackage systems attached or suspended from side walls, columns, buildings, roofs, or separate superstructures. This includes trackage for overhead or bridge cranes, wall cranes, semi-gantry cranes, and floating drydock cranes. NOTE: Rail inspections for monorails, "H" or "I" Beam, and other structural steel shape rail systems and trolley trackage for jib and other hoists are conducted by the crane inspector and/or building inspector.

1-5. Cooperation and Coordination

1-5.1. Intraservice Functions. Cooperation and coordination of track maintenance activities among the installation departments concerned should be continuous. Programs of properly planned and executed maintenance operations prevent undesirable interruptions of rail traffic on military installations. Measures for the protection of supplies in storage must be coordinated with the storage service primarily responsible for the care and preservation of stored items. Supply officers, through normal channels, provide standard items of materials and equipment for track maintenance.

1-5.2. Interservice and Interdepartmental Functions. Cooperation and coordination in conducting track maintenance activities are encouraged at all levels of command. Appropriate liaison should be established and maintained between major commands and installations in a geographical area. Cross-service assistance shall be provided as necessary in the interests of economy and maximum utilization of manpower and equipment.

1-6. Army Responsibility

Staff, command, and technical responsibility for maintenance and repair of utility railroad track at Army installations will conform to assignments set forth in AR 420-10 and 420-72. The American Railway Engineering Association (AREA) manual will be consulted on methods, tools, and procedures for railroad maintenance involving problems not covered herein and will be followed when not in conflict with current Army, Navy, or Air Force directives.

1-7. Navy Responsiblity

1-7.1. Naval Facilities Engineering Command. The Naval Facilities Engineering Command (NAVFAC) provides technical guidelines and advice for inspection and maintenance of trackage and related accessories. The Commanders and Commanding Officers of NAVFAC's Engineering Field Divisions provide technical assistance in operations and maintenance matters to shore installations.

1-7.2 Commanding Officer. The Commanding Officer at each Naval and Marine Corps shore installation is responsible for providing safe trackage and an adequate maintenance program. Normally, these responsibilities are delegated to the Public Works Centers or Public Works Departments, as appropriate. Design standards shall be in accordance with NAVFAC DM5. Inspection of trackage systems shall conform to the guidelines established in NAVSEA/NAVFAC Instruction 11230.1 or NAVFAC MO-322.

1-8. Air Force Responsibility

1-8.1. Directives. Policy for the maintenance, repair, and minor construction of railroads and appurtenances is set forth in AFM 85-1 and AFM 86-1, Chapter 2.

1-8.2. Major Command Level. Each major command will:

1-8.2.1. Insure that effective preventive and corrective track maintenance measures are established and accomplished at all installations under its jurisdiction.

1-8.2.2. Provide qualified technical supervision for personnel engaged in these operations.

1-8.2.3. Provide for training of personnel engaged in the maintenance of trackage and appurtenances.

1-8.2.4. Make certain that Base Civil Engineer personnel engaged in direct field supervision of maintenance operations, or those who function independently of direct supervision, are technically competent and thoroughly familiar with the performance of all phases of this activity, as outlined in this publication.

1-8.3. Air Force Installations. The Base Civil Engineer will:

1-8.3.1. Plan, initiate, and supervise the execution of track maintenance.

1-8.3.2. Insure that in-house track maintenance personnel are trained.

1-8.3.3. Investigate the occurrence of and reasons for failures and accidents.

1-8.3.4. Inspect and determine the effectiveness of safety measures.

Section 2. RAILROAD AND CRANE TRACKAGE MAINTENANCE

STANDARDS, POLICIES, AND CRITERIA

1-9. Standards

The standards or criteria contained in this manual have been developed by the Army, Navy, and Air Force with the concurrence and approval of the Assistant Secretary of Defense (MRA&L). Compliance with these standards is madatory in order that the maintenance of trackage at military installations will be uniform, will adequately support the operational missions of the installations, and will permit interservice assistance and support, where possible, in the interest of efficiency and economy.

1-10. Policies and Criteria

The extent of repair and maintenance of railroad trackage will be governed by the permanency of the installation, operational requirements, track classification and category, or limiting conditions established by the serving railroads. Work necessary to maintain base railroads at an equivalent of a Class 2 track as defined in the current Federal Railroad Administration (FRA) Track Safety Standards (Appendix B) will normally satisfy operational needs of military installations. However, safety, efficiency, and economy will be the controlling factors. The FRA Track Safety Standards provide descriptions of tolerances and defects for guidance in overall track inspection. Deviation from the standards in the FRA Track Safety Standards may require immediate corrective action to provide for safe operations over the trackage involved. In general, on heavily used sections of trackage, work planning should start when a deficiency on a section of trackage exceeds one-half (1/2) the allowable deficiency. Selection, installation, inspection, and maintenance of trackage systems shall be in accordance with referenced documents, except where criteria in Chapter 7 provide more stringent or restrictive criteria. In determining the extent and nature of Government maintenance, repairs, and rehabilitation of railroads on land that is held under lease, permit, or easement, the terms of such documents will be taken into account.

1-11. Engineering

The need and accomplishment of major repairs and rehabilitation of existing railroads will be based on the determination of qualified engineers. The services of such technical personnel will be used to assist in the establishment of railroad maintenace programs.

1-12. Specifications

The use of AREA specifications, or those of the railroad(s) serving an installation in lieu of Federal or Military Specifications, may be given consideration when such use would be to the advantage of the Government. Otherwise, the applicable Federal or Military Specification shall take precedence.

1-13. Categories

The term "trackage" includes rails, ties, rail accessories, switches, crossovers, ballast, roadbeds, and support structures. Also included for complete coverage of the trackage system are criteria for the maintenance of slopes, ditches, road crossings, culverts, bridges, trestles, overpasses and underpasses, grade separations, tunnels, signals, snow protection, signs, and markings.

1-13.1. Railroad Trackage System. Railroad trackage systems are divided into six categories according to their principal use.

Category	Service or Use
Running or access	Primary line, industrial and special purpose
Classification yard	Receiving, sorting, and holding
Sidings	Auxiliary (other than for meeting or passing) and house trackage (along or entering a building) and dead storage tracks
Team tracks	Freight transferred directly to highway vehicles
Storage	Hold purposes - low-use spur
Temporary	Generally to facilitate construction

1-13.2. Crane Trackage System. Crane trackage is divided into two major systems: ground level and elevated. Maintenance and inspection procedures are basically the same as those shown for railroad trckage. Operating speeds for cranes shall be initiated and promulgated by activity commanders to meet local safety requirements. Categories may be assigned by type or limiting size of equipment utilizing the trackage system.

1-14. Terms and Engineering Data

A glossary of railroad terms is provided in Appendix C of this manual. Engineering data useful in the maintenance of trackage are presented in Appendix D.

1-15. Active Trackage

The principal tasks to be considered in maintaining active trackage are: renewing ties, ballast, rails, and accessories; raising, realigning, and regrading tracks; oiling and tightening switchpoints and track bolts; cutting vegetation and cleaning ditches; and repairing bridges, trestles, and culverts. Overall maintenance policies and detailed guidance for maintaining these areas are covered in Chapters 2 through 6. Chapter 7 describes procedures for inspecting and reporting trouble areas within trackage systems at military installations. A well-maintained track is shown in Figure 1-1.

1-16. Inactive Trackage.

When trackage is in an inactive status, the maintenance policies will be consistent with the anticipated future mission of the installation and the particular trackage involved.

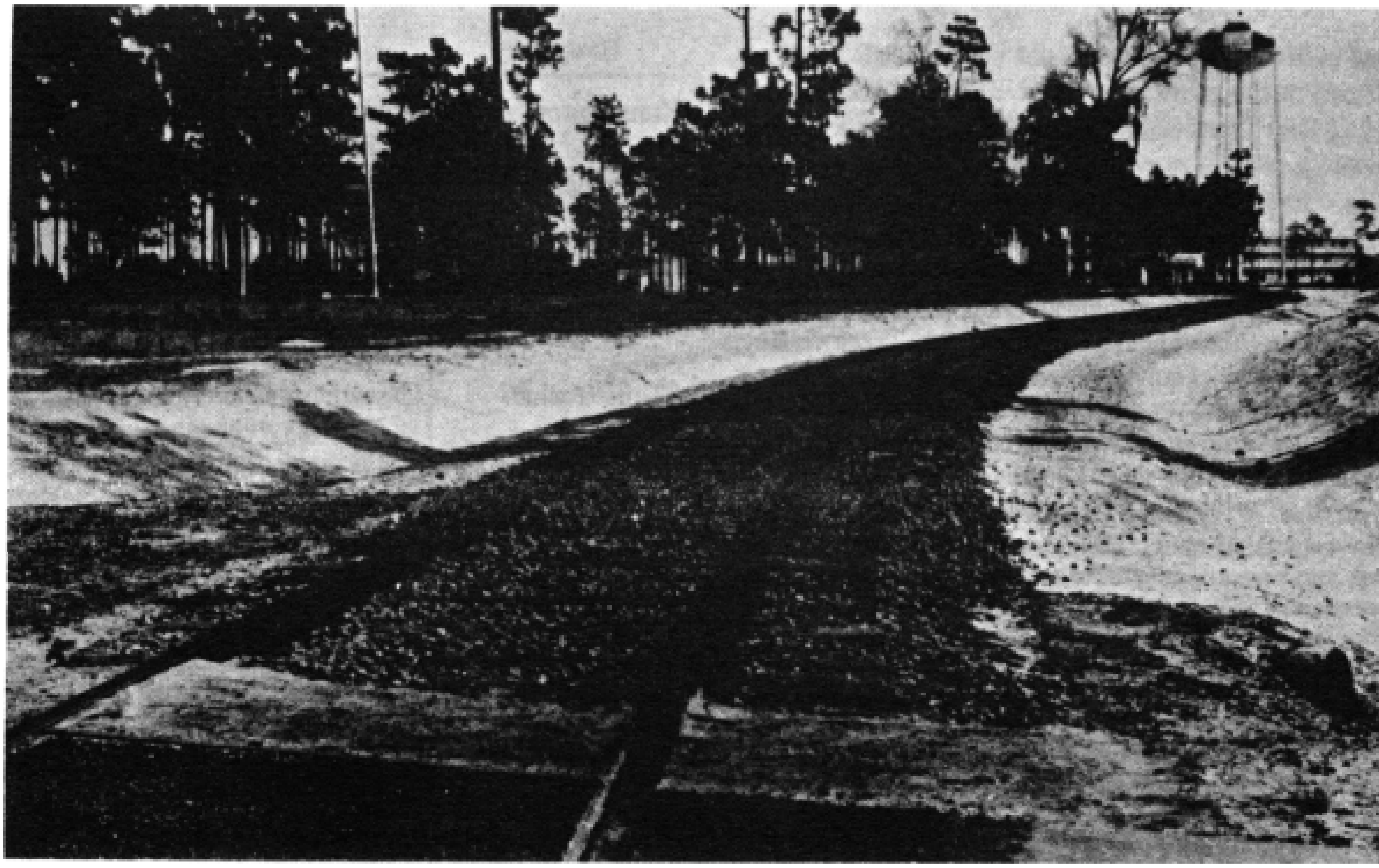


Figure 1-1. Example of well-maintained track.

1-17. Surplus Trackage.

Trackage that is planned for disposal should receive no maintenance except vegetation control. Useful material should be salvaged when such action is in the best interest of the Government.

1-18. Safety

The Occupational Safety and Health Act (OSHA) guidelines and regulations make certain safety equipment and procedures mandatory.. Safety precautions and safe maintenance practices are covered in detail in the following publications:

1-18.1. ARMY — EM 385-1-1.

1-18.2 NAVY — NAVMAT P-5100

1-18.3. Air Force — AFM 127-101

CHAPTER 2.
MATERIALS, TOOLS, AND EQUIPMENT

Section 1. MATERIALS

2–1. General

Maintenance and repair of railroad trackage require the use of special materials, tools, and equipment. It is important that personnel responsible for this maintenance be completely familiar with identification and nomenclature for purposes of use and requisitioning.

2–2. Material Nomenclature and Specifications

In requisitioning track materials, it is important that proper details be given to obtain the exact material required. Figures 2–1 through 2–14 illustrate the most common track materials and present specification details required for drawing clear requisitions.

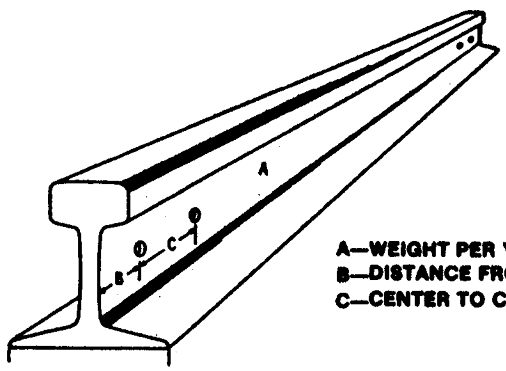


Figure 2–1. Rail details.

2–3. Stocks of Material

Recommended stock quantities for emergency and replacement use are outlined below.

2–3.1. Where deemed appropriate, it is recommended that the following quantities of material be stocked at a convenient location along running tracks or industrial trackage.

2–3.1.1. Two full-length rails of representative weight and section (Figure 2–1).

2–3.1.2. Two short-length rails of representative weight and section.

2–3.1.3. Two pairs of joint bars and compromise joint bars (when appropriate) with bolts and lock washers (Figures 2–2 and 2–3).

2–3.2. Classification/Receiving Yard or Industrial Area. At classification and receiving yard, or other congested areas, stocks should include:

2–3.2.1 One frog of representative number, weight, and section (Figure 2–4 and Table D-1).

2–3.2.2. One set of switch points (right and left hand) (Figure 2–5 and Table D-1). NOTE: Must match existing points in type, section, length, and drilling pattern.

2–3.2.3. Two guardrails (Figure 2–6). Tee rail or one piece manganese. NOTE: Guardrails may be straight on ends.

2–3.2.4. One full-length rail.

2–3.3. Central Storage. Recommended stock quantities at a designated central storage area are two full-length rails with track fastenings such as joint bars, bolts, spikes, rail anchors, and tie plates (Figures 2–7 through 2–11) for each mile of track.

2–3.4. Emergency. Minimum standby stocks for emergency use at central storage area are:

2–3.4.1. Switch stand repair parts (complete) (Figure 2–12).

2–3.4.2. Two sets of switch ties (Figure 2–13).

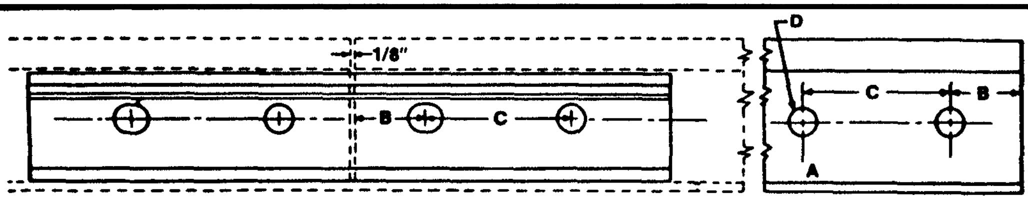
2–3.4.3. One care (30 to 50 tons) of ballast. NOTE: This may be deleted at small installations with short trackage.

2–4. Storage of Material.

Stocks of material in the warehouse, section tool house, or in open storage will be properly stored (Figures 2–14 through 2–16).

2–4.1. Rails and Track Accessories. Rails stored at points along a railroad for future use should be segregated by weight and section and stacked in neat piles (Figure 2–14). Store rails above probable high water in case of flooding, and at least 10 feet from the nearest track. Protect accessories from the effects of inclement weather. Always store materials so that they will not interfere with the movement of train crews or personnel frequenting the area.

2–4.2. Wood and Concrete Ties. Segregate timber crossties according to size and type, and store by stacking on high, dry ground. Treated ties may be stacked edge to edge (Figure 2–15). Avoid handling ties with sharp instruments other than tie tongs. Keep ground in the storage area bare of debris or vegetation for at least 2 feet around every stack of ties and clear of vegetation over 6 inches high within 10 feet of any stack; slope the ground so that water will not remain under the stacks or in their immediate vicinity. It is especially important that all decaying wood debris be removed and that fire prevention measures be observed around the storage area. Figure 2–16 shows the proper method of storing concrete ties.

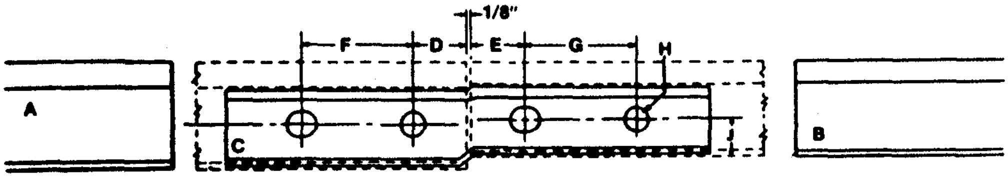


SPECIFY

A—WEIGHT AND SECTION OF RAIL
B—DISTANCE, END OF RAIL TO CENTER OF FIRST BOLT HOLE
C—DISTANCE, CENTER TO CENTER OF FIRST AND SECOND BOLT HOLES
D—DIAMETER OF BOLT TO BE USED

UNIT: PAIR

Figure 2–2. Joint bar details.



C = LEFT HAND (LH) OR RIGHT HAND (RH) DEPENDING ON LOCATION OF LARGER RAIL VIEWED FROM CENTER OF TRACK (THIS IS A LEFT-HAND BAR)

SPECIFY

A—WEIGHT AND SECTION OF LARGER RAIL
B—WEIGHT AND SECTION OF SMALLER RAIL
C—LH OR RH
D—DISTANCE FROM END OF LARGER RAIL TO CENTER OF FIRST HOLE
E—DISTANCE FROM END OF SMALLER RAIL TO CENTER OF FIRST HOLE
F—DISTANCE CENTER TO CENTER OF FIRST AND SECOND HOLE, LARGER RAIL
G—DISTANCE CENTER TO CENTER OF FIRST AND SECOND HOLE, SMALLER RAIL
H—DIAMETER OF BOLT HOLES IN RAIL. IF DIFFERENT, SPECIFY SIZES

UNIT: EACH; INCLUDES INSIDE AND OUTSIDE BARS

Figure 2–3. Compromise joint details.

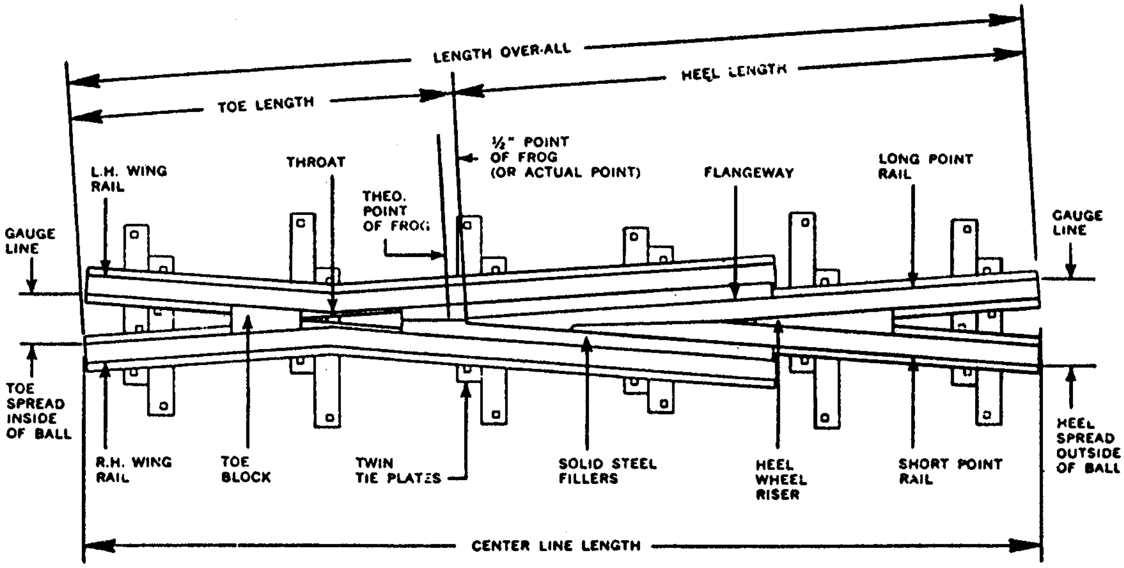


Figure 2-4. Frog details.

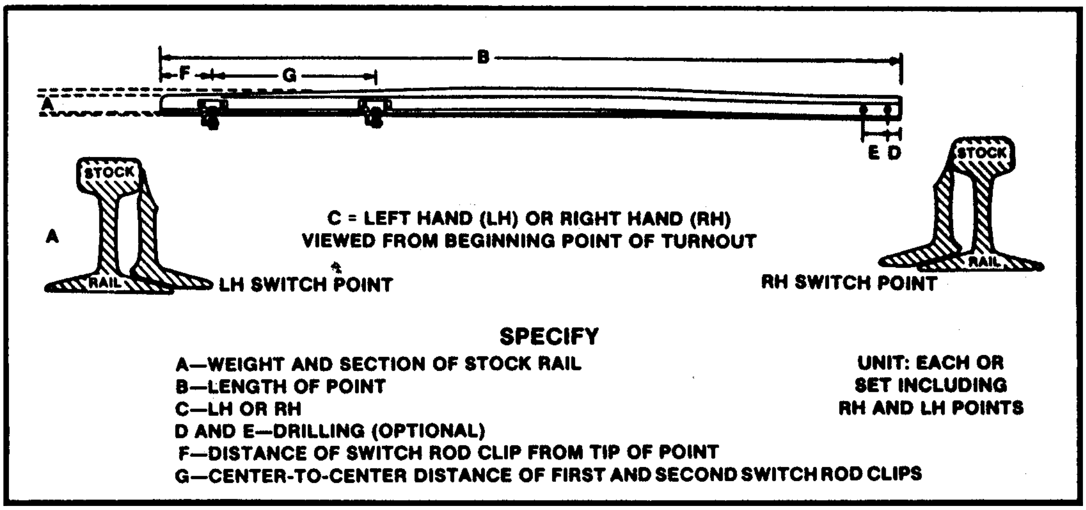


Figure 2-5. Switch point details.

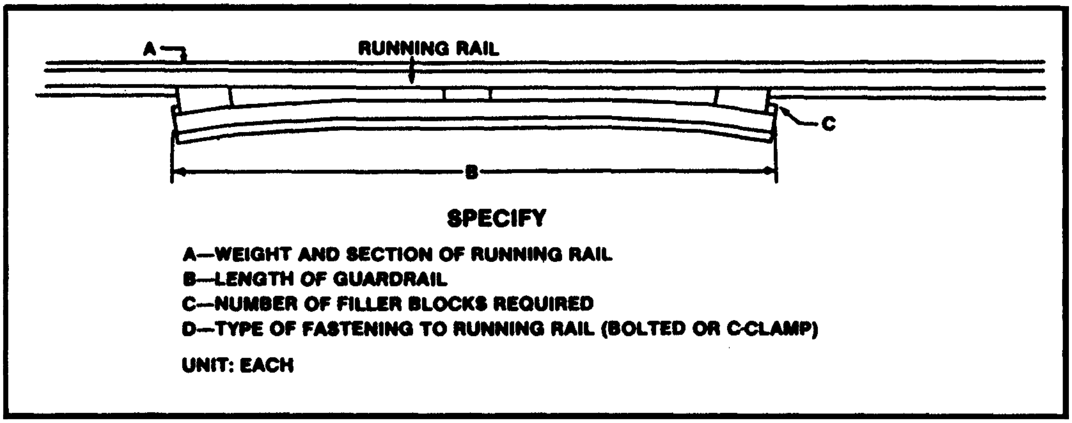


Figure 2-6. Guardrail details

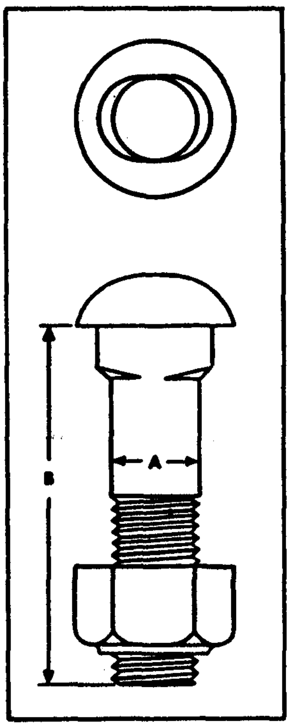


Figure 2-7. Track bolt details.

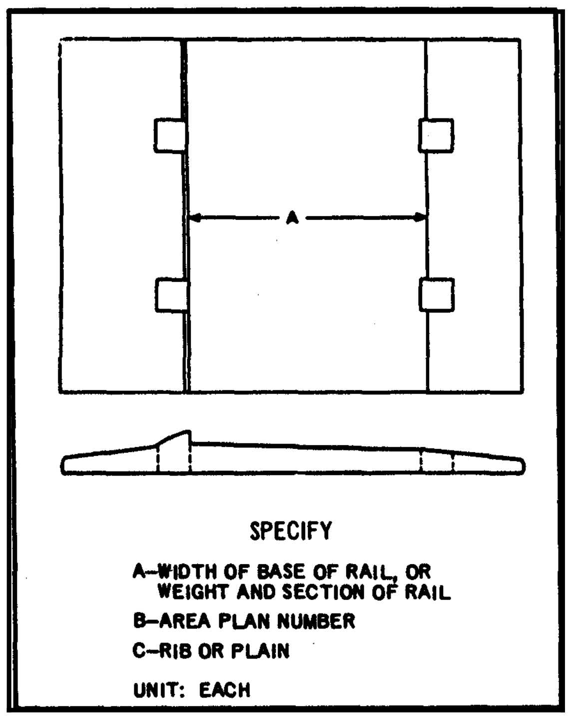


Figure 2-8. Tie plate details.

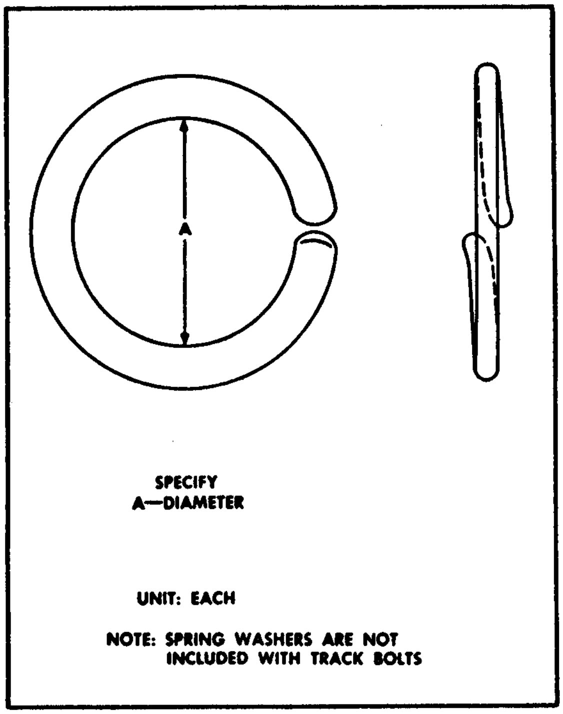


Figure 2-9. Spring lock washer details.

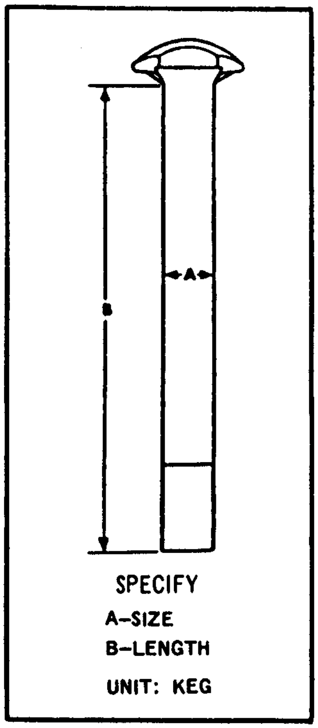


Figure 2-10. Track spike details.

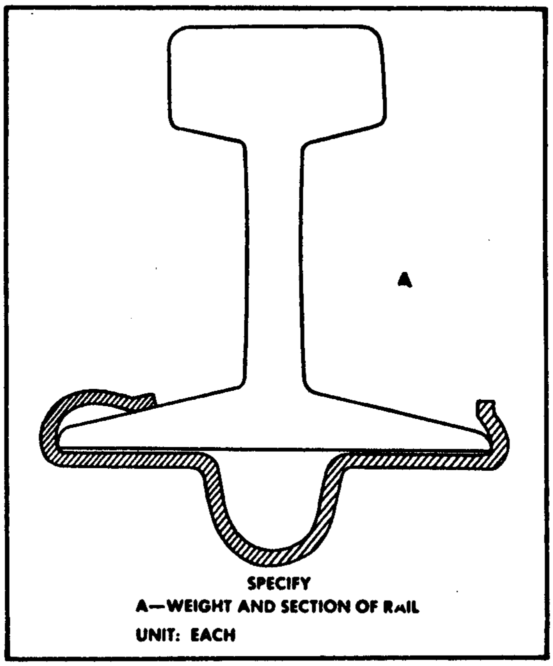


Figure 2-11. Typical rail anchor.

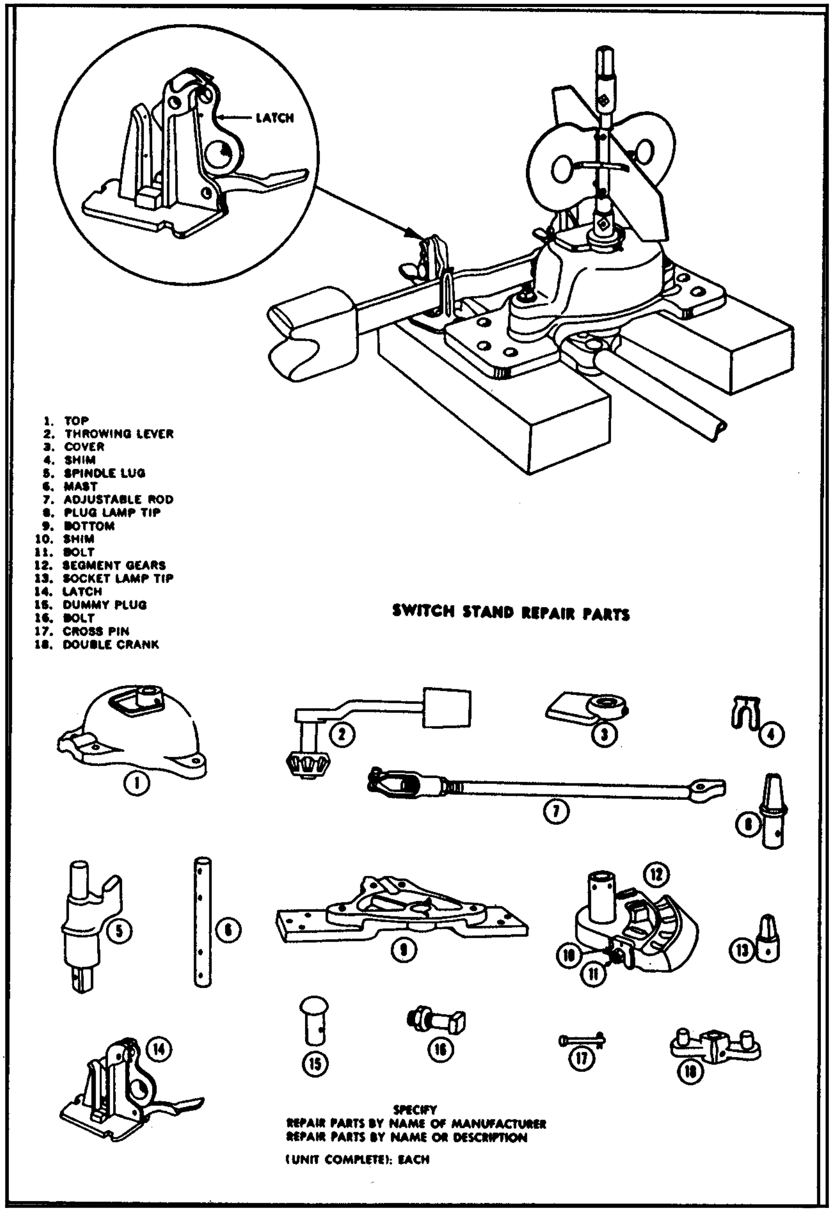


Figure 2-12. Details of switch-stand repair parts. Figure illustrates low stand with parallel throw.

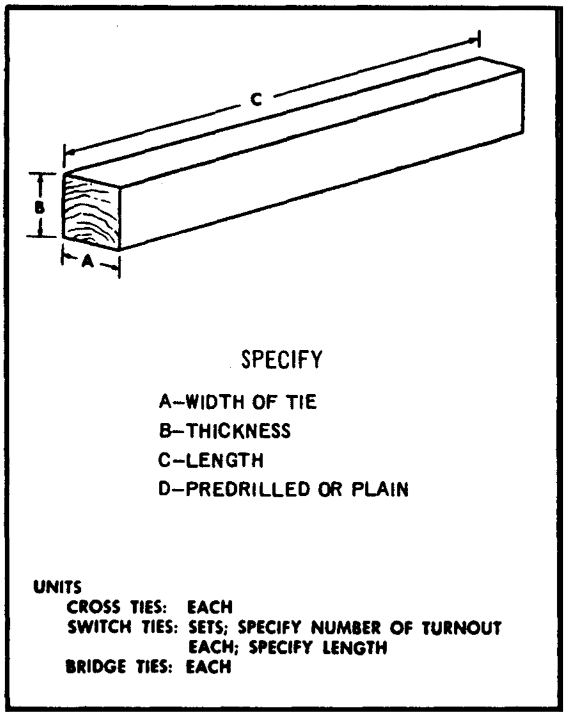


Figure 2-13. Switch, cross, and bridge tie details.

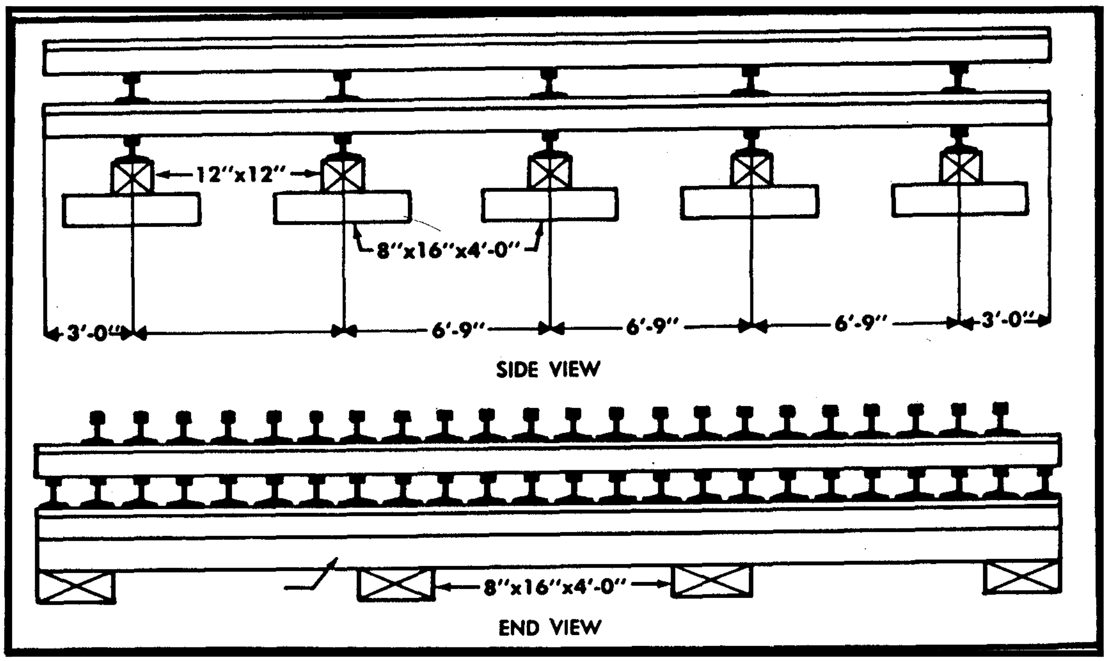


Figure 2-14. Proper method of stacking rails.

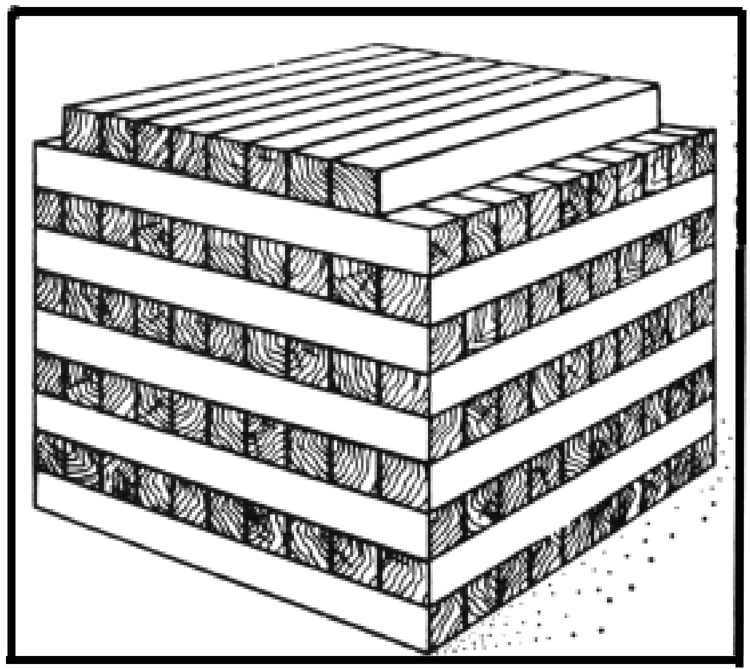


Figure 2-15. Proper method of stacking wood ties.

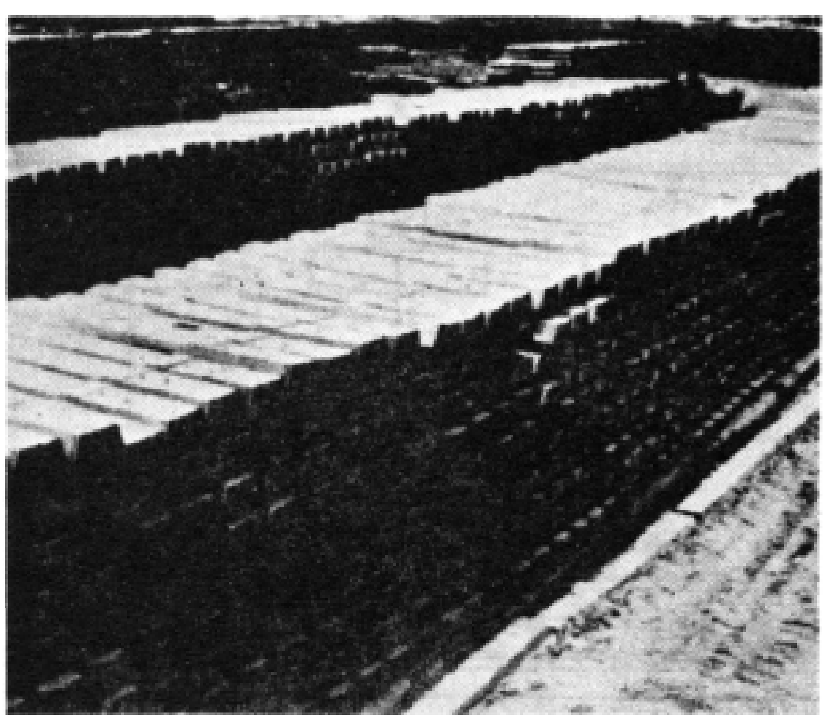


Figure 2-16. Proper method of storing concrete ties.

Section 2. TOOLS AND EQUIPMENT

2–5. Requirements.

Tools and equipment should be provided in quantities consistent with the maintenance to be performed. In specific instancies where additional or special tools and equipment are required, they should be procured through normal supply channels. Tools usually employed in track work are shown in Figure 2–17.

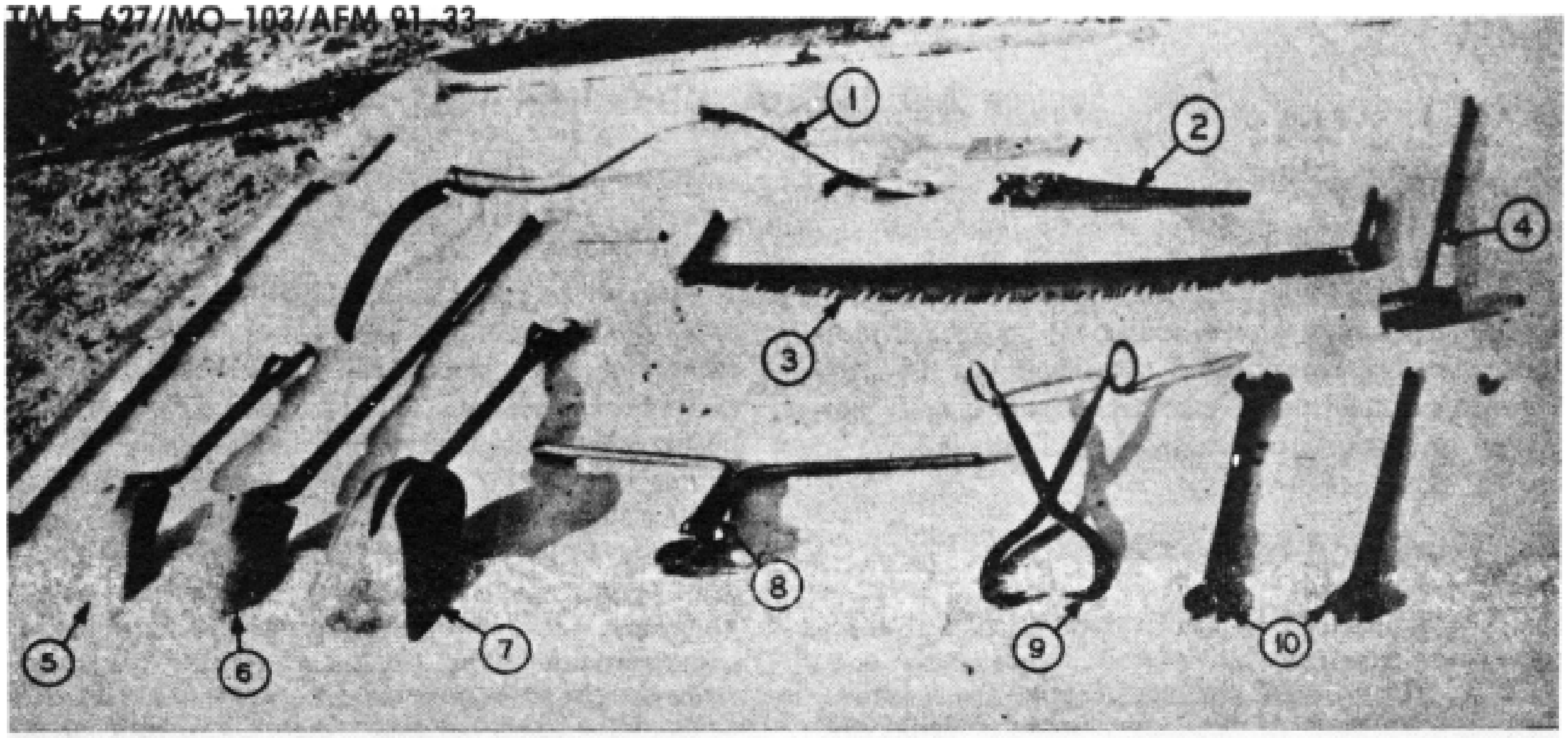
2–6. Care and Maintenance.

2–6.1. General. Tools and equipment shall be maintained in a constant state of good repair. They shall be kept free of rust and serviceable at all times. Cutting tools such as chipping hammers, drills, chisels, and saws must be kept sharpened and ready for use. Defective or wornout tools and equipment should be repaired or replaced. Personnel handling, using, and storing tools and equipment must do so in an orderly workmanlike manner, adhering to all safety precautions. Railroad maintenance personnel should be constantly aware of rail traffic dangers to life and limb, not only from their own standpoint but from the standpoint of the transportation of personnel and passengers. Tools and equipment must be kept clear of the right-of-way except during actual in-hand use. When loaded on trucks, track cars, or trailers, tools must be placed so that they will not fall off when bumped or moved (Figure 2–18).

2–6.2. Power Operated Equipment. Where railroad maintenance equipment includes power-operated machinery or specialized machinery such as snow plows, mechanical spreaders, and the like, maintenance shall be carried out as described in individual equipment manuals or in the manufacturer's instructions.

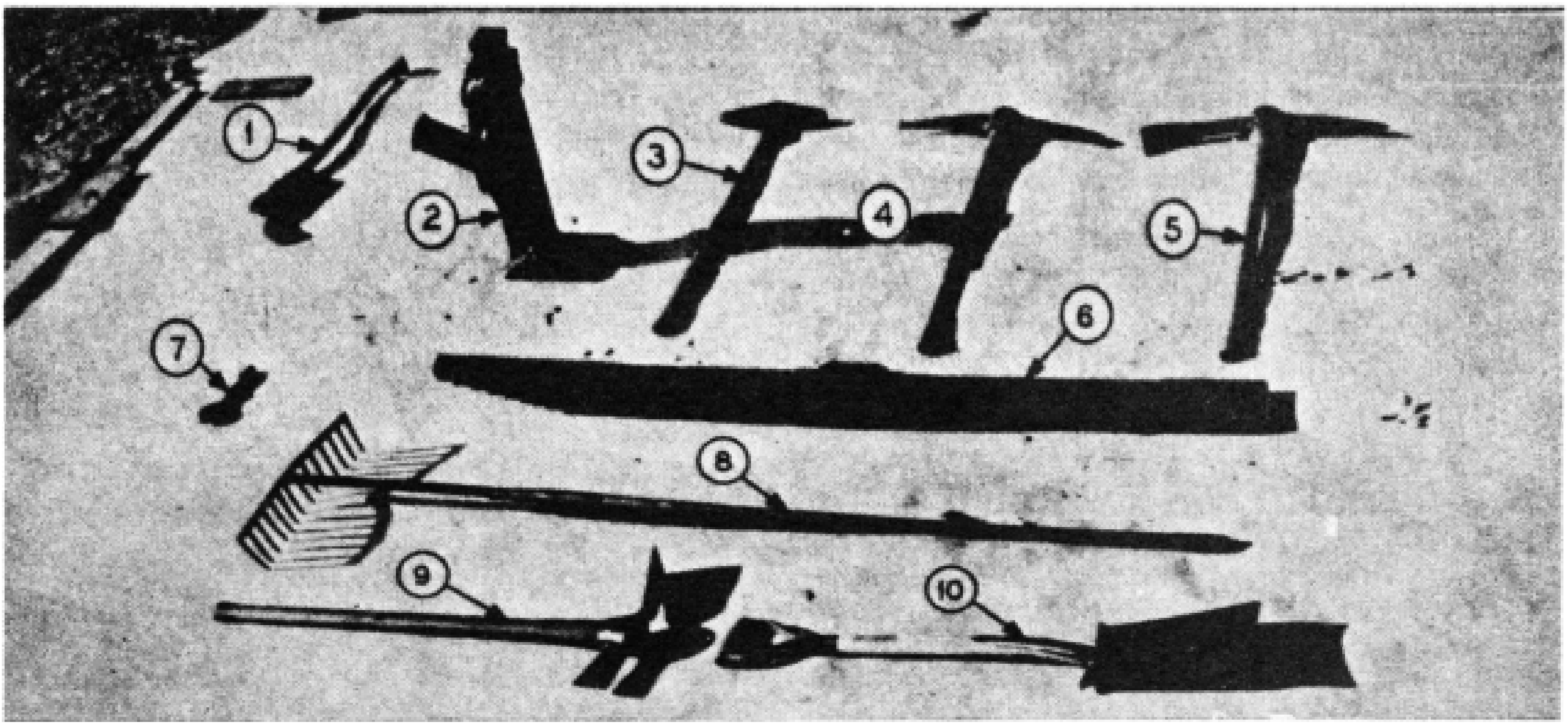
2–6.3. Special Tool and Equipment Maintenance Procedures. In areas where climatic conditions other than temperate exist, special instructions will be given and provisions made for the handling of tools and equipment. This applies to Arctic, tropic, and other severe climatic areas where intense cold, heat, or humidity affect the materials from which tools and equipment are made, as well as handling, storage, replacement, and repair. Adjustment shall be made in supplies and stocks to meet the local situation.

2–6.4. Storage. Tools shall be stored neatly in toolhouses when not in use. Small tools are best kept in toolboxes, whereas larger sharp tools, such as bars, picks, and forks, are best stored in racks designed to protect their points and at the same time be safe for personnel moving about the toolhouse. Power tools or machinery shall be housed against weather, and their accessories systematically stored for ready application.



A.

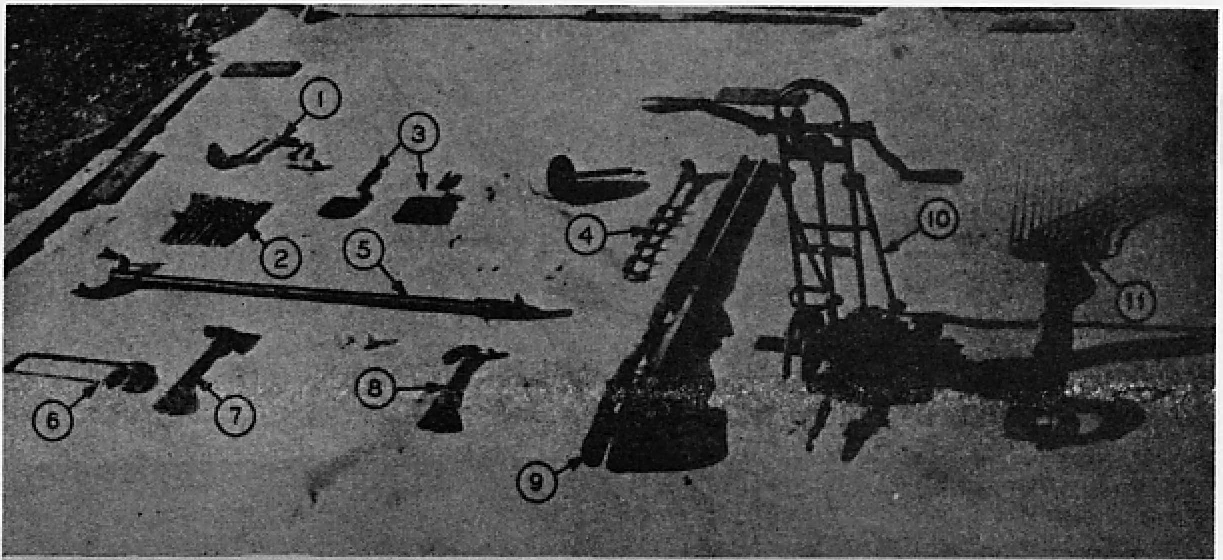
1. Scythe
2. Hand saw
3. Two-man saw
4. Sledge hammer
5. Short-handled, square point shovel
6. Long-handled, round point shovel
7. Scoop
8. Rail tong
9. Tie tong
10. Track wrenches



B.

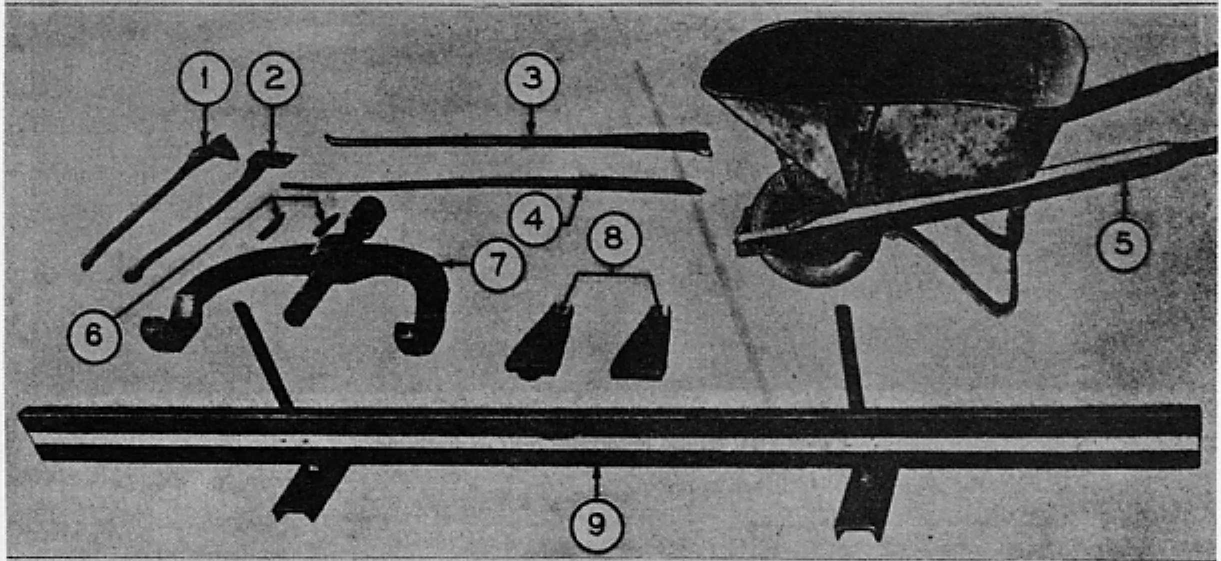
1. Brush hook
2. Track jack
3. Spike maul
4. Pick
5. Tamping pick
6. Level board
7. Spike-claw extension
8. Rake
9. Mattock
10. Spade

Figure 2-17. Track tools (Sheet 1 of 2).



C.

1. Drill brace
2. Wood drills
3. Paint brushes
4. Boring tool
5. Track gage
6. Hacksaw
7. Hatchet
8. Claw hammer
9. Post-hole digger
10. Rail-drilling machine
11. Ballast fork



D.

1. Tie adze
2. Ax
3. Claw bar
4. Lining bar
5. Wheelbarrow
6. Track drills
7. Rail bender
8. Sighting blocks
9. Spot board

Figure 2-17. (Sheet 2 of 2).

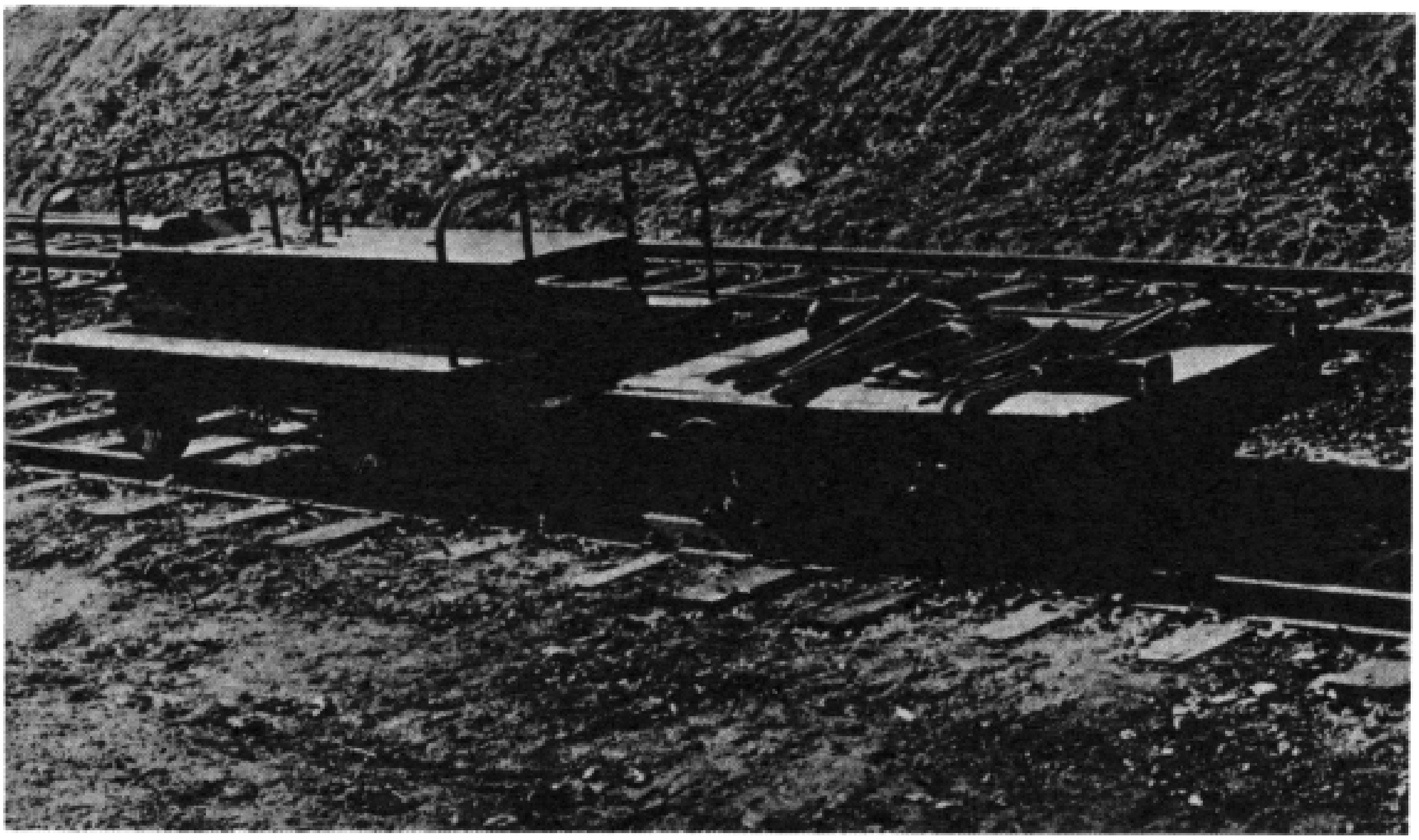


Figure 2-18. Method of carrying tools on track car.

CHAPTER 3
TRACK STRUCTURE ELEMENTS

Section 1. GENERAL

3-1. Purpose.

To present methods and procedures for maintenance of track elements in a manner that complies with the policies set forth in Chapter 1.

3-2. Scope.

The criteria for repair, maintenance, and rehabilitation presented in this part of the manual pertain directly to elements making up the track structure. Many track problems originate with faulty drainage (Chapter 4) or improper original construction. These problems must be solved prior to or during the repair or rehabilitation. Competent engineering assistance may be required to solve them when the determination of the cause of the deficiency is beyond the capaility of the maintenance force. Early attention to maintenance problems reduces costly repair and adds to the efficiency of overall operations.

Section 2. BALLAST

3-3. Purpose of Ballast.

Ballast is selected material placed on the roadbed for the purpose of holding the track in line and elevation. It provides uniform support for the track, anchors the track in place, drains water falling onto the roadbed, reduces heaving from frost, and retards the growth of vegetation. Economic factors as well as matching existing work will be considered in determining the type of ballast material for maintenance use.

3-4. Types, Sizes, and Application.

3-4.1. Crushed Stone, Slag, and Gravel. Ballast will have high strength, durability, and permeability. Crushed stone, slag, gravel, and similar materials may be used if they conform to AREA requirements for gradation, wear, and soundness. Coarse graduations, up to 2-1/2-inch maximum size, are preferred.

3-4.2. Pit-Run Gravel. Pit-run gravel is satisfactory for low-use tracks, whereas crushed stone or similar high quality material is required for running track. On weak subgrades, free-draining sand is used as subballast to reduce pumping and the formation of ballast pockets.

3-4.3. Sizes. Tables 3-1 presents maximum and minimum sizes recommended for ballast materials.

Table 3-1. Recommended Ballast Gradation

Type	Maximum Size in.	Minimum Size in.	Percent Fines Allowable by Weight
Crushed rock:			
Traprock	2-1/2	3/4	10
Limestone	2-1/2	3/4	10
Granite	2-1/2	3/4	10
Slag, broken and screened	2-1/2	1	15
Gravel:			
Screened and washed	1-1/2	1/2	10
Screened	1-1/2	1/2	20
Pit-run	Large rocks removed		

3-5. Reconditioning Ballasted Track.

Stone or hard slag ballast shall be cleaned when dirty enough to grow vegetation or when other foreign material restricts proper drainage. Pit-run gravel with fines exceeding 30 percent shall be replaced. Hand methods or mechanical means may be used for reconditioning ballast.

3-5.1 Stone, Slag, or Screened-Gravel Ballast. To recondition ballasted track, the following steps are necessary:

3-5.1.1. Clean ballast shoulder down to subgrade or top of the subballast (Figure 3-1).

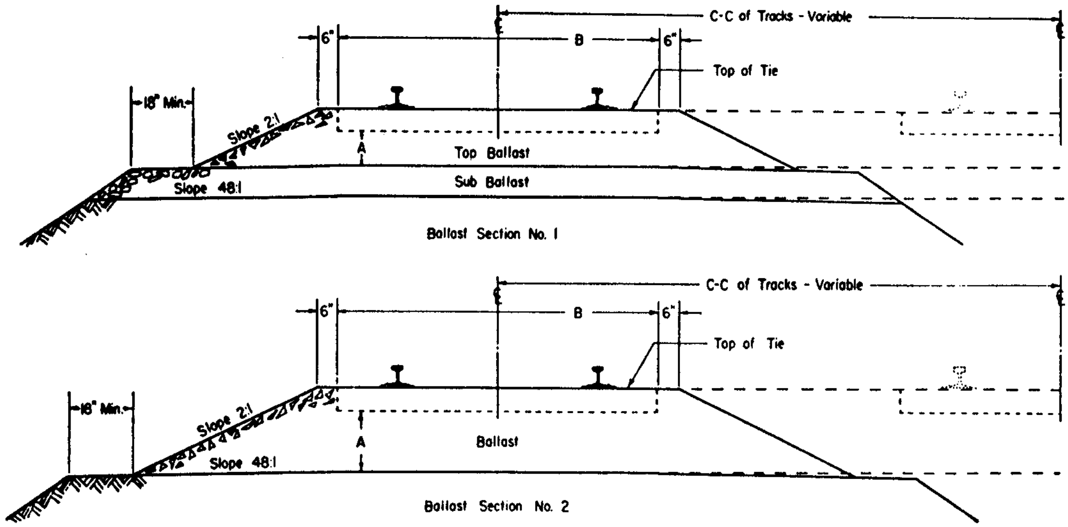


Figure 3-1. AREA ballast sections, single and multiple track, tangent.

3-5.1.2. Clean crib to bottom of ties.

3-5.1.3. Clean space between multiple tracks to bottom of ballast or, at least, to 6 inches below the bottom of the ties.

3.5.1.4. Clean the berm to the bottom of the ballast, preferably not less than 8 inches below the bottom of the ties.

3-5.1.5. Clean cross ditches or drains.

3-5.1.6. Dress subgrade and provide drainage in accordance with minimum slopes shown in Figure 3-2.

3-5.1.7. Clean the ballast removed.

3.5.1.8. Replace cleaned ballast under the track and add enough new ballast to make a standard section. Minimum ballast depth must be maintained at 6 inches below the bottom of crossties.

3-5.1.9. Collect refuse material, and distribute it along slopes of fill.

3-5.2. Pit-Run Ballast. To recondition pit-run ballast, the following steps are necessary:

3.5.2.1. Skeletonize the track by stripping or by raising the track on the old ballast (Figure 3-3).

3-5.2.2. Remove the ballast from outside the track to the original depth of the ties.

3-5.2.3. Dress subgrade and widen cuts or fills wherever necessary. Maintain a 2:1 maximum slope, preferably 3:1 to facilitate maintenance.

3-5.2.4. Clean existing cross drains, or construct new ones; be sure they are deep enough to provide adequate drainage. Never locate cross drains at rail joints.

3-5.2.5. Distribute enough clean ballast to provide for the lift and width desired.

3-5.2.6. Resurface track to uniform grade.

3-5.2.7. Collect refuse material, and place it along slopes of fills.

3-6. Distribution of New Ballast.

Except where the distribution of new ballast is needed for an intended raise out-of-face, the track is surfaced before distribution of new ballast.

3-6.1. Dumping. Ballast is usually unloaded by dumping from hopper cars (Figure 3-4). It is unloaded by having one or more cars opened at a time, allowing the required amount of ballast material to flow out as the train is moved along slowly.

3-6.2. Spreading. The unloaded material should be leveled by means of a ballast plow or spreader. Care must be taken to hold to the established grade set for the new material. Hand methods require special attention to placement of ballast under the full tie length (Figures 3-5 and 3-6).

3-6.3. Tamping. Ballast must be well packed with hand tools or machines, Figures 3-7, 3-8, and 3-9.

3-6.4. Frogs, Guardrails, and Switches. At turnouts, remove all excess ballast from frogs, guardrails, and the movable parts of switches.

3-6.5. Trimming the Ballast. Ballast should be trimmed to conform to the standard ballast section (Figures 3-1 and 3-2), using an appropriate template. Slopes shown are preferred; however, conditions may require different slopes. The portion of the subgrade outside the ballast line should be left with a full, even surface and the shoulder of an embankment clearly defined and properly dressed to the standard road-

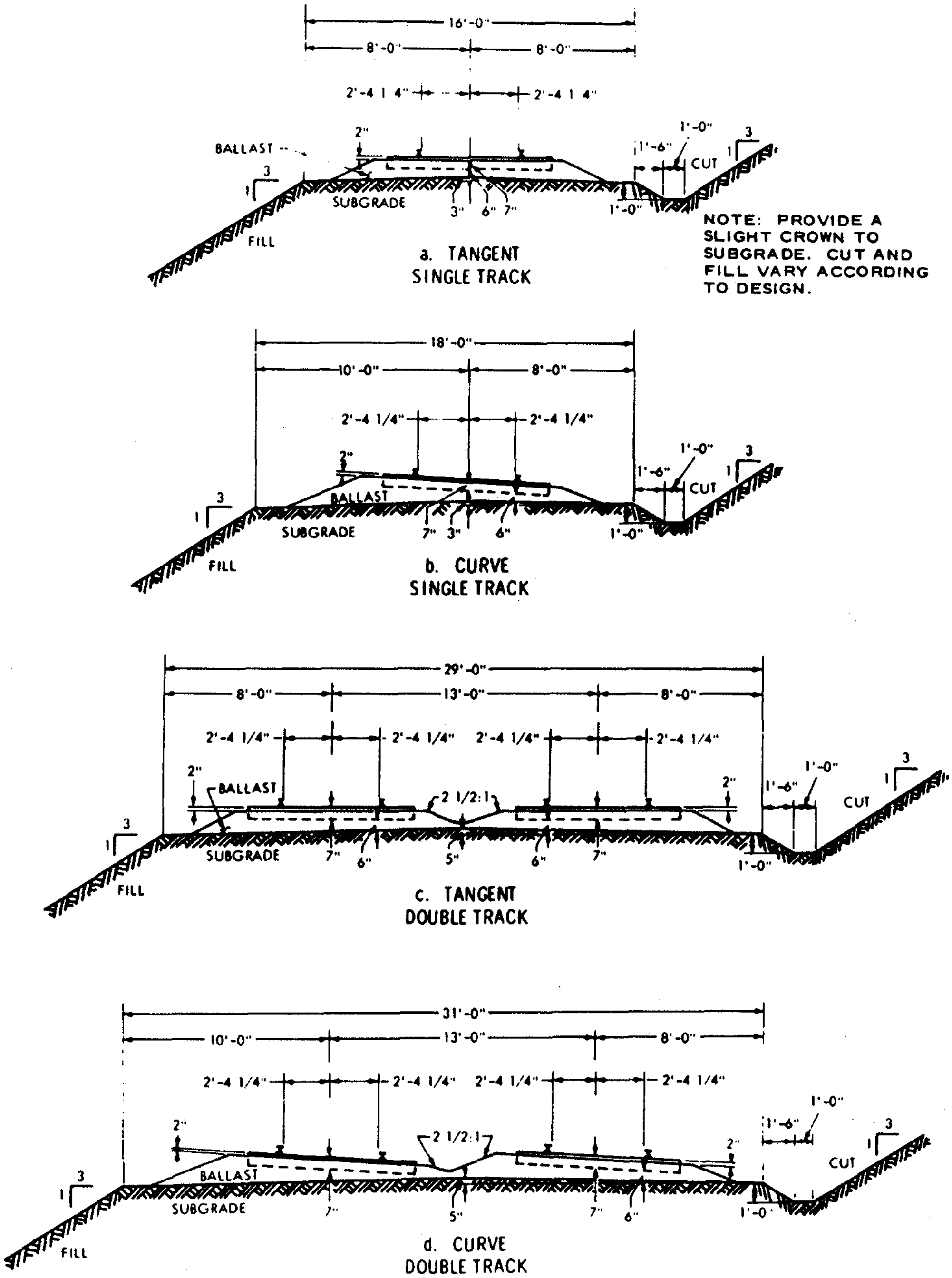


Figure 3-2. Details of standard ballast sections.

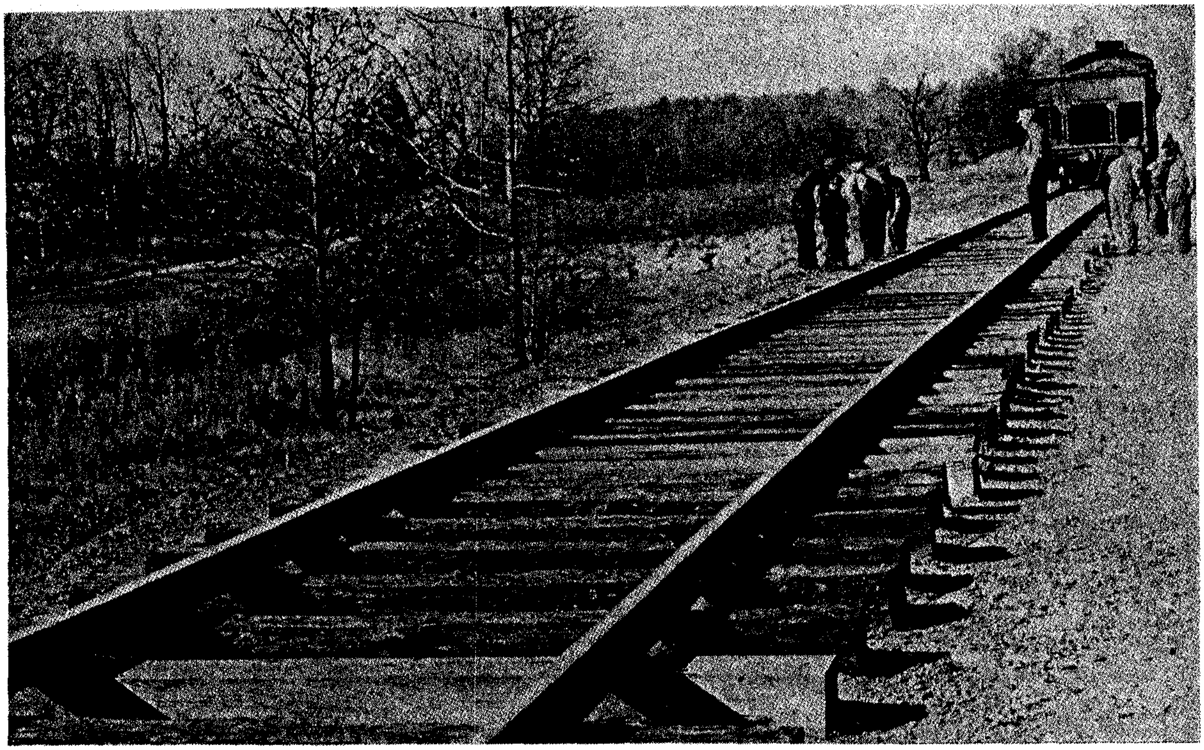


Figure 3–3. Track skeletonized to receive ballast.

way section. Clean or rake the berm. Surplus ballast left over from trimming should be disposed of in an appropriate area.

3–6.6. Cleanup. After the ballast is cleaned or renewed, remove all materials, tools, and equipment used to perform the work; install and secure promptly all stock guards, crossing planks, and similar facilities adjacent to or forming part of the track; and dispose of all rubbish and waste remaining from the operation. Do not litter the right-of-way.

Section 3. TIES

3–7. General.

Nearly all railroad trackage on military installations has been constructed on wood ties. The use of wood ties for most such trackage will be continued, but there are circumstances where the use of concrete ties may be warranted. Trackage constructed on concrete ties in recent years by several commercial railroads has indicated that some of the potential advantages of concrete over wood ties include longer in-use life, greater strength, and better ability to hold rails permanently in line and to gage.

3–8. Wood Ties.

The service life of wood ties depends on the kind of wood, the method of treatment, the mechanical protection afforded, the severity of use, and climatic conditions. The use of untreated wood ties can no longer be justified. Only treated wood ties are to be purchased or used. Design and specification of ties used in maintenance and repairs must conform to AREA Standards and/or Federal Specifications and should match the ties in existing adjoining work (see Appendix G).

3–8.1. Preservative Treatment. Pressure treatment with creosote has proved to be the most effective and practical preventive of decay (rot) and insects. Damage to wood fibers during spiking is less in treated than in untreated ties. Water repellance is better in treated than in untreated ties. Coal-tar creosote, solutions of wood-tar and coal-tar creosotes, and oil-borne solutions of pentachlorophenol are the most common preservatives used for wood ties. Pressure treatment is more effective than field treatment because preservatives applied under pressure penetrate the wood deeper and more uniformly than they do when applied in the field under no pressure. Consequently, field treatment is relied on only to

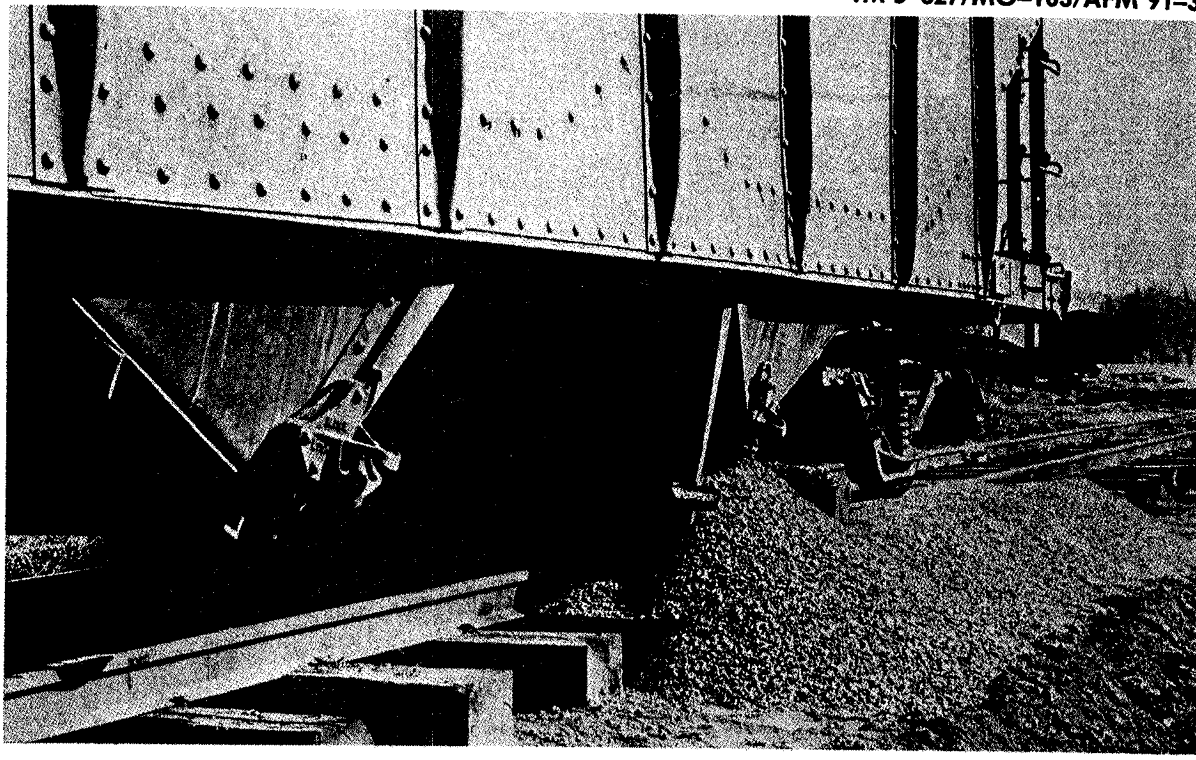


Figure 3-4. Distributing ballast from hopper car.

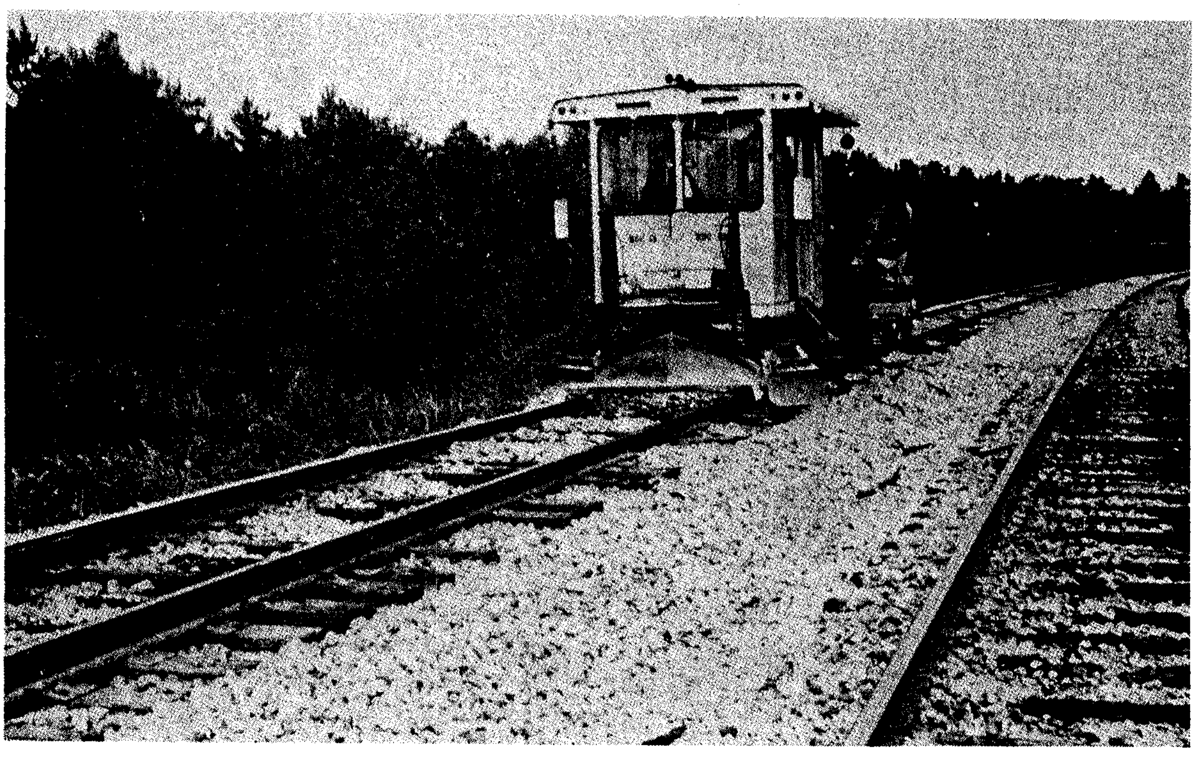


Figure 3-5. Ballast plow.

Figure 3-6. Hand-placing ballast after mechanical distribution.

Figure 3-7. Manually tamping ballast with compressed air tools.

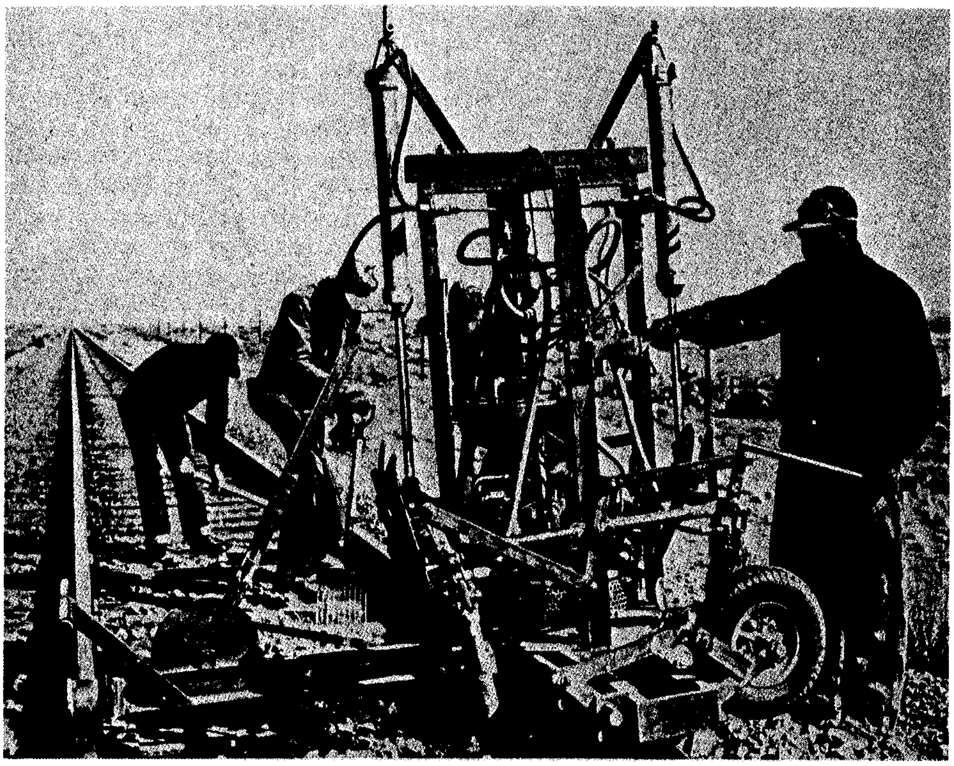


Figure 3–8. Machine tamping ballast.

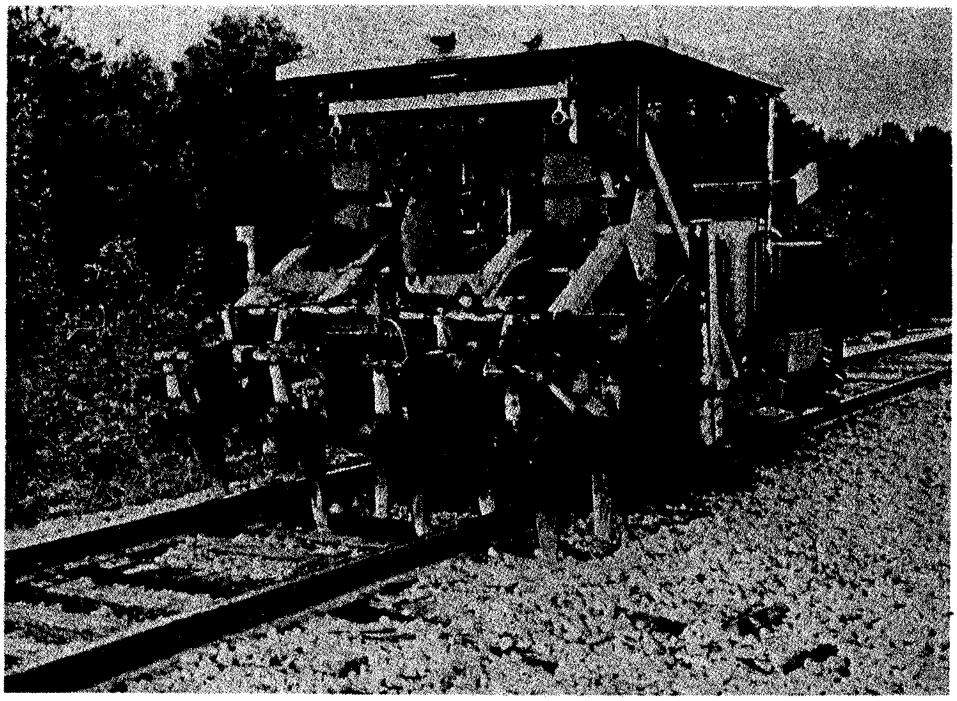


Figure 3–9. Large ballast tamping machine.

supplement pressure treatment; i.e., where it becomes necessary to penetrate the treated "shells" of pressure-treated ties by cutting, adzing or boring, etc.), the resultant exposed untreated wood is to be treated with field-applied creosote. Treating shall conform to the standards of the American Wood Preservers Bureau.

3-8.1.1. Any fabricating such as end trimming and, if required, adzing and boring or application of antisplitting devices (irons) (Figures 3-10 and 3-11 or dowels (Figure 3-12) should be performed before the ties are pressure treated. Seldom are the treated shells of such ties damaged while being properly handled and placed. Where the pressure-treated shells are unavoidably damaged, field-applied preservative is to be provided.

3-8.1.2. Because switch ties are not of uniform length (Figure 2-13) and because the locations of switch components cannot be predicted, switch ties are not adzed or bored before pressure treatment. The prefabrication of switch ties should consist of cutting and installation of antisplitting devices only. The field adzing and boring of switch ties is to be followed by carefully applied field preservative treatment.

3-8.1.3. The field treatment is to consist of two applications of hot creosote. On flat untreated surfaces (where ties have been adzed or cut), the material shall be brush applied. Unused bored holes or spike holes are to be filled with tight-fitting, soft wood, treated plugs firmly driven into the holes.

3-8.2. Handling Wood Ties. Broken, bruised, gouged, and otherwise damaged ties are the result of careless handling. Ties are not to be unloaded by dropping or throwing them onto rails, rocks, or hard or paved surfaces. Ties handled with tongs suffer less damage than ties handled with bars or sharp tools. Figures 3-13 through 3-16 illustrate the proper method of handling wood ties. The proper manner in which wood ties are to be stacked when they are not to be used immediately is shown in Figure 2-15 (para 2-4). Stacks of ties in areas exposed to sparks or other fire hazards can be protected by covering the stacks with earth or sand.

3-8.3. Safety. Creosote is a skin irritant, and splinters are a constant hazard in the handling of ties. All personnel who handle ties must wear appropriate gloves (Figure 3-16). Other common hazards are the dropping of ties and other heavy objects and tripping over tools and supplies. All personnel exposed to these hazards will wear safety shoes.

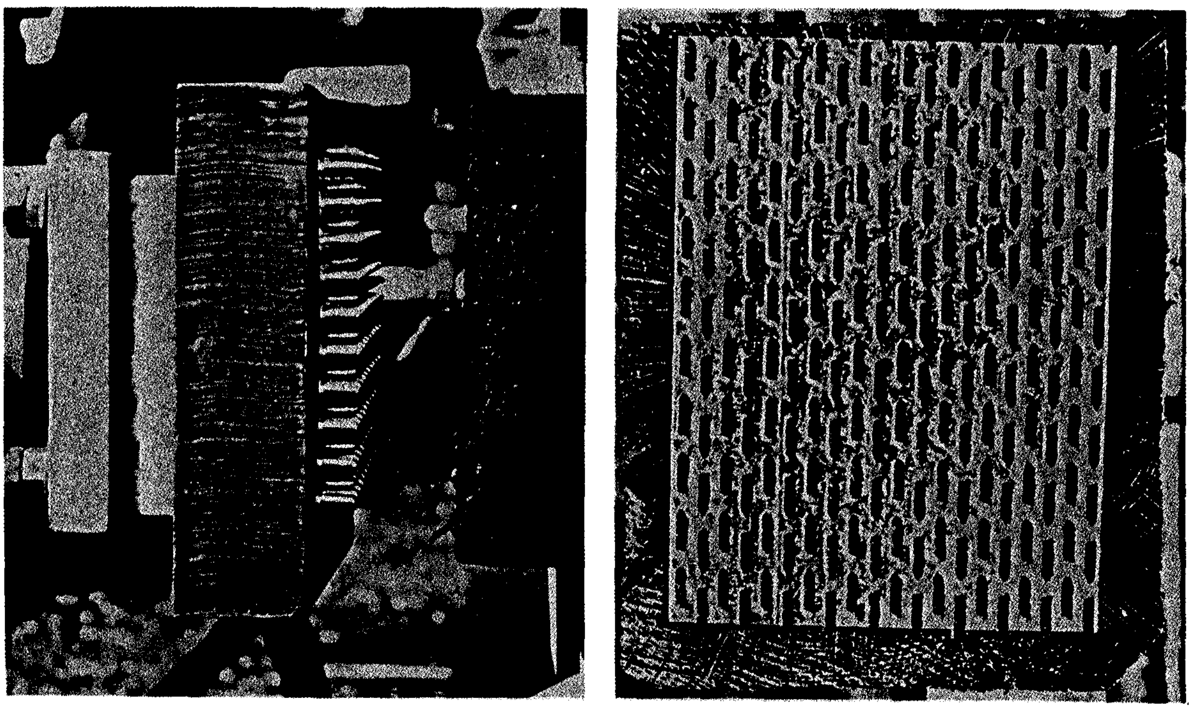


Figure 3-10. Antisplitting device.

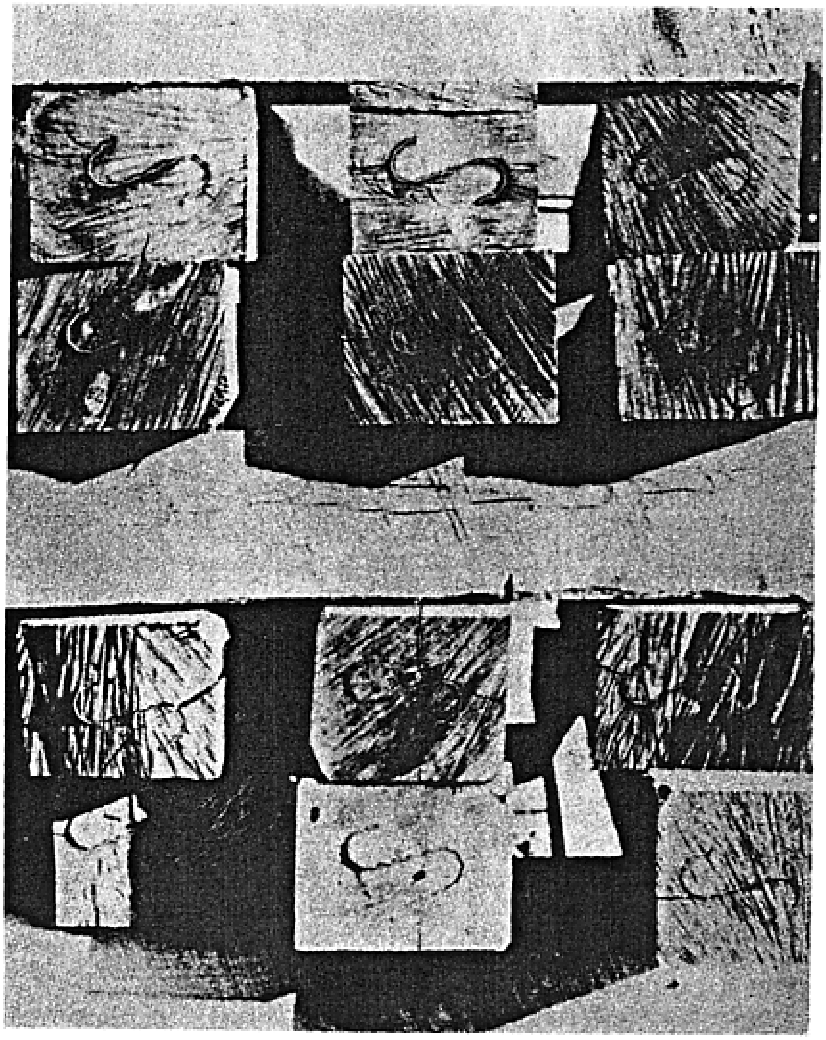


Figure 3–11. Antisplitting irons installed in ties.

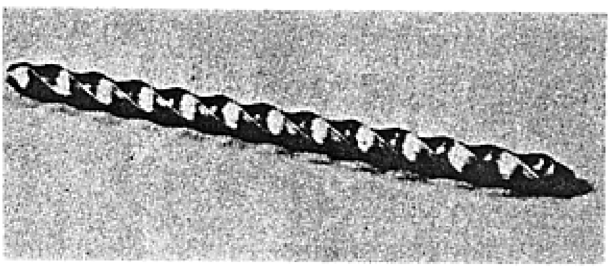


Figure 3–12. Tie dowel.

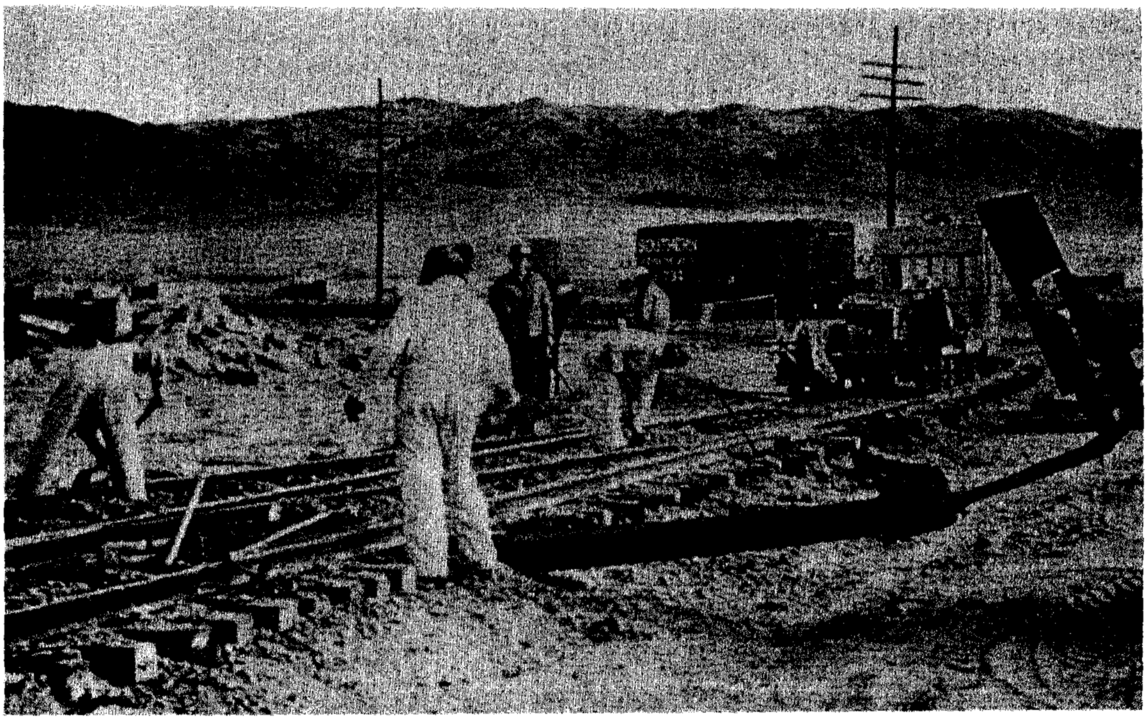


Figure 3-13. Typical switch tie installation.

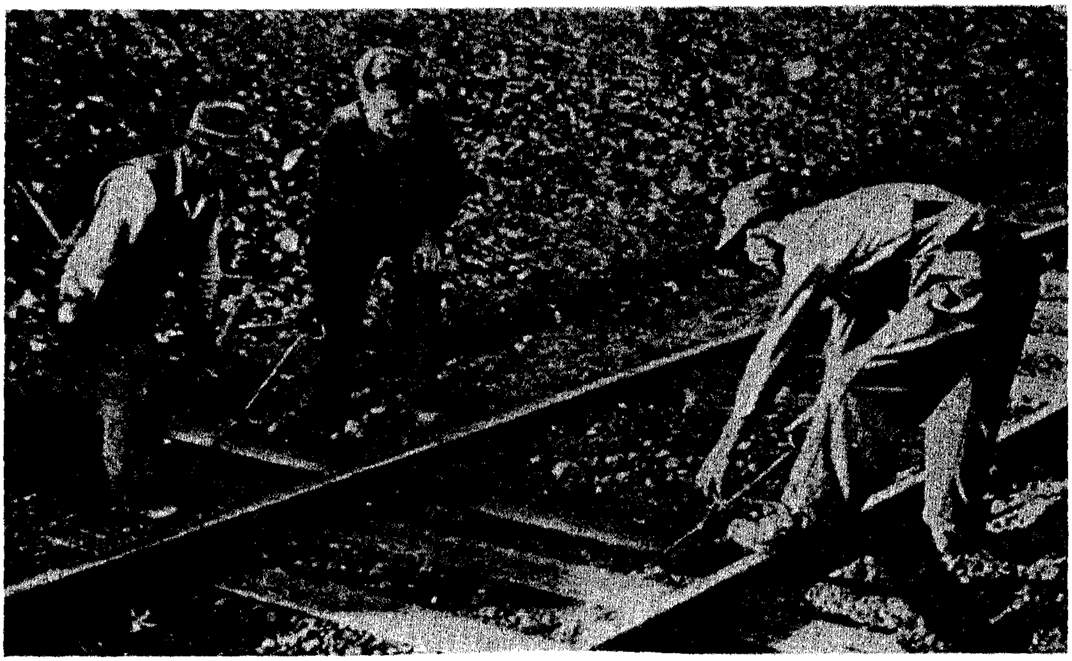


Figure 3-14. Installing ties with hand tools

Figure 3-15. Installing ties with a tie crane.

Figure 3-16. Handling treated wood ties.

3-9. Ties Other Than Wood.

Decisions on the use of ties other than wood are to be made by a qualified authority and shall be based on comparative cost estimates reflecting all factors. The longer in-use life of concrete ties may justify their use in areas where tie inspection and maintenance work entail pavement removal, or at critical locations where track maintenance work results in serious operational problems (i.e., crossings, paved streets, paved industrial areas).

3-9.1. Concrete and Composite Tie Data. The Federal Specification covering concrete and composite ties has not been completed. Meanwhile, specifications for the ties will be developed for individual installations by those responsible for engineering at the military installations or at the offices of higher echelons of the engineering elements of the Departments of the Army, the Navy, and the Air Force.

3-9.2. Other Material. Ties made of composite materials and other state-of-the art-materials leading to tie substitutes may be used as available and proven in service.

3-9.3. Handling Concrete Ties. Workmen must wear appropriate safety shoes when handling ties. All ties shall be unloaded and loaded mechanically. Figure 3-17 illustrates the proper method for unloading concrete ties. Where ties must be stacked, they shall be stacked mechanically. No ties shall be loaded, unloaded, or stacked by hand. Because each concrete tie weighs nearly 500 pounds, all ties are to be moved from the unloading area or from stacks to the work sites by rail or truck. After the ties have been distributed and placed mechanically as close as possible to their final position, then and only then are they to be manhandled into position in the track work.

3-10. Tie Sizes.

Current tie inventories at some military installations include wood ties of nonstandard dimensions. Such ties are to be used generally on side tracks and spurs, not on running tracks. Future purchases are to include only standard sizes of ties.

3-10.1. Wood Crossties. Wood crosstie dimensions for military trackage should be selected based on the

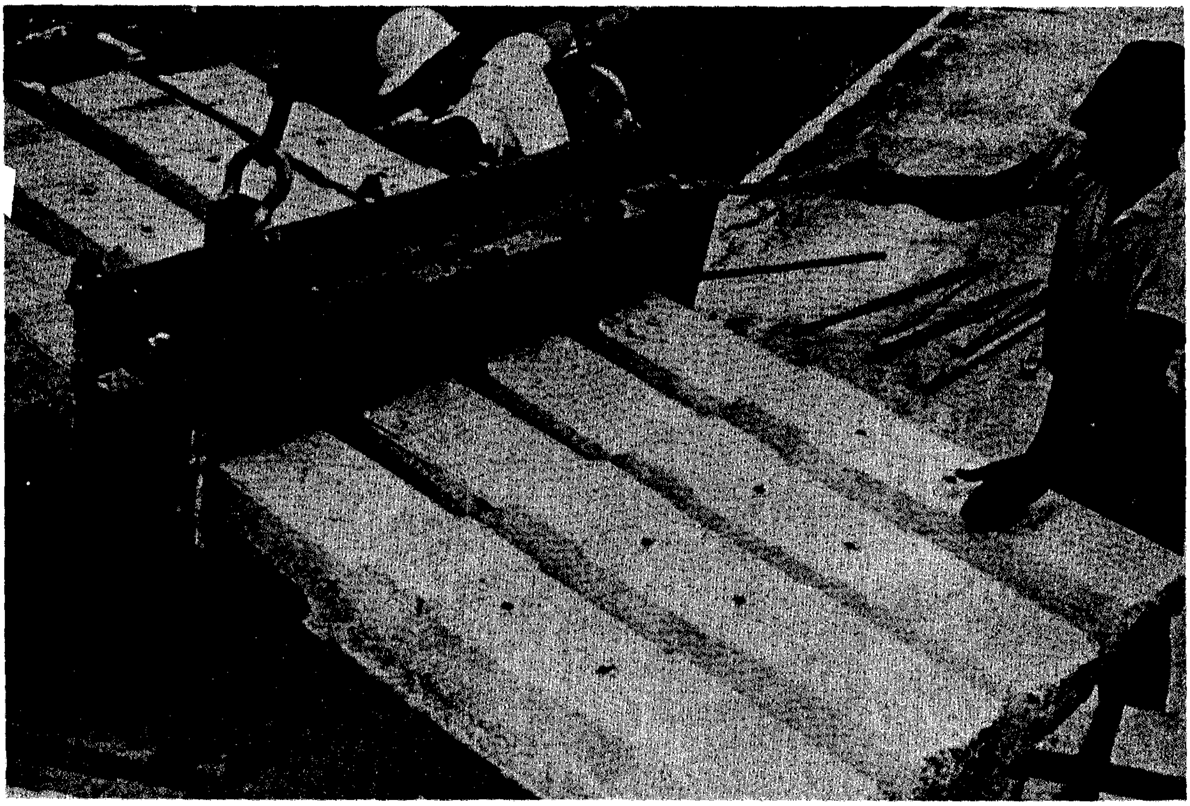


Figure 3-17. Handling concrete ties.

trackage category (para 1–10). Ties for running and access tracks should be at least 7 inches thick, 8 inches wide, and 8 feet 6 inches long. Ties 6 inches thick, 7 or 8 inches wide, and 8 feet long may be used for low-use trackage. In addition, ties 7 inches thick, 9 inches wide, and 9 feet long should be used where warrented, in accordance with AREA recommendations and this manual (para 4–11). Cross-sectional tie dimensions apply between 20 and 40 inches from the center of the tie.

3–10.2. Wood Switch Ties. Wood switch tie cross sections are 7 by 9 inches. The bill of materials in Figure 3–18 lists the lengths of 7- by 9-inch ties specified by AREA for No. 5 through No. 20 turnouts.

3–10.3. Wood Bridge Ties. The lengths of wood bridge ties are determined by the design of the bridge on which they are to be used. Normally, the minimum length is 10 feet, and the minimum cross section is 8 by 8 inches.

3–10.4. Concrete Crossties. The minimum length of concrete crossties is 8 feet 6 inches. Figure 3–19 shows a typical concrete tie. The dimensions of concrete ties may vary slightly between the products of different suppliers but will conform generally to the same configuration.

3–10.5. Concrete Switch Ties. Concrete switch ties are not currently available.

3–10.6. Concrete Bridge Ties. Standard concrete crossties may be used as bridge ties, *when approved by qualified engineering authority*.

3–11. Tie Replacement and Reuse.

In general, ties should not be replaced until decayed or mechanically worn beyond serviceability for the purpose intended. However, where general track reconditioning (ballast and rail removal) is under way, consideration should be given to replacing ties that are near the end of their serviceability so that the track need not be disturbed again in the near future. Installation of used ties is normally confined to light-traffic or temporary lines, sidings, and dead-storage tracks. Replacement usually is considered in the following order of priority: (1) running or access tracks, (2) classification yard, and (3) siding and storage tracks.

3–11.1. Spot Replacement. Spot replacement is the replacement of an occasional defective tie or a small group of ties (no more than 10 or 10 percent of the ties) from a length of track in which all the other ties are in satisfactory condition.

3–11.2. General Replacement. General replacement involves a larger number of ties (over 10 percent) from a length of track in which only occasional ties or small groups of ties are in satisfactory condition.

3–11.3. Identifying Defective Ties. Tie replacement will be made only after tie inspections have been completed and defective ties marked (Figure 3–20 and 3–21) for removal. Chapter 7 of this manual and the FRA Track Safety Standards (Appendix B) describe defective ties. Due to the movable parts at switches, the switch ties must be maintained in better condition than the crossties. Ties under the

Figure 3–19. Typical concrete tie.

Figure 3–20. Spot marking ties for removal.

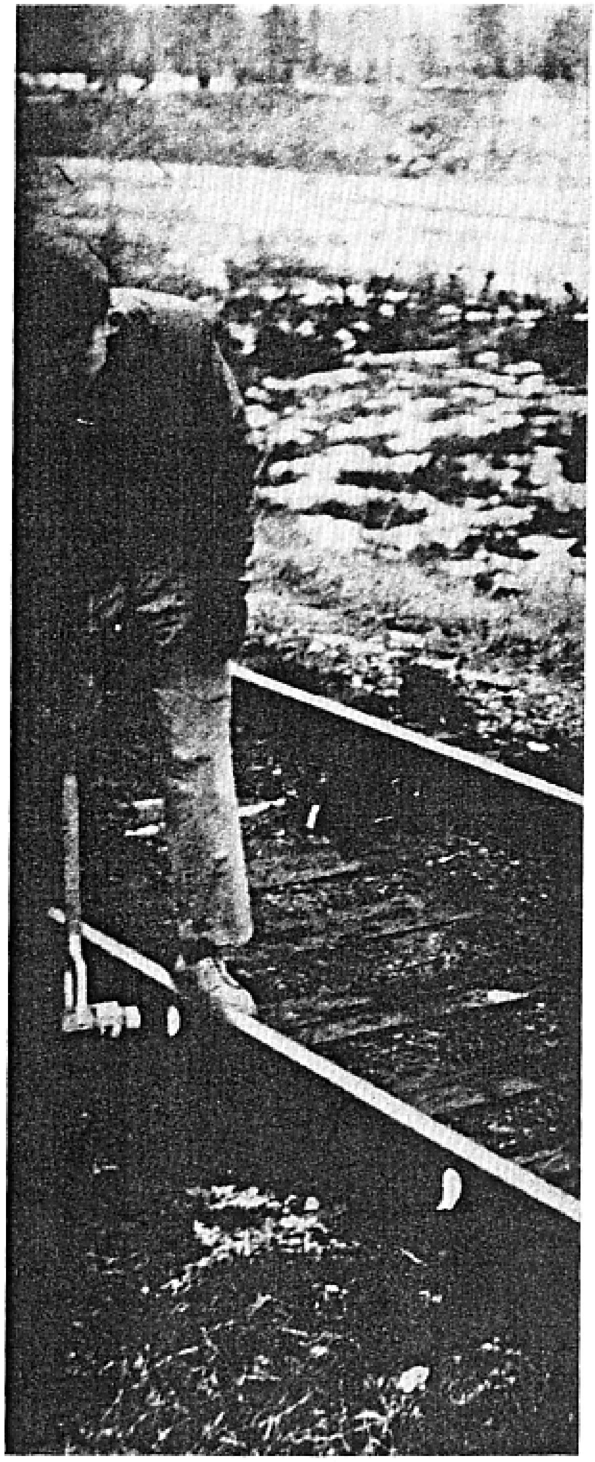


Figure 3–21. Spot marking rail with paint.

switch points and at the frog should never be allowed to reach the condition of crossties for Class 2 track. Only ties marked for removal will be replaced. Replacement ties shall be inspected prior to installation for compliance with applicable AREA Standards and/or Federal Specifications and for damage or deterioration while in storage or while being handled.

3-11.4. Tie Spacing. Tie quantity and spacing is based on roadbed conditions, trackage category, rail size, anticipated load, and experience or engineering judgement. Installation criteria for new construction and rework trackage should be specified for each section of trackage based on current instructions, design standards, need, and economics.

3-11.5. Spacing for Spot Replacement. For spot replacement of wood with wood ties, spacings will not be changed. However, the face-to-face separation between ties shall be at least 10 inches, but less than 16 inches. Skewed ties shall be straightened.

3-11.6. Spacings for General Replacement. When replacing wood with wood ties, standard spacings should be as designed: 22 to 24 ties per 39 feet of running track, and 20 to 22 ties per 39 feet for low-use trackage. In no case shall less than 18 ties per 39 feet be present in any section of trackage. Tie-spacing gages will be used except where variations in wood tie cross sections and placement make its use impractical. Figure 3-22 illustrates such a gage welded to a shovel. Proper spacings for concrete ties are to be determined by a qualified engineer.

3-11.7. Skewed Ties. A skewed tie is one having an axis other than perpendicular to the rails (except turn out rails). Skew distance, as shown in Figure 3-23, is measured along the base of a rail on the gage side. Measurements of skew distance may be made while checking gage; however, a visual check at any trackage system is adequate. Spotting ties that are over half the width of a tie out-of-line can be easily done while walking or riding over the trackage system. Single skewed ties are not serious. Sections of trackage with skewed ties indicate a problem area that should be investigated.

3-11.8. Alignment of Ties. When placing standard length wood ties in double tracks, align the outside ends of ties. For three or more tracks, align the outside ends of ties with the outer tracks; align the ties of inner tracks the same as for single track. For single track, align the east ends of ties of north-south tracks, and the north ends of east-west tracks. Under-length wood ties shall be centered under the track.

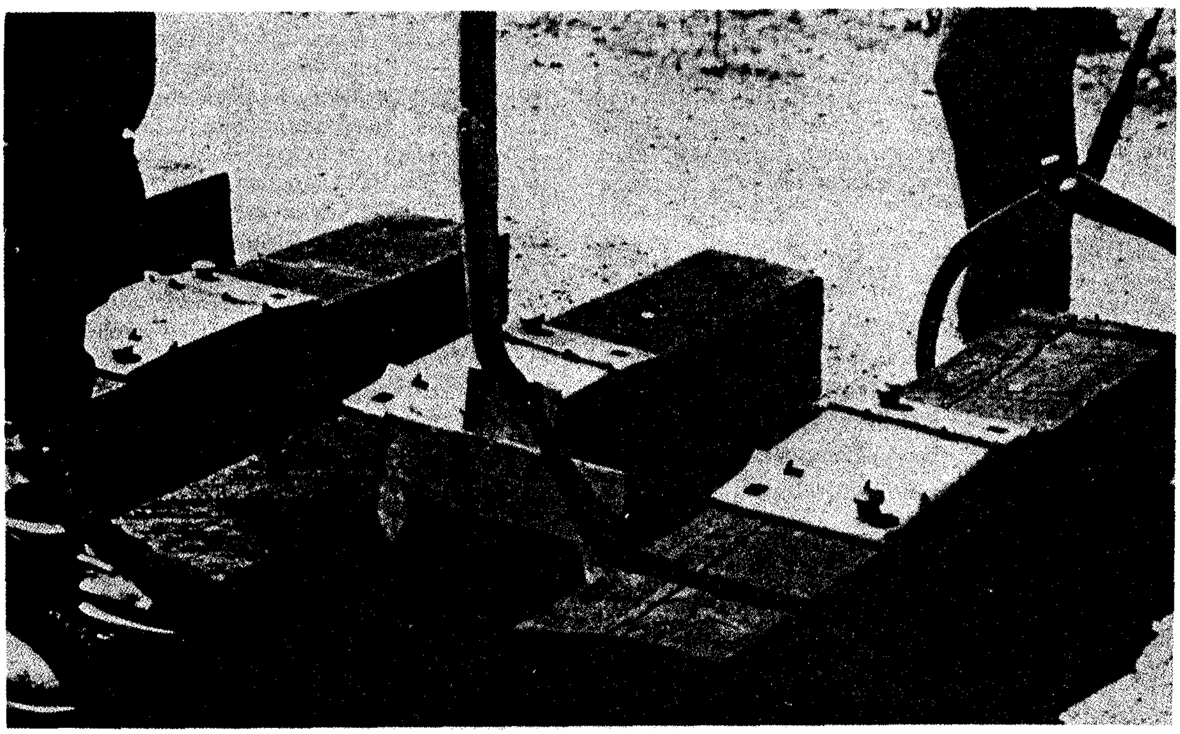


Figure 3-22. Tie spacing gage welded to shovel.

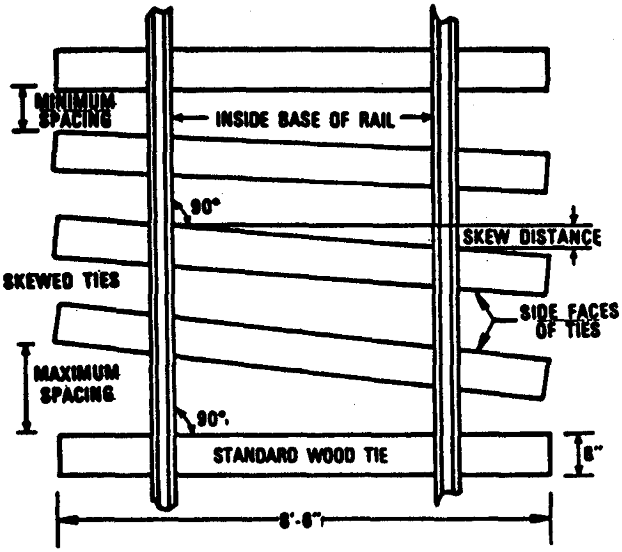


Figure 3-23. Railroad tie terminology and identification.

3-11.9. Procedures for General Tie Replacement. Traffic volume and the availability of alternate trackage may dictate replacement procedures. When a track can be removed from service without interrupting functions, a complete removal and replacement program is recommended. Verify and reference line and grade of existing trackage and remove the rail and ties. As in new construction, grade the ballast; salvage excess ballast; set the replacement ties and rail; and bring the track to proper alignment, grade, and surface. If the track cannot be removed from service, replace as many ties at one time as traffic permits.

3-11.10. Procedures for Spot Replacement. The following guidelines are applicable to the usual spot replacement programs:

3-11.10.1. After removing spikes, remove sufficient ballast from the crib to permit easy removal of the tie, pull the tie, and dress the roadbed.

3-11.10.2. Insert the replacement tie, accurately spaced and at right angles to the rail.

3-11.10.3. When replacement ties are wood, use the largest and best ties at rail joints. The distance from rail joint to the face of either adjacent wood tie shall not be more than 12 inches. Intermediate ties shall be evenly spaced.

3-11.10.4. Wood ties shall be laid heart-side down.

3-11.10.5. Spike wood ties to the rails at proper gage. Bolt concrete ties to the rails after placing the bearing pads.

3-11.10.6. Tamp ballast under the ties.

3-11.10.7. Avoid raising the track because ballast may run under adjacent ties. Instead of raising track, remove a little more ballast from under the tie being removed to facilitate the placement of the new tie.

3-11.10.8. Tamp under adjacent ties where one tie shows evidence of being cut by the rail base. The adjacent ties will then carry more of the load.

3-11.10.9. Tie plates will be used on running or access and heavy-use classification yard trackage. Tie plates are not required on temporary trackage except over bridges, trestles, or culverts and on curves sharper than 8 degrees (maximum radius 717 feet).

3-11.10.10. Avoid adzing ties. Adjust and tamp ballast to lower high ties. Where adzing is unavoid able, where different tie plates must be used, or where adzing is required to correct tie damage from a derailment, adze only the minimum depth. Then make a field application of preservative.

3-11.10.11. Fill unused spike holes with treated soft wood plugs, firmly driven into the holes.

3-11.10.12. Salvage all sound ties, spikes, and tie plates for appropriate reuse. Dispose of unsound ties and unusable materials.

Section 4. RAILS AND ACCESSORIES

3-12. General.

Design and specifications for rails and accessories should be in accordance with AREA Standards (Chapter 2, Section I). In repair and maintenance work it is important to match existing design of materials and construction wherever it is economically justifiable. In cases of individual rail replacement, where the existing rail does not meet the standard criteria listed herein and where the remaining track is performing satisfactorily, the same size rail should be installed. Rails must be connected at the joints so that the rails will act as a continuous girder with uniform surface and alignment. Rails and accessories obtained from suppliers or storage should be inspected before they are placed in track.

3-13. Rail Sections.

3-13.1. Standard Railroad Rail. Most of the existing substandard trackage at military installations consists of the 30- or 33-foot rails (Figure 2-1, para 2-3.1.). Rails required for replacement of worn or substandard trackage should normally be 39 feet long unless there is sufficient justification for using the shorter rail. The 90-lb/yd RA-A section, in 39-foot lengths, is satisfactory for most military installations except when wheel loading or spacing of supports require heavier rail. Heavier rail sections will be routinely used only to meet minimum requirements of the serving railroad when their locomotives are used on the installation. When it becomes necessary to relay the existing 90-pound or lighter rails on running or access tracks and it is desired to use 115-pound rail, approval must be secured from the appropriate military service headquarters.

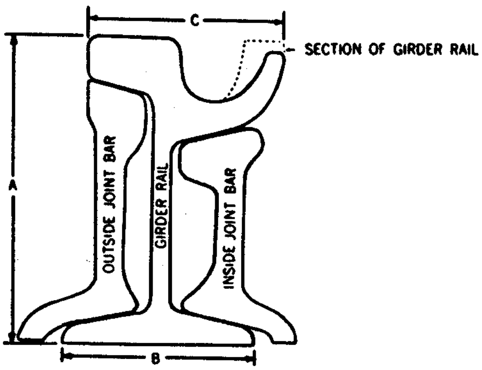
3-13.2. Ground-Level Crane Rail. Ground-level crane rail should be at least 135-pound CR for major replacement or new installations.

3-13.3. Elevated Crane. The rail section to be used shall be that which has been recommended by the crane manufacturer or equivalent to the existing rail. Rail sections shall accommodate all crane wheels.

3-13.4. Girder Rail. Rails of the street-railroad type, with deep webs, heads, and flangeways, are often used for trackage in pavement (Figure 3-24). (Figure 4-23 in Chapter 4 shows an installation of girder rail in a paved area.) Flangeways 2-1/2 inches wide shall be provided on tangent track and on curves of 8 degrees and under, and flangeways 2-3/4 inches wide on curves in excess of 8 degrees.

3-14. Rail Inspection.

All rails should be periodically checked. Some types of defects may be detected visually, and some by hitting the top of the rail with a hammer. Internal defects require the use of some type of electronic device to determine the type of defect. Figure 3-25 shows a sonic detector that can be used to detect defects within the joint bar area. A small ultrasonic tester is shown in Figure 3-26. Fissures are detected by a magnetic induction process.



R E SECTIONS

WEIGHT OF RAIL LB	A	B	C
128	7"	6"	6"
149*	7"	6"	6 1/8"
159	9"	5 3/4"	5 7/8"
174	9"	5 3/4"	5 7/8"

* GIRDER GUARDRAIL TO BE USED OPPOSITE GIRDER RAIL FROG

Figure 3-24. Details of girder rail.

Figure 3-25. Inspecting rail for flaws with a sonic detector.

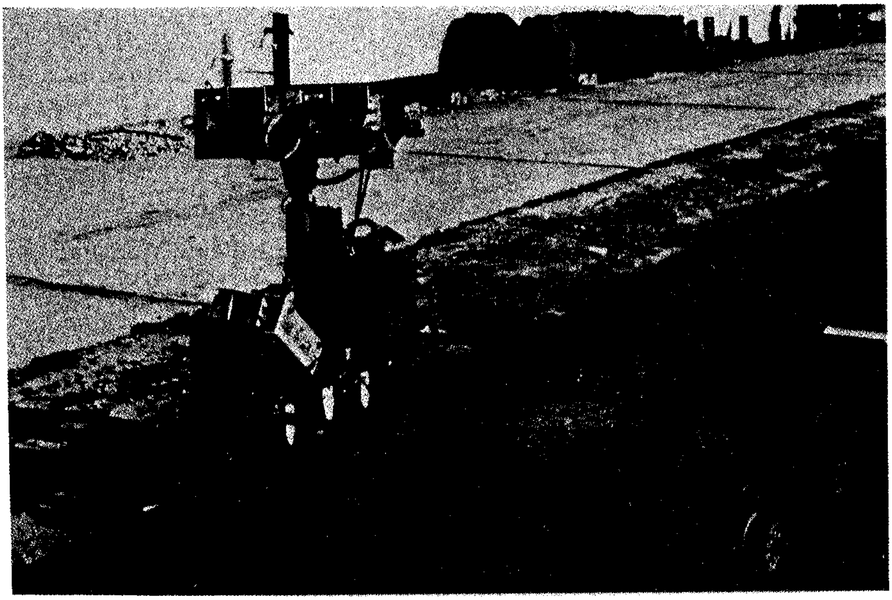


Figure 3-26. Ultrasonic rail detector.

3-15. Rail Failures.

Rails that are damaged to the extent of being hazardous to traffic should be replaced promptly. This applies particularly to locations such as switches, trestles, and the like where derailment might occur. Broken rails must be replaced immediately in any part of a track. Common causes of damage to rails are derailments, sliding wheels locked during braking, broken, flat, or unbalanced wheels, and stiff or unmoving trucks. Internal fissures can be detected only through the use of an ultrasonic testing device or some other type of rail flaw detector.

3-16. Common Rail Defects.

Figure 3-27 shows graphic examples of the following defects. Appendix B and Chapter 7 give additional descriptions, acceptable limits, and remedial actions to be taken.

3-16.1. Transverse Fissure. A transverse fissure is a crosswise break in the railhead, starting from a center or nucleus inside the head and spreading outward. The broken rail shows a smooth area around the nucleus, which may be either bright or dark, round or oval (Figure 3-27a).

3-16.2. Compound Fissure. A compound fissure is a horizontal split in the railhead that in spreading turns either up or down in the head (Figure 3-27b).

3-16.3. Horizontal Split Head. A horizontal split head is a horizontal break beginning inside the head of the rail and spreading outward; it is usually indicated on the side of the head by a lengthwise seam or crack or by a flow of metal (Figure 3-27c).

3-16.4. Vertical Split Head. A vertical split head occurs through or near the middle of the head. A crack or rust streak may show under the head close to the web, or pieces may split off the side of the head (Figures 3-27d and 3-28).

3-16.5. Crushed Head. A crushed head is a flattening or crushing down of the head (Figure 3-27e).

3-16.6. Split Web. Split webs are lengthwise cracks extending into or through the web (Figure 3-27f and g).

3-16.7. Piped Rail. A piped rail is a rail split vertically, usually in the web (Figure 3-27h).

3-16.8. Broken Base. A broken base is illustrated in Figure 3-27i.

3-16.9. Square or Angular Break. Square or angular breaks are illustrated in Figures 3-27j and 3-29).

3-16.10. Broken Base and Web (Bolt Hole Break). A broken base and web is a break in the web extending to the base (Figure 3-30).

3-16.11. Other Defects. In addition to the defects listed above, flaking, slivers, flowing, engine burn, mill defect, bolt hole crack, and top and side wear of the head are shown in Figure 3-27k-4. Most of these are considered minor.

3-17. Replacement of Rails.

Where rails are to be replaced or interchanged, the following rules apply:

3-17.1. Inspection. Before placing any rail in track, inspect it thoroughly for possible failures and defects.

3-17.2. Salvage. Do not place badly worn rails in running tracks; save them for use in storage tracks. Reject rail that cannot be straightened.

3-17.3. Curve-Worn Rails. Reset curve-worn rails with the worn side facing away from the gage side. On curves, use the worn rail as the low or inside rail. CAUTION: This type usage is not recommended as changes in stress can cause failure.

3-17.4. Weight and Section. Match weight, section, and amount of wear of adjacent rails as closely as practicable. Do not connect rails with full heads to rails with worn heads where the gage of track at the joints would be altered appreciably.

3-17.5. Compromise Joints. When, by necessity, rails of different weights or sections are connected, use compromise bars to match the weights and sections of the two rails (Figure 2-3). Compromise joints are either right-hand or left-hand. To determine which is needed, refer to Figure 3-31. If large rail is on your left, the joint is left-hand; if on your right, it is right-hand.

3-17.6. Length of Rail. Do not use rails less than 13 feet long in running or access tracks, in classification or receiving yards, or where there is considerable movement of cars. Reserve such rails for dead storage tracks or extreme ends of stub tracks.

3-17.7. Broken and Cracked Rails. Remove broken or cracked rails from track immediately. If it is not feasible to replace the broken rail at once, use a pair of fully bolted joint bars at the break as an emergency measure. Remove the broken or defective rail as soon as possible.

3-17.8. Drilling Bolt Holes. Drill or punch the full number and correct size of bolt holes to coincide with the holes in the joint bars used. Hold joint bars in place with rail or C-clamps while the bolt holes are drilled, to insure correct spacing (Figure 3-32).

3-17.9. Traffic Precautions. If a rail is broken or defective and safety at normal speeds is questionable, give "slow" orders (Figure 3-33) for that section of track and move trains under direction of a flagman. Never use these measures at hazardous locations; stop traffic until defective rails are replaced.

3-17.10. Cutting Rail. As soon as possible, remove rails that have been cut with an acetylene torch to make a temporary closure. Cut off at least 6 inches of the torch-cut end of the rail with a rail saw (Figure 3-34) or cutting tool before using the rail in track again.

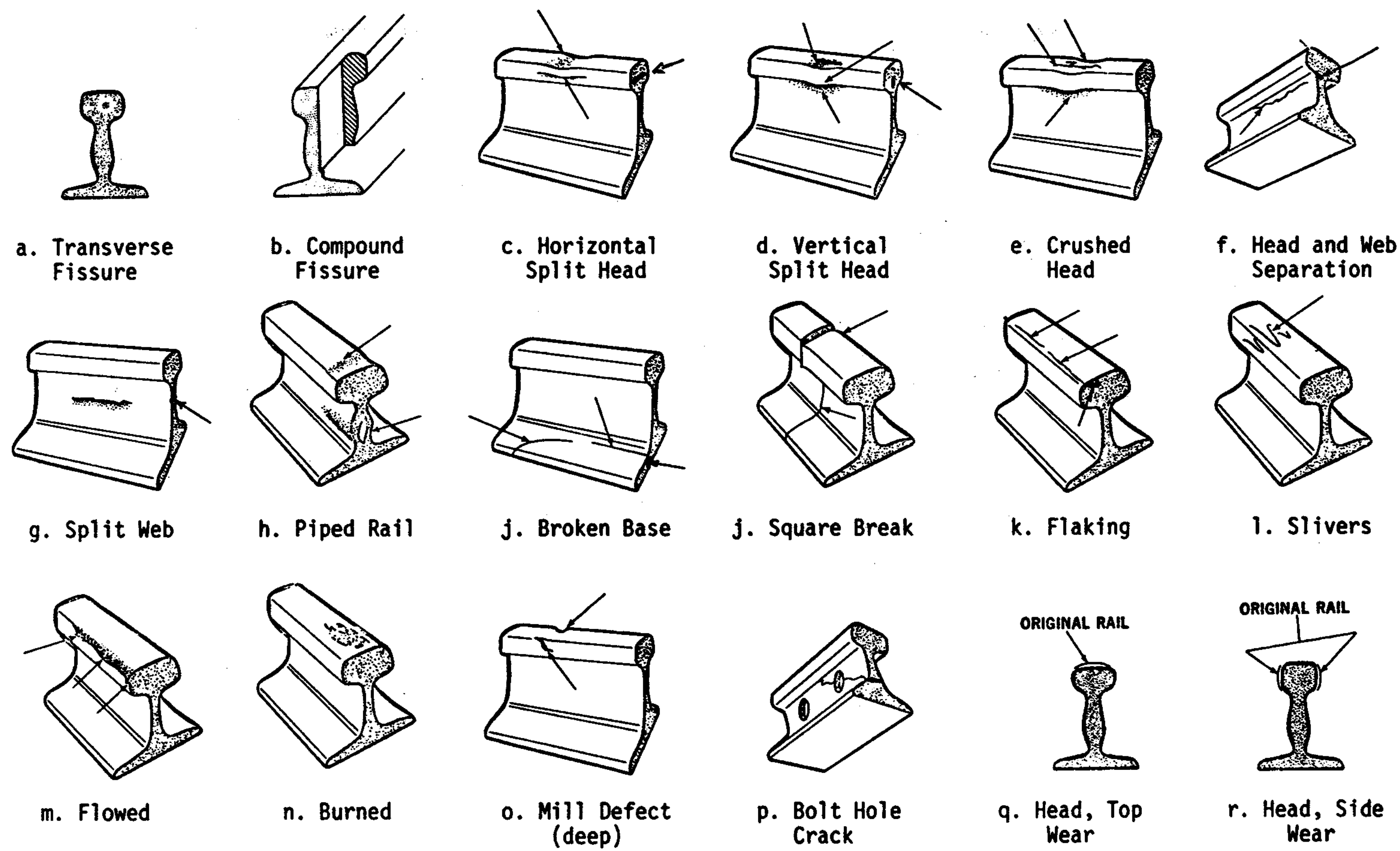


Figure 3-27. Types of rail failures.

Figure 3-28. Vertical split head.

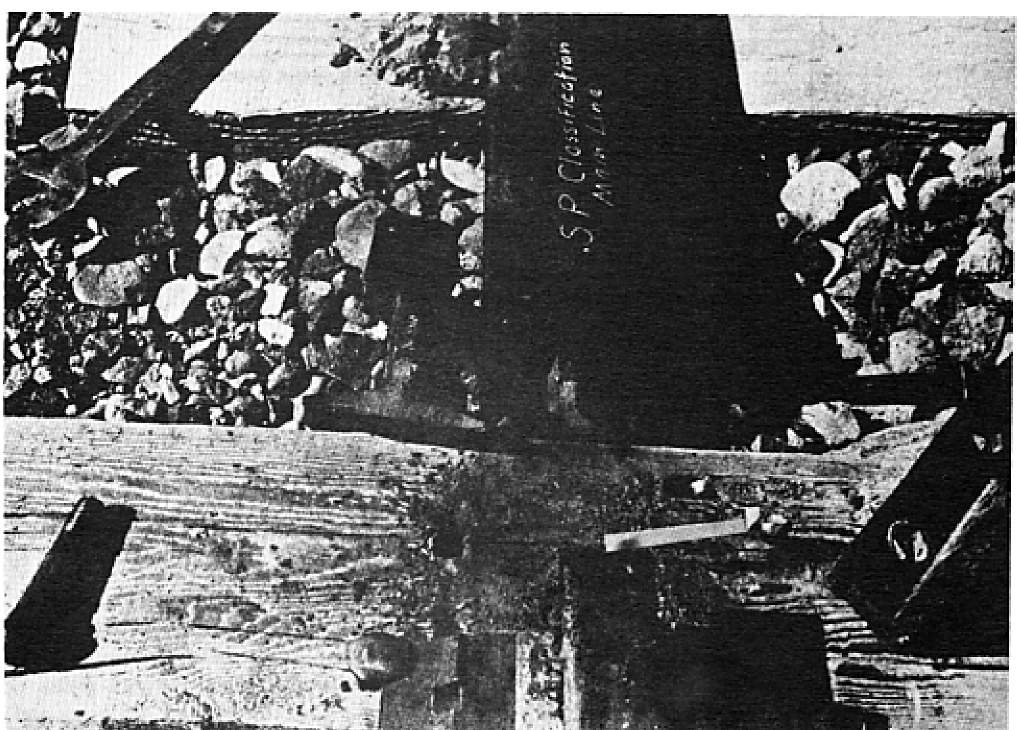


Figure 3-29. Square break in rail.

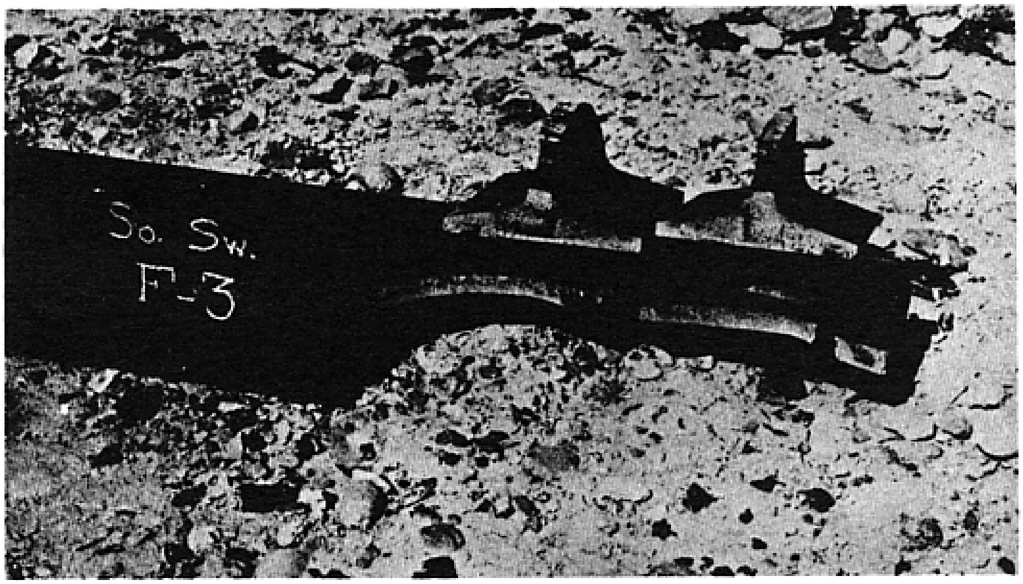


Figure 3-30. Broken base and web.

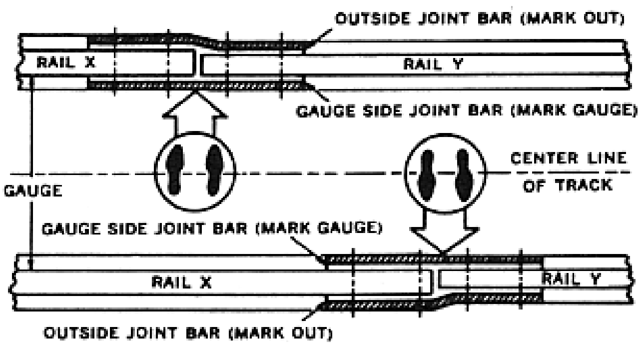


Figure 3-31. Compromise joint identification.

3-18. Welded Rail Replacement.

In continuous welded rail, a minimum of 13 feet shall be maintained between welds or joints. The method of welding shall be the preheated thermite process or another approved procedure. Joint bars are required on welded rail when there are existing bolt holes in the rail. Joint bars are mandatory if there are bolt holes in either piece of rail being used in new or replacement work. Existing rail holes (not at the ends), such as bolt holes and old gage rod holes may be maintained as is, provided there are no other potentially serious defects in the immediate area.

Figure 3-32. C-clamp.

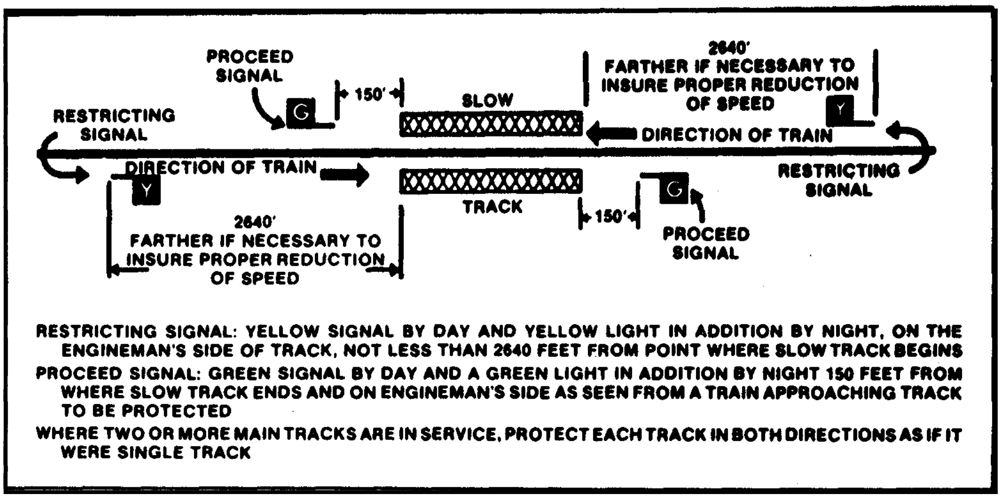


Figure 3-33. Details for establishing slow order.

3-19. Handling Rails.

Care must be taken in handling rails both in removing old rail for replacement and in delivering and placing new rail.

3-19.1. Precautions. Take care not to damage bolts, nuts, or rail anchors when removing rail from track. A crane should be used for loading rails when it is available. In most installation maintenance, it is necessary to load or carry rails by hand (Figure 3-35). Rail tongs must be used and the following precautions observed:

3-19.1.1. Divide the gang equally at ends of the rail. Utilize suitable lifting tools, distribute weight safely, do not overload crew (75 pounds per man is recommended maximum load), assure safe footing, and lift properly with back kept straight. Safety-toe shoes must be worn during such operations.

3-19.1.2. Designate one person to call directions.

3-19.1.3. Never attempt to throw rail.

3-19.1.4. Always load so that a person can jump clear if the rail should fall.

3-19.1.5. If there is a danger of operating personnel falling over rails distributed along the track,

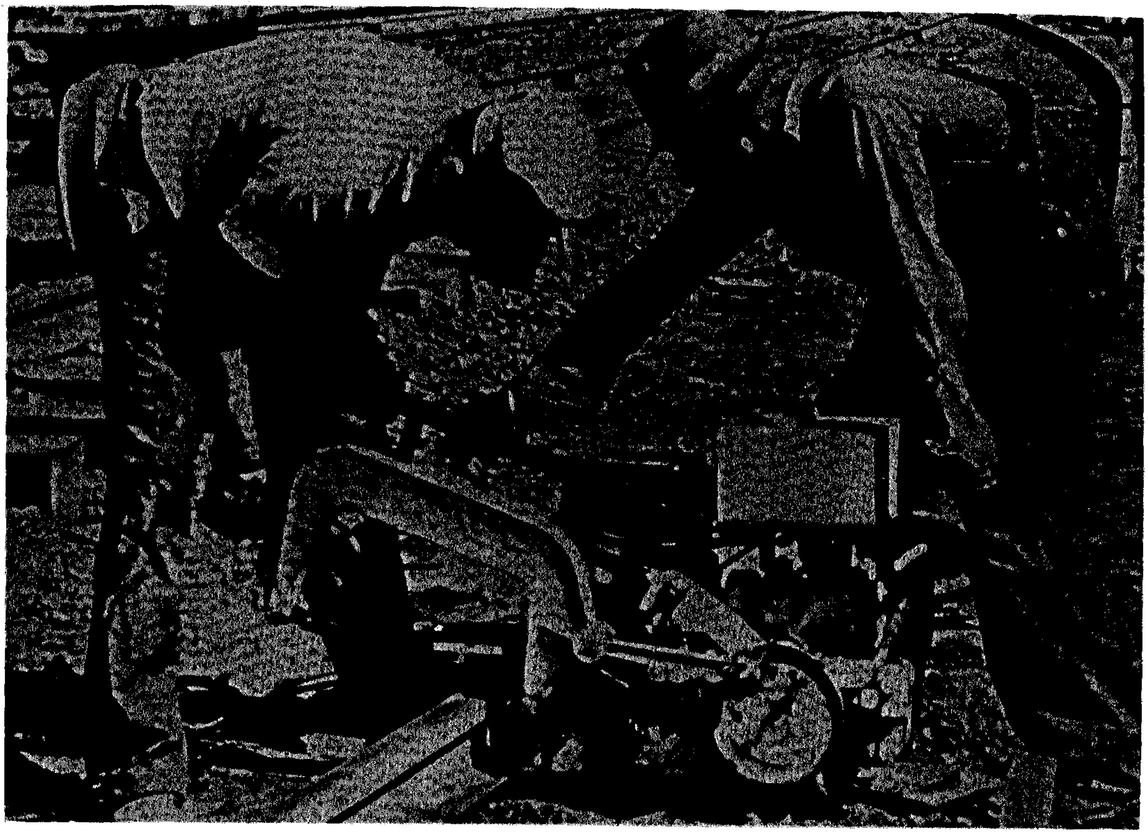


Figure 3–34. Cutting rail with a power saw.

report rail locations so they can be warned. Mark the obstructions with visible warning signs.

3–19.1.6. In yards and station grounds, stack rails well out of the way of operating personnel, and in a place convenient for distribution.

3–19.2. Distribution of Rails. Distribute rails so that they can be laid without unnecessary handling as follows:

3–19.2.1. Place rails base down (Figure 3–35), parallel with the track and with sufficient bearing to prevent bending or swinging, except where there is a hazard of movement due to vibration. Rail left between or adjacent to tracks must be left lying on side, unless on ground that is more than 1 foot below top of tie.

3–19.2.2. Rails should be unloaded opposite the locations in which they are to be placed in the track, allowing suitable gaps for short lengths.

3–19.2.3. Proper lengths of rail for road crossings, station platforms, bridges, and other special locations shall be unloaded in a safe and convenient location, where they will not constitute an obstruction.

3–19.2.4. To minimize the cutting of new full-length rails, shorter rails should be distributed in proper places to provide for proper spacing at insulated joints and for connections to switches.

3–19.2.5. No rail less than one-half rail length shall be used in main tracks, except that shorter rails not less than 13 feet long may be used for temporary closures and for connections within turnouts.

3–19.2.6. Joints, turnouts, and fastenings should be unloaded and distributed concurrently with the rail, except that small material must be left in the containers until the time of laying the rail.

3–20. Preparation For Laying Rails.

Bring grade to true line and elevation before laying new rail, particularly on curves that are out of line. No part of the track structure in use shall be removed until the replacement rail is ready to be installed. Full flag protection or slow-order protection must be provided in cases where rail is being laid under traffic. See Figure 3–33 above for details of establishing slow orders.

3–20.1. Tie Plates and Bearings. Tie plates shall bear fully and uniformly on the ties, and the bearings on each tie shall be in the same place.

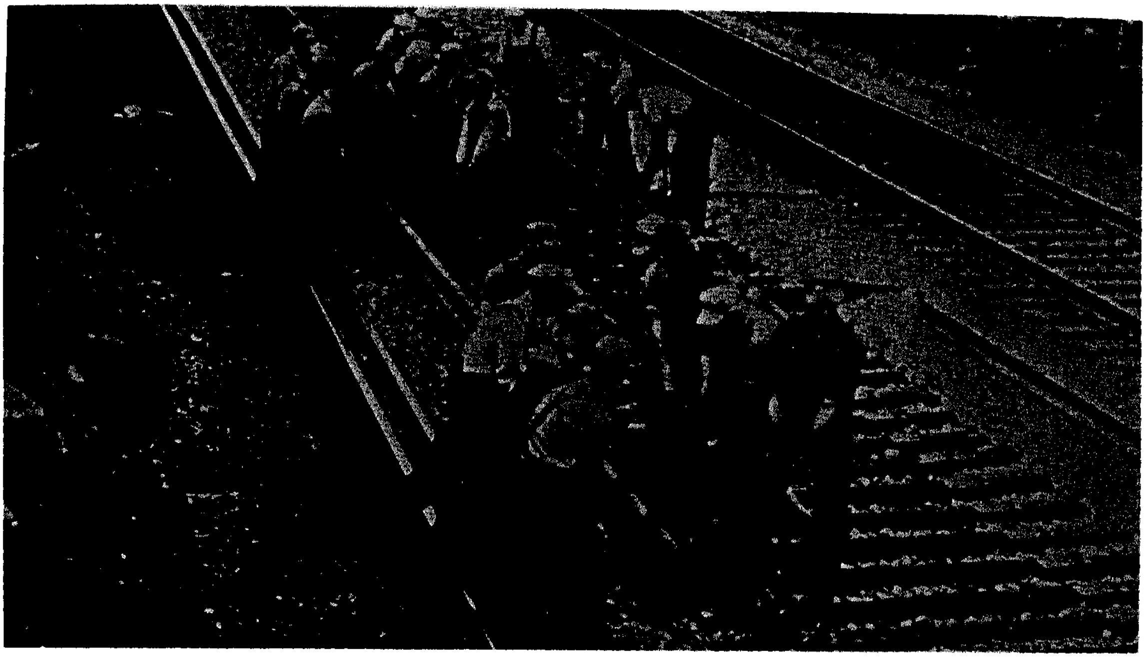


Figure 3-35. Handling rail manually.

3-20.2. Curved and Straightened Rails. When available, use a bender to precurve rails for sharp curves. Curvature must be uniform throughout the length of the rail. Straighten rails that have sharp crooks or bends (para 3-17.2).

3-20.3. Placement of Rail Accessories. Distribute bolts, spikes, tie plugs, tie plates, and rail anchors as close as possible to the site where they will be used, shortly before rail is laid. Do not put such articles on top of ties or in cribs when track is in use.

3-21. Steps In Laying Rails.

Never lay more rails than can be properly secured during the day in which they are laid to prevent damage to the rails or fastenings by normal traffic. Utilize mechanical devices to lay rails whenever possible. If this is not possible or practicable, extreme care must be exercised by personnel to preclude serious personal injury. Lifting and lowering of rails must be done with backs straight. A check list of the pertinent steps in rail laying follows:

3-21.1. Tamp loose ties to provide a good bearing under the new rail. Follow standards for spiking and bolting, and apply necessary rail anchors before permitting trains to pass over the rail.

3-21.2. See that insulating joints in the track circuit are spiked and supported as soon as possible, as insulating fibers are easily damaged.

3-21.3. Lay rails one at a time. To insure good adjustment, bring rail ends squarely together against suitable rail expansion gages, and bolt them before spiking. Under special conditions, certain departures from this plan are permissable. In areas of heavy traffic, when trains cannot conveniently be diverted to other tracks, stretches of rail not over 1,000 feet long may be bolted together, and then lined into place. Proper allowance for expansion must be maintained (Table D-8, Appendix D); requisite rail expansion gages should remain in place until rails are set in final position. Figure 3-36 shows section of rail being lined off ties in preparation for relay.

3-21.4. Never use switch points to make temporary connections. This is a dangerous practice.

3-21.5. Provide holes for complete bolting of cut rails according to standard drilling practices and the following rules: (1) New holes must be drilled (Figure 3-37) or punched and not slotted, or burned with a torch. They shall not be drilled between existing holes (para 3-17.8). (2) The distance from the end of a rail to the center of the first bolt hole should be at least twice the diameter of the hole. (3) The distance between centers of any two holes of the same size should be at least four times the diameter of the hole; in the case of holes of different sizes, the distance should be at least 3-3/4 times the mean diameter of the two holes.

2-21.6. Paint the contact surfaces of all rail ends and angle bars with a lubricant equal to black lubricating oil just before laying the rails.

3-21.7. Install standard metal, fiber, or wood shims between the ends of adjacent rails to insure proper space allowance for expansion, as indicated in Table D-10.

Figure 3-36. Rail being lined out.

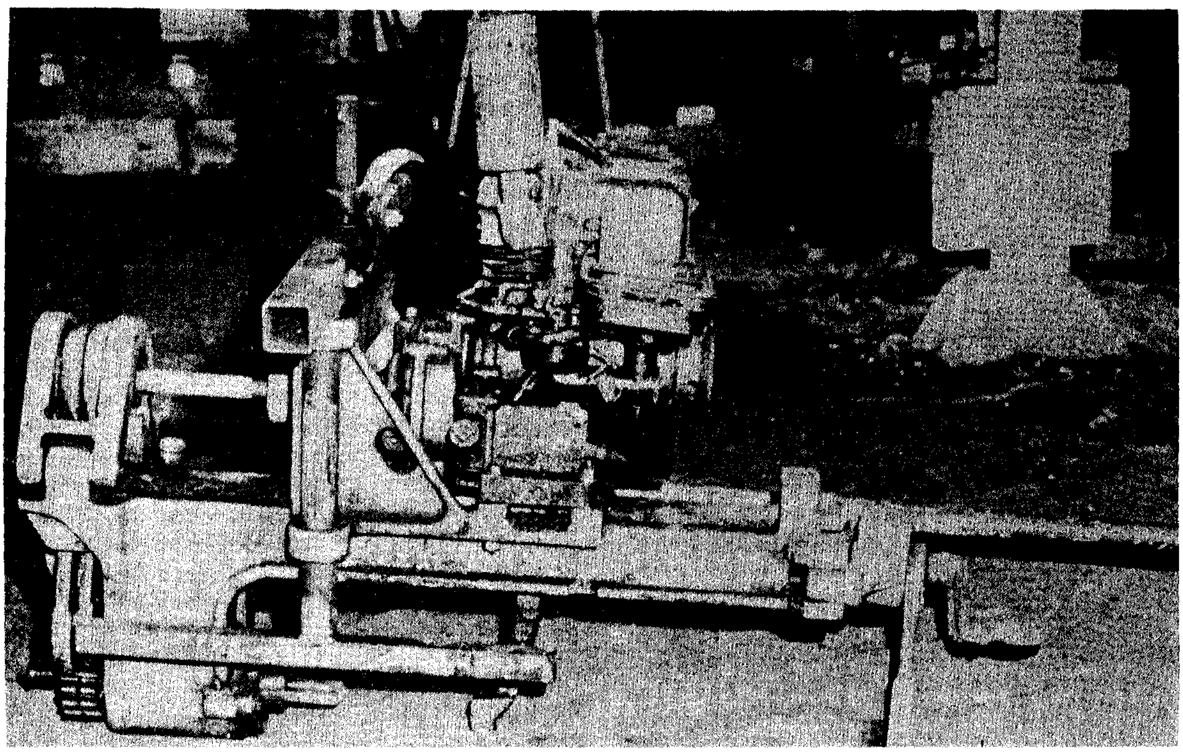


Figure 3-37. Rail drill.

3-21.8. Use a spike maul or a mechanical or pneumatic spike driver (Figures 3-38 through 3-40) to drive spikes. Spikes must be vertical and square with the rail. Straightening spikes as they are driven decreases the holding power. Hold rail against gage when spiking.

Figure 3-38. Driving spikes with a spike maul.

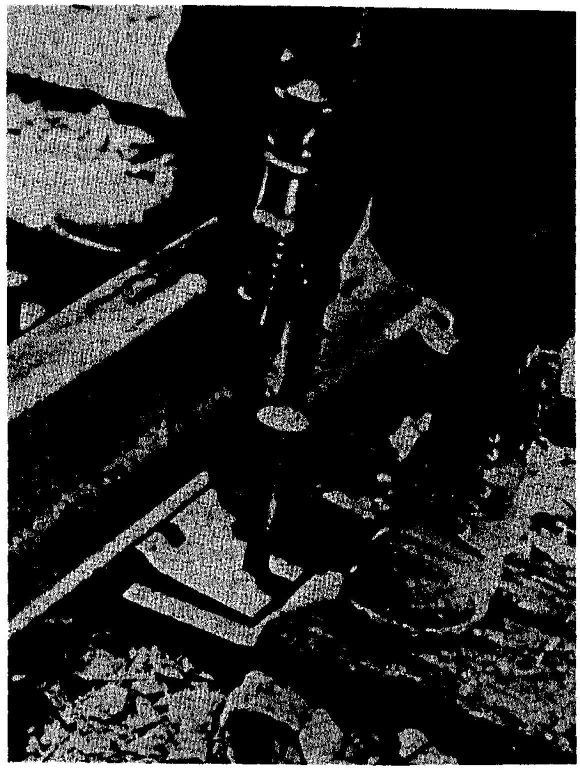


Figure 3-39. Driving spike through tie plate.

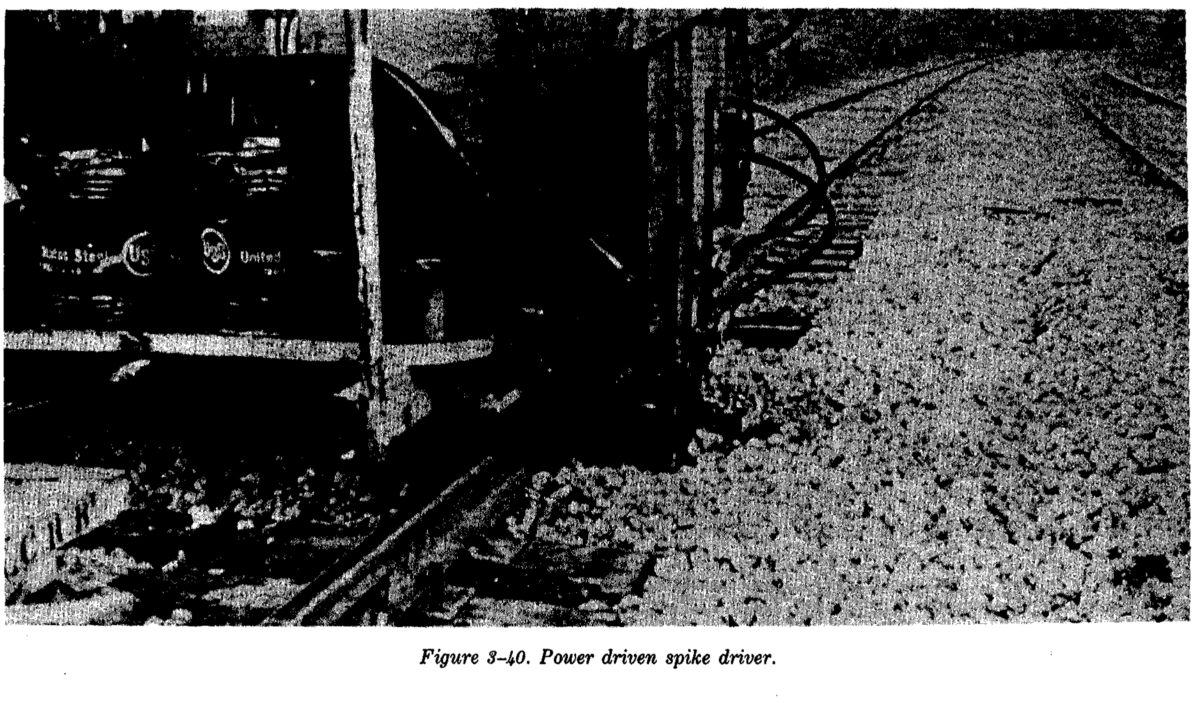


Figure 3-40. Power driven spike driver.

3-21.9. Use four spikes per tie on tangent trackage and on curves with less than 6 degrees of curvature (radius 955 feet or more). Spikes shall be staggered so that all the outside spikes and inside spikes on the opposite end of the tie are in relatively the same position in the tie, i.e., spikes should be in a "V" pattern with the "V" pointing in the direction of heaviest traffic. Spikes should be about 2 inches from the edge of the tie, except where tie plates are used, in which case they are driven through the spike holes (Figure 3-39).

3-21.10. On curves with more than 6 degrees of curvature (radius less than 955 feet) and at other critical points, use two spikes on the gage side of (inside) the rail and one on the field side (outside) (six spikes per tie), when using tie plates. If tie plates are not used, place one spike on the gage side and two spikes on the field side.

3-21.11. Drive spikes down snugly, but not tight against the rail. A space of approximately 1/8 inch should be left between the head of the spike and the base flange of the rail (Figure 3-41).

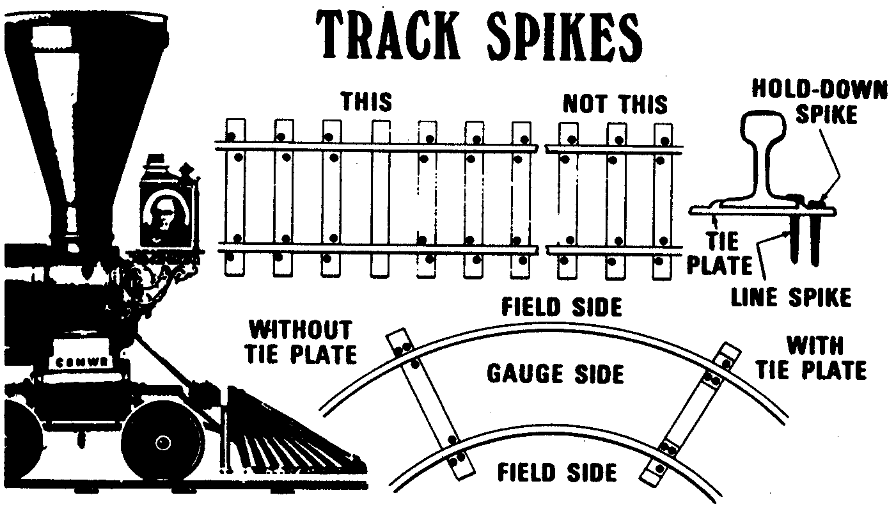


Figure 3-41. Proper spike placement.

3-21.12. Gaging shall be done at least at every third tie when laying the second line of rail.

3-21.13. Install rail anchors and gage rods, when required, before allowing traffic over new track.

3-21.14. When necessary to make a temporary connection for the passage of a train, the union shall be made with a rail of the section being renewed. The closure rail shall not be less than 13 feet long, and shall be connected to the new rail by a compromise joint if the rails are of different sections. The connecting rail shall have a full number of bolts and the required number of spikes.

3-22. Rail Joints.

3-22.1. General Requirements. Rail joints should fulfill the following requirements:

3-22.1.1. They should connect the rails so that they act as a continuous girder with uniform surface and alignment.

3-22.1.2. Their resistance to deflection should approach that of the rails to which they are applied.

3-22.1.3. Battered rail ends should be repaired by an approved method of welding and grinding.

3-22.2. Jointing. Lay rails so that the joints of one are opposite the middle of the other rail, with permissible variations as follows:

3-22.2.1. Except through turnouts and at paved road crossings, the staggering of joints should not vary more than 30 inches from the center of the opposite rail, preferably not more than 18 inches.

3-22.2.2. Do not locate joints within the limits of switch points, opposite guardrails, or within 6 feet of the ends of open-floor bridges or trestles.

3-23. Bonded Rails.

Where highway or train signals are actuated through the track circuit, or where petroleum fueling facilities or ammunition loading points require grounding of rails, rails must be constantly bonded by pin-connected (Figure 3-42) or welded bonds. The bonding may be applied to the outer side of the railhead, within the limits of the joint bars or outside of joint bars in the web of the rail.

3-23.1. Pin-Connected Bonds. For pin-connected bonding, the following steps are required:

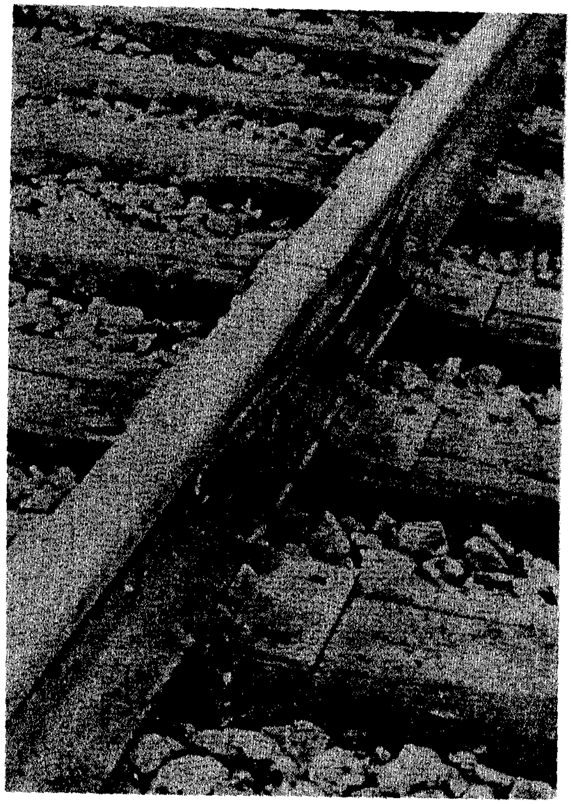


Figure 3-42. Properly pin-connected bonded rail.

3-23.1.1. Drill holes in head or web of rail the size of lugs on end of bond wires, and drive lugs into them to secure a firm fit.

3-23.1.2. Do not disconnect bonding wires or reverse bonded rails without an electrical maintenance crewman present. In emergencies when a broken rail, switch, or frog needs immediate repair, make as tight a connection as possible, but notify the electrical and communication maintenance officers at the first possible opportunity.

3.23.2. Welded Bonds. Use approved methods for welding bonds in lieu of pin-connected bonds where it is more practical.

3-24. Cutting Rails.

When available, use either a tooth or friction-type rail saw for cutting rails (Figure 3-34). When these automatic tools are not available, a rail chisel will suffice. In cases of extreme emergency, rails may be cut with gas cutting torches by qualified operators, but torch-cut rails should be replaced as soon as possible. When rails are cut with gas cutting torches, suitable face, eye, and other body protection must be afforded in the form of goggles, face shields, flameproof gauntlet gloves, and other protective devices to prevent injury.

3.24.1. Rail Saw. Manufacturers' instructions should be followed in the operation and maintenance of mechanical saws. General rules that apply are: keep the machine clean, inspect at regular intervals, use proper adjustment, and see that the railroad maintenance crew takes care in handling and operation.

3-24.2. Rail Chisel. When using a rail chisel, the striker and the man holding the chisel must not face each other. Both must wear prescribed goggles. The chisel must be sharp and the head properly rounded. Use a sledge, not a spike maul. Place the rail on a block with the base of the rail up and the block a slight distance behind the cut. Do all cutting on the base and the web of the rail. Do not drop rails to expedite cutting; use the chisel until the cut is completed.

3-25. Joint Bars.

3-25.1. Installation. Joint bars are installed with the full number of bolts, nuts, and spring washers. Rails weighing over 75 lb/yd are bolted so that nuts alternate between the inside and outside of the track (Figure 3-43).

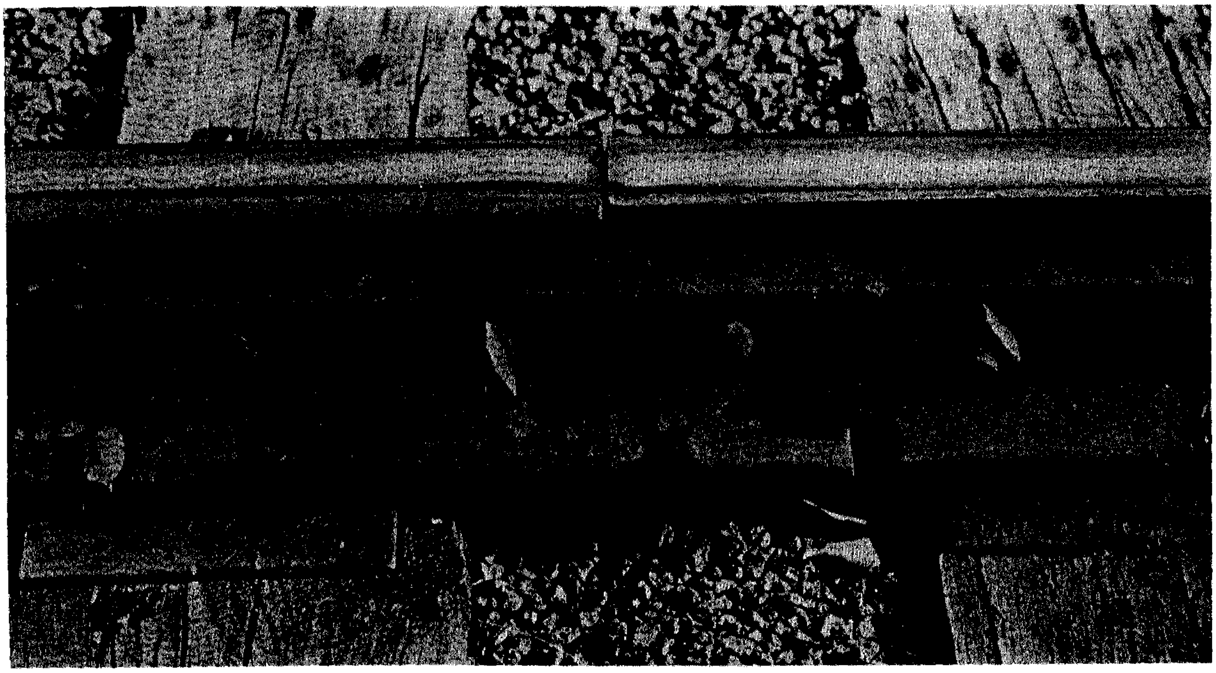


Figure 3-43. Joint-bar installation.

3-25.1.1. Keep joints tightly bolted to prevent injury to the rail ends. Use standard hand track wrenches (Figure 3-44) or a power wrench (Figure 3-45) as discussed below.

3-25.1.2. Take up wear in fishing spaces of rail and joint bars by replacing bars.

3-25.1.3. Oil all track bolts when installed and each time they are tightened. It is recommended that bolts be oiled and checked at least once every 3 months.

3-25.2. Track-Bolt Maintenance. The following practices are necessary to maintain track bolts:

3-25.2.1. In applying nuts on track bolts, the flat side of the nut should be placed next to the spring washer.

3-25.2.2. The applied bolt tension should be within a range of 20,000 to 30,000 pounds per bolt for the initial tightening and within a range of 15,000 to 25,000 pounds for subsequent tightenings. Use mechanical torque wrenches set in accordance with manufacturer's instructions.

3-25.2.3. Track bolts should be retightened as required, preferably one week and 1 to 3 months after the joint bars are applied and at intervals of 1 year thereafter. Annual retightening of bolts in paved areas may be waived based on engineering judgment and provided nondestructive tests and visual inspection are satisfactory. More frequent tightening is unnecessary and therefore uneconomical. Less frequent tightening requires too high an applied bolt tension to carry over the longer period.

3-25.2.4. Corrosion-resistant lubricant will be applied to bolt threads prior to the application of the nuts. This will reduce the variation in thread friction and promote the uniformity of tension obtained.

3-26. Compromise Joints.

Compromise joints (Figure 3-31) are used wherever rails of different weights or sections are connected. The bars must conform to the weight and section of each rail at the connection. The maintenance of compromise joints is the same as for joint bars (para 3-25).

3-27. Spikes.

3-27.1. Specifications. All spikes used for replacement, repair, and rehabilitation shall conform to AREA Standards. They must be smooth and straight with well-formed heads and sharp points and be free from nicks, cracks, or ragged edges. See Figures 2-10 and Table D-13.

3-27.2. Use. The standard 5/8- by 6-inch spike is used for all track spiking except when tracks are being shimmed. Shimming spikes are 6 inches plus the thickness of the shim taken at 1/2-inch intervals. NOTE: Smaller spikes may be required on lightweight substandard rail.

3-27.3. Location. Location of spikes shall be in accordance with Figure 3-41.

Figure 3-44. Using a hand wrench.

3-28. Bolts, Nuts, and Lock Washers.

All joints will be fully bolted with the proper size, type, and number of bolts, nuts, and lock washers for the type of joint bar used. These items must conform to AREA criteria (see Figures 2-7 and 2-9 and Table D-13).

3-29. Rail Anchors.

3-29.1. General. Rail anchors are used in track that is subject to serious movement from rail expansion or from traffic on steep grades. They must grip the base of the rail firmly and have full bearing against the face of the tie opposite the direction of creeping. (Note rail anchors in Figure 2-11.) The following general rules apply:

3-29.1.1. At locations where rail anchors are required, ties shall be firmly tamped and fully imbedded in ballast.

3-29.1.2. When the bearing of the rail anchor has been disturbed by removal of the tie, the anchor shall be removed and reset.

3-29.1.3. Ballast should be kept away from rail anchors.

3-29.2. One-Direction Traffic. See Figure 3-46 for placement of anchors for one-direction traffic. With very few exceptions, rail creepage is in the direction of traffic. The amount of creepage will vary with the kind of ballast used and with local conditions. Figure 3-47 shows tie skewing caused by rail creepage. A minimum of eight anchors per 39-foot rail length is recommended where the need exists. Additional anchors shall be used where needed. Rail anchors shall be spaced approximately uniformly along the rail length. To avoid skewed ties, the anchors shall be applied against the same tie on opposite rails. To provide for occasional reversal of traffic and to prevent excessive opening in case of a broken rail, at least two backup anchors should also be applied per rail length and boxed in around the tie with two of the forward anchors near the quarter points of the rail.

3-29.3. Two-Way Traffic. Effective anchorage is required where track conditions indicate a need to minimize the back and forth movement of rail resulting in the churning and bunching of ties. This condition is usually caused by train movements in both directions (Figure 3-46). The use of 16 rail anchors per 39-foot rail length is recommended, eight

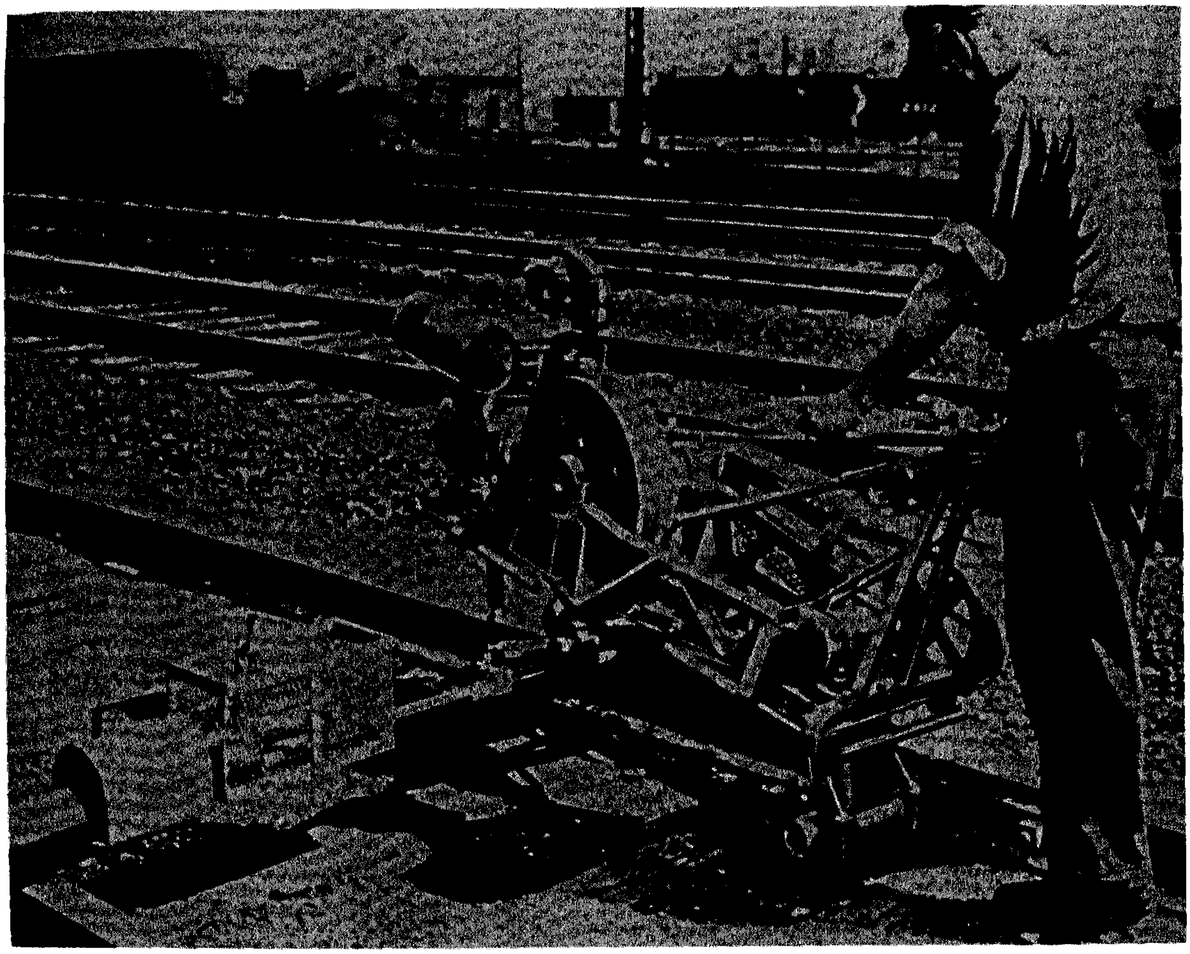


Figure 3–45. Using a power wrench.

anchors to resist movement in each direction for balanced traffic. If the traffic is much lighter in one direction, the number of anchors used to resist movement in that direction may be reduced. Additional anchors will be used where needed. The rail anchors should be spaced approximately uniformly along the rail length and against the same tie under opposite rails. The anchors to resist movement in the two directions shall be placed in pairs and boxed around the same tie. The arrangement of rail anchors for both one- and two-directional traffic is indicated in the diagram, Figure 3–46. It is important that the anchors be carefully applied and that they be in contact and remain in contact with the tie face.

3–30. Gage Rods.

Gage rods are recommended for use on sharp curves that are difficult to hold to gage, and where the track may shift because of unstable roadbed conditions. Two to four rods are used for each rail length, applied so that the rods are at right angles to the rail and the jaws have a firm grip on the base of the rail. Some types of gage rods prevent rails from canting or tipping. Where tipping has been encountered, this combination rod shall be used to maintain alignment and gage under unfavorable conditions. Gage rods are not required with concrete ties.

3–31. Turnouts and Crossovers.

3–31.1. General. The number of the frog in a turnout designates the nomenclature of the turnout (Figure D–1) and generally establishes: (1) length of switch points; (2) lead distance; (3) radius of lead curve; (4) length of the closure rails; and (5) number, length, and spacing of ties.

3–31.2. Replacement. For purposes of maintenance, the No. 8 turnout with a straight split switch, low switch stand, and solid manganese self-guarded

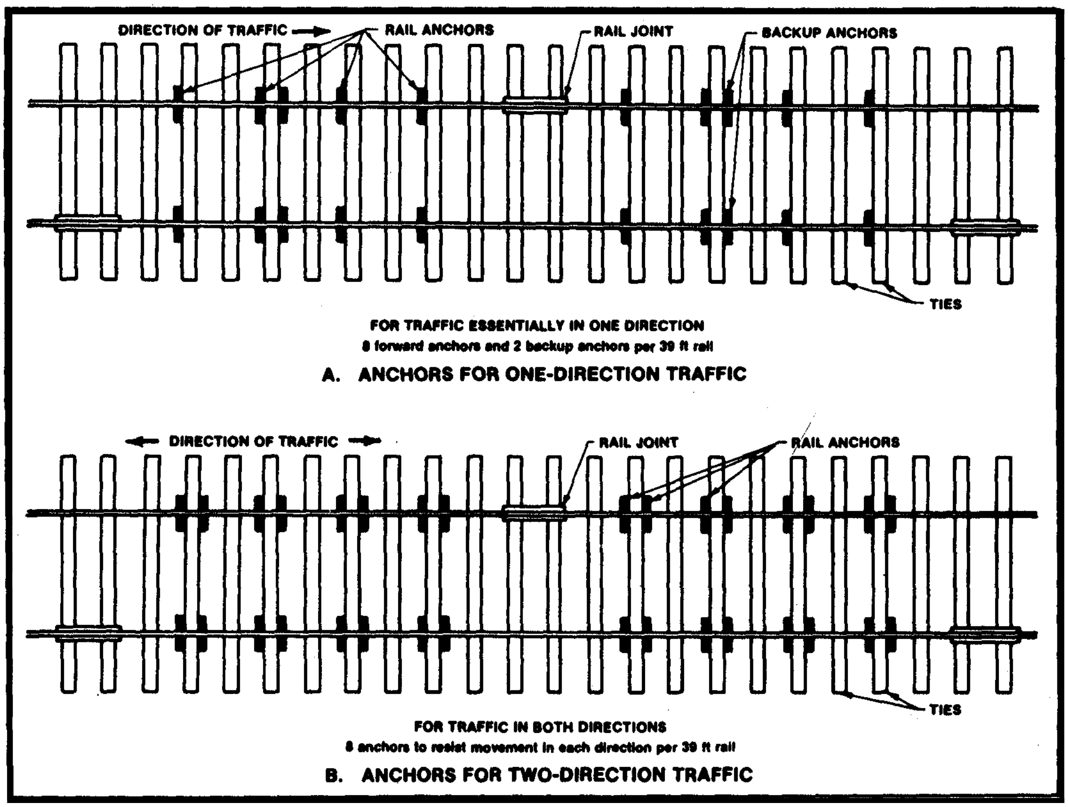


Figure 3-46. Anchor locations.

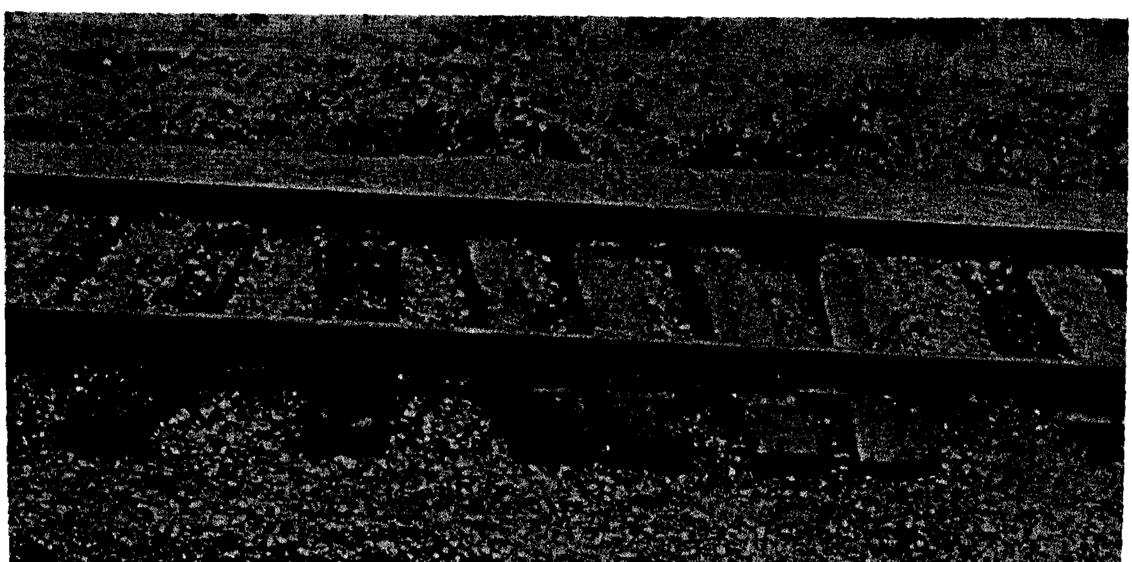


Figure 3-47. Result of rail creepage.

frog (Figure 3-48) is standard for replacement purposes wherever possible. Weight factors of switching equipment, installation layout, and site conditions must be considered in determining frog requirements. Under some circumstances, frog Nos. 7 through 10 will be needed to fit specific requirements of installation railroad trackage. Figure 3-49 illustrates a No. 8 turnout.

3-31.3. Crossovers. A crossover consists of two turnouts with track between, and it connects two adjacent and usually parallel tracks (Figure 3-50 and 3-51).

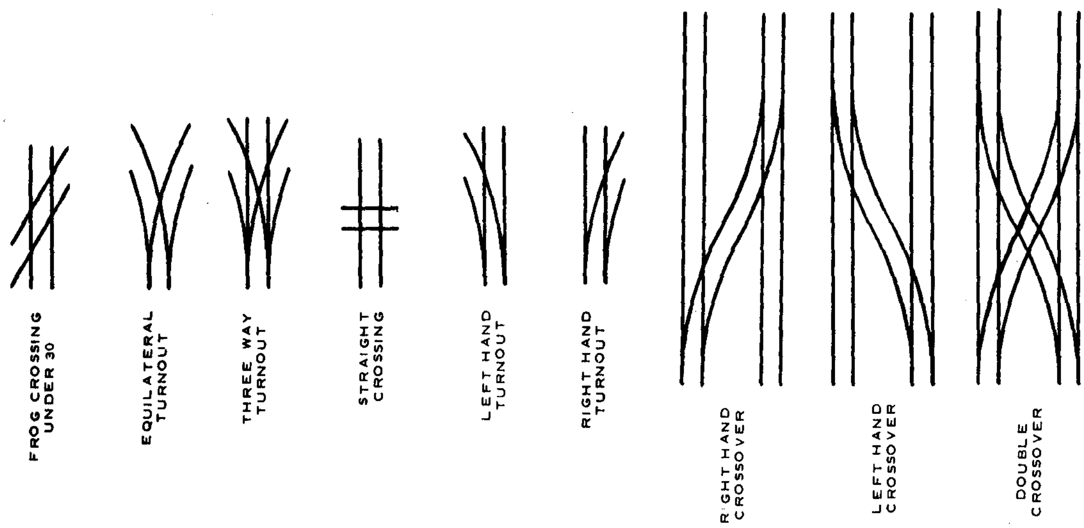


Figure 3-50. Track formations.

Figure 3-51. Crossover installation.

3-31.4. Location. Turnouts are located on tangent track wherever possible to minimize wear on switch points, frogs, and guardrails. When a turnout is from the inside of a curve, the degree of curvature of the turnout is approximately its normal degree plus the degree of curvature of the main line; if from the outside, the degree of curvature of the turnout is the difference between these two. Thus, if a No. 8 turnout was an angle of 12°24'23" is installed on the inside of a 4-degree curve, the curvature through the turnout is equal to 12°24'23" plus 4 degrees, or 16°24'23". Safety against derailment and economy in maintenance require that turnouts be located so that the total curvature does not exceed 16 degrees. Figure 3-52 shows a turnout on the inside of a curve, and Figure 3-53 shows a typical ladder turnout installation.

3-31.5. Position. To facilitate switching, it is desirable that all turnouts to spur tracks lead in the same direction (Figure 3-53).

3-31.6. Switch Ties. Switch ties are of the length and spacing specified in standard plans for the turnout. Policies governing installation and maintenance of crossties apply to switch ties (para 3-10.2.).

3-31.7. Switches. Lengths of switch points adopted as standard for various turnouts are as indicated in Table 3-2. Because a loose connection or a broken connection rod is a serious defect and is likely to cause a derailment, all connecting points and connection rods require close inspection. The following instructions are supplemented and illustrated by the standard plans (Figures 3-18, 3-48, 3-49, 3-54, 3-55, and 3-56).

Table 3-2. Standard Switch Point Lengths

Number of Turnout	Length of Switch Point ft
15	22-30
12	22-30
10	15-16.5
8	15-16.5
7	15-16.5
6	11
4	11

3-31.7.1. Match switch points to weight and section of stock rail. When points are renewed, renew stock rail also, if necessary, to secure a proper fit. Connect points to the operating rod to provide ample flangeway between the open point and the stock rail. Check both switch points for this adjustment. The correct throw of the switch is 4-3/4 inches, with an allowable minimum limit of 4 inches or according to switch design. Mechanisms for throwing switches in paved areas should be adjusted to provide the maximum throw permitted by the equipment. Provide all vertical bolts on switch connections with cotter pins, and place the bolts with nuts facing up. Center the slide and heel plates on the tie to provide a uniform bearing for the switch point.

3-31.7.2. If switch point protectors are used, the bolts should be checked regularly and retightened as necessary or the protector will not provide adequate protection for the switch point. When wear makes repairs necessary, manufacturer's instructions should be followed.

3-31.7.3. Check each switch to determine that it operates freely, that points fit accurately, and that rods do not foul on ties or ballast. Keep all operating mechanisms clean and thoroughly lubricated. Keep the switch free of ice, snow, and debris at all times. Frequency of switch maintenance is discussed in Chapter 7 and should be an item on the installation work plan.

3.31.7.4. Maintain surface, line, and gage throughout. Keep the gage side of the main track point in line with the gage side of the stock rail in advance of the point. Bend the stock rail with a rail bender at the proper place so that the point fits snugly against the rail when closed. Table 3-3 gives data on bends of stock rails for different lengths of switch points. Table D-1 and Figure D-1 give data regarding various turnouts. NOTE: In ground-level crane trackage switches, the rail in some switches will "bow-up." This is a "not serious" defect unless it causes binding or other difficulty in operation of the switch or the passing of a crane. Insure that ample flangeway is available between the open point of switch and the stock rail; this is controlled by flange width of crane wheels using the track system.

Table 3.3 Offsets for Bending Stock Rail

Length of Switch Point ft	Distance of Bend Ahead of Switch Point in.	Perpendicular Offset from Original Line at 10 Feet from Bend in.
30	7-3/8	1-7/8
22	5-1/2	3-1/8
16.5	8-1/4	3-5/8
15	4-1/16	3-7/8
11	5-1/2	5-5/8

3-31.8. Switch Stands. The switch-operating mechanism consists of a hand-operated switch stand with throw lever and a connecting rod. The switch stand is placed on the two 15-foot header ties at the point of switch. Where practicable, the switch stand is located on the right side of the track with respect to the normal direction of traffic. The switch stand is installed and maintained according to the following requirements:

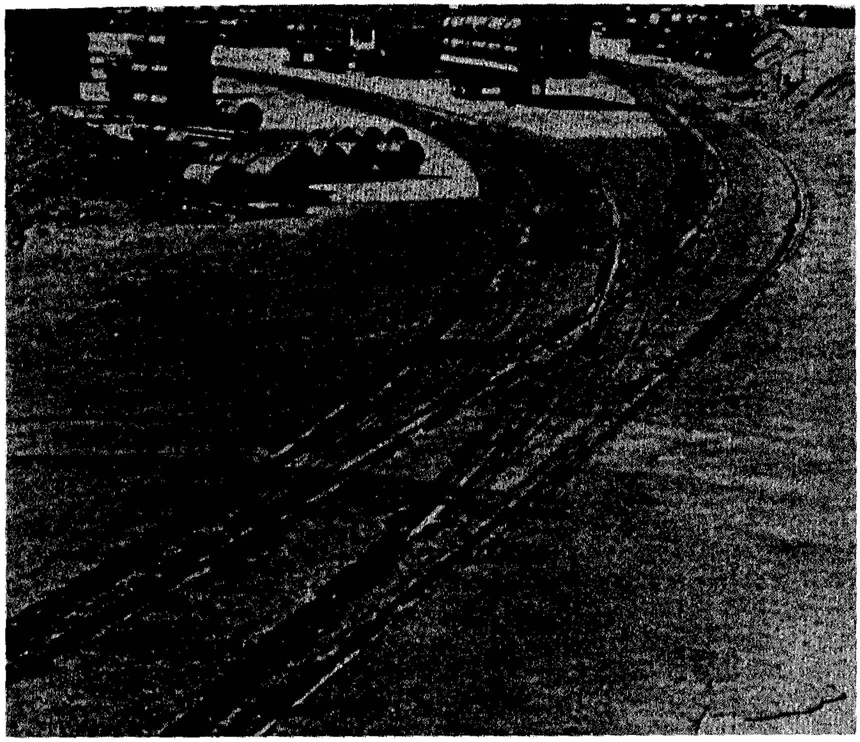


Figure 3-52. Turnout on a curve.

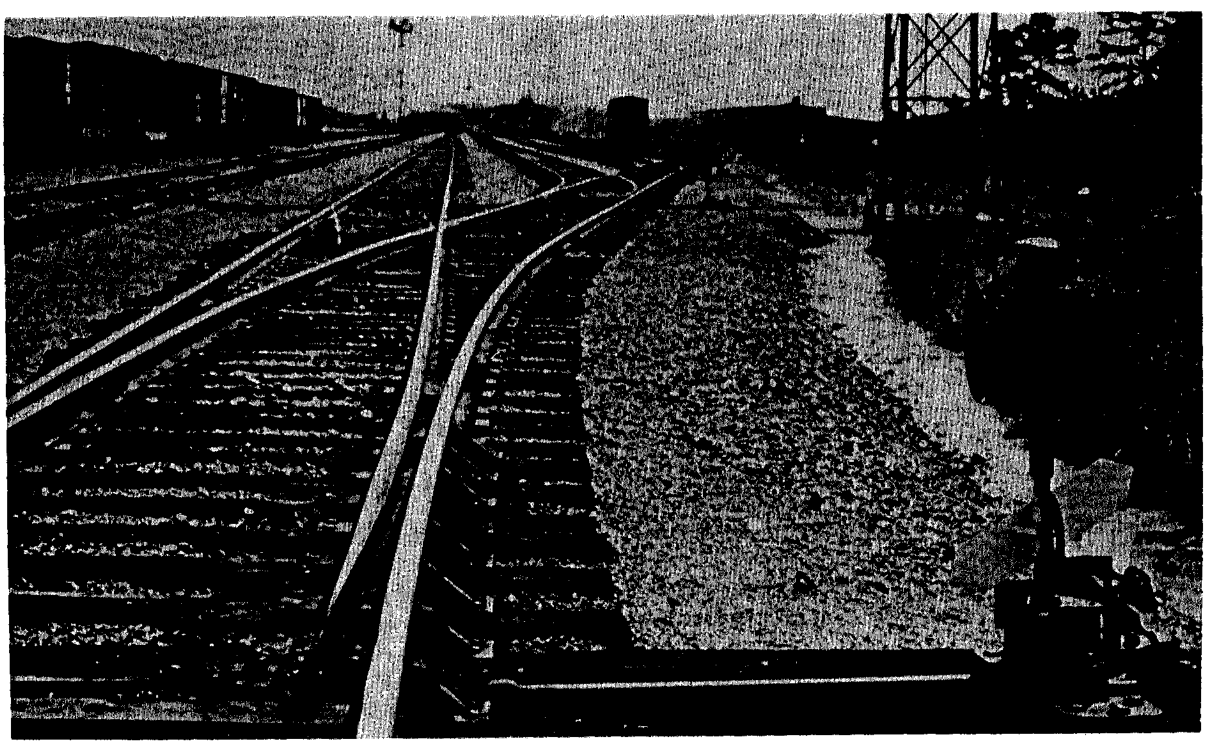


Figure 3-53. Ladder turnout installation.

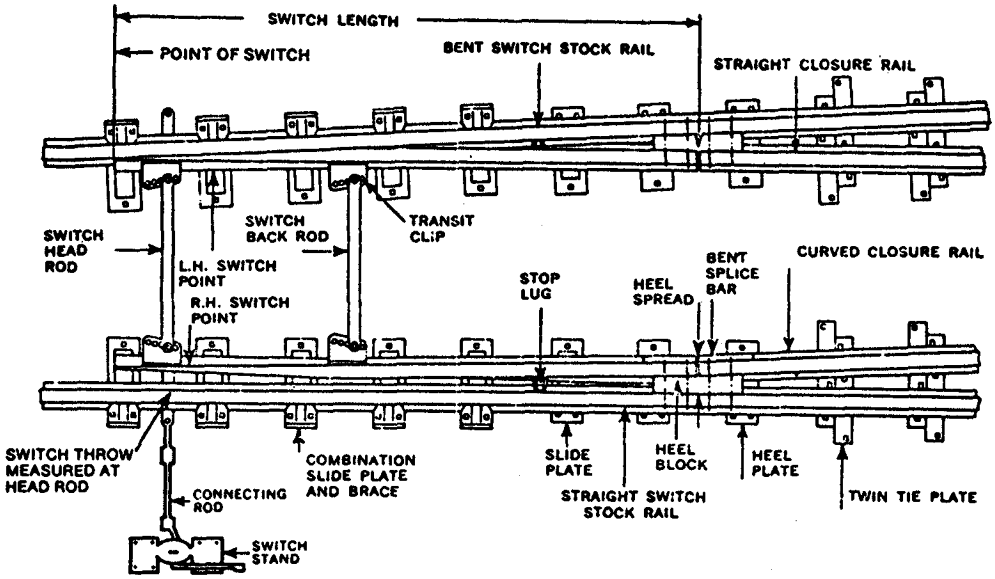


Figure 3-54. Nomenclature of switch parts.

3-31.8.1. Hand lever operates parallel to the track.

3.31.8.2. Throw of stand is adjustable from 4-1/2 to 5-1/2 inches; the adjustment is made so that each switch point has a throw of 4-3/4 inches. Throw of switch points should be a minimum of 4 inches.

3-31.8.3. Center of stand is approximately 6 feet 6 inches from centerline of track.

3-31.8.4. Colored targets and/or distinctly shaped targets are provided to indicate switch points clearly at locations where such indications are necessary. Figure 3-57 shows the type of switch stand most commonly used on military installations; it may be used in paved areas. Figure 3-58 shows the type of switch stand that clearly shows the setting of the switch by high target.

3-31.8.5. For night operations, switch targets are red and green reflectors or red and green lanterns mounted on the spindle. Green indicates switch normal and red indicates switch reversed.

3-31.9. Railroad Frogs. When necessary to purchase new frogs, the solid manganese self-guarded frogs (Figure 3-48) should be purchased; however, any supply of rigid bolted frogs on hand can be used. The above frogs should be used unless a variation is specifically authorized by a higher authority. The rigid frogs are preferred for all locations because of their maintenance free characteristics; however, the use of the turntable frog is mandatory for certain angles below 30 degrees, depending upon frog angle, curve radius, and flangeway width of crossing rail. Existing spring rail frogs should be replaced as soon as practicable with standard rigid frogs. When using standard bolted frogs, guard rails shall be installed to protect the frog point and assist in the prevention of derailments. Railroad frogs are installed in the following manner:

3-31.9.1. The frog number corresponds to the turnout number.

3-31.9.2. The frog is of the same weight and section as the rails through the lead.

3-31.9.3. All frogs are fastened to switch ties by hook plates (Figure 3-59), fully spiked. Spikes will be kept fully driven; all bolts must be tight, and any broken bolts shall be replaced immediately.

3-31.9.4. Correct line, surface, and gage shall be maintained.

3.31.10. Guardrails. Guardrails are not required with solid manganese self-guarded frogs, except under special circumstances. Guardrails may be either 8 feet 4-1/2 inches, one-piece manganese or 9 feet 5 inches tee rail with fillers (Figures 3-60 and 3-61).

3-31.11. Guardrail Placement. Requirements for guardrail placement are:

3-31.11.1. Guardrails are placed in accordance with Figure 3-59 or 3-60, and Figure 3-62.

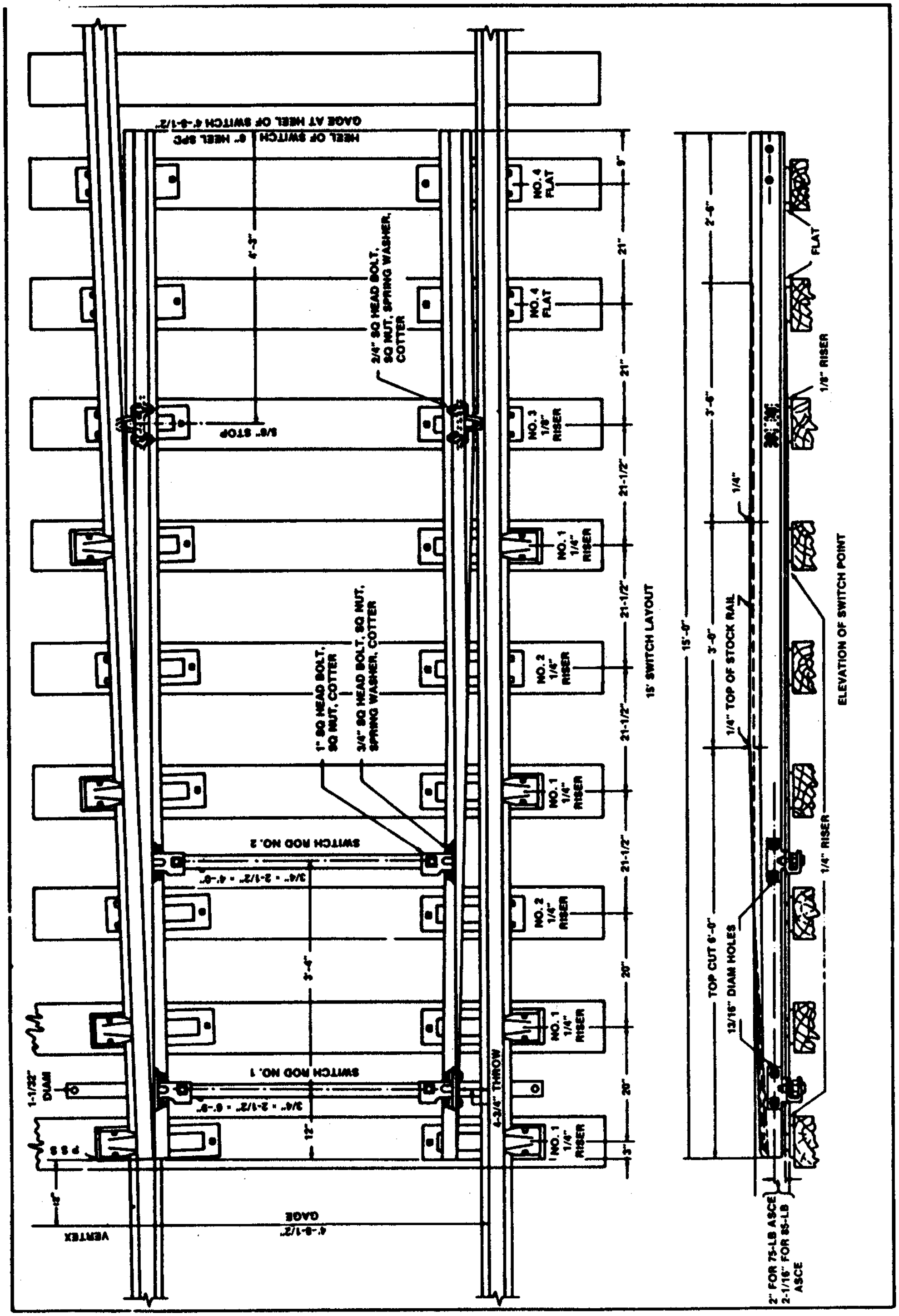


Figure 3-55. Layout and details of 15-foot switch.

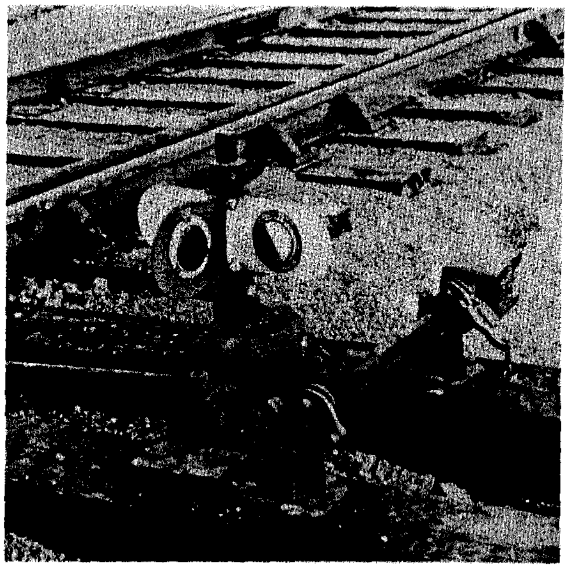


Figure 3–57. Switch stand with target.

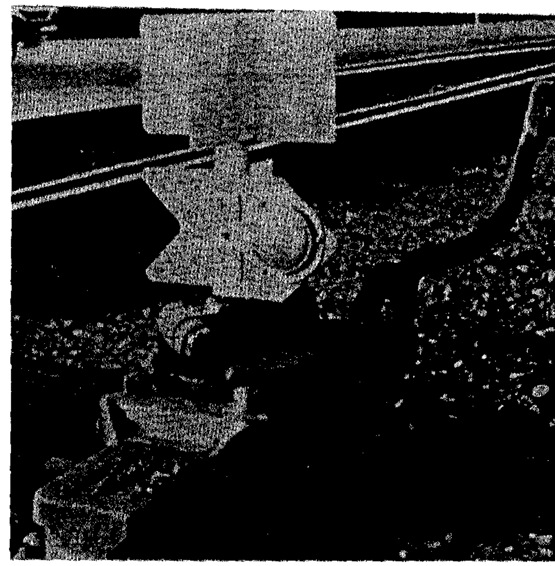


Figure 3–58. Switch stand with high target.

3–31.11.2. The gage of guardrails at frogs must be checked frequently. Normally, the distance from the gage line of the frog to the flangeway face of the guardrail is 4 feet 6–5/8 inches (guard check gage); however, if curvature through turnout exceeds 8 degrees, the distance must be 4 feet 6–3/4 inches regardless of track gage. The distance between the guard line of the guardrail and the guard line of the frog (guard face gage) should not exceed 4 feet 5 inches (Figure 3–62).

3–31.11.3. Ends of guardrails are placed on a tie or are otherwise protected to prevent loose or dragging objects from catching or fouling the rail.

3–31.12. Derails and Rerails. Derails and rerails (Figure 3–63) must be kept in good operating condition. Frequent observations should be made go see that the clearance point has not changed because of shifting or movement of running track. Derails are painted a bright chrome yellow to make them clearly visible. Rerail devices shown in Figure 3–63 are not permanent and should not be placed in track unless needed for rerailing cars.

3–31.13. Clearance Marker. Where derails are not used, a chrome yellow strip 10 inches wide should be painted across the web and base of each rail of the connecting track at the clearance point, or other distinctive marker should be used (Figure 3–64). The markings or markers must be located at sufficient distance from cross or converging tracks to provide adequate clearance between standing or moving trains, or at road crossings to prevent standing trains or cars from fouling the intersection.

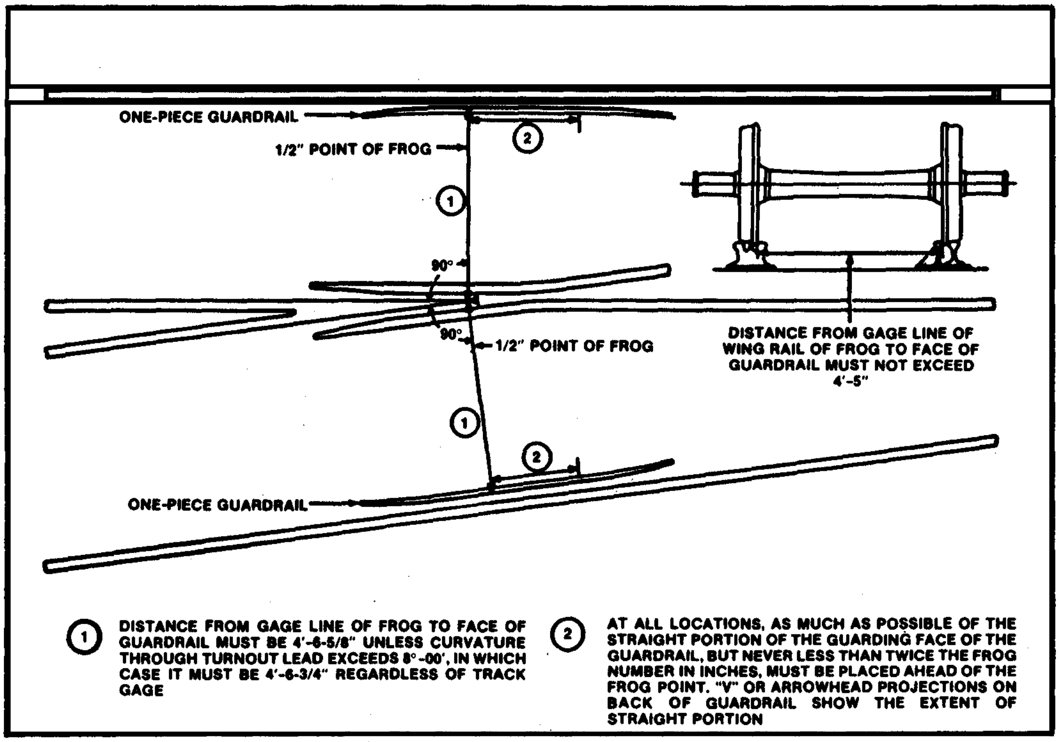


Figure 3-62. Gage at guardrails.

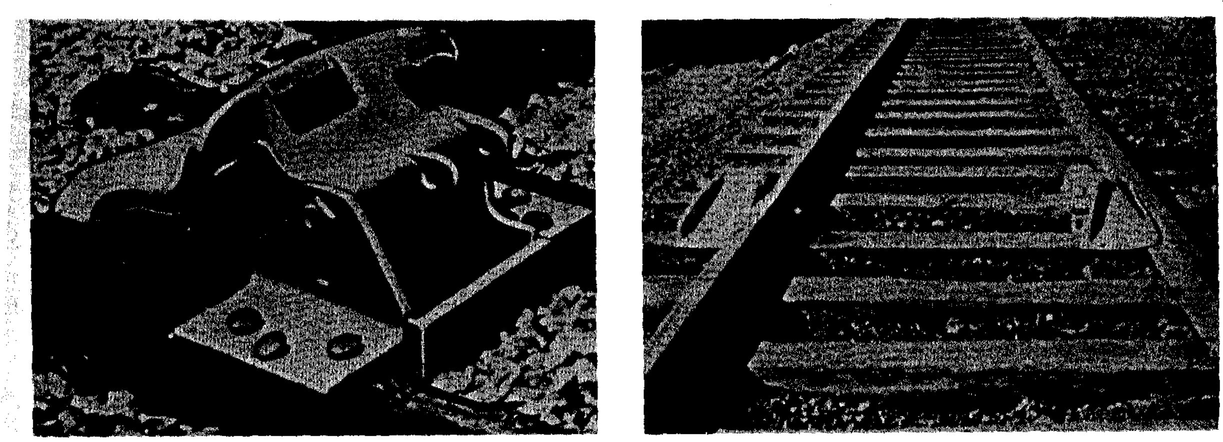


Figure 3-63. Derail (left) and rerail installations.

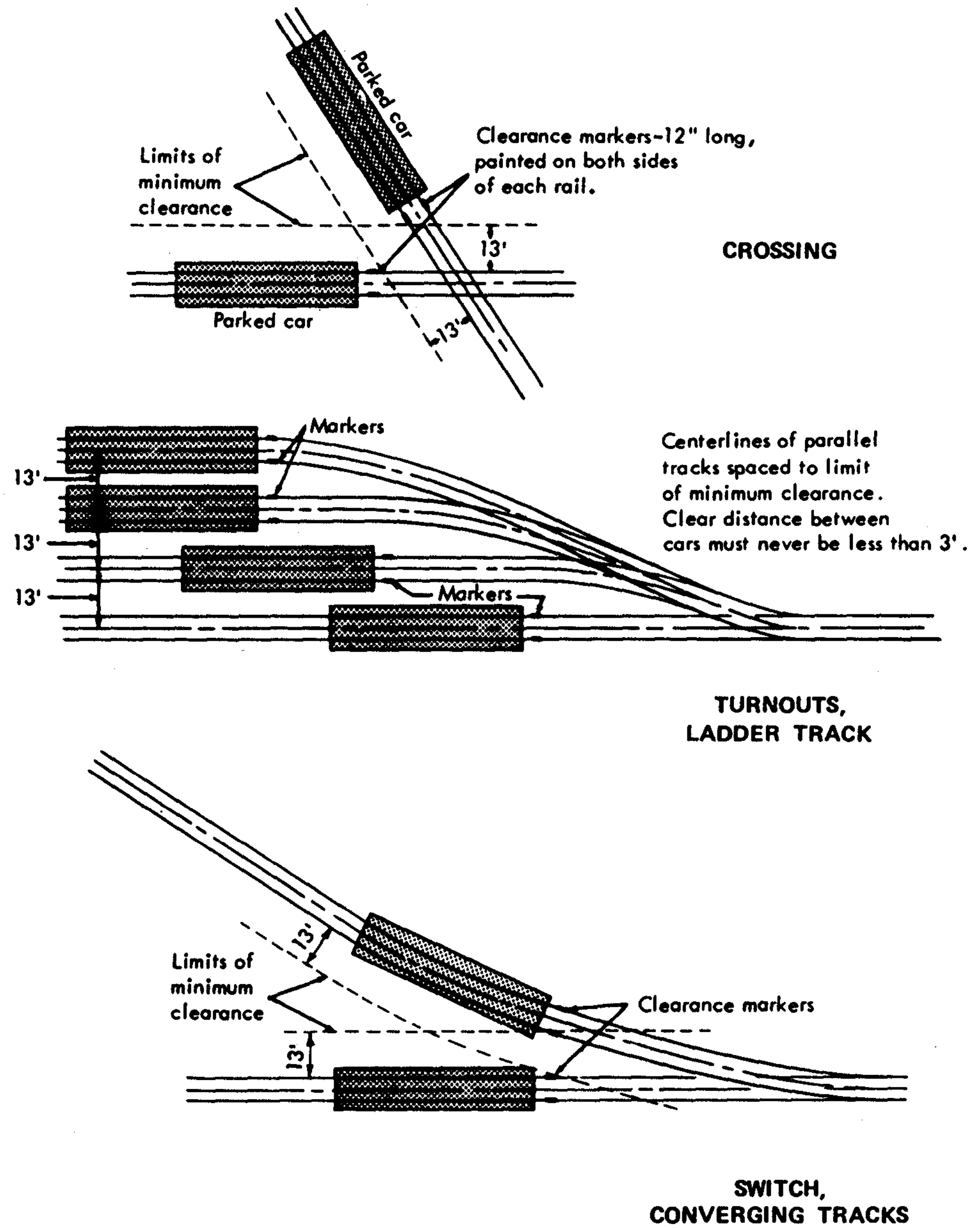


Figure 3-64. Locations of clearance markers.

CHAPTER 4. SPECIFIC MAINTENANCE OPERATIONS

Section 1. MAINTENANCE OF TRACK

4-1. Lining Track.

Track is aligned at the same time it is surfaced. The "line" rail is always aligned and surfaced first, then the second rail. The line rail is the north or east rail.

4-1.1. Horizontal Alignment. Existing systems, not conforming to grade and curvature standards, may be maintained as is, provided a record is on file describing each deviation from the standard and necessary operating restrictions are imposed. Restrictions shall be tailored to each specific situation and may include such items as maximum speed, use of push bars, and maximum car/engine combination. To assist cars or cranes in tracking and to reduce wear on sharp or substandard curves, it is suggested that tracks be oiled. Track oilers may be installed on Government-owned locomotives operating over sharp curvatures.

4-1.1.1. Railroad trackage. All curves shall have a designated degree of curvature. Curves with radii less than 300 feet or frogs No. 4 and below shall be approved by higher authority than the installation. The radius established by the activity is the base line, design, theoretical radius, or the radius that best fits the overall existing condition. Curve alignment that deviates from established uniformity more than the amount shown in Appendix B is considered defective. Spirals, as designed or as developed, shall have a smooth transition.

4-1.1.2. Ground-Level Crane Trackage. Horizontal rail alignment of curved crane trackage shall be designed or laid out based on analyzing portal crane float requirements for traversing curved track. This analysis of required float can be compared to the float capabilities of all cranes to clearly define the problem areas. The problems may result in limited restriction of crane operation, reworking the running gear on the crane, or realigning the trackage. It should be noted that the available design float of a crane may not necessarily be operational. Curved crane trackage cannot be checked or lined using the string-line method described herein.

4-1.2. Tangents. On tangent track, the line rail is brought to correct line by eye (Figure 4-1) or by use of a transit. The other rail is brought to line by correcting to proper gage. Figure 4-2 illustrates lining track operations.

4-1.3. Curves. Lining of track on curves is more complicated because the curve must not only be uniform throughout its length, but, in most cases, an easement (spiral) into the curve must be provided from both tangents.

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4-1.3.1. Compound or reverse curves should be provided with easements or spirals fom one curve into the other.

4-1.3.2. A transit is employed and curves are staked out in laying out new work or in making major changes to an existing track layout. A transit should be used in laying out new work or when making major changes to an existing track layout. The string-line method can also be used, but is not recommended for new work or major changes. String lining is best used for determining the degree of curvature and in locating and correcting irregularities in the alignment of curves. Field operations and methods of calculation are as given in the AREA manual and Appendix F.

4-2. Surfacing Track.

4-2.1. General. All tracks shall be laid and maintained to correct surface elevation. Surfacing out-of-face refers to raising the track structure to a new grade. Spot surfacing refers to raising low spots to the original uniform surface. Correct surfacing implies that a plane across the top of the rails at right angles to the rails is level on tangents and has the correct inclination on curves when superelevation (para D-2, Appendix D) is used. The track level is used in all surfacing work (Figure 4-3).

4-2.1.1. Pay special attention to surface and line of track at ends and approaches to bridges, trestles, and culverts; through turnouts and crossings; and at platforms.

Figure 4-1. "Eyeballing" track.

Figure 4-2. Operation of lining track.

4-2.1.2. Work against the current of traffic when raising track, except on heavy grades where it is desirable to work upgrade.

4-2.1.3. Before raising track during hot weather, be sure that rails will not warp or buckle. Consider the amount of rail openings at joints, tightness of bolts, position of rail anchors, and amount of ballast in cribs and at ends of ties. Where there is danger of buckling, loosen track joints in both directions from the danger point to allow for expansion.

4-2.1.4. In bonded-track territory, see that ballast clears the base of the rail to prevent leakage of current. Separate ballast and base of rail by a space of about 2 inches.

4-2.2. Grade. Profile grades shall not exceed the design grade except as noted below.

4-2.2.1. Railroad Trackage. Grades may be spot checked at random intervals with a hand level and rule. All grade changes shall be connected with a vertical curve. Switches may be installed on grade; however, no part of the switch should extend into a vertical curve.

4-2.2.2. Ground-Level Crane Trackage. On existing trackage with grades in excess of 1 percent, if cranes do not encounter acceleration or deceleration problems in traversing the tracks, no action is required. However, if problems are apparent or if other deficiencies dictate complete replacement of the track, the criteria of 1 percent maximum grade shall be followed. Curves, switches, and frogs shall be on a level grade in order to minimize the possibility of derailment. NOTE: If existing grade is not level or if there is a difference in elevation of 1 inch between the inside rail and the outside rail, crane float shall be analyzed to determine whether the wheel flanges will clear the rail and permit the truck assembly to swivel and cause derailment. Observing the position of the wheel flanges in relation to the top of the rail will reveal areas that may become critical. If wheel flanges clear the top of the rail, extreme caution must be taken during operations and immediate action initiated to correct the deficiency. The area in question should be classified as critical and well marked so that all crane operators and crews will be cognizant of the deficiency.

4-2.2.3. Elevated Crane Trackage. The rail should be kept near level grade. The rail gradient must be kept below the slope that will cause the crane to roll freely and present problems in starting or stopping the crane.

Figure 4-3. Surfacing track with a leveling beam.

4–2.3. Cross-Section Elevation. Vertical differences between rails shall be within the limits shown in Appendix B.

4–2.3.1. Railroad Trackage. On curved trackage with designed superelevation, the outside rail shall not be lower than the inside rail and the maximum cross-section elevation differences shall be within the limits shown in Appendix D for the designed superelevation based on degree of curvture and speed. On curved trackage in industrial areas traversed at low speeds, superelevation is not required.

4–2.3.2. Ground-Level Crane Trackage. When the difference in elevation between the elevation of the inside rail and the outside rail exceeds 1 inch, the crane float shall be analyzed and appropriate action taken.

4–2.3.3. Elevated Crane Trackage. The cross-sectional difference in elevation of rails shall not exceed the limits established by the activity based on engineering judgement for each specific trackage system or the tolerance recommended by the manufacturer when known.

4–2.4. Hand Jacking. There are two methods of surfacing track with track jacks: one is used where the lift is less than 2 inches, and the other where the lift is more than 2 inches. The two methods are discussed below:

4–2.4.1. In starting a raise or lift of less than 2 inches, jacking points should be spaced 8 to 12 feet apart. Place the first jack approximately 10 feet ahead of starting point of the raise. Place the second jack 10 feet ahead of the first jack. Raise both jacks to give an even grade from the starting point to the second jack. Tamp the ties to a point approximately halfway between the jacks. Bring the other rail to proper surface with the aid of the track level. Then move the first jack about 10 feet ahead of the second, raise the rail at that point, and tamp the ties halfway between the jacks. Follow the same procedure to bring the other rail to proper surface, using the track level to determine the amount of lift.

4–2.4.2. To lift the track more than 2 inches, locate both jacks as above, but reduce the spacing between jacks to avoid permanent bending of the rail. Raise the first jack to bring the rail to grade between 0 and 1. Then raise the second jack enough to provide reasonable runoff between the new grade and the low spot. Tamp ties to a point approximately one-fourth the distance between 1 and 2. Raise the second jack to bring the rail to proper grade, and move the first jack ahead the proper spacing. Tamp as before, and continue the same operations through the full length of track to be raised.

CAUTION: In both methods, jacks must be placed ahead of rail joints to prevent strain on joint bars (Figure 4–4).

4–2.4.3. In raising or surfacing track, the inner rail on curves and the line rail on tangents are the grade rails. Bring them to surface with the aid of the spot board, or refer them to grade stakes. Bring the second rail to surface with the aid of the track level.

4–2.4.4. Bring both rails to grade, tamp ties, set tie plates, gage track, and drive spikes fully before jacks are moved ahead.

4–2.4.5. Place track jacks in cribs between the ties outside the rail, and set them true vertically. If jacks are to be placed between rails, set them in trip position, and provide flag protection.

4–3. Tamping.

Systematic and uniform tamping is of great importance in maintaining correct surface and line. See Figures 3–7 through 3–9 and paragraph 3–6.3.

4–3.1. Tools. Pneumatic, electric, gasoline, or other mechanically operated or hand tampers may be used for tamping. The type of tool varies somewhat for different materials as follows:

4–3.1.1. For broken stone, crushed and washed gravel, or slag ballast, use a tamping pick or bar, ballast spade, or power tamper. Power equipment will be fitted with a tool having an end similar to a tamping pick face or vibratory tool.

4–3.1.2. For gravel, chats, or chert ballast use a shovel, ballast fork, ballast spade, tamping pick, tamping bar, or power tamper. For heavy traffic, a tamping pick, tamping bar, or power tamper should be used. With a power tamper use a tamping tool with a tamping end of sufficient area. For light traffic, shovel tamping is sufficient.

4–3.1.3. For spot tamping, tamping picks, ballast forks, ballast spades, shovels, tamping bars, or power tampers may be used.

4–3.2. Methods. After the track has been raised on jacks to a true surface, pack ballast firmly under the ties. Tamp so that a tight bearing is obtained between the tie and the raised rail, but without disturbing the surface. The following tamping methods apply:

4–3.2.1. Tool Positioning. Regardless of the kind of ballast or the kind of power tamper used, two tamping tools must always be worked opposite each other on the same tie. Start power tampers from a vertical position, and use them directly against the sides of the tie to be tamped. Work downward past the bottom corner, after which the tools may be tipped down to force the ballast directly under the tie.

4–3.2.2. Tamping Distances. In tamping ties, 8-foot crossties should be tamped from 12 inches inside the rail to the end of the tie, 8-foot 6-inch crossties should be tamped from 15 inches inside the rail to the end of the tie, and 9-foot crossties should be tamped from 18 inches inside of the rail to the end of the tie.

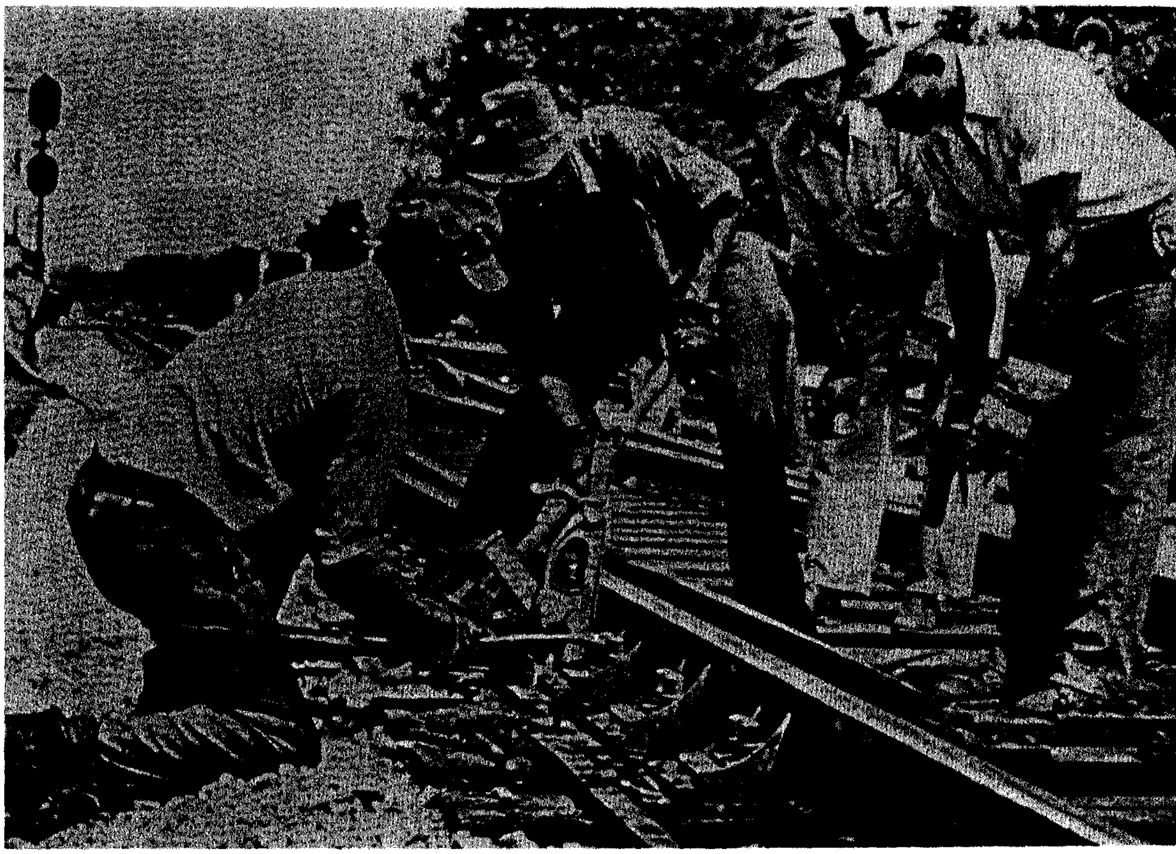


Figure 4-4. Jacking rail.

4-3.2.3. Cautions. Omit tamping at the center of the tie, between the above stated tamping limits, but this center area should be filled lightly with a ballast fork. Both sides of the ties must be tamped simultaneously, and tamping inside and outside the rail should be done at the same time.

4-4. Gauge Measurements.

Check gage of track at least annually and more frequently when the volume of traffic or local conditions warrant. Gage for railroad trackage is measured between the heads of the rails at right angles to the rails in a plane 5/8 inch below the top of the railhead. Gage for crane trackage is measured center to center of railhead.

4-4.1. Railroad Trackage..

4-4.1.1. Tangent Tracks and Curves. The standard gage of 4 feet 8-1/2 inches is used for tangent track and on curves up to 8 degrees (Figure 4-5). On curves over 8 degrees, the gage is increased 1/8 inch for each increment of 2 degrees to a maximum of 4 feet 9-1/2 inches, by moving the inside roll. The rate of change from standard to widened gage is 1/4 inch in 31 feet along the spiral curve or tangent adjacent to the curve, unless physical conditions do not permit the normal transition. The 1/4 inch in 31 feet rate of change from standard gage to widened gage for curves is a design standard and not trackage inspection criteria.

4-4.1.2. Turnouts and Crossovers. At turnouts and crossovers on curved track, the gage of the parent track is determined from the degree of curve, as described above. The degree of the turnout curve is determined by the algebraic sum of the two curves, i.e., curve of the turnout plus or minus the curve of the main track (para 3-31.4.), and the gage adjustment is made accordingly.

4-4.1.3. Ground-Level Crane Trackage. The gage on curved trackage shall under no circumstances require more lateral float than the crane can provide.

4-4.1.4. Elevated Crane Trackage. The gage of trackage shall be held within the tolerances specified by the crane manufacturer or as computed from the existing crane wheel spacing.

4-4.2. Limiting Factors for Corrective Maintenance. Variations in gage within the limits shown in Appendix B are acceptable, provided there are no alignment, attachment, or foundation defects which

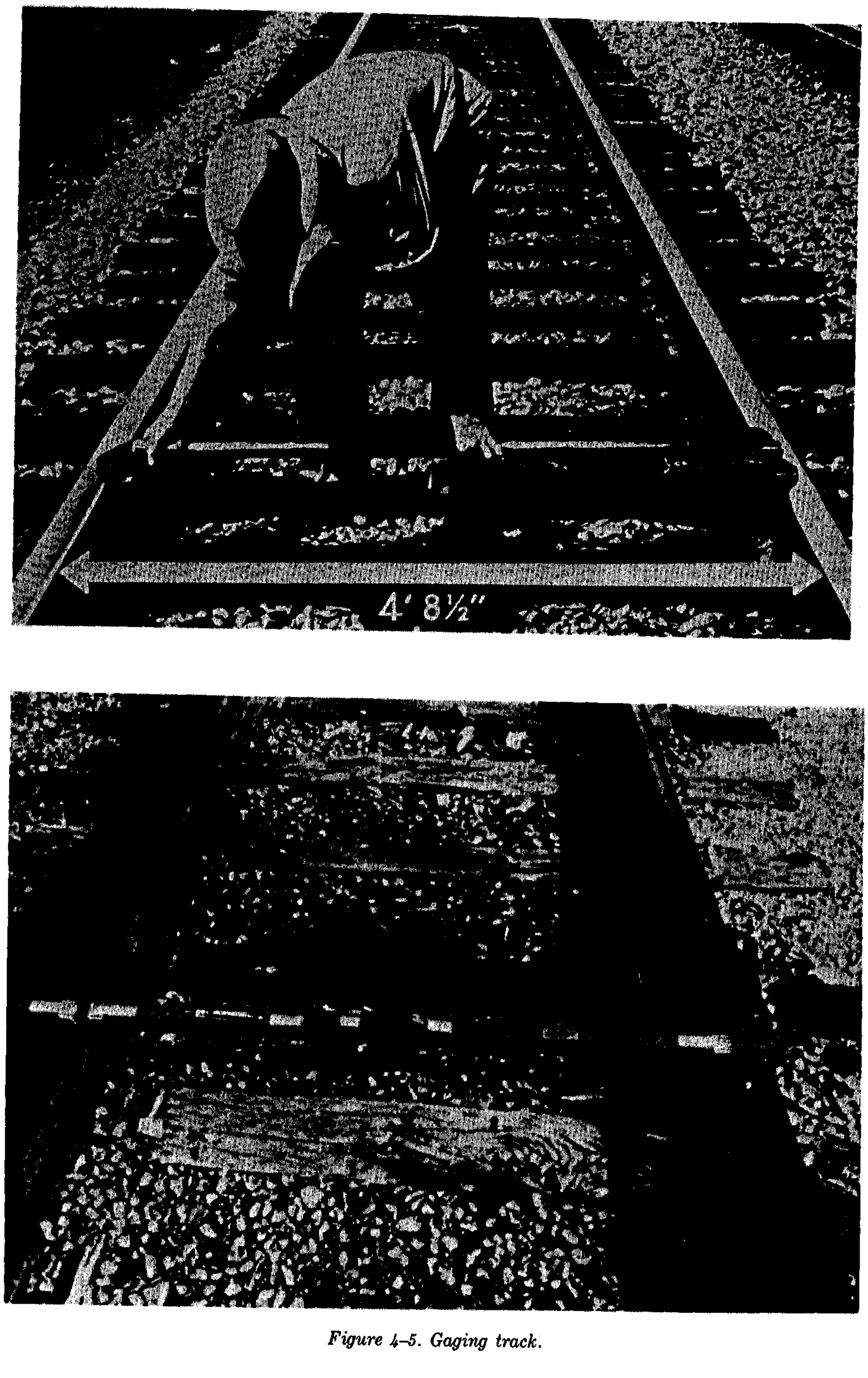


Figure 4-5. Gaging track.

would cause the train to start excessive or abnormal rocking or bouncing. Variations in gage and wide gage transitions are not serious provided the changes are relatively uniform and constant over two standard rail lengths, the fastenings secure, and the alignment within prescribed limits. Wide gage, caused by worn rail should be corrected by closing in or by interchanging the low and high rails.

CAUTION: Interchanging the low and high rails can cause failure due to the change in stress location.

4–4.3. Procedure for Regaging. The standard track gage is used in correcting gage. It will be checked frequently and replaced when it shows a variation of 1/8 inch or more. All spike pulling and driving is done on the rail opposite the line rail. The gage is not removed until all spikes have been driven. Spikes are pulled with the standard claw bar (Figure 4–6) or spike puller (Figure 4–7). At switches, frogs, and guardrails, where the claw bar will not fit between rails, the spike puller extension is used. Creosote-treated tie plugs are driven in all spike holes before respiking. Corrections to gage shall not be made by striking the head of the driven spike toward the rail. Spikes shall be removed, rail lined to gage, and spikes redriven.

4–5. Spiking.

Spiking will follow the standards set forth in paragraph 3–21, steps h through k.

4–6. Rules for Turnout Installation.

See paragraphs 2–2 and 3–31 for general discussion and Figures 2–1 through 2–14 for descriptions. Turnouts, crossovers, and their appliances are placed and maintained in accordance with standard plans and the following rules:

4–6.1. Locate point of frog and point of switch.

4–6.2. Relocate any main-track rail joints that come within the limits of switch point or guardrail.

4–6.3. Cut the lead rails, bearing in mind that the turnout lead is longer than the main-track lead.

4–6.4. First, put in headblocks and gage plate or two side plates, then all ties for the switch point and frog, and their slide plates, braces, heel plates, and guardrail plates. The plates and braces for the unbroken line or rail are lined and fully spiked in position, whereas those on the turnout side are held in place temporarily.

4–6.5. Bend a rail for the turnout stock rail according to the data shown in Table 3–3, paragraph3–31.7.d.

4–6.6. Couple the stock rail, main-track switch point (heel block to be placed later, if used), lead rails, and frog, on the ends of ties on the turnout side, doing such cutting and drilling as may be necessary to complete the main track from the point of the switch to the heel of the frog.

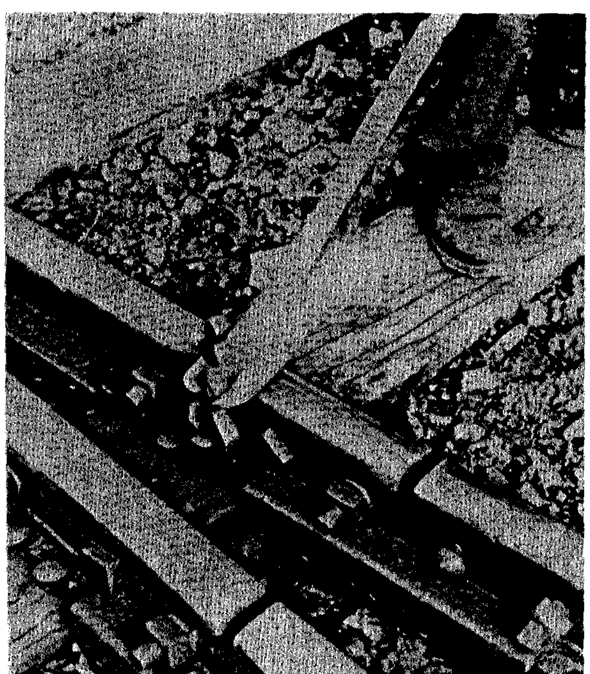


Figure 4–6. Pulling spikes with a claw bar and extension.

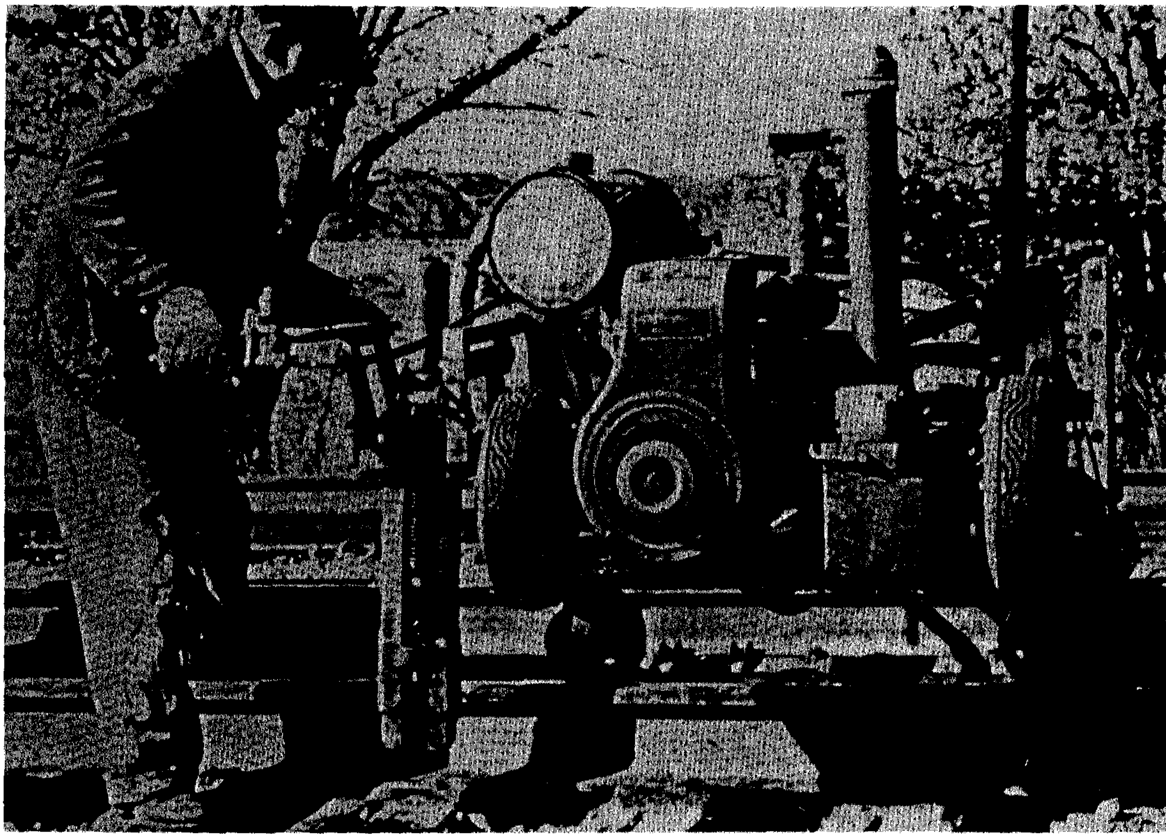


Figure 4-7. Power operated spike puller.

4-6.7. Take out the old main-track rail; set in the turnout parts in the following order: (1) place stock rail and switch point, (2) place the lead rail and frog, (3) make connections at the heel of the frog and at the stock rail, (4) spike frog to exact gage at the heel and the toe point, (5) place joint bars and tighten bolts, and (6) complete spiking from the frog to the heel of the switch point.

4-6.8. Do not permit train movement over main track until the guardrail has been correctly placed and spiked, all switch plates on the turnout side have been fully spiked in correct position, the switch point has been spiked against the stock rail, and the free end of the stock rail fastened to prevent movement.

4-6.9. In applying the switch plates on the turnout side: (1) see that gage is correct 12 inches ahead of switch point, and (2) put slide plates on tie where switch point begins to taper.

4-6.10. Adjust stock rail so that it does not bind against switch point and cause it to open. (To test this, operate the switch point and see that point touches the stock rail first.) Spike these slide plates, Install and spike remaining slide plates and braces, working each way from the center.

4-6.11. When putting on slide plates, use a bar (not a pick), and do not attempt to draw the gage with a spike.

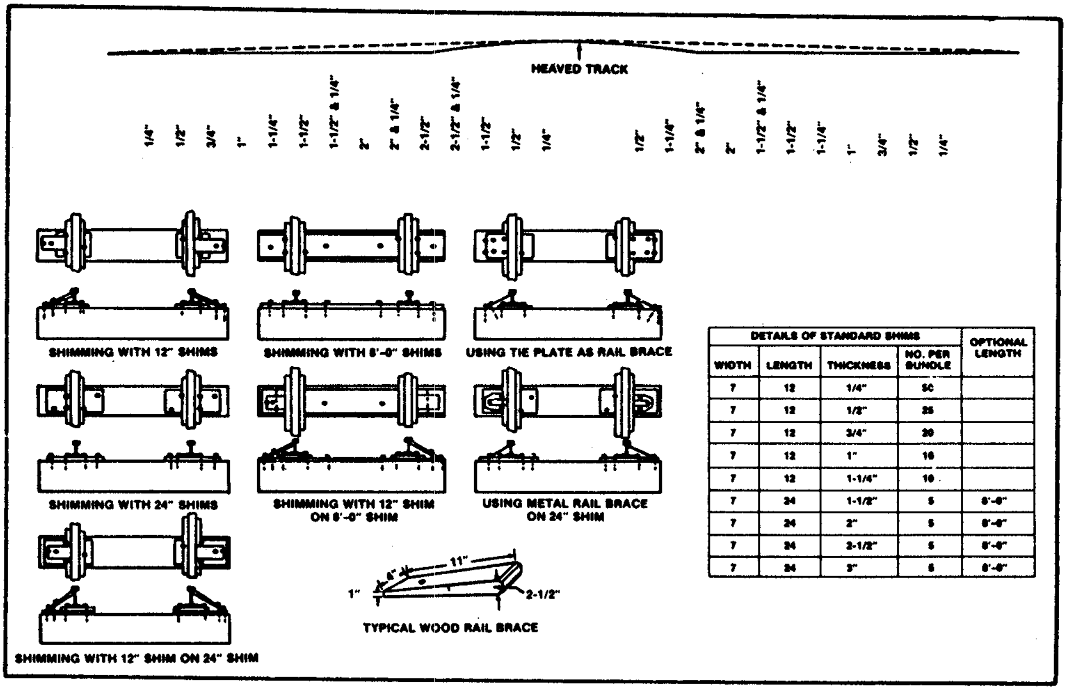
4-6.12. Put in the remaining switch ties, and line and surface main track.

4-6.13. Couple switch point for the turnout lead, set lead rails, and spike turnout lead to proper line for turnout curve.

4-6.14. Complete the work by setting the remaining guardrail (and switch-point guardrail if staggered switch points are installed), setting and adjusting the switch-operating mechanism, checking the line, gagging, spiking, and surfacing.

4-7. Shimming Track.

4-7.1. General. Heaving of track in winter and spring months is generally an indication of poor drainage or poor ballast conditions, which must be corrected as soon as frost leaves the ground. Until the cause can be eliminated, heaving can be corrected temporarily by using shims to raise the rails on either side of the high spot, thus providing an easy grade (Figure 4-8). The length of this temporary raise is



DETAILS OF STANDARD SHIMS				OPTIONAL LENGTH
WIDTH	LENGTH	THICKNESS	NO. PER BUNDLE	
7	12	1/4"	50	
7	12	1/2"	25	
7	12	3/4"	20	
7	12	1"	10	
7	12	1-1/4"	10	
7	24	1-1/2"	5	3'-6"
7	24	2"	5	3'-6"
7	24	2-1/2"	5	3'-6"
7	24	3"	5	3'-6"

Figure 4–8. Application of wood shims and rail braces in shimming track.

called the runoff. *NOTE:* Criteria for maximum runoff are contained in Appendix B.

4–7.2. Methods. When shimming is necessary, it will be done so as to provide easy and safe runoff gradients. When one side of the track is heaved more than the other, proper cross level will be restored when shims are installed; care must be taken on curves to maintain proper curve elevation. Heaved ties will not be adzed or otherwise cut to lower their height; shimming under ties is prohibited except in an emergency, in which case the shims shall be removed, and the condition otherwise taken care of as soon as possible.

4–7.3. Rules for Shimming and Bracing. When installing shims, the track level and gage will be used to insure proper gage and surface.

4–7.3.1. Before a shim is placed on a tie, all spike holes in that tie must be plugged with treated wood tie plugs, the tie shall be free of ice, snow, and other obstructions within the area of the shim, and full bea ring of the shim on the tie shall be provided.

4–7.3.2. Two shims of the same length will not be used together under one rail on a tie. One 12-inch shim may be used on top of a 24-inch or on top of a 3-foot 6-inch shim. One 24-inch shim may be used on top of a 3-foot 6-inch shim. One 24-inch shim may be used on top of a 24-inch shim that has been placed on top of a 3-foot 6-inch shim. Where possible, use only one shim. Where two shims are required, the lower shim must be of maximum thickness. Where three shims are required, the two lower shims shall each be of maximum thickness.

4–7.3.3. When tie plates with special shallow base patterns or with shallow ribs on their bases are in use, they should be installed on top of shims. When tie plates with deep ribs on their bases are in use, they should not be installed on top of shims. Shims shall never be installed on top of tie plates.

4–7.3.4. In all cases where a 12- or 24-inch shim, or a 12-inch on top of a 24-inch shim, is installed, all spikes used shall be long enough to provide a minimum penetration of 4 inches in the tie. In all cases where a 3-foot 6-inch shim is installed, it will be properly and independently spiked to the tie with 7–1/2-inch shimming spikes. In all cases where a 12- or 24-inch shim is installed on top of a 3-foot 6-inch shim, all spikes through the shorter shims shall be long enough to go through the 3-foot 6-inch shim and have a minimum penetration of 1 inch in the tie.

4–7.4. Precautions.

4–7.4.1. Driving shims at an angle between the spikes weakens the track and is prohibited. Shims shall be placed squarely on top of the tie and the spikes driven through the holes provided.

4-7.4.2. Wood or other types of rail braces should not be used where shimming is done on tangent track or on curved track equipped with shoulder tie plates of a type that is to be used on top of shims. Where shimming is done on curved track not yet equipped with tie plates, or equipped with shoulder tie plates of a type that will not be used on top of shims, wood or other approved rail braces shall be installed with the shims.

4-7.5. Reestablishing Normal Surface. As the frost leaves the ground and the heaved places return to their proper level, the shimming may be reduced from time to time in order to maintain proper surface. When the frost has left the ground, all shims shall be removed without delay from the track and any imperfect surface corrected. Removed shims and shimming spikes should be carefully preserved for future use.

Section 2. MAINTENANCE OF TRACK IN STREET CROSSINGS AND IN PAVED AREAS

4-8. General.

Prompt attention must be given to correcting deficiencies as they occur at crossings and around tracks in paved areas. The maintenance of the track bed and trackage will be the same as that outlined in the foregoing chapters and sections, except that inspection will be more difficult and additional maintenance is required for the paving, planking, etc., to insure smooth and safe operation of vehicles in the area. Because track maintenance in paved areas is more costly and time consuming, materials supporting and contained in the track structure must have as low a maintenance potential as possible. For that reason, materials that will resist deterioration and changes in grade and gage are recommended.

4-9. Drainage.

Drainage is critical. It can present more problems at crossings than at other points on a railroad. Catch-basins, gutters, ditches, pipe drains, and/or culverts, as appropriate, must be provided to intercept and divert both surface and subsurface water at depressed or downhill crossings. Base materials underlying tracks and pavement must be of appropriate, well-graded, granular materials; pavement surfaces must be adequately crowned and sloped to direct water into the catch-basins and ditches. Additional information on drainage is included in Section 3 of this chapter.

4-10. Ballast.

Ballast under a properly maintained pavement or crossing normally requires little or no maintenance. However, if the ballast is not installed properly on a good foundation in the beginning, or if the surface over the ballast permits infiltration of water, silt, and other debris, the ballast can become fouled and interfere with the drainage. If the track through the crossing is not well ballasted, or if the ballast is fouled, the ballast and subballast should be removed not less than 2 feet below the bottom of the ties, not less than 2 feet beyond the ends of the ties, and to the first rail joint away from the crossing and replaced in accordance with criteria set forth in Chapter 3, Section 2.

4-11. Ties.

The condition of crossties under crossings or pavement cannot be determined without removing the crossing materials or paving. If untreated ties were originally installed, they may be seriously damaged by insect attack or decay in a short period of time (Figure 4-9). The first indication of tie failure may be settling of the rails or paving or a change in track gage. When tracks are torn up to replace the ties, it not only interferes with train operations, but also with the use of the area or crossing by vehicular traffic. When the trackage has been uncovered for repairs, the whole trackage system in the crossing or paved area should be brought up to proper condition. Drainage and ballast should be investigated and replaced or restored before the new ties are installed. Also, all the ties should be replaced at this time. Normally, 9-foot treated wood ties are used through the limits of a crossing. However, concrete ties should be considered when replacement is needed because they require little or no maintenance and hold the track in gage.

4-12. Rail.

As a general rule, bolted rail joints are not allowed within a crossing. Where crossing widths and rail lengths are such that joints have to be included, they shall be properly welded. The nearest bolted joints should be at a minumum of 6 feet outside of the crossings. Every precaution must be taken to insure adequate and continuing bonding of rail through the crossing. All rail and metal fittings used within a crossing shall be given a coating of an approved rust inhibitor. Rail shall be gaged and lined accurately and double spiked to the ties. The ballast under the track shall be solidly tamped to bring the track to grade. If concrete ties are used, the rails will be firmly bolted to the ties and the track then brought to grade.

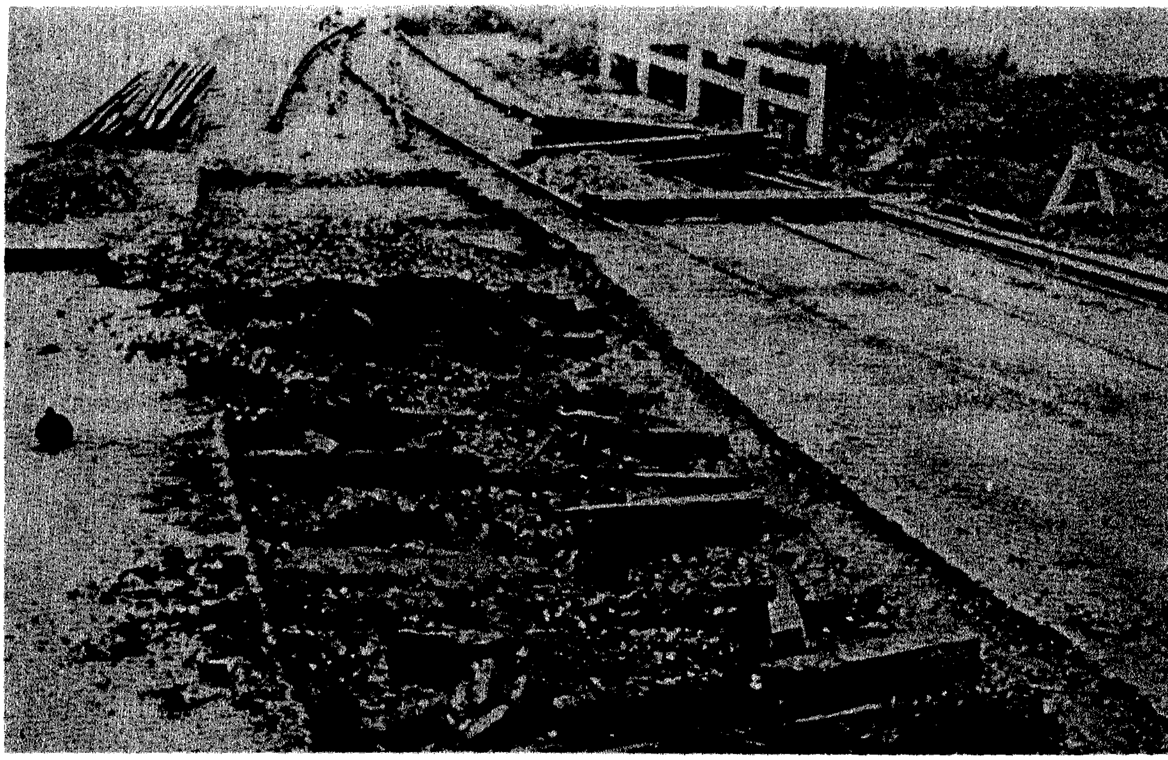


Figure 4–9. Ties decayed under paved area.

4–13. Crossing Surfaces and Materials.

4–13.1. General. Crossing surfaces must be as smooth as possible, and the materials selected for this purpose must be suitable for the type of traffic using the crossing. Although it may be desirable to match the material and texture of approach pavements, consideration must be given to a material and an installation that is economical to maintain and that will have a long service life. Materials such as Portland cement concrete or bituminous concrete are economical to install, but are costly to remove and replace. Wood plank and prefabricated materials may be a little more costly to install, but are removable and reusable and therefore are more economical to use in the long run. Further, because they are easily removed and replaced, they facilitate the inspection of the track. In plank-type crossings, the flangeways are often open down to the ties, which exposes the subgrade and ballast to the water, silt, and debris that flow to this opening. Regardless of the materials used, flangeways must be provided, 2–1/2 inches for tangent and nominally curved track. On curves over 8 degrees, the flangeways must be widened to 2–3/4 inches. Rubber and plastic crossing pads and rubber flangeway fillers are available for some types of crossings and should be installed, especially in areas where small-wheeled vehicles use the crossing.

4–13.2. Street and Highway Crossings. Street or highway crossings should be at least 4 feet wider through the crossings than the width of the approach pavements (Figure 4–10). When the corssing has to be repaired or replaced and the crossing is the same width as the approach pavements, the crossing width should be extended 2 feet on each side. The additional width is necessary to reduce the hazards of vehicles running off the sides of the crossing (Figure 4–10). The most frequently used crossing materials are listed below:

4–13.2.1. Bituminous Concrete. Where traffic is light, the entire crossing may be constructed by bituminous concrete. In very light traffic areas, the flangeways may be formed by running the locomotive wheels through the hot mix after it has been placed and rolled (Figure 4–11). Some finishing may be required to smooth the material that has been shoved out of the flangeway. However, at crossings with a high volume of traffic or heavy truck traffic, a flangeway guard is needed to protect the edges of the asphalt section between the rails. The guard may be constructed of wood (Figure 4–12). Metal flangeway guards may be fabricated from used rail (Figure 4–13) or purchased from commercial sources (Figure 4–14).

4–13.2.2. Portland Cement Concrete. Constructing a crossing with cast-in-place concrete requires closing

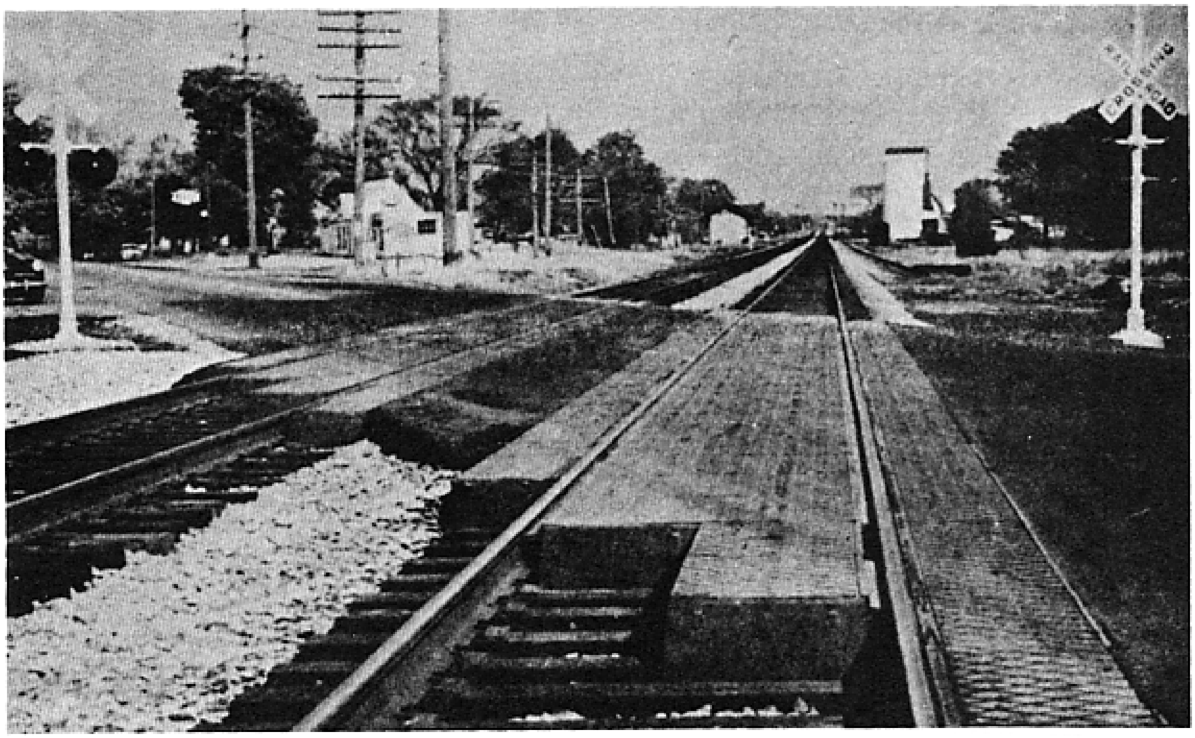


Figure 4–10. Double track crossing.

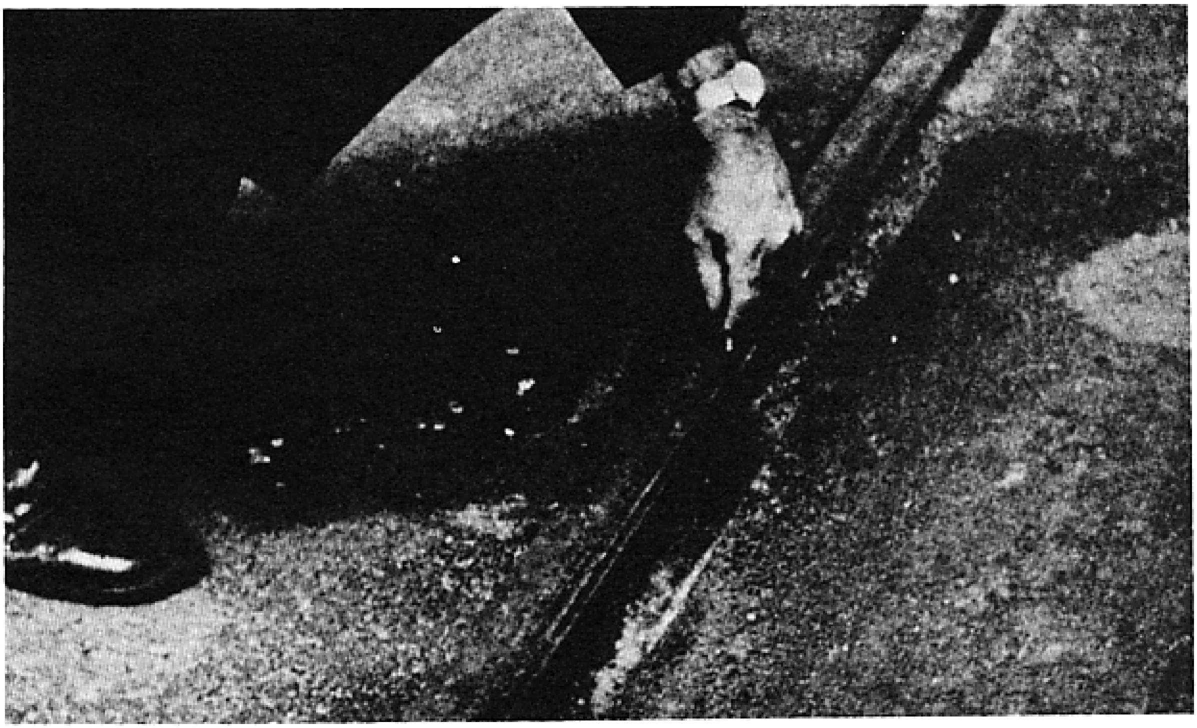
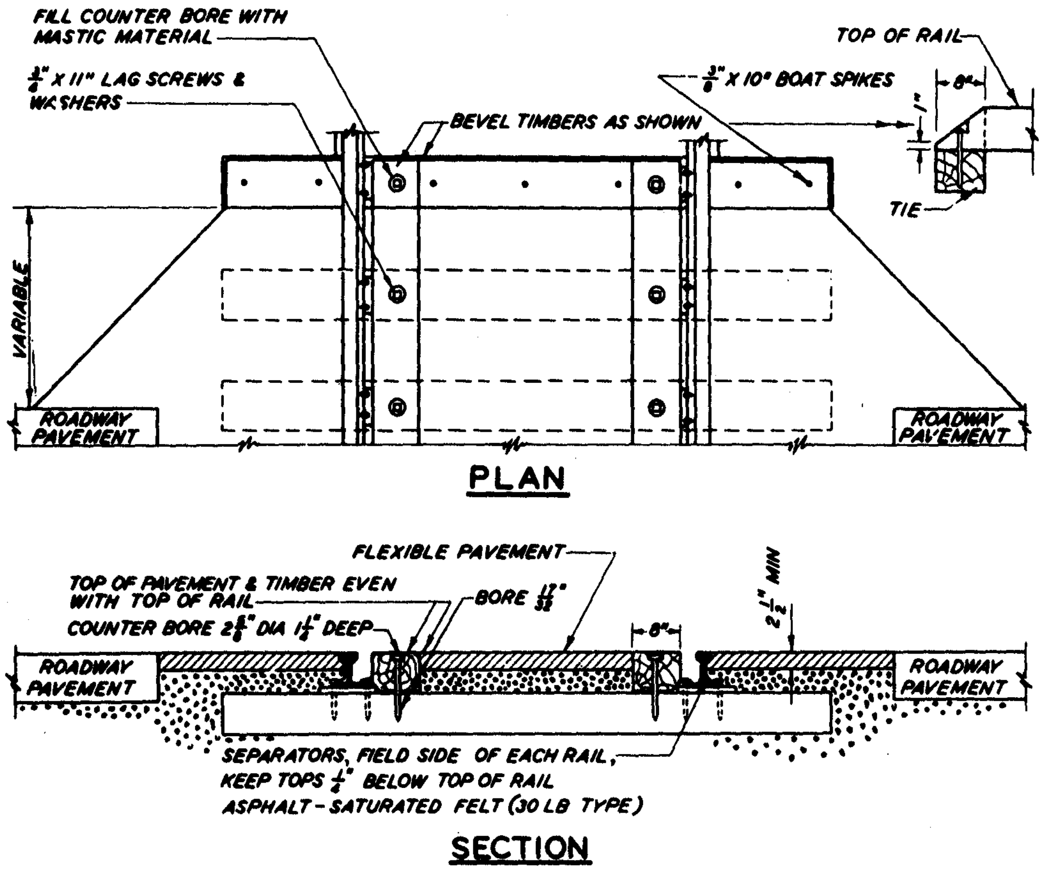


Figure 4–11. Bituminous concrete crossing flangeway made with engine wheels



NOTE: ALL TIES THRU THE CROSSING SHALL BE SAWED FORM A, SIZE 4, AND SPACING SHALL NOT EXCEED 20 INCHES.

Figure 4-12. Bituminous crossing with wood flangeway guard.

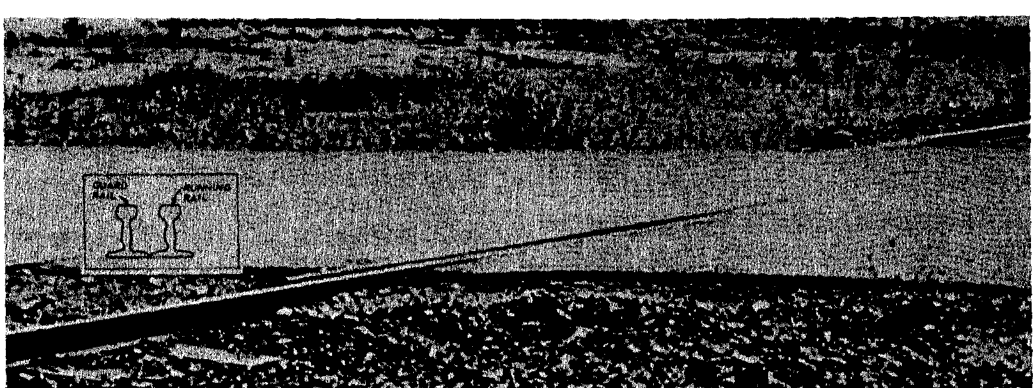


Figure 4-13. Used rail flangeway guard.

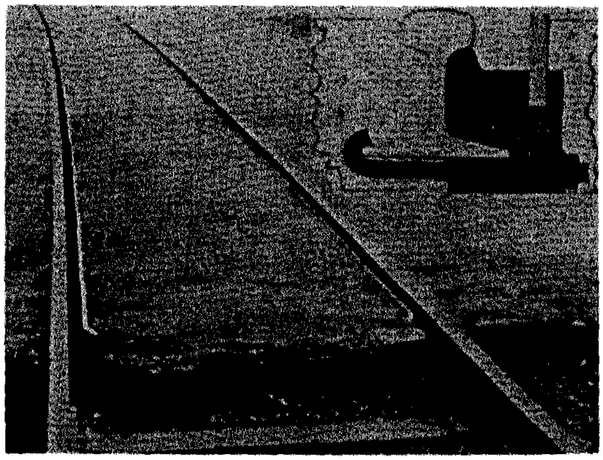


Figure 4-14. Metal flangeway guard.

the crossing or limiting vehicular traffic to one lane during construction and concrete curing. This type of crossing, however, provides a smooth riding and durable surface (Figure 4-15). A poured concrete crossing is costly to remove and replace.

4-13.2.3. Precast Concrete Planks. This type of material provides a long-lasting surface for all volumes of traffic. Several types of Portland cement concrete planks are available on the market for this purpose. Special care must be taken to insure even support throughout the length of each plank. Figure 4-16 gives plan and section views for a typical installation; Figure 4-17 shows a typical installation. Some types of precast concrete crossings are available with rubber fillers for the flangeway (Figure 4-18).

4-13.2.4. Wood Plank Crossings. This type of crossing has been successfully used for many years. Treated timber will last for a long time, but may require retightening of lag screws from time to time as they will become loose as the timbers flex under traffic. A well-maintained wood plank crossing is shown in Figure 4-19.

4-13.2.5. Prefabricated Rubber Planks. Prefabricated rubber planks provide a smooth riding, durable, and maintenace-free crossing. A typical installation is shown in Figure 4-20. This type of crossing, as well as other prefabricated types, is salvageable and can be reused..

4-13.2.6. Modular Plastic Crossings. Modular plastic crossings are durable, smooth riding, and practically maintenance free. The sections are molded and if a section is damaged, it can be replaced without disturbing any other sections (Figure 4-21).
Used rail crossings are slippery when wet and do not afford a smooth ride to small-wheeled vehicles.

4-13.2.7. Used Rail. Crossings have, on occasion, been fabricated from rail that has been worn beyond further use in the track system (Figure 4-22). These rails, which should be the same weight as the running rails, are laid side by side, head up, between and parallel to the running rails with adequate flangeway. Used rail crossings are slippery when wet and do not afford a smooth ride to small-wheeled vehicles.

4-13.2.8. Two-Component Epoxy and Rubber. A poured in place two-component epoxy combined with rubber is available which seals the ballast from intrusion of water. This type crossing is expensive.

4-14. Track in Paved Areas.

The type of vehicular traffic, in particular the size of wheel and type of tire, determines the type of material and construction used adjacent to and between rails in paved industrial areas. Normally, cast-in-place Portland cement concrete or asphaltic concrete pavements are used with flangeway guards appropriate for the vehicular traffic (Figure 4-23). Where small-wheeled, solid-tired vehicles are used, a rubber flangeway filler is recommended. Flangeways may also be formed by the use of girder rail (A in Figure 4-23) through the crossing or pavement, or by placing used rail on its side with the head against the web of the running rails (B in Figure 4-23).

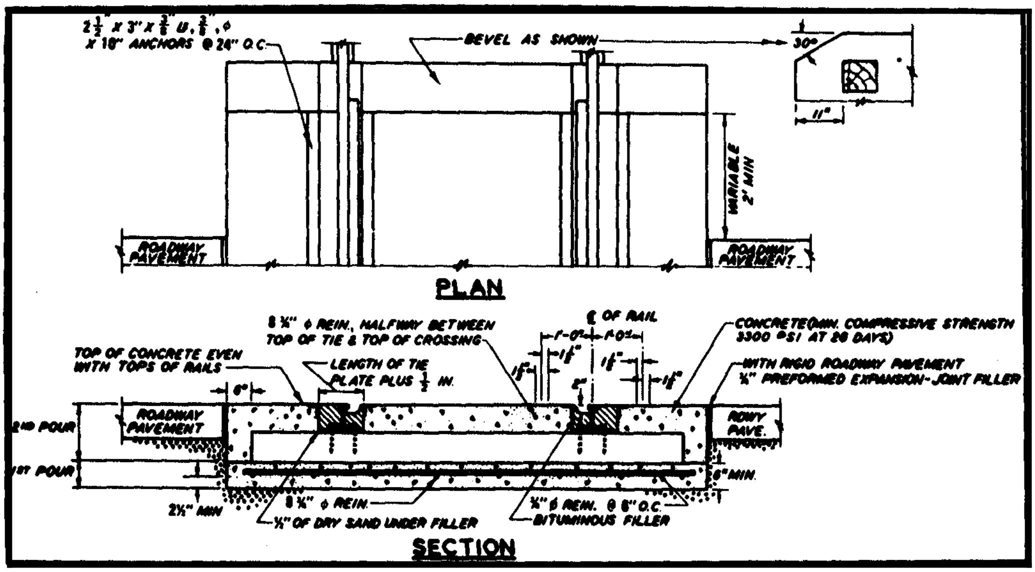


Figure 4-15. Cast-in-place concrete crossing.

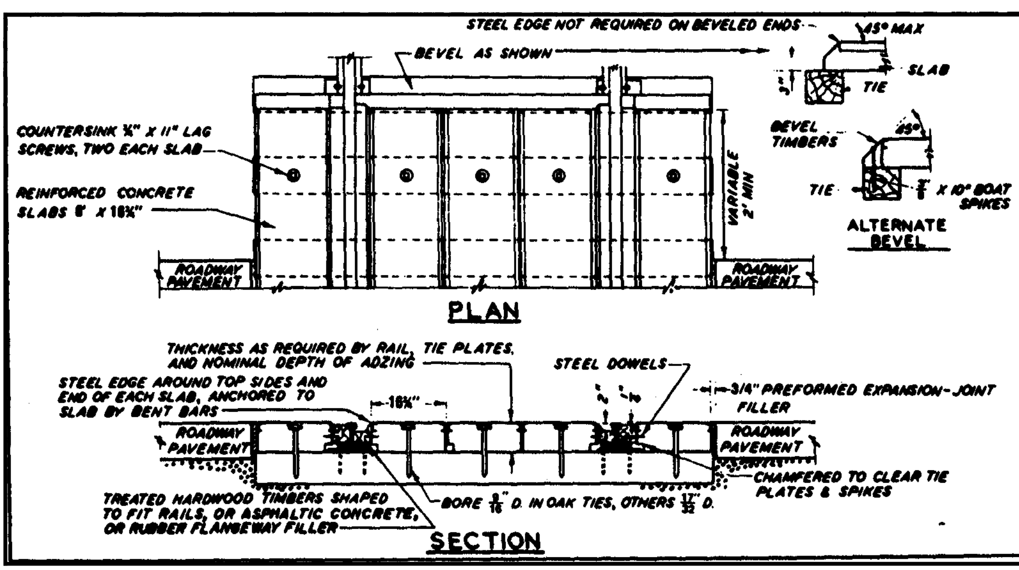


Figure 4-16. Precast concrete slab crossing.

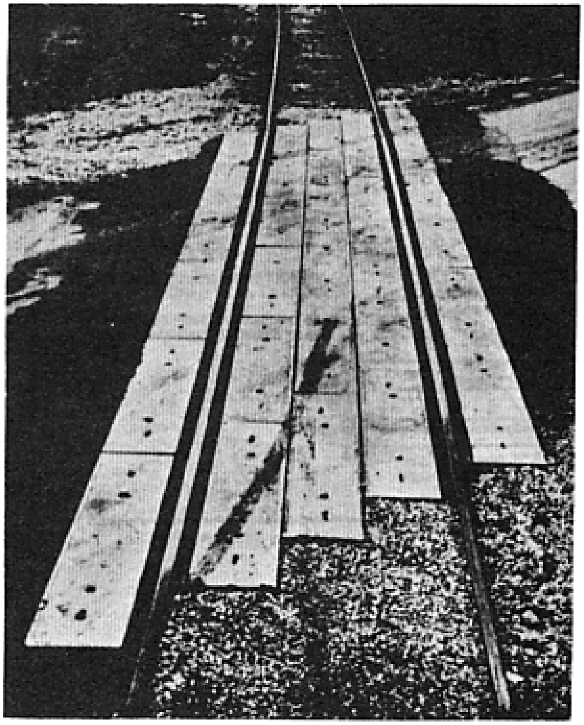


Figure 4–17. Precast concrete plank crossing.

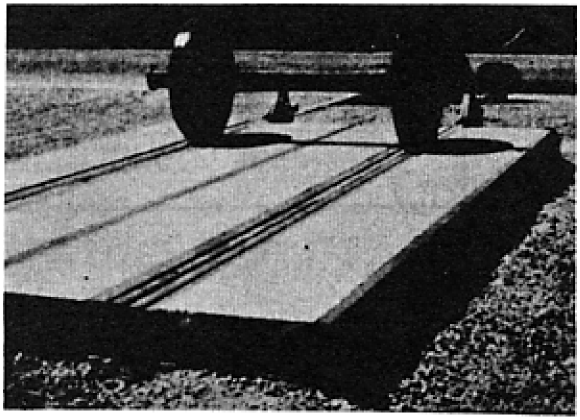


Figure 4–18. Precast concrete plank with rubber flangeway filler.

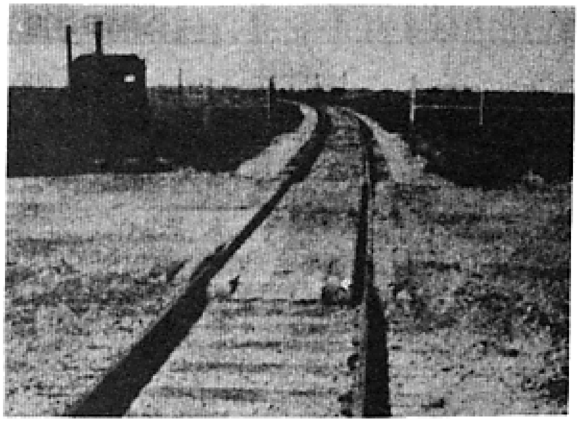


Figure 4–19. Timber crossing.

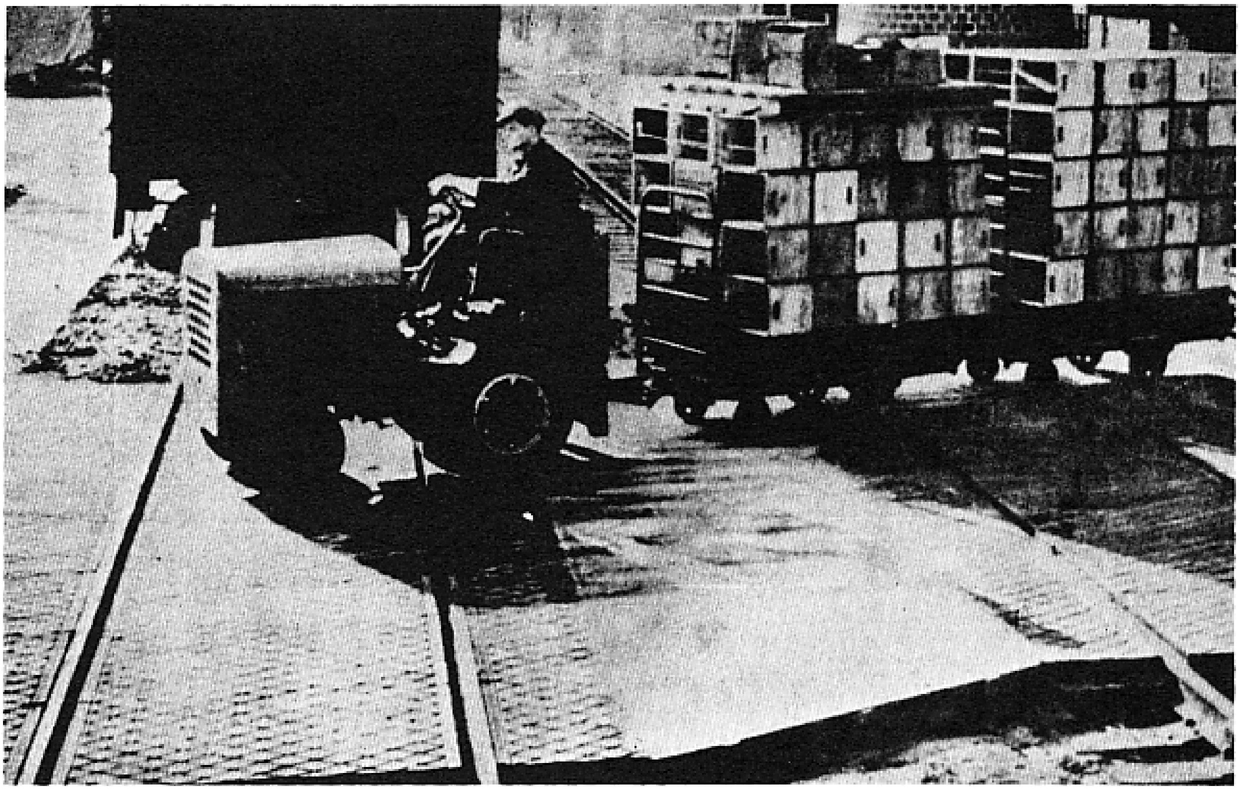


Figure 4-20. Rubber plank crossing.

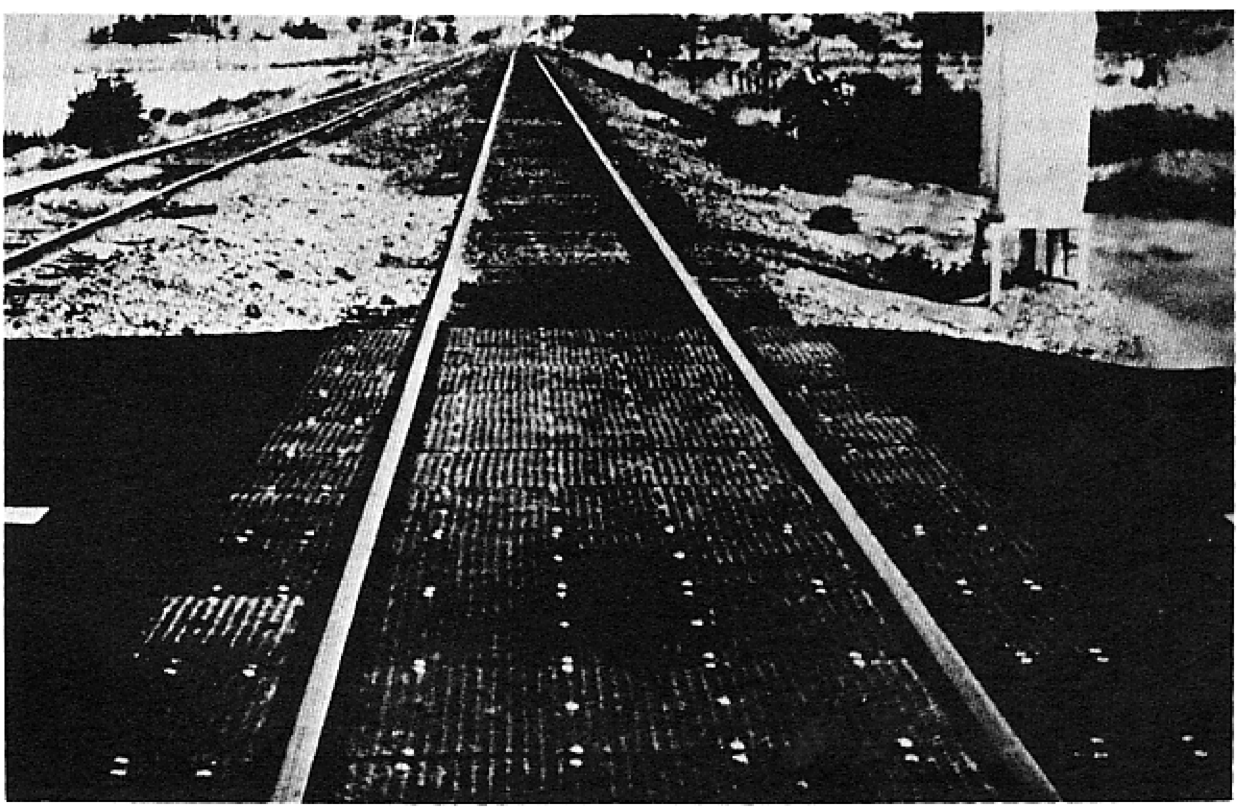


Figure 4-21. Modular plastic crossing.

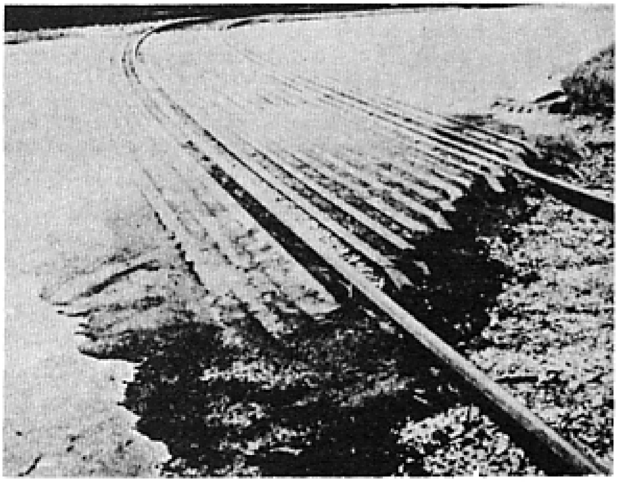


Figure 4–22. Used rail with asphalt filler.

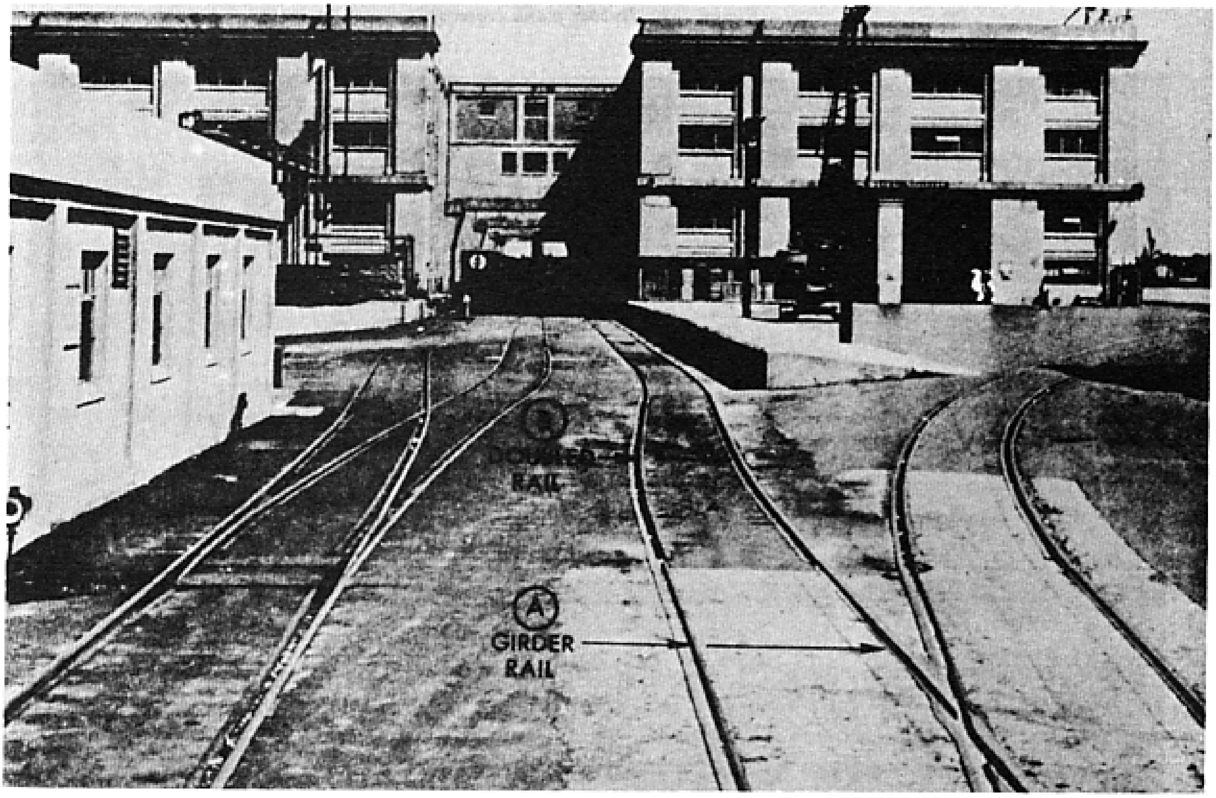


Figure 4–23. Trackage in paved area.

4-15. Signs and Signals.

Crossing sign and signal maintenance must be given a high priority to assure legibility and visibility.

4-15.1. Highway Crossing Signs and Signals. Standard highway-railway grade crossing signs are shown in Figure 4-24, a crossing signal in Figure 4-25, and location of signs and signals in Figure 4-26. For details of appropriate types of crossings and signals, see DOT Manual on Uniform Traffic Control Devices, Bulletin No. 6 of the Association of American Railroads (Railroad-Highway Grade Crossing Protection), and Chapter 9 of AREA Manual.

4.15.2. Maintenance of Signal Circuits. Electric and/or electromechanical signal inspection and maintenance should conform to AREA requirements and to manufacturer's recommendations. Circuit continuity checks, battery water level observations, trickle charger operating tests, relay point checks, light bulb tests, and related checks and inspections must be made periodically as specified or required by the installation's maintenance program or the serving railroad. Indicated defects must be corrected promptly.

4-15.3. Signal Cables. Signal cables are buried around main track switches and signal locations. Cables are buried at toe of ballast between instrument housing, switches and signals in the track circuit system territory, at interlocking plants, and at switches equipped with electric locks, as well as automatic block signal location. Maintenance employees working on roadbed at these locations should be informed by signal forces as to exact locations of these cables. Machine operators must exercise care to avoid damage to underground cables at these locations. In case of doubt as to location of cables, do not work digging machines within interlocking home signal limits.

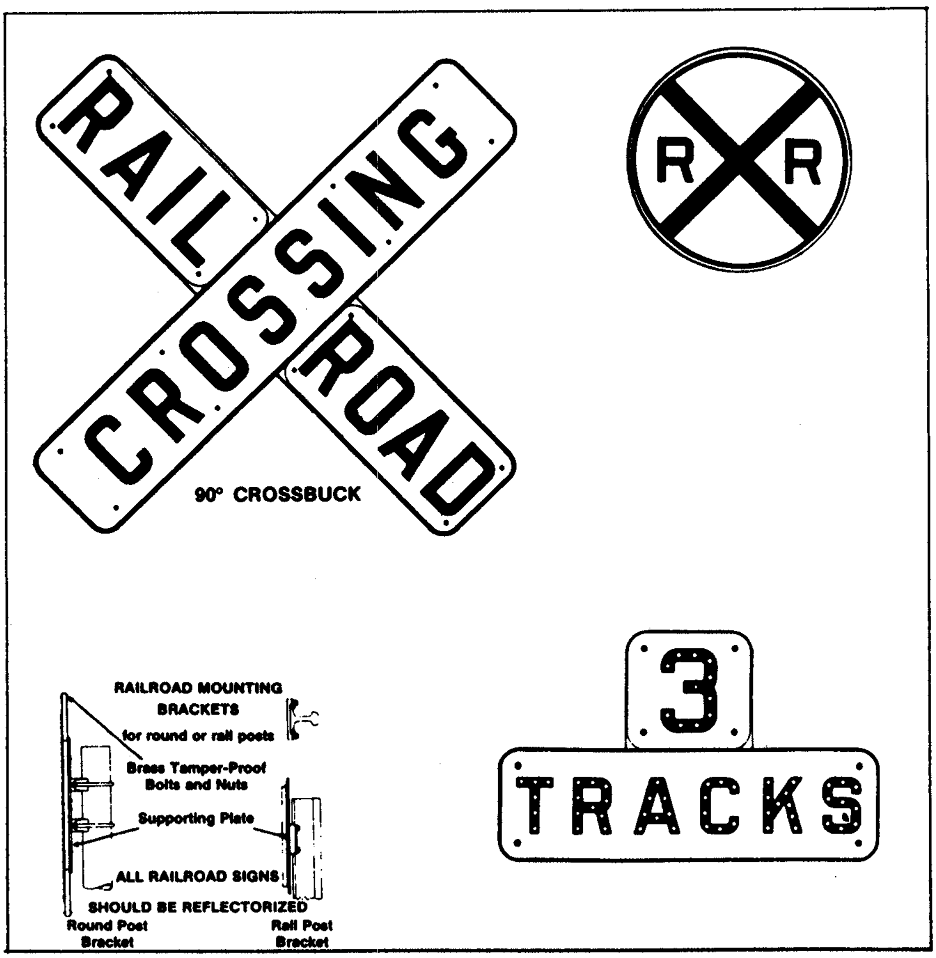


Figure 4-24. Typical grade crossing signs.

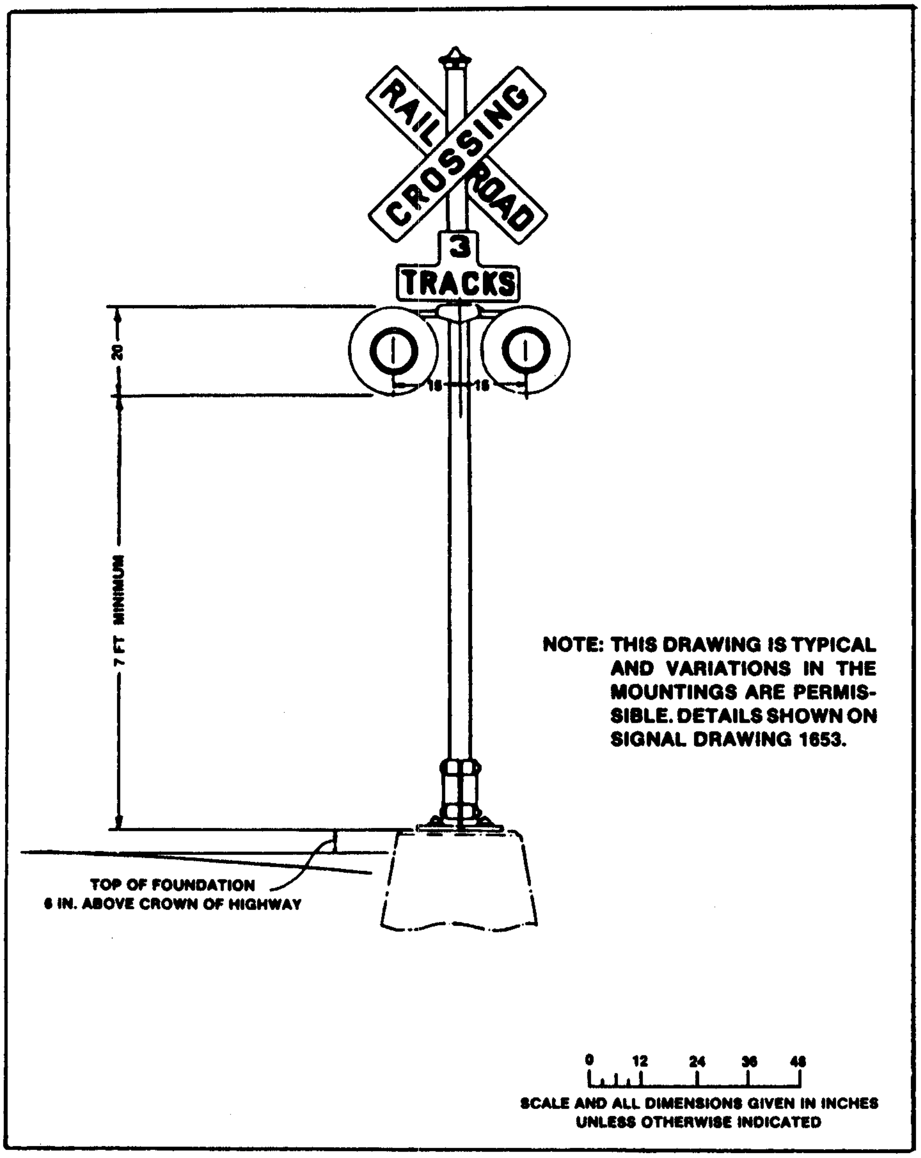


Figure 4-25. Highway crossing signal, flashing-light type with red signal sign.

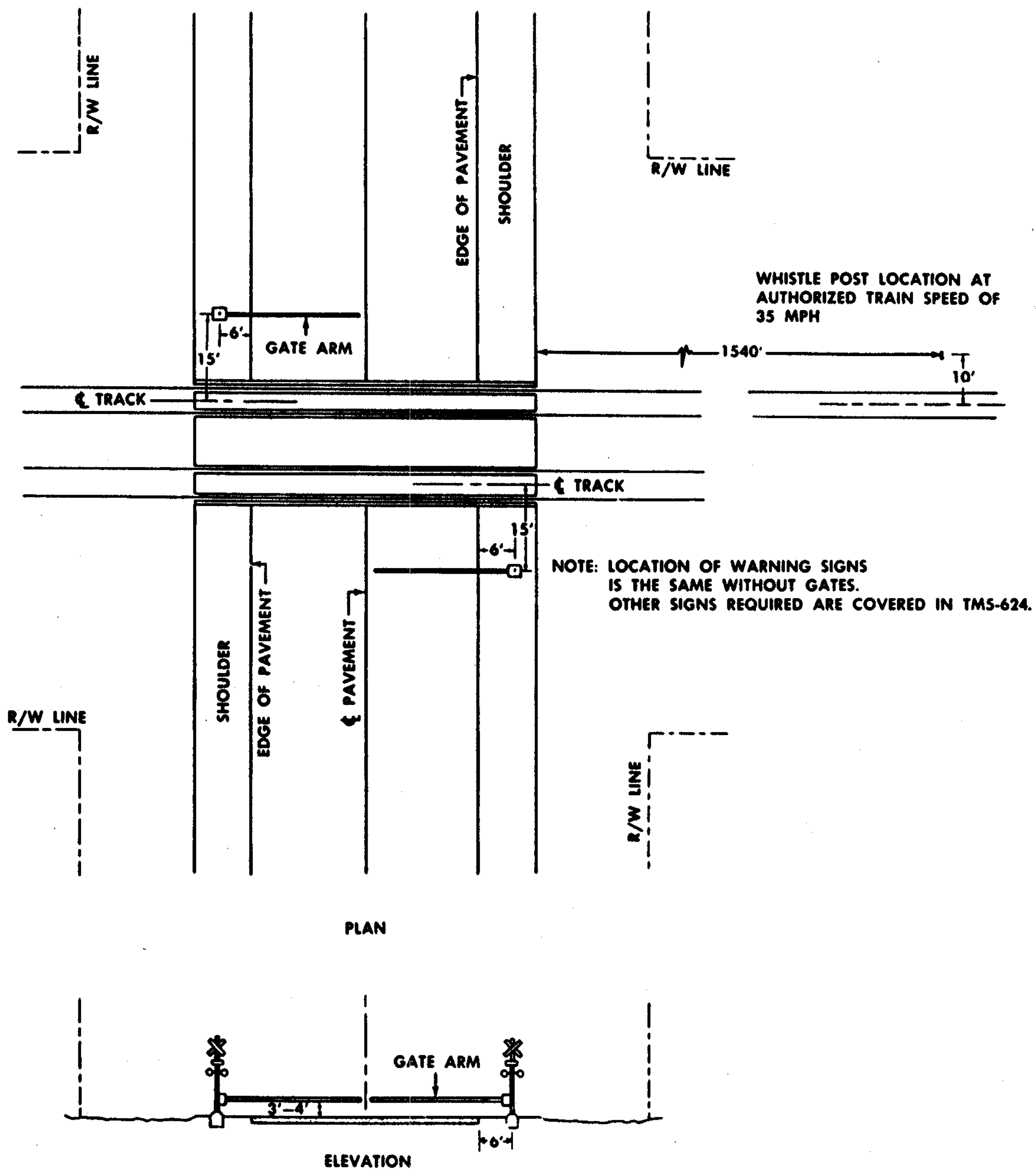


Figure 4-26. Location of warning signs and signals.

Section 3. MAINTENANCE OF ROADBED

4-16. General.

Good drainage is the most important single factor in roadbed maintenance. To provide maximum support for the track structure, subgrades should be kept as dry and stable as possible. Poor drainage not only affects the roadbed and the underlying earth structure (Figure 4-27) but also the side cuts and other track side areas. Where drainage deficiencies occur that cannot be corrected by normal maintenance practices, engineering assistance will be requested. Open ditches and pipe drains shall be maintained to function at maximum capacity. Weed control and efficient methods of ice control and snow removal are important factors in conjunction with water runoff. Inadequacies in the original drainage system shall be corrected as they become evident.

4-17. Inspection and Repair.

Alert, methodical, and timely inspection, with prompt correction of large and small defects, is necessary for the economical maintenance of drainage systems. The object is to preserve the original track and roadbed section by preventing obstructions that tend to divert or impede the flow in the drainage system. Emergency repairs to drainage systems must be made when conditions require such action, but a general program of repairing and cleaning should be conducted annually, preferably in the spring or after periods of unusual storms or rainy weather.

4-18. Subsurface Drainage.

Water falling on ballast soon soaks through to the subgrade. Impervious subgrade not properly graded so that the water will drain off to the side ditches will cause pools to form, which soften the subgrade, resulting in low spots in the summer and possible heaving in the winter. Poorly drained subgrades are reflected in poor track surface. Resurfacing or raising track instead of providing proper subdrainage is only a temporary measure. Slopes for drainage may vary from 1 inch in 2 feet to 1 inch in 5 feet. The only remedy to eliminate wet spots is to reshape the subgrade so that water will flow toward the ditches. Also, stabilization can be obtained by cement-subsurface grouting (Figure 4-28). If the trouble is localized in a very small area, subdrains may be used to drain off the excess water.

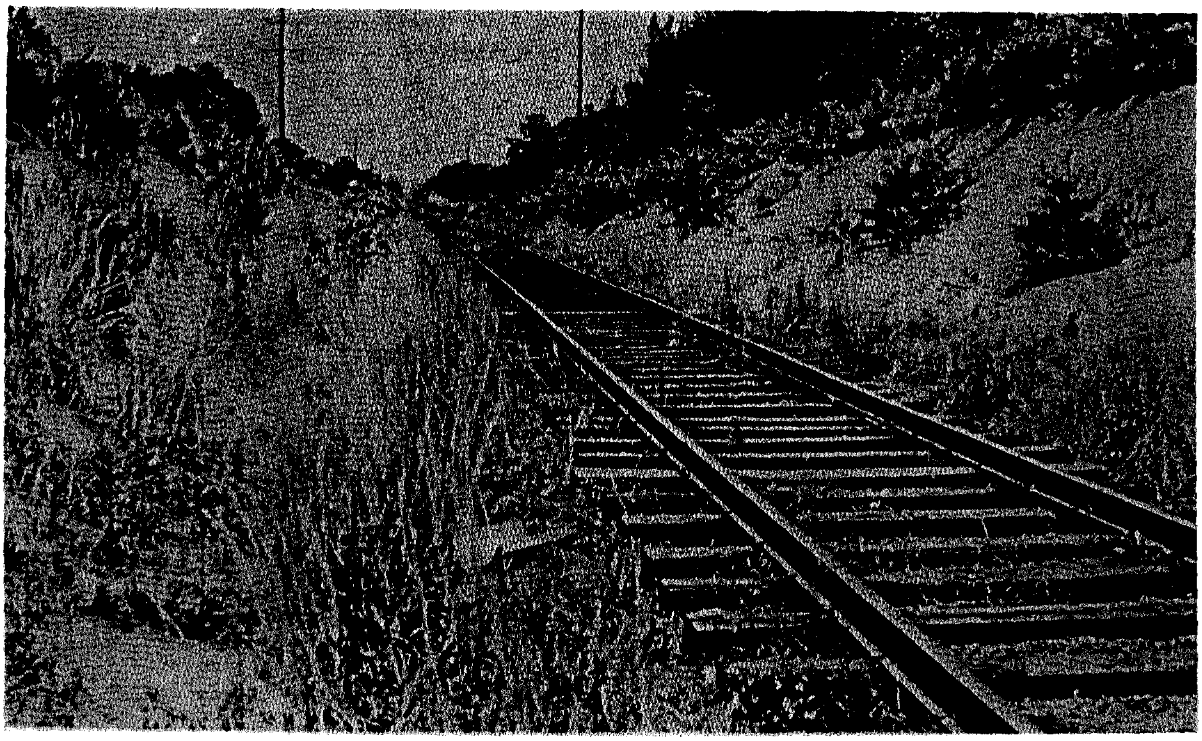


Figure 4-27. Ditches fouled by silt and vegetation.

Figure 4-28. Cement grouting soft roadbed.

4-19. Surface Drainage.

All surfaces must be sloped toward the drainage systems, and slopes maintained to minimize erosion during runoff. Drainage ditches and structures shall be kept in condition to dispose of runoff quickly. Obstructions that cause water to remain in pools shall be removed. Erosion of ditch sides and bottoms can be controlled by lining them with native grasses or by check dams, riprap, or pavement.

4-19.1. Ditch Maintenance. Where ditch maintenance is a constant problem because of faulty design or construction, permanent corrective measures may be required. For example, if the gradient is unsuitable, the ditch may scour (too steep) or may accumulate silt (too flat). Unchecked growth of vegetation (Figure 4-27) obstructs water flow and raises the water level in the ditch. This water can penetrate and soften the roadbed or restrict the drainage of the roadbed. Some soil wears away readily, and the slopes are eroded by rainfall and undermined by the flow of water in the ditch unless the gradient is correct and the streambed clear. Erosion of the ditch side slopes increases the silting in the ditch (Figure 4-29). Therefore, the side slopes must be stabilized or flattened to reduce erosion. Maintenance and repair measures must be determined to fit existing conditions.

4-19.2. Causes of Drainage Failure. Causes of failure have been mentioned generally in the preceding paragraphs. The following describe these causes in more detail.

4-19.2.1. Erosion. Erosion occurs when the velocity of the water or wind on the slope of an embankment or ditch causes the water to dislodge the soil from these areas and carry it away. The degree to which the velocity affects the ditch and side slopes depends upon the stability of the soil or the protection it has been given by additional stabilization. Loose, sandy, or silty soils are easily eroded at almost any velocity. Such soils must be stabilized by vegetative cover or often by riprap or concrete blankets. Riprap or concrete blankets have to extend sufficiently below the ditch bottom to prevent undermining. The most satisfctory solution to erosion control is to flatten the slope to reduce the velocity of the water to the rate that will keep erosion to a minimum and yet prevent unacceptable silting. This may require reconstruction, such as installing check dams or flattening the slope, that is beyond the scope of maintenance.

4-19.2.2. Lack of Drainage. When drainage is inadequate, unwanted water remains in the roadbed long enough to soften the subgrade. Dirty ballast can reduce the drainage of water as effectively as a stopped drain. Improperly shaped subgrade or pock-

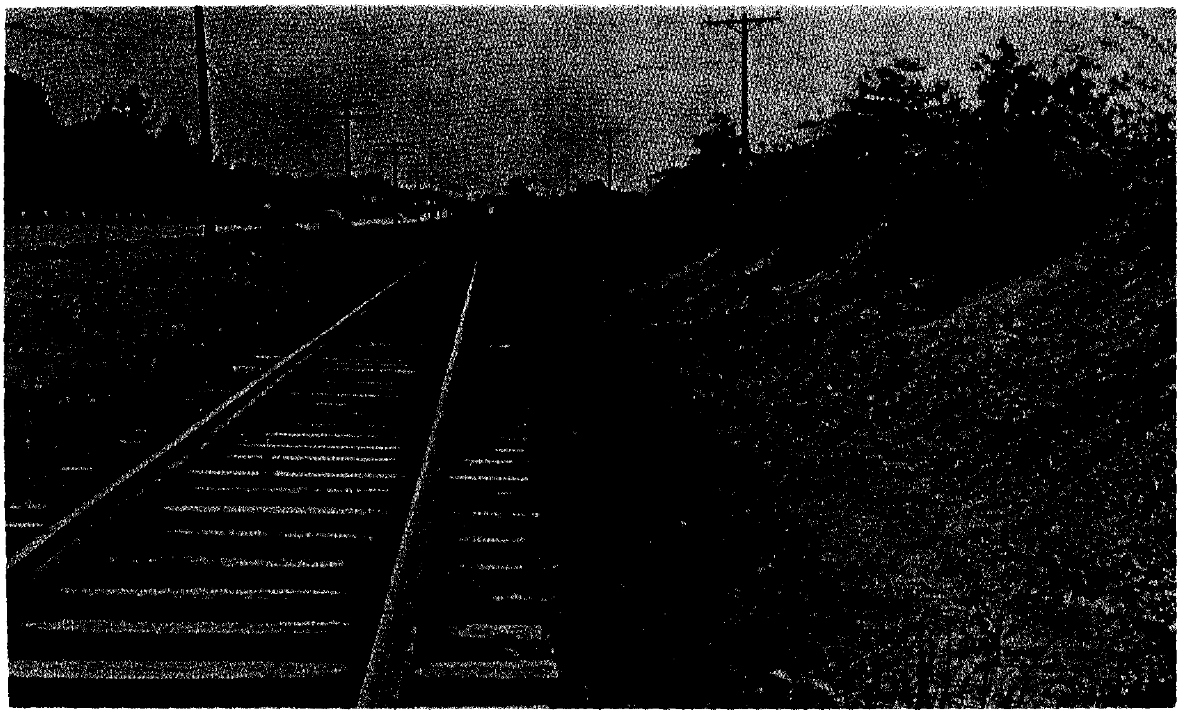


Figure 4-29. Erosion of side slopes.

ets that have developed in the subgrade can impound water to the detriment of the track system. Subdrains may become clogged, or the buildup of silt in the adjacent ditches will reduce the flow of water from beneath the track structure. Besides weakening the subgrade, trapped water during the winter can cause heaving. If this water freezes, it further retards the drainage which increases the problem (Figure 4-30).

4-19.3. Corrective Measures. Where it can be used effectively, offtrack power equipment gives more economical results for the cleaning of intercepting and drainage ditches than other methods. Handwork may be necessary where equipment is not available or where conditions prevent access of mechanical equipment. Ditching of ordinary material in side ditches in cuts may be subdivided into two principal classes, shallow cuts and deep cuts.

4-19.3.1. Shallow Cuts. Ditching in shallow cuts can be done with road graders that are equipped with blades for shaping ditches and slopes, by draglines, or under some conditions, by tractor-drawn scrapers. Such ditching shall not be done by hand where the magnitude of the work justifies the use of heavy equipment.

4-19.3.2. Deep Cuts. Where the volume of material to be removed is comparatively small, the work usually can be performed with graders. Handwork will not be resorted to unless a careful analysis shows the use of power equipment is not possible.

4-19.3.3. Use of Road Machinery. Where the volume of material to be removed is large, the cuts are long, or the points of disposal are remote, the use of power ditchers or other heavy excavating machinery is justified whenever it is available. For example, if the terrain is such that draglines can work along the top of the cut, comparatively deep cuts can be cleaned quickly, at less expense than by other methods, and with no interruption of railroad transportation. Power scrapers or trucks and power shovels may be the most practical machinery to use.

4-19.3.4. Use of Car-Mounted Machinery. Where the depth of the cut, the desire to use the excavated material, or other conditions justify, power-operated ditchers or draglines mounted on cars are effective. A work train is necessary, and the usual arrangement is to place the ditcher or dragline between two air-dump cars. Before using work trains and on-track equipment, a very careful analysis shall be made of the situation to see whether the cleaning can be done satisfactorily by methods not affecting train movements. Where the personnel and equipment capability of the organization are not adequate to perform extensive maintenance, repair, or rehabilitation of railroad trackage, consideration shall be given to the use of contractual services.

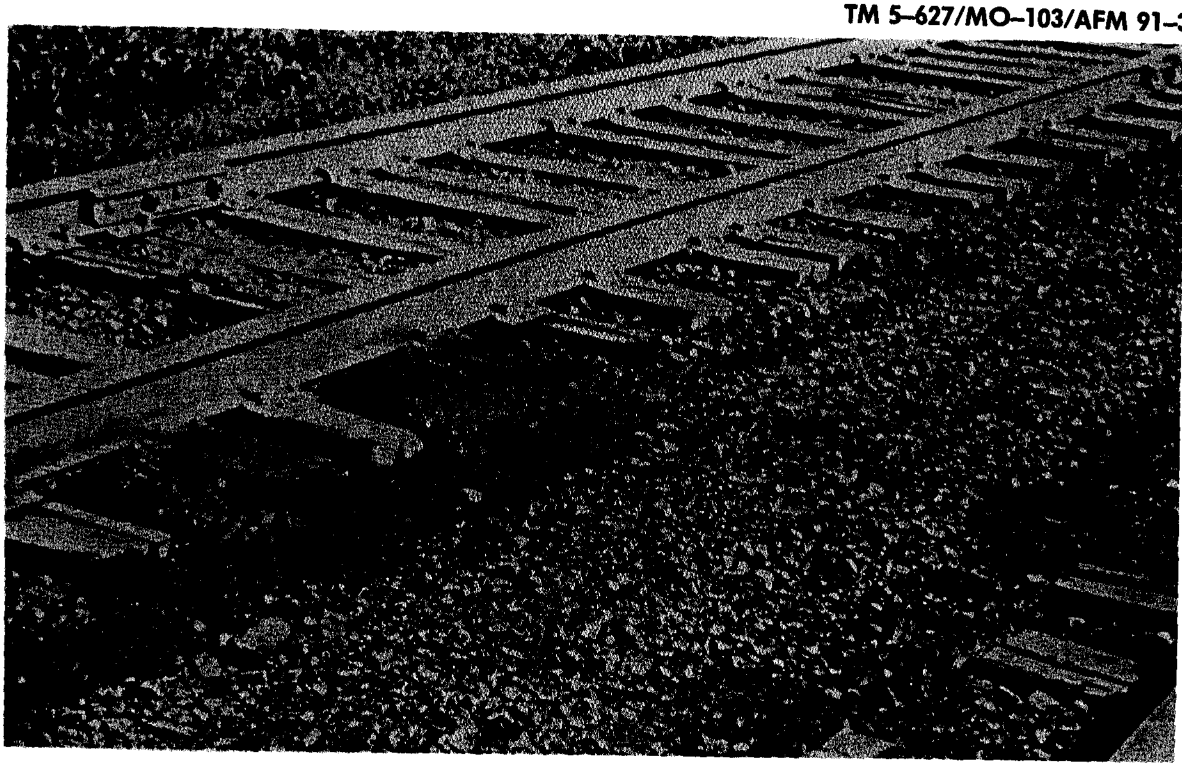


Figure 4-30. Inadequately drained roadbed.

4-19.3.5. Disposing of Surplus Earth Material. In all cases, waste material should be disposed of so it will not wash back into the cut. Material removed from side ditches shall never be cast on the adjacent slope. When waste dirt is disposed of along embankments, it should be deposited at an elevation below the bottom of the ballast.

4-20. Storm Pipe Drains.

A regular program of maintenance of pipe drains should be conducted. As-built record plans must be kept current regarding changes in the system. Limits of covered drain shall be marked with adequate signs to facilitate inspection and maintenance.

4-20.1. Routine Maintenance.

4-20.1.1. Outlet Ditches. Ditches leading from outlet pipes shall be kep clean, with adequate width, depth, and grade to insure proper drainage. Side banks should be maintained with sufficient slope that the material involved will not slide. Ditches should be maintained free of vegetation, debris, and other obstructions. Irregularities in alignment and grade tend to cause silting and scouring and should be avoided.

4-20.1.2. Outlet Pipes. Screens on outlet pipes shall be kept in place to prevent small animals from entering pipes. When silting occurs at the outlet, screens shall be removed and the opening cleaned. Special care should be given outlets to make certain that stoppage does not occur.

4-20.1.2.1. Overflow. Occasionally, drainage pipes discharging near bridges and culverts are subject to overflow or backwater during high water. Inspection should be made as soon as water recedes, and if necessary the pipe drainage system flushed.

4-20.1.2.2. Inspection. Frequent inspection of the mains shall be made through the risers. Any tendency to silt must be carefully watched, and, when it occurs to a marked degree, the entire system of mains should be flushed with water from a water car or other convenient supply. This is especially necessary for systems involving near level grades.

4-20.1.2.3. Vegetation. Trees, bushes, or vegetation with deep roots shall not be allowed to grow near any line of subsurface drainpipe. The roots, seeking water, may fill the pipes and cause stoppage in the system.

4-20.2. Correcting Failures. Rapid silting of main drains indicates an obstruction, a level spot, or reverse grade, which must be located and corrected. In excavating for obstructions, care shall be exercised to prevent fouling the drains. The excavation should be backfilled with permeable material similar to that specified in the original design. Any tendency toward further development of water pockets or soft spots and heaving must be studied, and test holes dug to detemine the direct cause of failure. If failure caused by a defect in the pipe drains occurs, immediate repairs shall be made. If heaving is caused by obstinate water pockets or soft spots that are not tapped with laterals, laterals should be installed.

4-21. Soft Spots and Water Pockets.

4-21.1. General. Soft spots and water pockets exist in localities where soil conditions are unfavorable to satisfactory maintenance, particularly in clay. They will be found in both fills and cuts, but more generally in clay cuts. In soft spots the ballast generally has settled into the roadbed, forming a trough or pockets under the track. This condition usually causes the subballast and roadbed to be pushed out laterally and oftentimes raised (see Figures 4-31 and 4-32), thus forming walls that prevent the water draining from the track. This condition invariably results in water pockets. The usual methods of surfacing and tamping track have no permanent effect in correcting soft spots and water pockets. Soft spots and water pockets shall be given prompt attention because they soon develop into a serious defect. The longer they exist, the more hazardous they become, and the greater the resulting maintenance expense or time and cost involved in providing a permanent remedy.

4-21.2. Corrective Measures. In minor areas of soft spots or water pockets, the maintenance crew may take corrective action by increasing drain fields. However, in addition to pipe drains, various new methods of stabilizing soft spots and water pockets have been developed, such as roadbed grouting, the driving of poles or ties, and the use of sandpiles. In severe cases the situation should be studied by the engineers to see which method will probably give the most economical and satisfactory results.

4-21.2.1. Pipe Drain Method. Test holes shall be made at intervals frequent enough to determine accurately the profile of the bottom of the water pockets. Lateral drains shall be spaced so as to tap all the pockets; 16 feet center to center will usually suffice. The main and laterals shall be placed in stable material, with the minimum depth of the main 24 inches, and of the lateral 12 inches below the bottom of the deepest pocket, unless the surface of solid rock or hard shale lies at a lesser depth; in this case, the minimum depth of the main can be reduced to 12 inches below the bottom of the deepest pocket. Quite often the "softest" cuts are of a clay material overlying rock or shale. Usually this harder underlying stratum is not on a uniform plane, but is irregular, and if it is uniform it will not conform with the grade of the main. To prevent dislocation of the drainpipe, it is well to place the pipe into the rock or shale to a depth at least equal to the diameter of the pipe.

4-21.2.2. Grouting.

4-21.2.2.1. Principle. As has been described previously, water pockets are caused by ballast being driven into the subgrade due to traffic passing over the rails. After the ballast has been driven into the subgrade (impervious soils), heaving occurs along the shoulder of the roadbed. This heaving material is an earth slurry created by the action of traffic vibrating the ballast against the grade, thus mixing earth and water and forcing it out at the toe of the ballast section. As a rule, free water is indicated below the area under vibration. The grouting method for curing this condition consists of pumping a concrete slurry into the void in the subgrade. The grout is pumped into place until the void is filled and its pressure has raised the roadbed back to the desired elevation. It is possible to determine that the void (water pocket) is

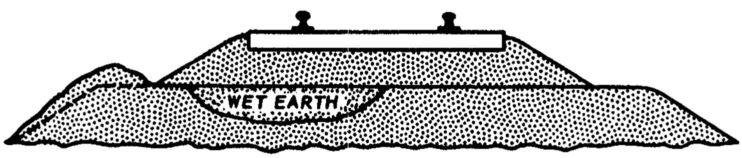


Figure 4-31. Effect of water pocket under one end of ties.

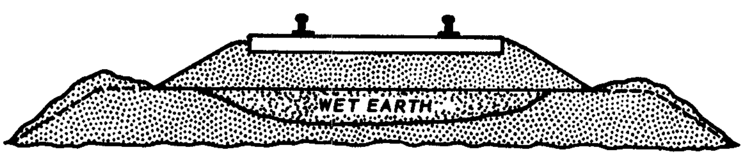


Figure 4-32. Effect of a water pocket under the middle of ties.

filled by observing leakage of the grout up through the surface or along the fill section. The grout consists of a very find sand and enough cement to provide a partial set of the slurry (a rigid concrete base is not desirable). Immediately following the grouting, the track should be checked for elevation and lined out-of-face.

4-21.2.2.2. Machinery and Equipment. If grouting is necessary and grouting equipment is not available at the installation, the equipment used in pavement mudjacking and undersealing is suitable for railroad grouting.

4-21.2.2.3. Other Material. Under certain conditions, bituminous materials may also be used for subsurface sealing. The methods for placing are similar to those for cement grout slurry. *

4-22. Slides.

4.22.1. General. Slides usually occur in unconsolidated material, but may occur in open faces of rock formations. Gravity is a primary cause, supplemented by lubricating water; undermining (natural or artificial); clay-type material; certain types of geological structure; increase of load; and, in the case of rock slides specifically, by joint planes; fault planes; schistose structure; or strata dipping toward an open face. In the latter cases, slides are often accentuated by clay seams in partings of the rock. Where embankments are subjected to hydrostaic head for a length of time sufficient to saturate the embankment, slides may occur suddenly and without warning, particularly if the material is distrubed, as by spreading operations.

4-22.2. Corrective Measures. Each slide shall be considered an individual problem. The cause of the slide should be determined by thorough and expert examination, under the direction of an engineer, of the soils, drainage conditions, and geological conditions related to the slide. The prevalence of unstable material will be ascertained in order to arive at a decision as to economic preference between the removal of sliding material and the application of suitable control methods. The removal or prevention of the cause of a slide is as important as the restoration of the roadway.

4-22.2.1. Piles or Retaining Walls. Piles or retaining walls for the prevention or correction of slides may be used based on engineering evaluation.

4-22.2.2. Diversion of Surface Water. Surface water must be intercepted and diverted by surface ditches.

4-22.2.3. Drains. Underground water must be drained away, or intercepted at its underground source, and diverted. Slides caused by the flow of underlying material often may be controlled by constructing subsurface drains containing perforated pipe and draining around the toe of the slide. When this unstable underlying material is deep, tunneling to intercept the flow may be necessary. When feasible, water cutoff is usually more economical and effective than trenching or tunneling. Subsurface drains with perforated pipe are sometimes necessary to remove underground water from the slide itself when it is impractical to remove all the sliding material in hillside or cut slides. This control method is usually coupled with removal of sliding material, slope modification, and water cutoff, or intercepting drainage.

4-22.2.4. Terracing. Terracing or benching the slope lightens the load and may lessen or prevent sliding. This may be done in addition to using other methods of control. The removal of the entire moving mass in hillside or cut slides may be more economical than control methods.

4-22.2.5. Compacted Berms. Firmly compacted berms, approximately one-third the height of the fill, will help stabilize the fill and may be used in connection with drainage control methods. Weighting of the toe of a slide is useless if movement exists throughout the mass. When used, the weight must rest upon or be carried down to solid material.

4-23. Frost Heave.

4-23.1. General. When water collects unevenly under the track and expands because of freezing, the track is lifted above the wet spots and produces what is known as "heaved track" (Figures 4-31 and 4-32). The extent of heaving caused by frost action depends on the character and condition of material in the ballast and subgrade, the amount of moisture retained, and the extent and duration of low temperatures.

4-23.2. Corrective Measures. Maintaining shimmed track is costly in maintenance time, and the repeated spiking of ties due to placing and adjusting shims and braces reduces the service life of the ties. However, such maintenance may be necessary until permanent corrective action can be taken. Careful study and considerable work and expenditure are warranted for protection against trackage heave caused by frost action.

4-23.2.1. Drainage. On existing tracks, proper drainage is the principal factor in eliminating and heaving of track.

4-23.2.2. Isolated Cases. Where heaving occurs in isolated places on fills, much may be accomplished by digging out the soft areas of the subgrade to a depth of 2 feet or more and carrying the excavation to the shoulder to afford proper drainage and so decrease the tendency to form water pockets. The excavation should be backfilled with clean coarse gravel or similar material and an adequate depth of good ballast applied.

4-23.2.3. Underdrains. In wet cuts, the installation of perforated underdrains backfilled with porous material provides excellent results.

4-23.2.4. Subgrade. If the subgrade obstructs drainage of the ballast section, it will be graded off and replaced with permeable material to the depth necessary to correct the condition.

4-23.2.5. Shoulders. In some cases where the embankment is built of impervious material, grading the shoulder off the ends of the ties and to a depth of 3 or 4 feet and replacing it with pervious material may be justified. Before undertaking such a project, careful exploration must be made to assure that the wet spots will be drained. Where depressions exist in the roadbed, free drainage to the shoulders must be assured before this method will function.

4-23.2.6. Stabilization. Cement or soil slurry (Figure 4-28) or bituminous subsealing may be used to permanently stabilize roadbed areas subject to freezing where heaving is extensive and the expenditure is justified. Installation of membrane materials may be considered in special cases. Traffic loads, frequency of use, and dependence of the installation on its railroad facility must be considered, as well as availability of maintenance crewmen and equipment to do the work.

4-24. Drainage of Yard Tracks.

Railraod yards are usually located on fairly flat terrain and require special drainage treatment. Because large, open ditches in railroad yards are objectionable, pipe storm drains and subdrains are required unless natural soils are particularly suitable for self draining. Periodic inspections, rodding, and cleaning of installed drainage systems are necessary if they are to function satisfactorily. As conditions change at a given installation and additional facilities are added, or as clearing and building of adjacent areas increase the water shed of the area, it may be necessary to adjust subsurface and runoff facilities at yards.

4-25. Vegetation Control.

The elimination of vegetation from areas where it is not required for erosion control is essential to economical maintenance of tracks, as well as to the appearance of the roadway. Vegetation should be controlled or eliminated to at least the limits of the ballast section to minimize the danger of firs. Proper visibility of traffic signals must be maintained. Dirty ballast permits the growth of weeds that interfere with drainage and shorten the life of ties. The remedy is to clean the ballast. Use approved herbicides to eliminate vegetation from ballast and other areas of the roadway. Consult a specialist in this field for the best material and method to use. Weeds along the roadway can be controlled by mowing, burning, or by using herbicides. **NOTE:** It is mandatory that personnel handling herbicides be certified.

4-26. Snow and Ice Control.

Snowfall in amounts sufficient to obstruct railroad traffic or hinder operations can be expected at northern installations. Ice and packed snow can be a problem at crossings and in industrial areas where the tracks are in the pavement.

4-26.1. Snow Plan. A snow plan should be prepared in advance of the snow season in conjunction with the snow plan for installation roads. The plan must contain data on materials, manpower, and procedures to be used under varying storm conditions.

4-26.2. Snow Fences. Snow fences keep snow from drifting onto the roadbed in localities where heavy snowstorms are frequent. Effective placement of snow fences can be assured by keeping records of locations where drifts have occurred during the winter season.

4-26.3. Snow and Ice Removal. Snow and ice will be removed promptly from switches, frogs, guardrails, and flangeways at highway crossings. Also, snow and ice will be removed promptly from loading platforms, track scales, turntables or transfer tables, and from any other places where personnel or property may be endangered.

4-26.4. Chemical Control. Snow and ice control chemicals, sodium chloride (salt), calcium chloride, and urea are effective in melting ice and packed snow. The lowest temperatures at which these chemicals are effective under field conditions are: urea, +25°F (-4°C); and calcium chloride, -20°F (-29°C).

4-26.5. Snow-Melting Heaters. Snow-burning cans may be used to advantage. At switches where serious snow and ice conditions are expected over long periods, snow-melting pots or switch heaters may be used. Electrical switch heaters are not recommended because of the high operating cost.

4-27. Roadway Cleanup.

During surfacing, lining, gaging operations, and the like, all deficiencies noted should be corrected each working day. The shoulder line must be clearly defined, berms cleaned or raked, and drainage ditches cleaned. All scrap metal shall be collected and taken to a designated storage place. Old ties unfit for further track use or for cribbing shall be disposed of by burial in landfill or by another method of disposal that does not conflict with pollution laws. All rubbish and waste must be cleared from the work, and the entire right-of-way left in a safe and workmanlike condition.

CHAPTER 5.
STRUCTURES

Section 1. TYPES OF STRUCTURES

5-1. General.

This chapter provides guidance for maintaining structures that are a part of the trackage system and some that may affect railroad operations. Bridges, trestles, and box culverts are used for water crossings, pedestrian walkways, roadways, other tracks, and drainage systems. Tunnels and cuts are used to penetrate hills or pass under bridges and other structures. The ensuing paragraphs of this chapter describe effective, preventive maintenance and/or the corrective measures appropriate for the several types of deficiencies usually encountered.

5-2. Supporting Substructures.

Bridges, trestles, and buildings shall be inspected using designated procedures and checkpoints. Supporting structures for elevated cranes should be inspected following each crane load test when cranes are load tested to 125 percent or more of the manufacturer's rated capacity. Inspection reports shall be reviewed and random observations made of rail supports, connections, braces, and beam to column joints for indications of movement, deterioration, or stress. Broken and defective components shall be scheduled for rapair or replacement. For wood, steel or concrete columns, beams, braces, girders, and other structural members, indications of settlement, misalignment, or deflection shall be recorded. Deflection, movement, or settlement under routine in-service loading exceeding established limits shall be investigated, analyzed, the degree of damage documented, and the classification of hazard determined. Structural conditions leading to a critical or catastrophic category of a section of trackage shall be based on a review of the structural analysis and on a condition survey conducted by competent engineers in sufficient detail to establish the safety of the structure.

Section 2. MAINTENANCE OF STRUCTURES

5-3. Bridges and Culverts.

Railroad bridges may be constructed of steel, concrete, masonry, or wood. Steel bridges may be through-truss, through-panel girders, deck truss, or deck panel girder types. These bridges may be open deck or ballasted deck. As far as the bridge structure is concerned, maintenance procedures are generally the same for all types. However, track maintenance will differ between the open deck and ballasted deck bridges.

5-3.1. Open Deck Trackage. On open deck trackage, bolts that secure the ties to the stringers may work loose as the bearing areas of the ties on the stringers become worn, as the ties swell and shrink with moisture changes, or as rot or insect damage develops. Loose bolts on a number of adjacent ties can result in excessive gage and alignment deficiencies. Figure 5-1 shows an open deck pile trestle specially designed for dumping hopper bottom dump cars.

5-3.2. Ballasted Deck Trackage. Ballasted deck trackage is maintained in the same manner as on a regular roadbed. The only extra maintenance required in the trackage is to keep the drainholes unplugged and free draining (Figure 5-2).

5-4. Guardrails.

On structures and approaches, guardrails are installed to guide equipment and prevent it from leaving the rail. Maintaining guardrails in first class condition requires that loose spikes be replaced or redriven, broken tie plates be replaced, and joint bars and track bolts be tightened. These maintenance operations should be performed at least quarterly on heavily used trackage.

5-5. Expansion and Bearing Assemblies.

All expansion joints must be maintained clean and free of incompressible material, which, when struc-

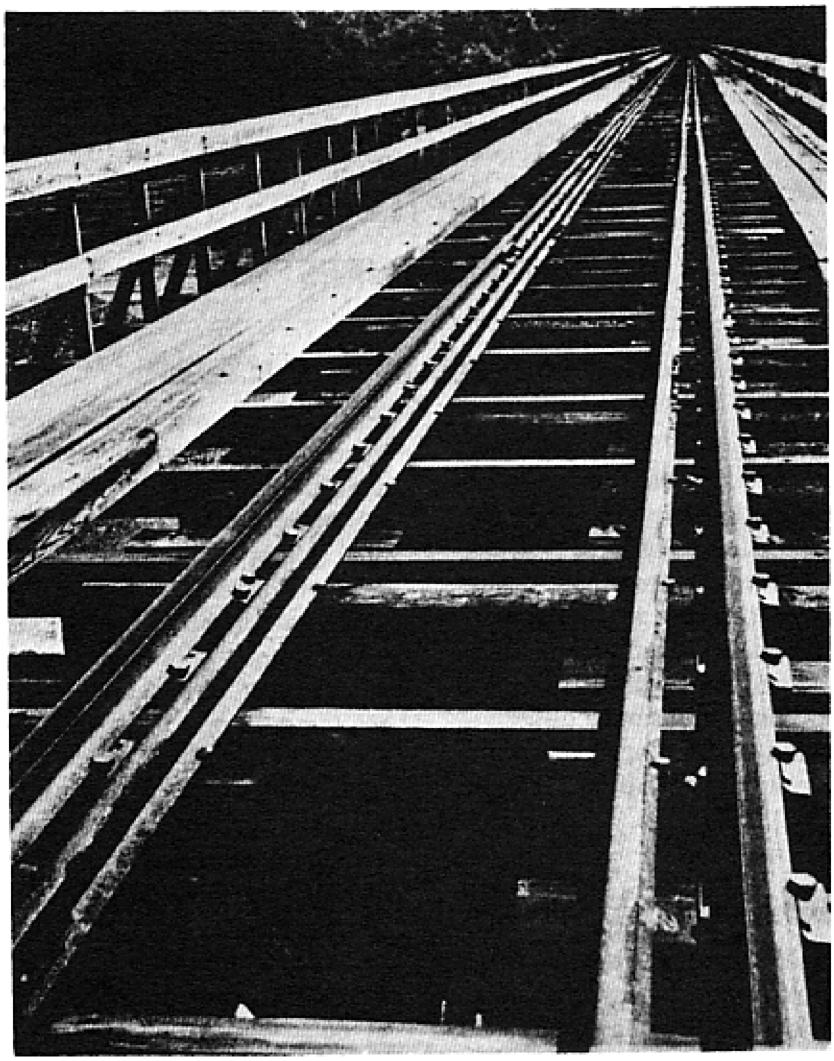


Figure 5–1. Open deck pile trestle (special).

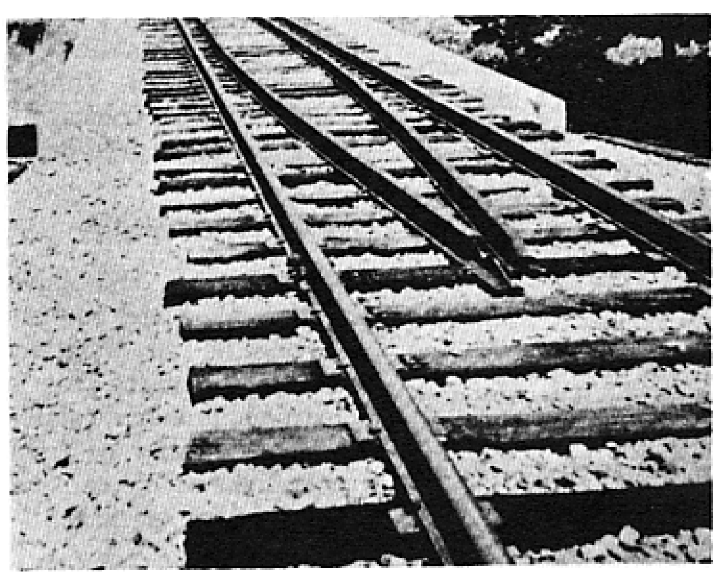


Figure 5–2. Ballast deck trackage.

tures expand, could cause stresses exceeding design capability. Bearing assemblies must be kept clean and well lubricated. Bearing assemblies and expansion joints should be lubricated and/or cleaned annually or semiannually.

5–6. Corrosion.

For those metal portions of trackage structures, the most common form of preventive maintenance is periodic painting. Effective painting requires proper preparation of the surfaces to be painted and the use of proven primers and/or paints. For metals in normal environments, a nominal cleaning with hand or power tools should provide adequate preparation for painting. Where surfaces are subject to corrosive environments (industrial or marine), abrasive blast coatings should be applied immediately to the carefully prepared and cleaned surface. The most corrosion-resistant top coating for such surface is a vinyl paint conforming to DOD Interim Specification VR-3 or VR-6. What type and how many coats to apply will depend on the condition of the existing surface and coating and on the frequency at which it is repainted. (Refer to Paints and Protective Coatings Manual TM 5–618, AFM 85–3, and MO–110.)

5–7. Structure Drainage.

Periodic inspection of the weepholes near the bases of structures will reveal those that have become plugged and ineffective. A small wrecking bar or smaller tool should be sufficient to unplug the weepholes. The following measures should be taken for weepholes that frequently become plugged. If the plugging material is earth, sand, or debris carried into the hole from behind the structure, a screen should be inserted at the rear of the weephole. To prevent plugging of the weepholes by animals or birds who enter from the front face of the structure, a screen should be placed across the front of the hole.

5–8. Concrete Structures.

The most effective preventive maintenance for concrete structures is waterproofing the surface. Both cementitious and bituminous coatings are used for this purpose. Both provide a degree of waterproofing that tends to minimize or eliminate the absorption of moisture that can result in concrete deterioration. Where color is a consideration, bituminous coatings are not used.

5–8.1. Repair of Concrete Structures. The repair of structural concrete requires careful preparation. The best concrete used for such repair will be ineffectual unless it is applied to sound, properly prepared concrete in the original structure. All deficient concrete must be removed to expose hard, strong material. The area to be repaired must be cleaned (may require washing with acid and water) and kept clean until the application of the repair material.

5–8.2. Materials for Repairs. Concrete for repairs may be Portland cement concrete or a system of epoxy resin grout and concrete. The depth and extent of the needed repair, the environment to which the repaired structure is subjected, the required flexibility, and the time available for making the repair determine whether conventional Portland cement concrete or the epoxy system is to be used. Relatively thin concrete repairs or patches of limited extent can best be accomplished with the more expensive epoxy system. Deep repairs of large extent are usually accomplished with Portlant cement concrete which, incidentally, takes longer to attain its design strength.

5–9. Trestles.

To the maximum possible degree, all wood should be prefabricated before being pressure treated. All dimensions of individual members shall be anticipated, including the locations and sizes of all holes to be drilled in each member (Figure 5–3). Rot, insects, and marine borers can be expected to attack wood where it has been cut or drilled in the field. Field-applied preservatives at such points are mandatory but are not as effective as pressure-applied preservatives. Preventive maintenance for wood structures includes periodic checking and renewal of surface-applied preservatives. Exposed cutoffs, daps, and recesses cut into piling and timber are especially vulnerable. Cutoff pile tops are frequently covered with flexible fabric or metal so as to shed rain. Timber trestles, piling, and other wood structures should be examined for soundness by boring with an auger when deterioration is suspected or when necessary to make an engineering analysis.

5–10. Undercutting.

When scour develops into undercutting of structure footings and foundations, immediate and effective corrective measures must be taken to prevent loss of the entire structure. An engineering analysis should be undertaken to determine the scope of safe and proper repair.

5–11. Structure and Approach Trackage

Adequate and effective maintenance of trackage on structures and structure approaches is as essential as the maintenance of the structures. Poor trackage maintenance can cause excessive vibration and undue stresses in structures and can result in disastrous derailments.

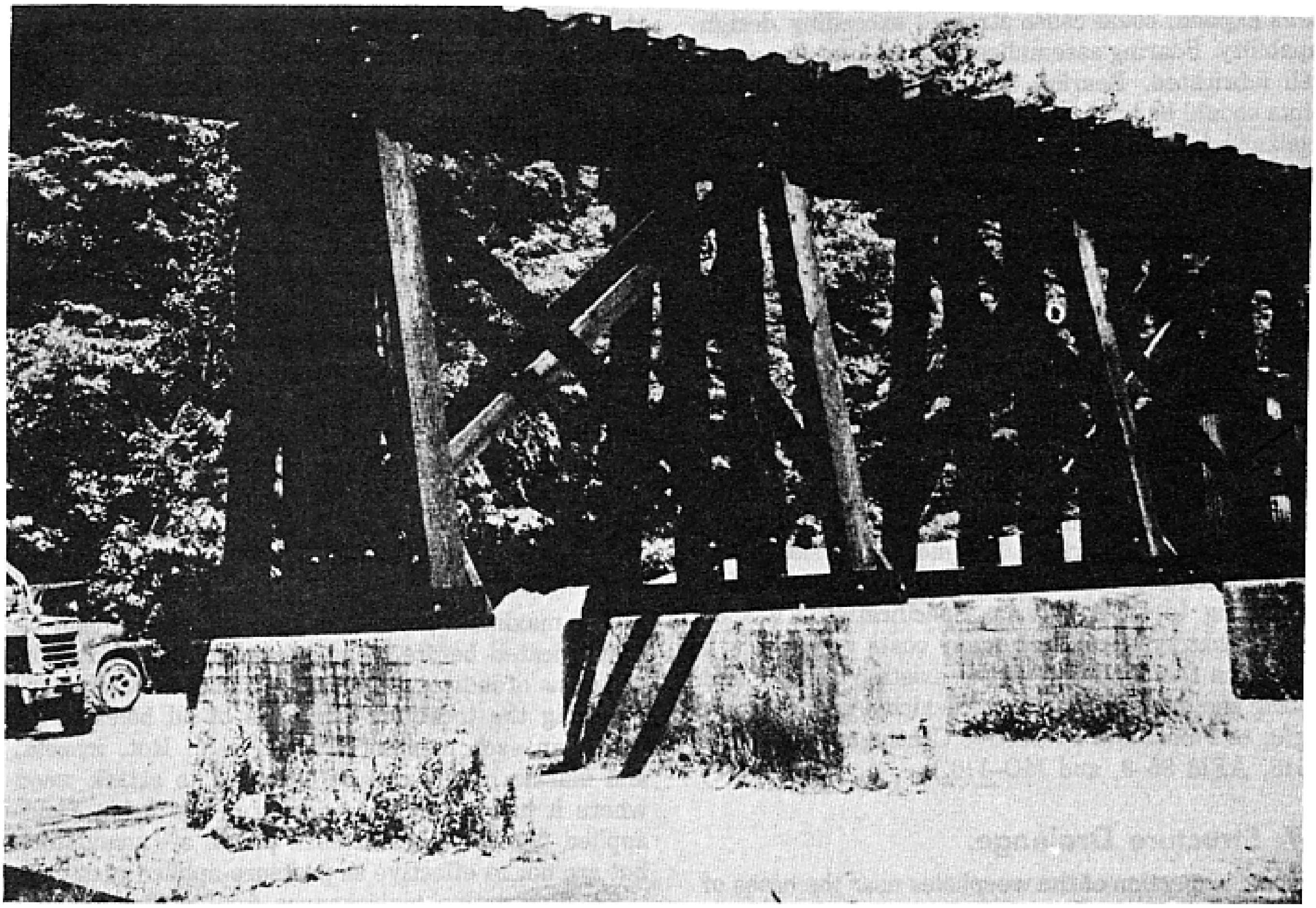


Figure 5-3. Trestle on concrete piers.

CHAPTER 6.
SAFETY

Section 1. ACCIDENT CAUSES AND SAFETY MEASURES

6-1. General.

The greatest single cause of accidents on military installation trackage is insufficient clearance for moving railroad cars and/or personnel. In many cases, minimum clearance limits are violated by building additions, stacked materials, parked vehicles, and protruding piping or wiring attached to platforms and walls. Other prominent accident causes are unsafe equipment, unstable loads, tripping hazards, lack of illumination, lack of warning devices, restricted visibility, and unauthorized crossings. Just plain carelessness is another cause of accident around the tracks and railroad cars. Hazards shall be classified by degree as required by Military Standard 822-A, System Safety Program Requirements as described in paragraphs 7-8.1 through 7-8.3.4.

6-2. Fixed Structures.

Fixed structures that impair safe clearance are listed below in the general order of prevalent hazards.

6-2.1. Platforms. Floors and elevated platforms in excess of 3 feet 9 inches in height must be a minimum of 6 feet 2 inches from the center of the track (Figure 6-1). This clearance is often lost for several reasons. Old, wood platforms may sag and lean toward the track, or timbers may become loose and bend outward from the platform. In strengthening platforms, timber should not be scabbed on to overlap the existing timbers that have deteriorated or become weakened, or other construction added that extends the platform trackwise. A reduction of the 6-foot 2-inch clearance, even by several inches, could result in an injury to a riding trainman or, if the obstruction protrudes far enough, it could strike and damage the stirrups and grab irons on the cars.

6-2.2. Retaining Walls. Retaining walls must also have a minimum clearance of 8 feet 6 inches (Figure 6-1). This minimum clearance may be lost by the wall creeping or bulging from pressures on the other side.

6-2.3. Pipes and Wires. Utilities services should not be attached to existing platforms and buildings or retaining walls having proper clearance. The pipes, cables, and wiring affixed to brackets or fasteners that protrude from the surface to which they are attached reduce the clearance, sometimes to an unacceptable degree.

6-2.4. Buildings. Additions to existing buildings should not encroach upon the minimum clearance (8 feet 6 inches), or windows, shutters, or doors that swing outward should not be installed. The latter are particularly dangerous because they often are not noticed or may be opened as a train is passing by. It is important that structural plans as well as plans for installing outside piping and wiring be approved to assure that such hazards are not created. Window-type air conditioners should not be installed in buildings within the clearance zone, as they often protrude significantly into the area involved. Canopies and other overhanging elements must be high enough to clear locomotives and cars (Figure 6-1).

6-2.5. Gates. At many installations, trackage may pass through boundary perimeter and/or security fences. Gates should be securely fastened in open position to prevent them from swinging toward the moving train, striking the locomotive and/or cars or a riding trainman.

6-2.6. Overhead Structures. Pipe trestles, bridges, elevator bins, chutes, and other overhead structures must meet the clearance criteria on Figure 6-1. Equipment used to load or unload cars must be raised to a safe clearance prior to train movements. Suitable devices must be installed to keep this equipment in a raised position at this safe clearance not in use.

6-3. Safe Clearance Limits.

6-3.1. Parked Vehicles. Areas adjacent to railroad trackage on military installations are sometimes used for vehicle parking. Suitable bumpers or rail guards will be installed to prevent personnel from parking vehicles inside the safe clearance limit. In the loading areas, hand trucks, fork lifts, and other materials handling equipment must not be left carelessly at less than safe distances from the track.

6-3.2. Trucks. Trucks often load directly into or unload directly from the railroad cars. They must be

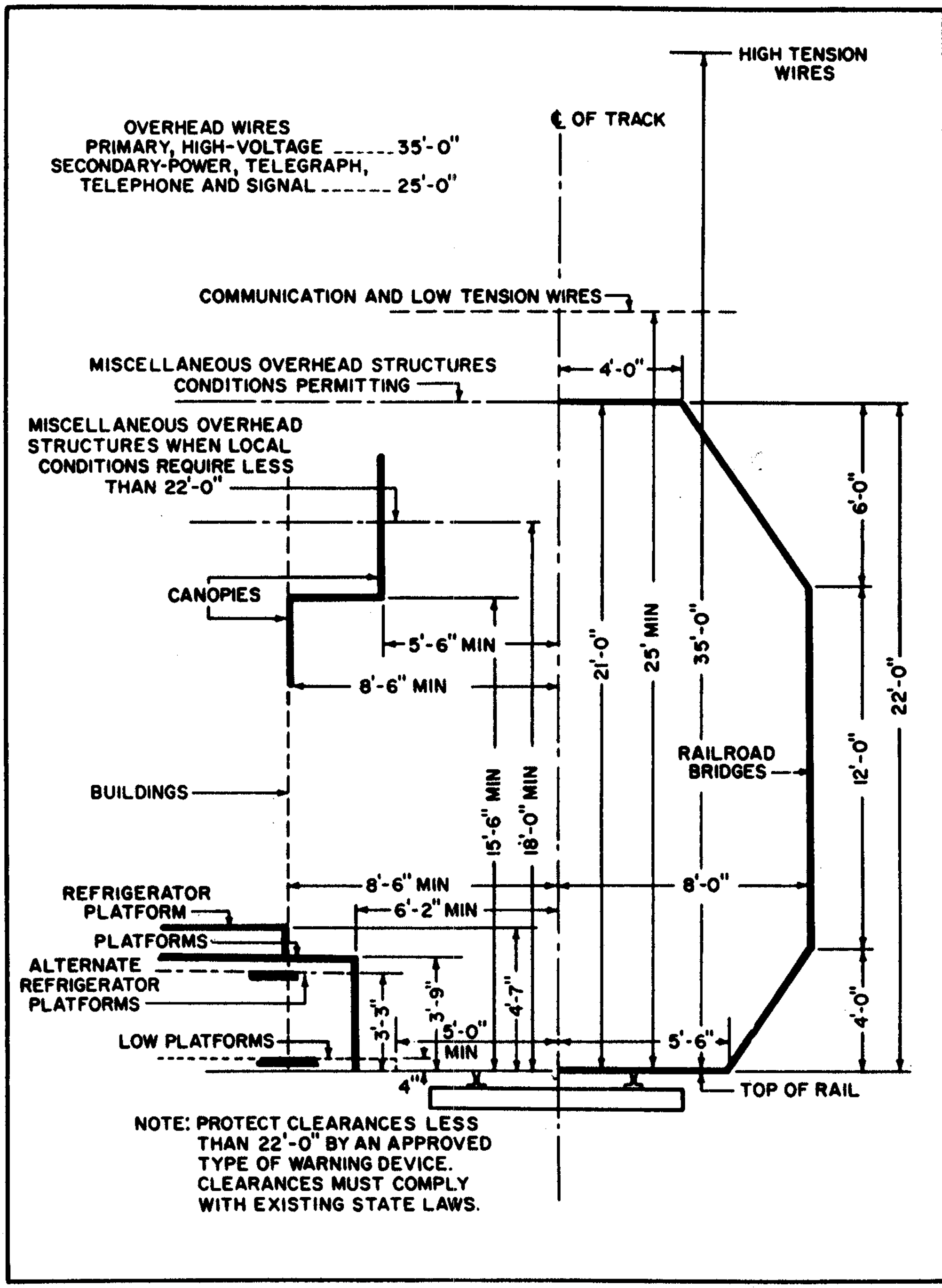


Figure 6-1. Minimum safe clearances.

moved at least 8 feet from the centerline of the track before moving the railroad cars. Trucks at loading docks in restricted areas must park so that neither the truck tractor nor the trailer encroaches on the safe clearance limits.

6-3.3. Stored Materials. Materials are often stored adjacent to railroad tracks. Palleted or stacked material must clear the track area by not less than 8 feet from the track centerline. Loose material such as sand, gravel, coal, etc., must be stored in bins or at least in an area that is barricaded on the trackward side. Coils of cable must be placed or blocked so that they cannot roll toward the track. Drums must be placed and stacked so that they will not tumble or roll toward the track. The 8-foot clearance criterion applies to short- or long-time stored materials. Flammable or explosive materials must be stored at clearances specified by the activity safety engineer, fire marshal, or ordnance officer.

6-3.4. Curves. The clearances shown in Figure 6-1 may have to be increased in the areas of switches and curves. The sharpness of the curve and the overhang of the longest cars brought into the installation will determine the increase in clearance required. The clearances shown are for tangent track and new construction. Clearances for reconstruction work or for alteration depend on existing physical conditions and, where reasonably possible, should be improved to meet the requirements for new construction. On curved track, the lateral clearances shall be increased 1 inch per degree of curvature, with a maximum increase of 18 inches. When the fixed obstruction is on tangent track but the track is curved within 80 feet of the obstruction, the lateral clearances shall be increased as follows:

Distances from Obstruction to Curved Track ft	Increase per Degree of Curvature in.
0-20	1
21-40	3/4
41-60	1/2
61-80	1/4

6-4. Other Obstacles or Hazards.

6-4.1. Track Condition. Track conditions such as broken rails, broken rail joints, rotten ties, loose spikes, and maladjusted switches can cause derailment. Procedures for correcting these conditions are outlined in Chapters 3 and 4.

6-4.2. Drainage. Lack of adequate drainage can cause a softening of the roadbed. This can lead to track settlement, which in turn can result in broken rail joints or loose spikes. Shoulder erosion creates hazardous footing, which may result in missteps or falling. Procedures for correcting drainage deficiencies are outlined in Chapter 4, Section 3, and Chapter 5, Section 2.

6-4.3. Housekeeping. Tools, track hardware, ties, rails, spillage from hopper cars (coal, gravel, etc.), trash, and refuse left along the track are serious hazards.

6-4.4. Excavations. Open trenches are hazards. Excavated earth and stone from these trenches, if left on the shoulder or at an inadequate distance from the track, add to the danger. Trenches must be marked clearly or covered with planks or gratings when work is not being done. Excavation must also be adequately shored to prevent collapsing and shifting or settling of the roadbed. Permanent pits, trenches, and other openings under or around the track must have flush-fitting gratings or covers, which will be kept in place at all times, when not in use.

6-4.5. Accessories and Devices. Accessories such as lamps, rerailers, and derailers must be kept in good working condition. Lamps or lights must be lit during periods of poor visibility. Crossing signals and gates, switch stands, interlocking devices, etc., must be maintained in serviceable condition to prevent accidents. Bumpers or wheel chocks must be maintained in operable condition. Only experienced personnel shall be involved in the use of rerailers.

6-4.6. Safety Operations. Any operation in which cars are moved must be accomplished with safety in mind. Maintenance personnel must stay clear of cars being pulled or poled, coupled or uncoupled, or rerailed. To minimize potential accidents, only authorized personnel will ride cars. Blind corners caused by buildings, walls, etc., must be protected by railings or barricades. Personnel should give standing cars a clear berth and must wait for a passing train to move a sufficient distance to enable them to observe the adjacent track for other train movements before proceeding across the tracks. Temporary or nonstandard road crossings shall be properly posted. Figure 6-2 is an example of good housekeeping and safety practices.

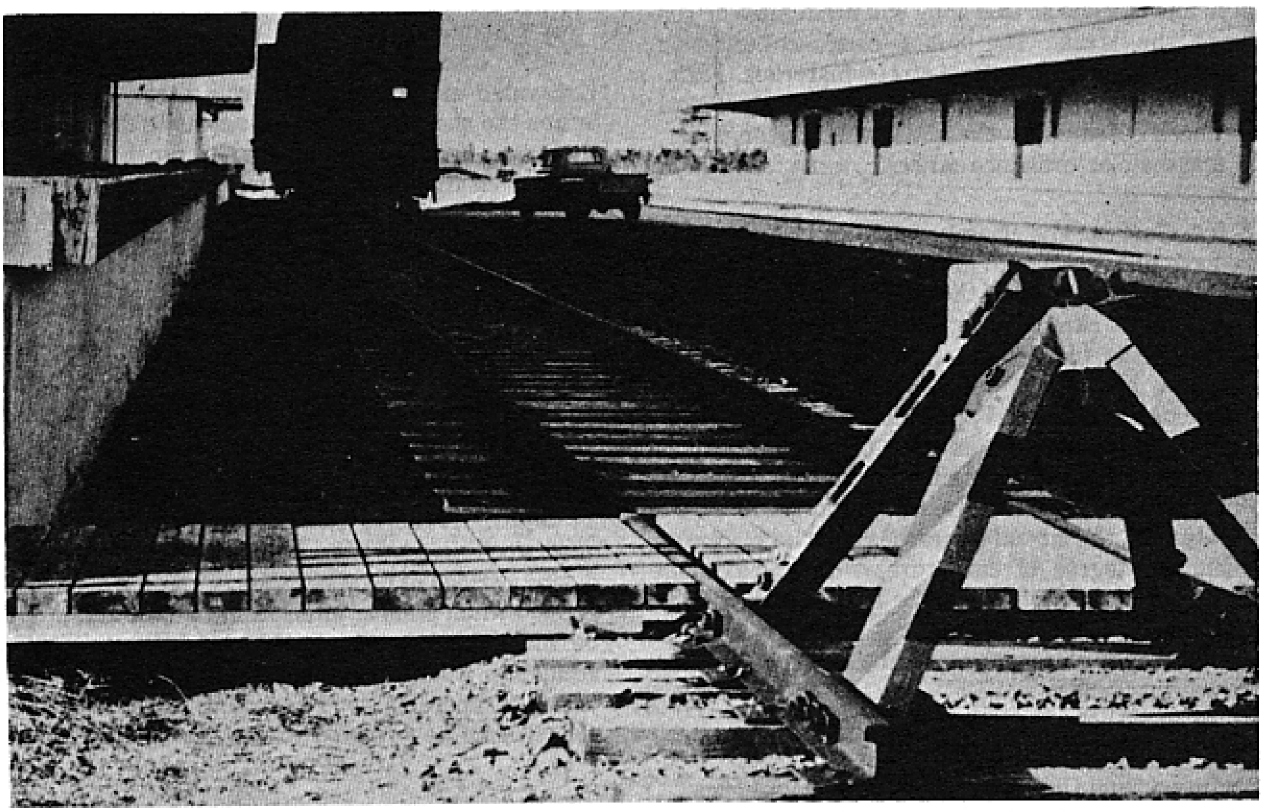


Figure 6-2. Good housekeeping and safety practice.

Section 2. SAFETY PRECAUTIONS

6–5. Procedures.

In addition to guidance concerning hazards given in the foregoing paragraphs, the following procedures must be carried out to assure maximum safety in railroad operations and maintenance.

6–5.1. Inspection. The safety inspections shall be made as directed by the installation Safety Engineer, but not less than once annually in conjunction with maintenance inspections as outlined in Chapter 7.

6–5.2. Safety Inspection Checklist. The following checklist must be used by safety inspectors, and a copy of their report shall be furnished to the installation Safety Engineer and the installation office responsible for maintenance of trackage (Chapter 1).

6–5.2.1. Clearances measured from the centerline of the track to all fixed structures. Clearances not meeting the criteria of Figure 6–1 must be reported.

6–5.2.2. Openings in all structures that have doors, windows, etc., opening out into the clearance limit.

6–5.2.3. Fixtures, pipelines, and other utilities erected or installed inside the clearance limits.

6–5.2.4. Missing or inoperative warning devices or signs. Condition of and/or obstructions of signs.

6–5.2.5. Gates that cannot be securely held open.

6–5.2.6. Unsafe condition of track shoulders or trackbed such as erosion, open ditches, trenches, or pits. Broken, loose, or missing gratings or covers.

6–5.2.7. Improperly working switches and derailers. Loss of or improper marking of clearance points.

6–5.2.8. Improper use of wheel chocks, unsafe car stationing (without set brakes or wheel chocks on grades), loose chocks and bumpers, and condition of cattle guards.

6–5.2.9. Condition of cranes, chutes, and loading or unloading devices that might affect the safe clearance criteria. This applies to all overhead structures.

6–5.2.10. Parking areas and trucks or other equipment encroaching on the clearance limits.

6–5.2.11. Materials stored an inadequate distance from track or projecting into the clearance limits from storage areas or loading docks.

6–5.2.12. Condition of rails, joints, and ties that may create a hazard.

6–5.2.13. There shall be no missing, loose, broken components, bad welds, accumulation of debris, heavy corrosion, or severe deterioration of the following trackage appurtenance: (1) ladders, platforms, and hand rails; (2) rail stops; (3) guardrails and fences; (4) crossing signs and other warning signs; and (5) any other features that could cause an accident.

6–6. Maintenance Inspectors and Track Crews.

Maintenance inspectors and/or track crews are responsible for reporting obstructions or hazards along the tracks such as trash, loose hardware, and any other objects that foul the safe clearance limits. Maintenance personnel shall remove or clean up such obstacles as they go along. More detailed responsibilities of these personnel are provided in Chapter 7.

Section 3. SAFETY WARNINGS AND SIGNS

6–7. Installation of Warnings and Signs.

When hazards exist because of inadequate clearances, construction work, blind corners or approaches, proximity of flammable or explosive storage, heavy vehicle or pedestrian traffic, crossings, and any other condition or situation that would jeopardize operations, people, or property, appropriate warning signs or signals that shall be posted or installed. Signs must be clearly visible and maintained in a legible condition. Signals must be maintained to be operable at all times. Signs may be fixed and installed at proper clearances from the track or may be portable and temporary. Signs must be standard "blue" signs or metal flags unless otherwise prescribed. Signs shall be removed when no longer required. Typical signs are STOP, DERAIL, STOP—TANK CAR CONNECTED, and DANGER—MEN WORKING.

6–8. Clearance Markings for Crossings, Turnouts, and Ladder Tracks.

Clearance markers shall be painted on rails of adjacent tracks where the minimum clearance is reduced. Chrome yellow paint shall be used. The marker shall be 12 inches long, painted on both sides of each rail at the clearance point. Figure 3–64 (para 3–31.13.) shows typical clearance markers. In paved areas, a 12- by 24-inch yellow marker shall be painted between the tracks at the clearance point.

6–9. Whistle and/or Ring (Bell) Signs.

These signs are usually shop fabricated (Figure 6–3). Whistle and ring signs are placed at the distances from the crossings as specified in applicable state or municipal requirements, or where no such requirements exist, the AREA Standards.

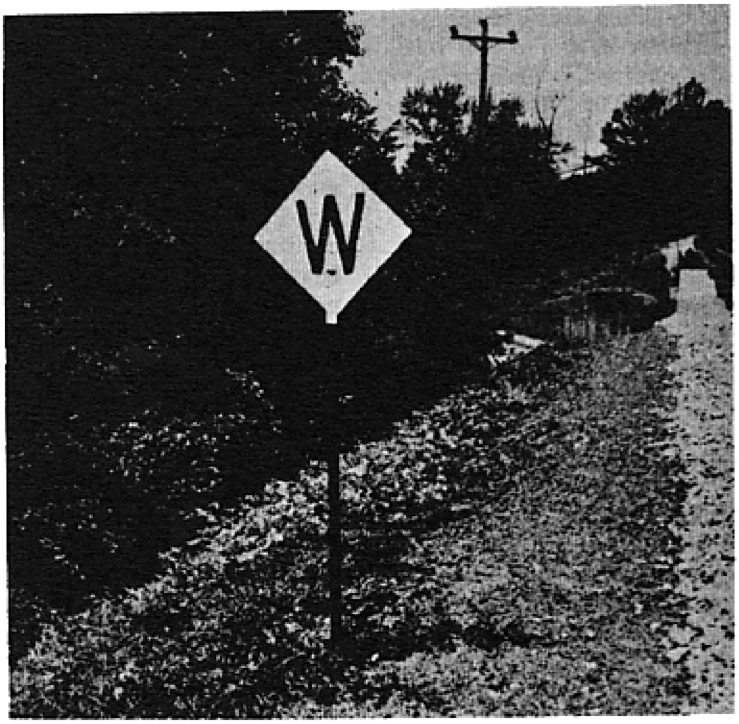


Figure 6–3. Whistle sign.

CHAPTER 7. MAINTENANCE INSPECTION AND SERVICES

Section 1. GENERAL

7-1. Purpose.

Chapters 1 through 6 of this manual describe procedures for effectively maintaining trackage systems at military installations. The planning and developing of an effective track maintenance program must be based on thorough and timely track inspections by competent inspectors. This chapter describes procedures for inspecting trackage systems and systematically detecting, identifying, and reporting deficiences and trouble areas within those systems. Inspection criteria shall be formulated by the ruling activity based on but not necessarily limited to the standards shown in Appendix B.

7-2. Responsibility.

Providing qualified trackage inspection at each military installation is the responsibility of the department tasked with the maintenance of the trackage and other real property as shown in Chapter 1. In making inspection, as in performing maintenance and repair work, the safety precautions of Chapters 1 and 6 of this manual must be observed.

7-3. Inspection of Railroad and Crane Trackage.

Railroad and crane trackage inspections shall be performed at the frequencies and in the detail specified by agency policy. In general, inspections shall consist of observing and functioning of the trackage as related to safety, maintenance, and design parameters. Examination will be by sight, sound, feel, instrumentation, and nondestructive testing. Inspection of trackage includes rails, ties, subgrade, supports, foundations, drainage appendages, and accessories. Primary emphasis shall be given to insuring maximum safety by maintaining all facilities in a safe and sound condition. Deviations from the standards set forth herein shall be approved by waiver from the appropriate service (see Chapter 1).

7-3.1. Preparation. Prior to the investigation of a segment of crane or railroad trackage the inspector shall become familiar with as many available factors of the operation as possible. All pertinent information and data available should be reviewed. These may include results of previous investigations, statistical information on safety performance, and causal factors of accidents determined in accident investigations. Ommission, deletion, or uncorrected defects noted on these previous reports give clues to the inspector on locations where detailed investigations may be required. In addition, to save time and facilitate a more complete investigation, as well as to gain the cooperation of the activity, the following preparations should be made: (1) notify the personnel responsible for the track and those responsible for operations over the track in the territory to be inspected, and (2) set a date and location for the start of the inspection. If time permits, secure the following information from the activity in advance of the investigation:

7-3.1.1. Timetables and special instructions covering territory to be inspected, showing method of operation, maximum allowable speeds, permanent speed restrictions, equipment, and loading restrictions.

7-3.1.2. Trains or cranes per day in each direction, average tonnage, and amount of hazardous materials movement.

7-3.1.3. Locations, speeds, and reason for existing temporary slow orders.

7-3.2. Inspection.

7-3.2.1. Duties of Inspector. The inspector's primary duty is to conduct effective investigations to determine whether the crane or railroad trackage is complying with the safety standards and regulations. Effective investigation requires identification, professional evaluation, and accurate reporting of safety conditions and practices. Inspections may vary considerably in scope and detail, depending upon the circumstances in each case.

7-3.2.2. Records. The examination of records, of track components, and the measurement of track geometry for the determination of compliance with requirements are the responsibility of the inspector.

7-3.2.3. Personal Safety. The inspector's first concern is his own personal safety, as well as the safety of any personnel accompanying him. He will make sure he has current lineup of all train, crane, or other equipment movement and has permission to occupy designated tracks between designated times. When afoot on the railroad track, he must always be alert, expect a train on any track at any time in either direction, and be prepared to promptly clear such train. Extra personal care must be exercised under adverse weather conditions.

7-3.2.4. Safety Rules. The inspectors should know and comply with the safety rules of the installation. They will also wear the safety equipment specified by the activity.

7-3.3. Advanced Notice of Investigation.

7-3.3.1. Schedules Inspection. Since the efficiency and safety of an inspection can be significantly improved by the assistance of operating personnel, advance notice of investigation will be given in all cases where feasible. The inspectors should give ample notice of the territory to be investigated, a proposed date for starting this investigation and an invitation to have a representative of the activity accompany them on the investigation. The activities representative should have immediate knowledge of all conditions noted by previous inspections and can assist in providing accurate locations or distances to named locations and furnish proper track designations.

7-3.3.2. Time Frame. Sufficient time should be provided in planning an investigation to allow activity representatives to prepare themselves and/or permit reasonable adjustments to be made in the schedule.

7-3.3.3. Unscheduled Inspection. These instructions, however, are not to be construed to prohibit unaccompanied investigations when other activity personnel are unavailable to furnish assistance.

7-3.4. Inspection Equipment and Tools. In order to make a proper track inspection, certain tools and equipment are necessary. The basic equipment needed is a track level and gage, a frog gage for rigid frogs, a hammer for sounding rail in paved areas, a rule, a cord 62 feet long, report forms, and a copy of this manual.

Section 2. INSPECTION AND REPORTING

7-4. Categories of Inspection.

7-4.1. Continuous Operator Inspection. Daily or prior to use, safety checks listed in activity regulations shall be conducted. In addition, on-the-job observations shall be going on at all times when equipment is working. Crane and railroad operations personnel (operators, engineers, trackmen, riggers, etc.) shall be encouraged to observe and report track problems, deficiencies, obstructions, and the "feel" of the track. When walking down the track, the inspector/operator can look for broken rails and other rail defects, faulty switch-point closures, indications of wide gauge, poor line or surface, loose crossing planks, wheel flanges striking frog points, working spikes and joints, pull-aparts, evidence of the imminence of track buckling, scour at bridges, and the threat of slides. All these things can contribute to train accidents and should be brought to the attention of the responsible person for correction.

7-4.2. Preventive Maintenance Inspection. Preventive maintenance (PM) inspection is a visual, continuous routine (shop level) working-inspection. It is performed in conjunction with daily assigned maintenance and repair tasks. *When possible, deficiencies are corrected during the inspection and no record made.* Uncorrected deficiencies shall be reported to the supervisor for action, inclusion in the repair work schedule, adjustment of operating speed, and/or closure of section of trackage.

7-4.2.1. The PM inspection is designed to detect and correct those trackage deficiencies that develop from day to day. If the track walker can correct an observed deficiency in a half-hour or less, it should be done; if not, it must be reported. From these reports, the essential trackage maintenance and repair work schedules are developed and implemented.

7-4.2.2. The types of deficiencies PM inspection is designed to detect, and which the track walker may be able to correct include but are not limited to: insufficient switch lubrication; shortage of or lack of fuel and untrimmed wicks in lighted switch targets; loose or missing joint bolts, rail spikes, plates, or anchors; condition of derails and wheel locks; ice or debris-fouling switches and flangeways in paved areas; defective bumper blocks; and poor housekeeping (para 6-4). Uncorrected items may include but are not limited to: broken ties, defective switch points, inoperative switches, operator reported rough or soft spots, poor drainage, substructure failure, defective rail, settlement, condition of supporting columns, and misalignment. The most important sections to be checked are the switches, curves, and any area where a derailment has occurred.

7-4.3. Overall Track Inspection. Because overall track inspections of trackage are more inclusive and exacting than the PM inspections, only qualified personnel should be assigned to make them. Annual inspections are required except where snow, ice, and subfreezing temperatures or unusual climatic conditions are an important factor. In these circumstances overall track inspections should be scheduled more frequently. Where winters are a significant maintenance factor, one overall track inspection is scheduled in the early fall or late summer and one soon after the spring thaws. Reports of overall track inspections are used: (1) to plan the immediate work needed to prepare for and to recover from the effects of winter; (2) to determine if a condition exists that requires engineering investigation, additional testing, or evaluation; (3) to develop the several annual reports of trackage work and the single or multiyear maintenance plans required; and (4) as the basis of Backlog of Maintenance Reports.

7–4.3.1. Methods of Detection. Overall track inspections should include all checks performed during the PM inspections plus all other detectable deficiencies. Visual inspections should include observations of all readily accessible components of the trackage system including rails, ties, rail accessories, switches, crossovers, ballast roadbeds, support structures, and appurtenances. Basic checkpoints for trackage inspection are listed in Chapter 6 and Appendix B. Using the inspection reports and relating them to the installation's basic trackage requirements, its inhouse capabilities, priorities, available funding, and other factors, the annual and the long-range trackage maintenance and repair programs are developed and programmed. Also, these reports can be a factor in the development of future trackage programs. Since all rail flaws are not visible to the eye, rail inspection that will detect internal flaws is significant (para 3–14 and 7–5) to an overall track inspection. The detection of internal rail flaws by a detector car has been standard practice on American railroads for a number of years. These cars use both the induction and ultrasonic methods. The cars are available by contract on an hourly rental basis. An overall track inspection report of running track cannot be completely comprehensive without the inclusion of a report showing the results of nondestructive rail tests.

7–4.3.2. Checklists and Reporting. Provide overall track inspectors with checklists that include, but are not necessarily limited to, all the types of deficiencies included in paragraph 6–5.2 and Appendix B. The inspectors will report in detail the condition of all the trackage and track elements. Their reports will recommend the priority(s) of work and the best method(s) of correcting reported deficiencies. Exceptionally complex and/or unusual trackage maintenance/repair problems may have to be subjected to indepth engineering review for best resolution.

7–4.3.3. Classification of Hazards. Inspectors should designate the degree of hazard (negligible, marginal, critical, or catastrophic, see para 7–8.1) as required by the reference in Chapter 6 based on their judgment. Where there is a doubt regarding the seriousness of a defect, or a questionable safety condition, use shall be stopped over the section of trackage involved until the deficiencies are corrected or until safe use has been determined. Deficiencies designated as critical or catastrophic by inspection personnel shall be evaluated by the cognizant engineering or maintenance organization to determine corrective action and interim precautionary measures including use-restrictions.

7–4.3.4. Support Structures. All subgrades, ballast, foundations, and bridges or trestles shall be inspected for signs of settlement or failure. Special attention should be given to looking for openings in quaywalls, bulkheads, or other waterfront retaining structures that may permit fill material to wash out and cause trackage settlement and failure. Buildings supporting elevated cranes shall be inspected in accordance with designated criteria.

7–4.3.5. Paved Areas. In asphalt, concrete, or grouted areas visual inspection shall include observations for exposed rail defects, trackage movements exceeding the limits stated herein, and signs of distress in adjacent pavement. Potentially serious defects or suspected failures shall be cause for removal of paving and a detailed investigation of trackage. Pavement shall be maintained so that it does not interfere with railroad or crane operation and to insure safe vehicle movement.

7–4.3.6. Measurements. Visual observations or spot-check measurements shall be made of grade, track gage, cross-section elevation, curve radius, horizontal alignment, vertical mismatch, supports, and other features to insure that appropriate criteria are met. Instrument surveys may be requested by the inspector to verify visual observations or spot-check measurements, establish new alignment, investigate problem areas, and/or determine deviation from the established standards.

7–4.3.7. Track Geometry. Horizontal alignment, grade, cross-section elevation, and/or gage shall be investigated when any of the following conditions exist:

7–4.3.7.1. There are indications of abnormal wear on the railheads or on wheel flanges.

7–4.3.7.2. New rails are being installed or any portion of a rail is realigned.

7–4.3.7.3. Operating crane or railroad engine bind have difficulty in starting or have trouble with movement.

7–4.3.7.4. When a potential deficiency of trackage can be observed, heard, or felt.

7–4.3.7.5. There are indications of substructure settlement, failure, or other structural changes.

7-4.3.7.6. Visual observations indicate that the acceptable limits may exceed those limits established by the activity.

7-4.3.7.7. Tests, inspection, experience, or engineering judgment indicate operation or rail alignment problems.

7-4.4. Optional Operational Observations. An operational observation is the observation of engine, crane or car working on the trackage system. The purpose of an operational inspection is to assist in the identification of problem areas which could develop into unsafe trackage. Conditions which may be discovered include the following: (1) soft spots in the ballast; (2) weak or disintegrated ties; (3) looseness, binding, or vibration; and (4) from our off-track, generally downgrade, position we can look for "daylight" under wheel treads and other evidence of wheels trying to climb the rails, as well as for dragging equipment.

7-4.4.1. Frequency. Operational inspections on active trackage systems shall be performed at irregular intervals to insure that the trackage systems will sustain the prescribed load in a safe manner. Railroad sidings, storage trackage, and sections of crane or railroad trackage blocked or seldom used should have operational inspections within a maximum interval of five years. However, visual observation of trackage during routine traffic loading after repair and during investigations is recommended. Low-use trackage serving hazardous loads such as ordnance or fuel shall have an operational inspection within 2 years prior to use.

7-4.4.2. Routine Traffic Observations. Trackage shall be inspected while equipment is operating. Observations for looseness, binding, deflection, or vibration shall be made by sight, sound, and feel. In addition, rail joints, ties, tie plates, ballast or grout, general alignment, rail condition, supporting structures, and other accessories may be observed for deficiencies during operational inspection. Observations may be made (1) during routine annual inspections, (2) by operators in conjunction with daily safety checks, (3) by maintenance-of-way supervisor from the lead car or engine, or (4) by inspectors adjacent to the trackage. When the operational inspection is performed onboard a train or engine, supplemental observations of passing rail traffic at randomly selected and suspected defective areas shall be made. There is no requirement for physical measurements of rail or trackage systems under load; however, when practical and accessible, rail systems shall be observed for deflection. Guidelines for maximum allowable deflections as established by the inspection shall be determined by visual judgment. In the event unusual movement is observed or felt, deflections appear to be larger than the guideline limits established, or the cause of deficiency cannot be immediately determined, an investigation and engineering analysis of the immediate vicinity shall be made prior to determining the degree of hazard. Results of the investigation and engineering analysis, not the deflection limit per se, shall determine when use of a section of trackage must be discontinued.

7-4.4.3. Loads. Loads defined below should be moved over track systems slowly enough so that observations can be made.

7-4.4.3.1. Railroad Trackage. Loads on rails shall be provided by routine rail traffic that normally operates on the track. If a typical train is not observed, the load on the rail may be provided by a locomotive, engine, or test car. When a test car is used, it shall be loaded to give the maximum anticipated load on at least one axle and as close to the total anticipated load as practical.

7-4.4.3.2. Ground-Level Crane Trackage. The operational inspection shall be conducted by using the heaviest crane or the crane with the largest wheel load that can operate on the track. NOTE: The inspection may be conducted with no load on the hook and with the boom parallel to the track.

7-4.4.3.3. Elevated Crane Trackage. Elevated crane trackage systems shall be inspected after completion of each crane load test. Sections of elevated crane rail trackage not observed during crane load tests shall be observed during the operation of the heaviest crane that can operate on the track with no load on the hook and the trolley positioned adjacent to the rail being observed.

7-4.5. Interim (Emergency) Inspections. Trackage is often damaged during severe weather. Interim inspections must be made during or immediately following heavy rain, ice, and/or windstorms and extremely high tides or waves. Damage that affects operation safety will be reported immediately.

7-5. Nondestructive Testing.

It is recommended that all active ground-level crane, elevated crane, and railroad rails be tested nondestructively for defects at 5-year intervals, unless maintenance problems or visual inspection dictate a necessity for more frequent testing. Illustrations of defects and criteria for unacceptable rails are included in Chapter 3 and Appendix B. New rail and accessories shall be accepted according to the latest Government specification and/or standard industry practice. The nondestructive test results shall be used to establish a baseline for future inspection and to identify areas requiring observation. Nondestructive testing of new, stockpiled, or relay (used) rail put into service, may be deferred until the next regularly scheduled test at the discretion of the commanding officer. During the interim period, the rail may be given a safety-use rating based on other tests, observations, and inspections recommended by this manual.

7-5.1. Sounding. Sounding with a hammer is one of the best and least expensive methods of testing rail, and is a practical way to inspect relatively short sections of trackage, elevated crane trackage, and other trackage systems where ultrasonic testing is impractical. Light tapping with a small hammer about every 6 inches will reveal looseness between the rail and anchor plate, and defects before they become serious. Similar to ultrasonic testing, all nonstandard responses should be investigated and recorded for future comparison. This system may be used to test rail when electronic inspection is impractical. However, depending on rail usage, age, history, and experience, the activity should consider using an inspection schedule shorter than the programmed 5-year interval when using sounding as the nondestructive method.

7-5.2. Ultrasonic Testing. Ultrasonic inspection is a nondestructive test method for revealing internal discontinuities in dense homogenous materials by means of acoustic waves of frequencies above the audible range. Ultrasonic testing is the preferred method for nondestructive testing of readily accessible rail. Sonic testing devices, which are available locally or those which are available from commercial sources, can be used for this purpose. Ultrasonic testing is an economical method of checking long lengths of trackage and rail encased in pavement. Ultrasonic testing of new rail may be deferred until the next regularly scheduled 5-year test interval.

7-5.2.1. Calibration. Ultrasonic inspection equipment shall be calibrated to insure reliable interpretation of responses. The approximate smallest defects that can be consistantly detected include, but are not necessarily limited to, the following simulated, "not-serious" defects: (1) a 1/4-inch-diameter hole drilled horizontally through the railhead; (2) a bolt hole through the web; (3) a horizontal 1/2-inch-long sawn crack between the head and the web; and (4) a vertical 1/2-inch-long sawn crack in the web.

7-5.2.2. Test Results. All discontinuities shall be reported, the nature and size of defect estimated, and responses compared with standards or past test results. Rejection or degree of hazard of all potential defects shall be based on assessment of ultrasonic inspection results, visual inspection, experience, engineering judgment, and the criteria established by the activity. In-place welded joints, welded repairs, and rail castings, such as frogs and certain types of swtiches, may have confused or erratic responses when ultrasonically tested; therefore, interpretation requires experience and/or engineering judgment to preclude an erroneous classification of defect.

7-5.3. Other Nondestructive Tests. Magnetic particle (MIL STD 271), dye penetrant, and other nondestructive test methods have limited capability for surface inspections; However, they may be advantageous in investigating potential defects indicated by other inspections. Eddy current or other approved, nondestructive test methods brought about by state-of-the-art advances may be used to supplement or replace sounding or ultrasonic testing based on local conditions, availability, economics, experience, and/or engineering judgment.

7-6. Miscellaneous Inspections and Tests.

Other inspections may be used to determine the safe condition of trackage under unique or unusual circumstances or to make a detailed engineering investigation of specific, critical components of a trackage system. The inspections performed and the frequency shall be those considered necessary by the activity or as recommended by the audit. Prior to use, the availability, limitations, and practicability of any special investigation shall be evaluated. Special inspections, such as the following, may assist in determining the condition of trackage:

7-6.1. Building Inspection. Review comments made by the building/structural inspector to verify that work affecting trackage has been scheduled.

7-6.2. Underwater Damage Assessment Television System. Divers or the Underwater Damage Assessment Television System may be required to conduct underwater inspections of waterfront containment structures (bulkheads) and dock pilings supporting trackage.

7-6.3. Seismograph. Under certain conditions seismographic instruments may be beneficial in determining voids in fill material or embankments, level of water tables, or location of slippage planes in the foundation below trackage systems.

7-6.4. Strain Gages. When the structural analysis for the anticipated maximum loading of a structure indicates certain members may be overstressed or marginal, a load test (duplicating or exceeding maximum total moment and shear experienced in-service) with stress and strain instrumentation is appropriate.

7-7. Track Records.

Up-to-date records of all trackage at each military installation are basic to the administration of trackage maintenance and repair programs. As in every type of inspection, the thoroughness with which trackage inspections are made is important. Of equal importance is the accuracy and thoroughness with which the inspection reports are prepared. Deficiencies in track elements such as switches, bridges, culverts, and road crossings will be identified and reported.

Deficiencies in hard to identify elements such as individual ties, joints, and rails will be summarized in the reports. Field identification of those deficiencies will be accomplished by durable markings; for example, each tie to be replaced is indicated by inspector-applied markings. (See Figures 3-20 and 3-21 in paragraph 3-11.3.) In order to manage and administer trackage inspections, maintenance programs, and design, the following information should be available in a usable condition so that it may be referred to easily and readily. Where documents do not exist, a long-range program should be established to obtain the appropriate information for retention in activity files.

7-7.1. Inspection Reports. Inspection reports should be filed and maintained in accordance with current directives. If track charts (Appendix E, Figure E-1) are used, the inspection report form should reference a track chart. Each inspection report should record the inspection findings of only a specific segment of track. When track charts are used, only that track shown on the referenced track chart should be reported. Where more detailed reports are required than can be shown in the limited space provided in the inspection report form, the form may be supplemented with photographs and other supporting material. Until reported deficiencies have been corrected, it is essential that the reports and appropriate supporting material be conveniently accessible, in accordance with current directives. The current degree of hazard for each section of trackage shall be shown on the track chart, map, or other prominent document.

7-7.2. Track Charts. Track charts, although not required by all departments, are a useful tool in scheduling maintenance and repair work and for indicating areas of important track elements that require other than the usual amount of maintenance and repair. Track charts or plans should be maintained as part of the real property records. The charts or plans shall be kept up to date and used for programming future work, scheduling current work, indicating abnormal conditions, and recording maintenance and inspection data. Charts or plans can be in any format and shall be usable as a working document. Curve data shall be recorded for all curves.

7-7.3. Plan and Profile. Detailed plan and top of rail profile or grades of crane and railroad track systems should be kept current and may be shown on the track chart or separately. Size and type of rail, switches, degree of curve, frogs, and other rail appurtenances should be indicated on the plan. Reference points for location and elevation checkes should be accurately referenced.

7-7.4. Cross Section. Cross sections of substructures shall be maintained, when known and available, especially the investigation reports of substructures under crane or railroad tracks around piers, drydocks, trestles, wet areas, and the major supporting substructures of elevated cranes.

7-7.5. Historical Data. Historical data on each system shall be retained or developed and include the following: (1) dates that the system was installed; (2) weight of rail, gage of track; (3) history of maintenance and repair; (4) replacement of rail; (5) methods of accomplishing previous work; (6) general overall trackage condition; (7) maximum capacity; (8) original intent or use of trackage; (9) engineering calculations to establish maximum loading; (10) HQ approval of railroad curves with radii less than 300 feet; (11) justification of exceptions to standards, waivers; (12) valid structural analysis for all supporting structures based on or exceeding current maximum loading; and (13) other pertinent information.

7-7.6. Proposed Projects. Maintain a list of pending work including: (1) major repair projects (approved, submitted, and needed), (2) minor work to be accomplished with local funding, and (3) major replacement projects which are being considered for MCON funding. Use "multiyear" renewal program for rail replacement when practical.

7-7.7. PM Inspection Reports. Local formats in existence may be used. As a minimum, PM inspection reports should include: (1) date, (2) sections of trackage inspected, (3) unrepaired deficiencies, (4) number of and size of broken or missing parts, (5) suspected misalignment or defect, and (6) guides and instructions used for the inspection. The current PM inspection report and the one for the preceding period shall be retained. Work authorization documents or shop repair orders, usually the action following PM inspections, shall be kept for 5 years.

7-7.8. Overall Track Inspection. As a minimum, activity track files shall contain the latest complete control inspection report, supplemental engineering inspection reports, and all engineering investigation reports made since the last complete annual or special report. Modification and alteration approvals including engineering investigations and field checks shall be kept for 5 years. Current operational inspection records shall be kept until superseded.

7-7.9 Nondestructive Testing. Current nondestructive test records shall be kept on file for all rails. Data collected from the ultrasonic or induction tests shall be retained as necessary for baseline and defect growth comparisons. A narrative report should be included to explain any unusual observations.

7-7.10. Program Review Report. The program review, HQ/command assistance, or IG inspection report and activity responses shall be retained until superseded.

7-8. Inspection Check Points.

The types of deficiencies inspectors are required to note are described in Chapters 1 through 5 and Appendix B of this manual. The day-to-day deficiencies PM inspectors are expected to note are relatively few in number, and all are quite simple to detect. They are mentioned in paragraph 7-4.2. Engineering inspections and interim inspections should note and report all the types of deficiencies covered by PM inspections, plus all of the other shortcomings of trackage that are described in Chapters 1 through 5 and Appendix B of this manual. Careful visual inspections can detect many of the shortcomings; others are more complex and can be detected only by certain techniques.

7-8.1. Degree of Hazard. A *hazard* is any real or potential condition that can cause injury or death to personnel, or damage to or loss of equipment or property. *All* trackage should be classified according to one of the four categories shown below. Certification shall be made on sections of trackage at intervals not to exceed 2 years. Overall track inspections (para 7-4.3) shall be used as the basis for determining the degree of hazard. Tests of inspections made between overall track inspections that indicate previously unreported critical or catastrophic defects or other unsafe conditions shall automatically cancel the existing degree of hazard over the specific section of trackage involved. For inactive trackage or trackage used infrequently, the inspection and hazard level determination may be performed just prior to use. When there is any doubt as to the degree of hazard over a given section of trackage, the degree of hazard shall not be made until a detailed investigation and engineering evaluation has been completed to determine whether or not the section of trackage involved can be certified safe or whether or not restricted operations may continue pending repair.

7-8.2. Hazard Level Category. Hazard level is a qualitative measure of hazards stated in relative terms. For purposes of this standard, the following categories of hazard levels are defined and established: personnel error, environment, design characteristics, procedural deficiencies, or subsystem or component failure or malfunction (para 6-1 and MIL-STD-882A).

Category	Hazard Level
Negligible	Will not result in personnel injury or system damage. Minor defects that will not affect operation over trackage systems.
Marginal	Can be counteracted or controlled without injury to personnel or major system damage. Routine maintenance and repairs should be scheduled.
Critical	Will cause personnel injury or major system damage, or will require immediate corrective action for personnel or system survival. Operation over trackage systems must be restricted.
Catastrophic	Will cause death or severe injury to personnel, or system loss. Operation over trackage systems shall be stopped.

7-8.3. Defect Classification. The basic rule of thumb or general guideline for determining a critical hazard of a defective rail and continuing use at DOD installations is 1/4 inch of alignment or movement. All irregularities in top or side rail wear, difference in elevation at breaks or joints, deflections, and movements exceeding 1/4 inch should be investigated. Common rail defects are illustrated in Figure 3-27. Defects are listed in the hazard category in which they normally occur. Exceptions and variations are expected; therefore, experience and/or engineering judgment must be used to determine the degree of hazard for each defect. General guidelines to assist inspectors and engineering investigators in determining the degree of hazard of a defect are described below.

7-8.3.1. Negligible. Deficiencies that are negligible are those which do not affect the safety of operation, such as:

7-8.3.1.1. Defects, such as breaks, fractures, or defective welds, corrected by the application of fully bolted angle bars.

7-8.3.1.2. Damaged rail with temporary repair (complete weld repairs are considered nondefective).

7-8.3.1.3. Weld irregularities.

7-8.3.1.4. Minor mill or mechanical defects.

7-8.3.1.5. Surface scratches or cracks.

7-8.3.1.6. Possible defects on portions of rail systems made from casting, such as frogs and certain types of switches, having confused or erratic readings when ultrasonically tested.

7-8.3.1.7. Other small defects based on activities' investigation, engineering judgment, and/or experience.

7-8.3.2. Marginal. Trackage systems with small defects such as missing nuts, loose spikes, etc., less than specified in Appendix B, shall be repaired, when possible, during regularly scheduled track work operations. Records of unrepaired rail defects and substandard trackage shall be kept current and the trackage continually observed during all future inspections to identify any further degradation which might result in defects.

7-8.3.3. Critical. Trackage with critical defects may continue in use provided the operating speed over the defective section is reduced and the defect or defects are carefully inspected at intervals of not more than every 6 months or as prescribed in Appendix B. Trackage systems with critical defects may be scheduled for restricted operation at the discretion of the officer in charge provided all of the following actions are taken:

7-8.3.3.1. Replacement or repair is scheduled.

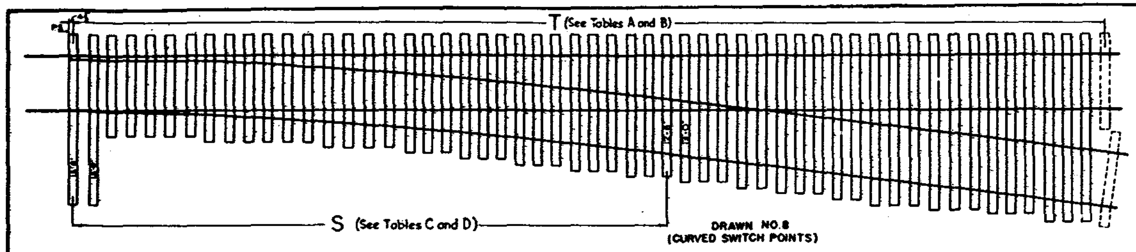
7-8.3.3.2. Deficient areas are clearly and specifically marked with warning signs when practical, or specified in written instructions and restrictions.

7-8.3.3.3. Operators are informed to proceed with extreme caution.

7-8.3.3.4. Reduced speed operation is approved following an engineering inspection.

7-8.3.3.5. Additional PM inspections or checks of the defect are schedules. (For infrequently used trackage, inspections may be made just prior to use.)

7-8.3.4. Catastrophic. Sections of trackage with catastrophic defects involved shall not be used until repaired, except as noted below. Serious trackage defects include conditions which engineering judgment and experience have determined to be unsafe, and (Appendix B) requiring immediate change out of rail. **NOTE:** Temporary or emergency repair of defective rails may reduce the degree of hazard to critical or marginal depending on the severity of the defect, for example see paragraph 7-8.3.1 above, items a and b. On trackage systems which have catastrophic rail defects or on dangerous or unsafe sections of trackage, general usage shall be stopped until the section(s) of trackage have been repaired or replaced. Sections of trackage that are defective, damaged, misaligned, or otherwise failing to meet the lowest standards established in Appendix B of this manual shall be barricaded or marked with warning signs (when practical) and service discontinued. When necessary to use trackage in the catastrophic category, the officer in charge shall be responsible for safety and visually supervise each operation over the defective sections.



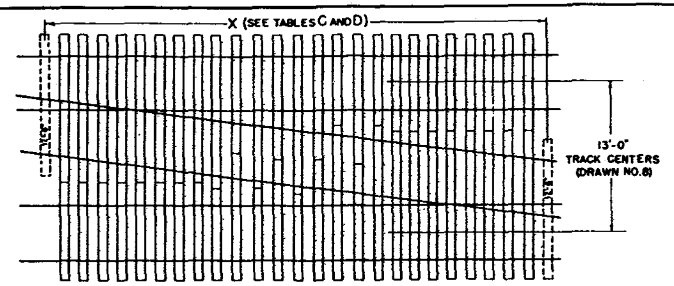


TABLE A BILL OF SWITCH TIES FOR TURNOUTS WITH STRAIGHT SWITCHES

Frog Number	Length of Switch Rail	Toe Length to ½" Pt.	Lead P.S. to ½" Pt.	Lengths and Quantities of Ties 9'-0"	9'-6"	10'-0"	10'-6"	11'-0"	11'-6"	12'-0"	12'-6"	13'-0"	13'-6"	14'-0"	14'-6"	15'-0"	15'-6"	16'-0"	16'-6"	Quantity of Ties	Board Measure	Track Lengths of Cross Ties Replaced T
5	11'-0"	3'-6½"	42'-6½"	4	6	3	3	2	1	2	1	2	1	1	2	3	2	2	2	37	2352	60'-11"
6	11'-0"	3'-9"	47'-6"	4	6	3	3	2	3	2	1	2	1	2	2	3	3	2	2	41	2628	69'-8"
7	16'-6"	4'-8½"	62'-1"	7	9	4	3	3	3	2	1	2	2	2	2	4	3	3	2	52	3263	88'-0"
8	16'-6"	5'-1"	68'-0"	7	9	4	3	3	4	2	1	3	2	3	2	5	3	3	3	57	3630	97'-8"
9	16'-6"	6'-4½"	72'-3½"	7	9	4	4	3	4	3	3	3	3	2	3	5	3	3	4	63	4041	105'-8"
10	16'-6"	6'-5"	78'-9"	7	10	5	4	4	4	3	3	3	3	3	3	4	4	4	4	68	4360	115'-11"
11	22'-0"	7'-0"	91'-10½"	10	10	7	4	5	5	3	4	4	3	3	3	5	5	3	4	78	4935	132'-9"
12	22'-0"	7'-9½"	96'-8"	10	10	7	5	5	5	4	4	4	3	4	3	6	5	4	4	83	5289	141'-4"
14	22'-0"	8'-7½"	107'-0½"	10	10	7	6	7	6	4	4	5	4	4	5	6	6	5	5	94	6064	159'-2"
15	30'-0"	9'-5"	126'-4½"	15	12	9	8	7	6	5	5	5	5	4	5	6	6	6	6	110	6985	182'-3"
16	30'-0"	9'-5"	131'-4"	15	12	9	8	7	6	6	7	5	6	5	4	6	6	6	6	114	7232	191'-0"
18	30'-0"	11'-0½"	140'-11½"	15	14	10	9	8	7	5	5	6	6	5	6	7	7	7	7	124	7930	208'-1"
20	30'-0"	11'-0½"	151'-11½"	15	15	11	10	9	6	6	5	7	6	5	7	8	9	7	7	133	8534	226'-7"

TABLE B BILL OF SWITCH TIES FOR TURNOUTS WITH CURVED SWITCHES

Frog Number	Length of Switch Rail	Toe Length to ½" Pt.	Lead P.S. to ½" Pt.	Lengths and Quantities of Ties 9'-0"	9'-6"	10'-0"	10'-6"	11'-0"	11'-6"	12'-0"	12'-6"	13'-0"	13'-6"	14'-0"	14'-6"	15'-0"	15'-6"	16'-0"	16'-6"	Quantity of Ties	Board Measure	Track Lengths of Cross Ties Replaced T
5	13'-0"	3'-6½"	44'-6½"	5	5	3	3	2	2	2	1	2	1	1	2	3	2	2	2	38	2410	62'-11"
6	13'-0"	3'-9"	49'-9"	5	5	3	3	2	3	2	2	2	1	2	2	3	3	2	2	42	2691	71'-11"
7	13'-0"	4'-8½"	54'-8½"	5	6	4	3	3	3	2	2	2	2	2	2	4	3	3	2	48	3085	80'-7"
8	13'-0"	5'-1"	58'-11½"	5	6	4	3	3	3	3	3	3	2	3	2	5	3	3	3	54	3520	88'-7"
9	19'-6"	6'-4½"	74'-1¼"	9	8	5	4	4	4	2	3	3	3	2	3	5	3	3	4	65	4132	107'-6"
10	19'-6"	6'-5"	78'-11"	9	8	5	5	4	4	3	3	3	3	3	3	4	4	4	4	69	4410	116'-1"
11	19'-6"	7'-0"	83'-6"	9	9	5	5	4	4	4	3	4	3	3	3	5	5	3	4	73	4667	124'-1"
12	19'-6"	7'-9½"	87'-3½"	9	9	5	5	4	5	4	4	4	3	4	3	6	5	4	4	78	5029	131'-11"
14	26'-0"	8'-7½"	108'-7½"	12	10	9	7	6	5	4	4	5	4	4	5	6	6	5	5	97	6200	160'-9"
15	26'-0"	9'-5"	113'-5"	12	10	9	7	6	6	5	4	5	5	4	5	6	6	6	6	102	6566	169'-4"
16	26'-0"	9'-5"	118'-5"	12	12	9	8	6	6	5	4	5	6	5	4	6	6	6	6	106	6773	178'-1"
18	39'-0"	11'-0½"	147'-0½"	20	16	11	8	7	6	5	5	6	6	5	6	7	7	7	7	129	8145	214'-2"
20	39'-0"	11'-0½"	156'-0½"	20	17	10	9	6	8	6	6	7	6	5	7	8	9	7	7	138	8775	230'-8"

TABLE C BILL OF SWITCH TIES FOR CROSSOVERS WITH STRAIGHT SWITCHES

FROG NUMBER	LENGTH OF SWITCH RAIL	TOE LENGTH TO ½" PT.	LEAD P.S. TO ½" PT.	LENGTHS AND QUANTITIES OF TIES INCLUDES THE TOTAL NUMBER OF SWITCH TIES FROM POINT OF SWITCH TO POINT OF SWITCH 7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0	12'-6	13'-0	13'-6	14'-0	15'-0	QUANTITY OF TIES	BOARD MEASURE	TRACK LENGTH (PARALLEL TRACKS) OF CROSS TIES REPLACED=S+X S	X
5	11'-0"	3'-6½"	42'-6½"	1	4	8	8	12	6	8	6	2	4	2	8	4	1	4	78	4365	37'-7"	26'-0"
6	11'-0"	3'-9"	47'-6"	2	2	10	8	12	6	9	7	6	4	2	10	2	2	4	86	4833	42'-7"	29'-6"
7	16'-6"	4'-8½"	62'-1"	2	4	12	14	18	8	9	9	6	4	2	12	4	2	4	110	6087	55'-6"	36'-5"
8	16'-6"	5'-1"	68'-0"	1	4	16	14	18	10	8	8	10	4	2	16	4	1	4	120	6660	59'-10"	43'-2"
9	16'-6"	6'-4½"	72'-3½"	1	6	16	14	18	10	10	8	10	6	6	16	6	1	4	132	7384	64'-1"	46'-9"
10	16'-6"	6'-5"	78'-9"	4	4	18	14	20	14	8	8	12	6	6	18	4	4	4	144	8043	70'-7"	50'-3"
11	22'-0"	7'-0"	91'-10½"	4	6	20	20	20	16	10	12	12	6	8	20	6	4	4	168	9356	82'-1"	57'-0"
12	22'-0"	7'-9½"	96'-8"	2	6	22	20	20	16	13	13	12	8	8	22	6	2	4	174	9705	86'-10"	60'-7"
14	22'-0"	8'-7½"	107'-0½"	5	6	28	20	20	16	16	18	14	8	8	28	6	5	4	202	11295	94'-0"	74'-1"
15	30'-0"	9'-8"	126'-4½"	4	8	28	30	24	22	18	16	18	10	10	28	8	4	4	230	12889	113'-4"	77'-7"
16	30'-0"	9'-5"	131'-4"	4	8	30	30	24	22	18	16	16	12	14	30	8	4	4	240	13382	118'-3"	81'-2"
18	30'-0"	11'-0½"	140'-11½"	6	6	36	30	28	22	24	22	16	10	10	36	6	6	4	262	14548	124'-8"	94'-6"
20	30'-0"	11'-0½"	151'-11½"	6	8	38	30	30	28	23	21	18	12	10	38	8	6	4	280	15548	135'-8"	101'-8"

TABLE D BILL OF SWITCH TIES FOR CROSSOVERS WITH CURVED SWITCHES

FROG NUMBER	LENGTH OF SWITCH RAIL	TOE LENGTH TO ½" PT.	LEAD P.S. TO ½" PT.	LENGTHS AND QUANTITIES OF TIES INCLUDES THE TOTAL NUMBER OF SWITCH TIES FROM POINT OF SWITCH TO POINT OF SWITCH 7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0	12'-6	13'-0	13'-6	14'-0	15'-0	QUANTITY OF TIES	BOARD MEASURE	TRACK LENGTH (PARALLEL TRACKS) OF CROSS TIES REPLACED=S+X S	X
5	13'-0"	3'-6½"	44'-6½"	1	4	8	10	10	6	8	6	4	4	2	8	4	1	4	80	4481	39'-7"	26'-0"
6	13'-0"	3'-9"	49'-9"	2	2	10	10	10	6	9	7	6	4	4	10	2	2	4	88	4959	44'-10"	29'-6"
7	13'-0"	4'-8½"	54'-8½"	2	4	12	10	12	8	9	9	6	4	4	12	4	2	4	102	5730	48'-2"	36'-5"
8	13'-0	5'-1"	58'-11"	1	4	16	10	12	10	8	8	8	6	6	16	4	1	4	114	6439	50'-9"	43'-2"
9	19'-6"	6'-4½"	74'-1½"	1	6	16	18	16	12	10	10	10	4	6	16	6	1	4	136	7568	65'-11"	46'-9"
10	19'-6"	6'-5"	78'-11"	4	4	18	18	16	14	10	8	12	6	6	18	4	4	4	146	8143	70'-9"	50'-3"
11	19'-6"	7'-0"	83'-6"	4	6	20	18	18	12	12	10	10	8	6	20	6	4	4	158	8820	73'-8"	57'-0"
12	19'-6"	7'-9½"	87'-3½"	2	6	22	18	18	12	13	11	12	8	8	22	6	2	4	164	9185	77'-6"	60'-7"
14	26'-0"	8'-7½"	108'-7½"	5	6	28	24	20	20	18	16	12	8	8	28	6	5	4	208	11568	95'-7"	74'-1"
15	26'-0"	9'-5"	113'-5"	4	8	28	24	20	22	16	14	18	10	8	28	8	4	4	214	12049	100'-4"	77'-7"
16	26'-0"	9'-5"	118'-5"	4	8	30	24	24	22	18	14	16	10	8	30	8	4	4	224	12463	105'-4"	81'-2"
18	39'-0"	11'-0½"	147'-0½"	6	6	36	40	32	24	22	20	14	10	10	36	6	6	4	272	14978	130'-9"	94'-6"
20	39'-0"	11'-0½"	156'-0½"	6	8	38	40	34	26	21	15	22	12	12	38	8	6	4	290	16031	139'-9"	101'-6"

NOTES

1. Data—For tabulation of general turnout and crossover data for straight switches, see Plan Basic No. 910.
2. Data—For tabulation of general turnout and crossover data for curved switches, see Plan Basic No. 920.
3. Lengths of switch ties in tables are based on 8'–6" cross ties.
4. Board measure given in tables is based on switch ties 7" x 9".
5. Data in tables are based on locating ties under switches and frogs as indicated on AREA Trackwork Plans of these units and on spacing of other ties approximately 20" center to center.
6. Lengths shown for crossovers in Tables "C" and "D" are based on 13'–0" track centers and should be modified to suit for other track centers.
7. Cross ties may be used for lengths 8'–6" and less in Tables "C" and "D" and board measure of switch ties reduced accordingly.

Courtesy of

American Railway Engineering Association

BILLS OF SWITCH TIES FOR TURNOUTS AND CROSSOVERS

PLAN NO. 912-58

Adopted March 1958. Revision of Plan No. 912-52.

Figure 3-18

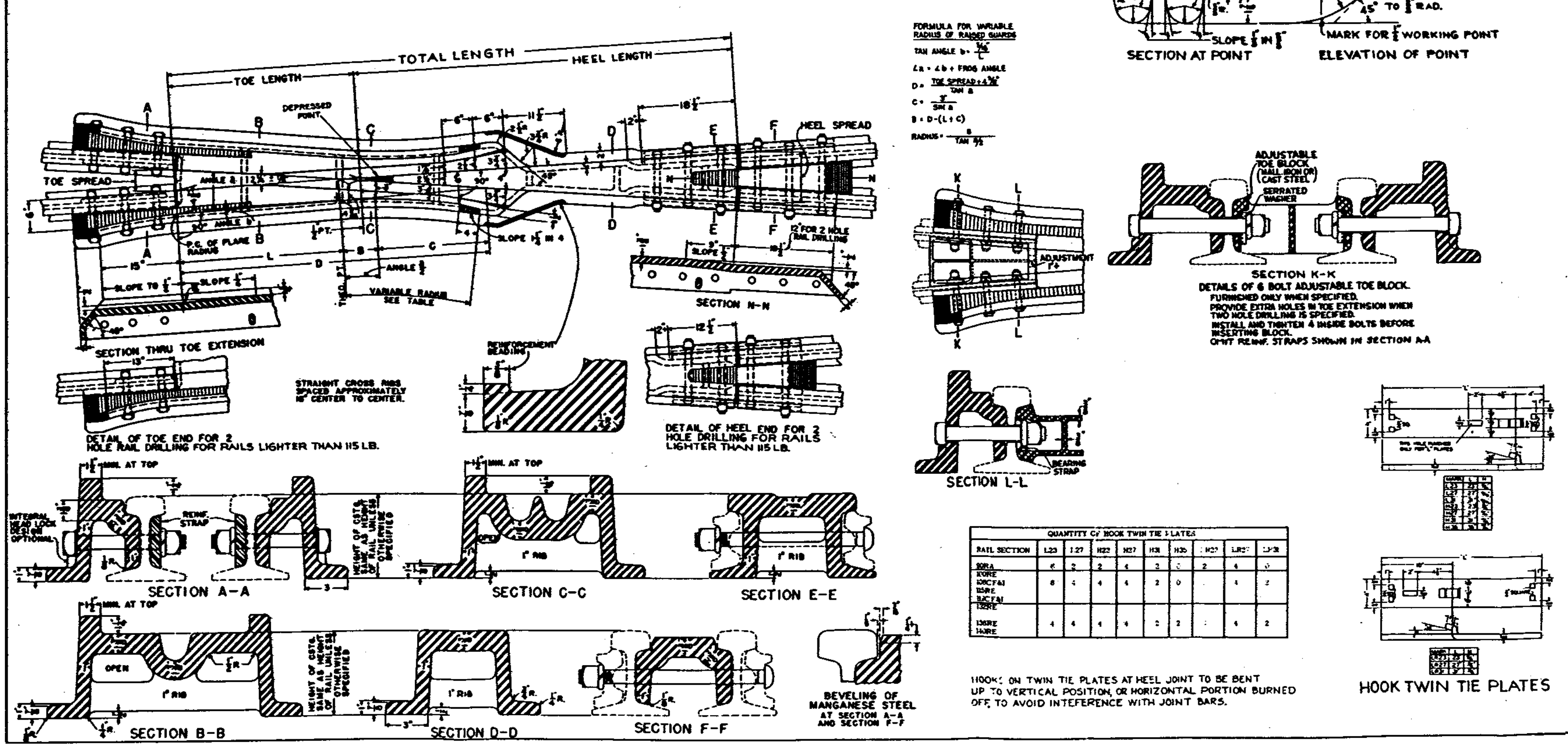
DIMENSIONS OF RAISED GUARDS						
RAIL SECTION	∠b	∠a	D	C	L	B
90RA	0°-40'-42"	7°-55'-52"	4'-4-1/32"	21-3/4"	23"	7-5/16"
100RE 106CF&I	0°-41'-44"	7°-53'-54"	4'-5-5/32"	21-27/32"	2'-0"	7-11/32"
115RE 119CF&I 132RE 136RE 140RE	0°-34'-40"	7°-43'-50"	5'-0-25/32"	22-5/16"	2'-7"	7-15/32"

RAIL SECTION	TOE LENGTH	HEEL LENGTH	TOTAL LENGTH	VAR. RADIUS	TOE SPREAD	HEEL SPREAD
90RA	2'-3"	5'-0"	7'-3"	8'-9"	2-7/8"	8"
100RE 106CF&I	2'-4"	5'-3"	7'-7"	8'-10"	3"	8-3/8"
115RE 119CF&I 132RE 136RE 140RE	2'-11"	6'-0"	8'-11"	9'-2"	3-7/8"	9-1/2"

NOTES

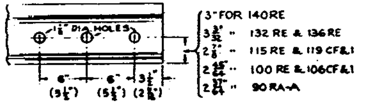
1—This plan is for use with AREA recommended standard rail sections and drilling from 90 RA-A to and including 140 RE rails. Purchaser shall specify rail section and whether 4 or 6 hole joint drilling is required.

2—Workmanship and materials shall be per current AREA specifications.



QUANTITY OF HOOK TWIN TIE PLATES									
RAIL SECTION	L23	L27	H22	H27	H31	H35	[illegible]	[illegible]	[illegible]
90RA	6	2	2	4	2	[illegible]	2	4	[illegible]
100RE 106CF&I 115RE 119CF&I	8	4	4	4	2	0	[illegible]	4	2
132RE 136RE 140RE	4	4	4	4	2	2	[illegible]	4	2

HOOKS ON TWIN TIE PLATES AT HEEL JOINT TO BE BENT UP TO VERTICAL POSITION, OR HORIZONTAL PORTION BURNED OFF TO AVOID INTEFERENCE WITH JOINT BARS.



RAIL END DRILLINGS

Courtesy of

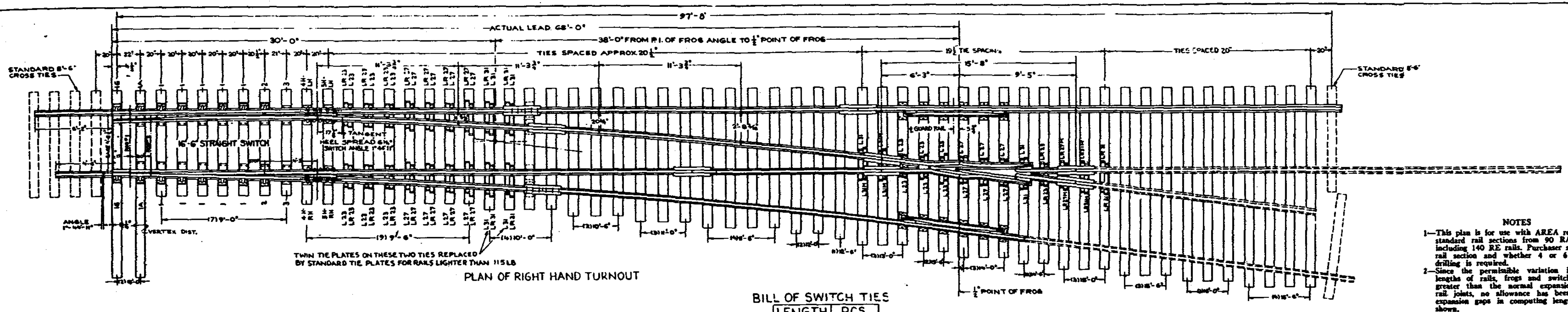
American Railway Engineering Association

NO. 8 SOLID SELF-GUARDED MANGANESE STEEL FROG

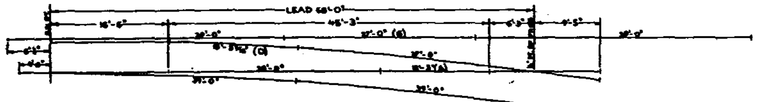
PLAN NO. 8-62 SHEET 4

Adopted March 1962.

Figure 3-48



PLAN OF RIGHT HAND TURNOUT



TYPICAL RAIL LAYOUT DIAGRAM

(SEE TABULATED VARIATIONS IN LENGTHS OF RAILS (A),(D) & (G) WHEN SELF GUARDED MANGANESE FROG IS USED INSTEAD OF RAILBOUND MANGANESE FROG.)

TURNOUT DATA (FOR RAILBOUND FROG)		
FROG	NUMBER	8
	ANGLE	7°-09'-10"
	TOE LENGTH	6'-3"
	HEEL LENGTH	9'-5"
	TOTAL LENGTH	15'-8"
	TOE SPREAD	8 5/16"
	HEEL SPREAD	14 3/4"
SWITCH	THICKNESS OF POINT	1/4"
	LENGTH OF SWITCH POINT	16'-6"
	SWITCH ANGLE	1°-44'-11"
	HEEL SPREAD	6 1/4"
ACTUAL LEAD		68'-0"
STRAIGHT CLOSURE RAIL LENGTH		45'-3"
CURVED CLOSURE RAIL LENGTH		45'-5 7/16"
CENTERLINE RADIUS		462.73'
DEGREE OF CURVE		12° 24' 23"
TANGENT ADJACENT-HEEL OF SWITCH		17 7/8"
TANGENT ADJACENT-TOE OF FROG		—

BILL OF SWITCH TIES

LENGTH	PCS.
9'-0"	7
9'-6"	9
10'-0"	4
10'-6"	3
11'-0"	3
11'-6"	4
12'-0"	2
12'-6"	1
13'-0"	3
13'-6"	2
14'-0"	3
14'-6"	2
15'-0"	5
15'-6"	3
16'-0"	3
16'-6"	4
TOTAL NO.	58
BOARD MEAS.	3717
TRACK LENGTH REPLACED BY SWITCH TIES	97'-8"

1. LENGTH OF SWITCH TIES ARE BASED ON 8'-6" CROSS TIES

2. BOARD MEASURE GIVEN IS BASED ON 7"x9" SWITCH TIES

BILL OF TRACK MATERIAL

QUANTITY	DESCRIPTION
1	16'-6" NON-INSULATED STRAIGHT SWITCH COMPLETE PER SHEET 2
1	NO. 8 MANGANESE FROG COMPLETE (RAILBOUND, PER SH. 3. OR SELF GUARDED, PER SH. 4)
2	GUARD RAILS (8'-4 1/2" ONE PIECE MANGANESE OR 9'-5" TEE RAIL) COMPLETE PER SHEET 3 (OMIT WHEN SELF-GUARDED FROGS ARE SPECIFIED)
1	39'-0" STRAIGHT STOCK RAIL PER SHEET 2
1	39'-0" BENT STOCK RAIL PER SHEET 2
2 *	39'-0" RAILS
1	30'-0" RAIL
2	27'-0" RAILS (G) (ONE RAIL ONLY TO VARY IN LENGTH)
1	18'-5 7/16" RAIL (D)
1	15'-3" RAIL (A)
9 *	STANDARD JOINTS COMPLETE
114 *	TIE PLATES
3 *	KEGS OF TRACK SPIKES
1 *	SET OF SWITCH TIES

* THIS MATERIAL NOT FURNISHED BY TRACKWORK MANUFACTURER UNLESS OTHERWISE SPECIFIED

RAIL LENGTH VARIATIONS WHEN SELF-GUARDED FROGS ARE SPECIFIED			
RAIL SECTION	RAIL (A)	RAIL (D)	RAIL (G)
90RA	18'-3"	22'-5-7/16"	22'-7"
100RE 100CT&I	18'-2"	22'-4-7/16"	22'-10"
[illegible] 115RE 132RE 135RE 140RE	18'-7"	21'-9-7/16"	23'-7"

NOTES

1—This plan is for use with AREA recommended standard rail sections from 90 RA-A to and including 140 RE rails. Purchaser shall specify rail section and whether 4 or 6 hole joint drilling is required.

2—Since the permissible variation in standard lengths of rails, frogs and switch points is greater than the normal expansion gaps at rail joints, no allowance has been made for expansion gaps in computing lengths of rails shown.

3—Bill of material includes only track material and does not list any material for operating the switch.

4—Purchaser shall specify type of guard rail and frog wanted.

5—Workmanship and materials, including beveling and hardening rail ends, shall be per current AREA specifications.

Courtesy of

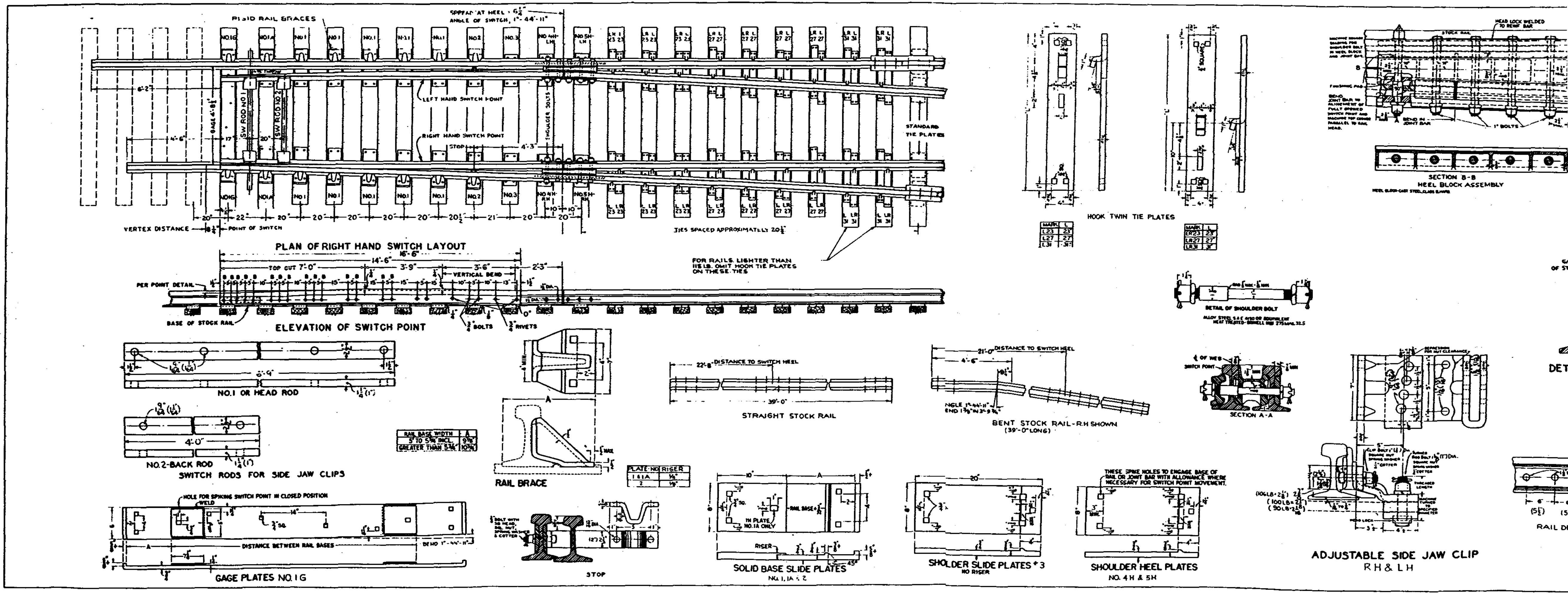
American Railway Engineering Association

NO. 8 TURNOUT

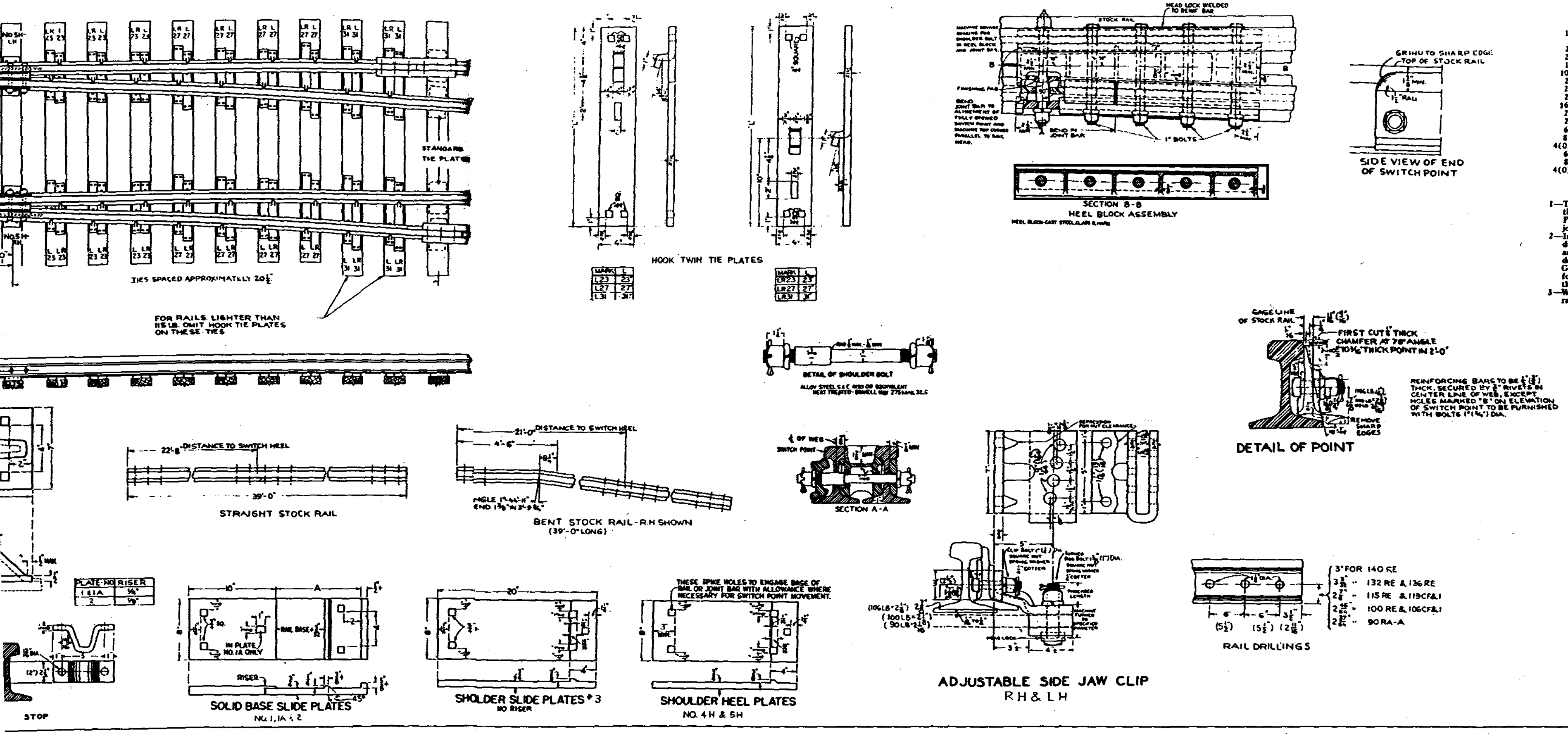
PLAN NO. 8-71 SHEET 1

Adopted March 1971. Revision of Plan No. 8-62 Sheet 1

Figure 3-49



Adopted March 1962.



BILL OF MATERIAL
16' 6" NON-INSULATED STRAIGHT SPLIT SWITCH

1 Pair 16' 6" switch points complete with reinforcing bars, clips and stops attached.
2 Non-insulated switch rods.
2 Heel block assemblies complete.
1 No. 1G non-insulated gage plate.
10 No. 1 solid base slide plates.
2 No. 1-A solid base slide plates.
2 No. 2 solid base slide plates.
2 No. 3 shoulder slide plates.
16 Rigid rail braces.
2 No. 4H heel plates (1 R.H. & 1 L.H.)
2 No. 5H heel plates (1 R.H. & 1 L.H.)
6 L23 hook twin tie plates.
8 L27 hook twin tie plates.
4(0) L31 hook twin tie plates.
6 LR23 hook twin tie plates.
8 L27 hook twin tie plates.
4(0) LR31 hook twin tie plates.

NOTES

1—This plan is for use with AREA recommended standard rail sections and drillings from 90 RA-A to and including 140 RE rails. Purchaser shall specify rail section and whether 4 or 6 hole joint drilling is required.

2—In the interest of standardization, above standard rail sections are divided into two groups of rails, namely: A, for rails 115 lb and heavier and B, for rails lighter than 115 lb. This plan is drawn on basis of Group A and when the detail dimensions for Group B are different than shown for Group A, the dimension for Group B is shown in parenthesis either below or following the Group A dimension.

3—Workmanship and materials, including beveling and hardening rail ends, shall be per current AREA specifications.

Courtesy of

American Railway Engineering Association

16'-6" STRAIGHT SPLIT SWITCH NON-INSULATED

PLAN NO. 8-62 SHEET 2

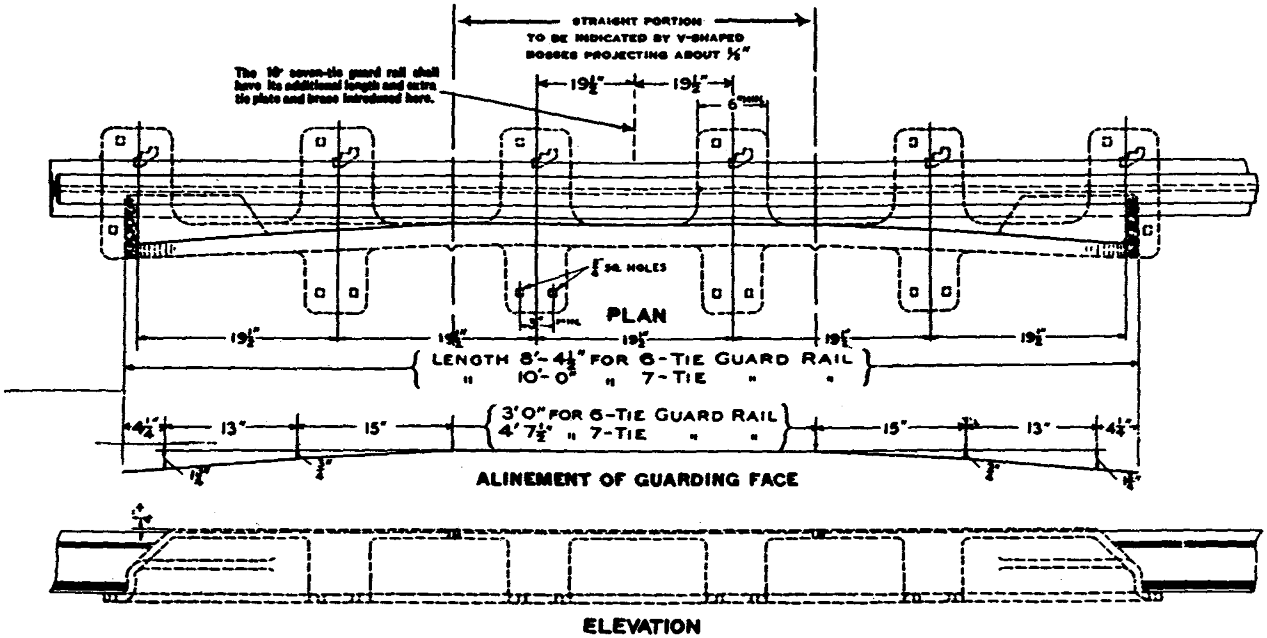
Figure 3-56

NOTES

1.—Broken lines are not intended to indicate design of braces and body of guard rail, as same are subject to variation.

2.—The 8'-4½" One-Piece Six-Tie Guard Rail has been designed especially for use with rigid frogs up to and including No. 14.

The 10'-0" One-Piece Seven-Tie Guard Rail has been designed especially for use with rigid frogs over No. 14, and for locations where this length will more fully meet requirements than the 8'-4½" length.



SPECIFICATIONS

1.—**GUARDING FACE**—The alinement shall be straight in center of guard rail and the flare on each end shall be preferably a double bend, consisting of two straight portions, in order to give the smallest practicable angle of contact for the wheel flange. The Guarding Face shall have a minimum depth, exclusive of top and bottom fillet, of ¾" throughout its length. The radius at top of guarding faces shall be approximately ⅜".

2.—**HEIGHT**—Guard rails approximately ¼" higher than running rail are recommended where conditions will permit, but height should be not more than 1" above top of running rail.

3.—**PLATES**—The tie plates shall be integral with the guard rail, have a minimum width of 6" (7½" width recommended), a minimum thickness of 11/16" and shall be spaced on 19½" centers. Each plate shall have two spike holes outside of rail. One hole shall be ¾" square, located so spike head will clear base of rail, and the other hole shall be staggered to provide three or more positions for spiking, so as to allow leeway for gaging guard rail with frog, re-spiking when worn, and use with two or more sections of rail if desired.

4.—**BRACES**—Braces shall be integral with guard rail, located for the four intermediate ties, shall be of sufficient length, have ample bearing on ties, and be adequately designed to prevent overturning of guard rail. Each brace shall have two spike holes or spike notches ¾" square spaced not less than 3" centers. The principal member of braces shall have a minimum thickness of ½".

5.—**WALLS**—The walls shall have a minimum thickness of ½".

6.—**REINFORCING**—The guard rail shall be suitably reinforced so as to effectively resist bending between the braces.

7.—**FOOT GUARDS**—Foot guards cast integral with guard rail are recommended, but separate foot guards of approved design, attached to guard rail or running rail, may be used.

8.—**MARKING**—The manufacturer's name or trade mark, the year cast and height of guard rail shall be legibly indicated by raised letters, on a portion of the body of the casting that is not subject to wheel wear.

9.—**SETTING**—One-Piece Guard Rails are suitable for use with rigid frogs, and to guide the wheels when passing through the spring flangeway of spring rail frogs and must be installed with not less than 2" of the straight portion of the guarding face of the Guard Rail back of the ½" point of frog, and a *minimum* length of the straight guarding face in advance of the ½" point of frog as shown in the following table:

Frog Number	*Minimum* Length of Straight Guarding Face in Advance of ½ Inch Point
20, 18	30"
16	26"
15	24"
14, 12	18"
11	16"
10, 9, 8, 7, 6	14"
5, 4	12"

Wheels passing through the rigid flangeway of spring rail frogs should be protected by the straight portion of the guarding face of the guard rail, from the ½" point for two-thirds of the toe length of the spring rail. For width of flangeway and guard face gage see Plan Basic No. 790.

FOR GENERAL SPECIFICATIONS SEE APPENDIX "A"

ALTERNATES

GUARDING FACE—Curved flares of approved alinement.

LENGTH AND PLATE SPACING—Tie plates to be spaced 19½" centers plus or minus ½" (19" minimum or 20" maximum) modifying overall guard rail length accordingly.

CANTED PLATES—Plates to be canted under running rail.

Courtesy of

American Railway Engineering Association

MANGANESE STEEL

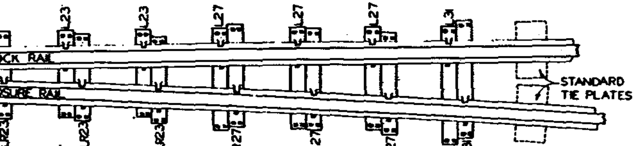
ONE PIECE GUARD RAIL

Length 8'-4½" for Installation on 6 Ties
Length 10'-0" for Installation on 7 Ties

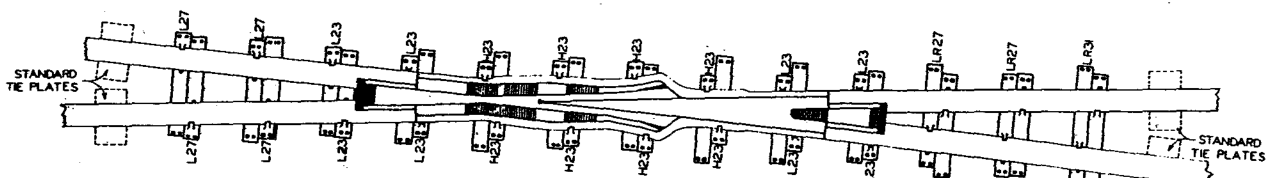
PLAN NO. 510-40

Adopted March, 1940. Supersedes Plan No. 510, Revised March, 1934.

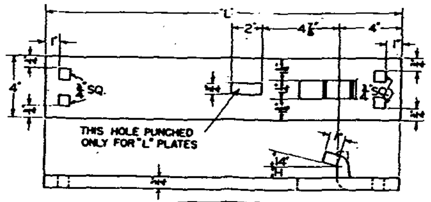
Figure 3-60



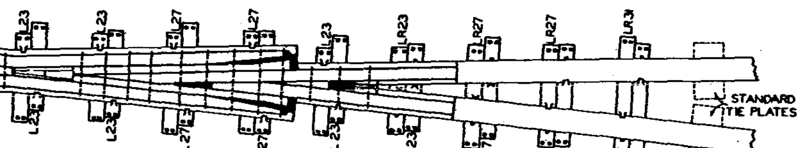
TH GRADUATED RISERS



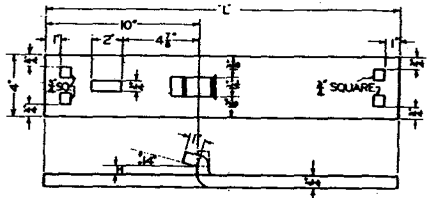
SOLID MANGANESE STEEL FROG



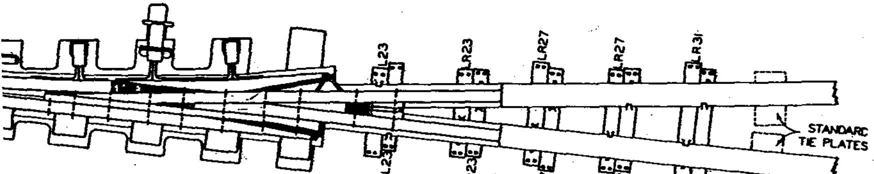
MARK	L	H
L23	23"	[illegible]
L27	27"	[illegible]
L31	31"	[illegible]
H23	23"	[illegible]
H27	27"	[illegible]
H31	31"	[illegible]
H35	35"	[illegible]



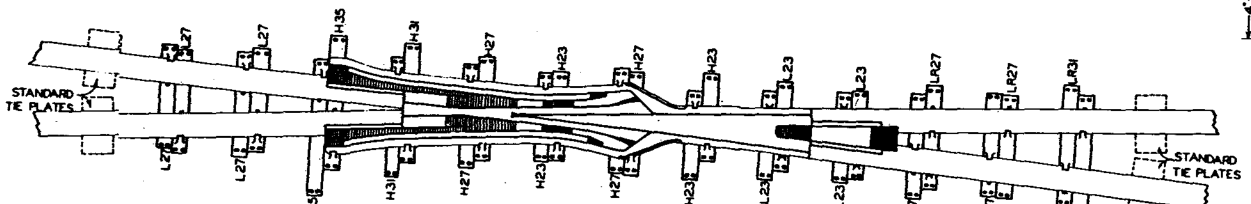
GID BOLTED FROG



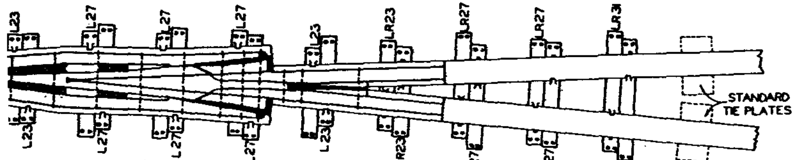
MARK	L	H
LR23	23"	[illegible]
LR27	27"	[illegible]
LR31	31"	[illegible]



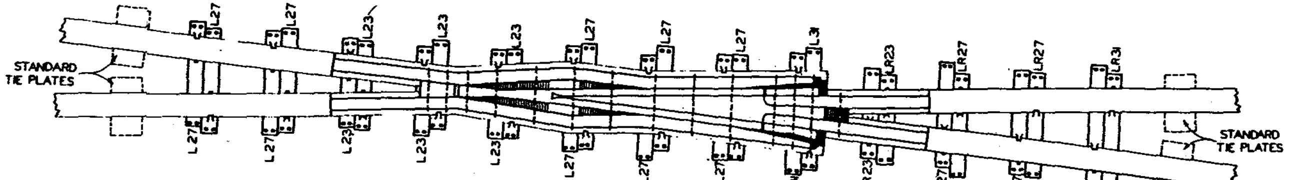
SPRING RAIL FROG



SOLID MANGANESE STEEL SELF GUARDED FROG



ND MANGANESE STEEL FROG



RAIL BOUND MANGANESE STEEL FROGS
FOR RAILS 112 LB. AND HEAVIER

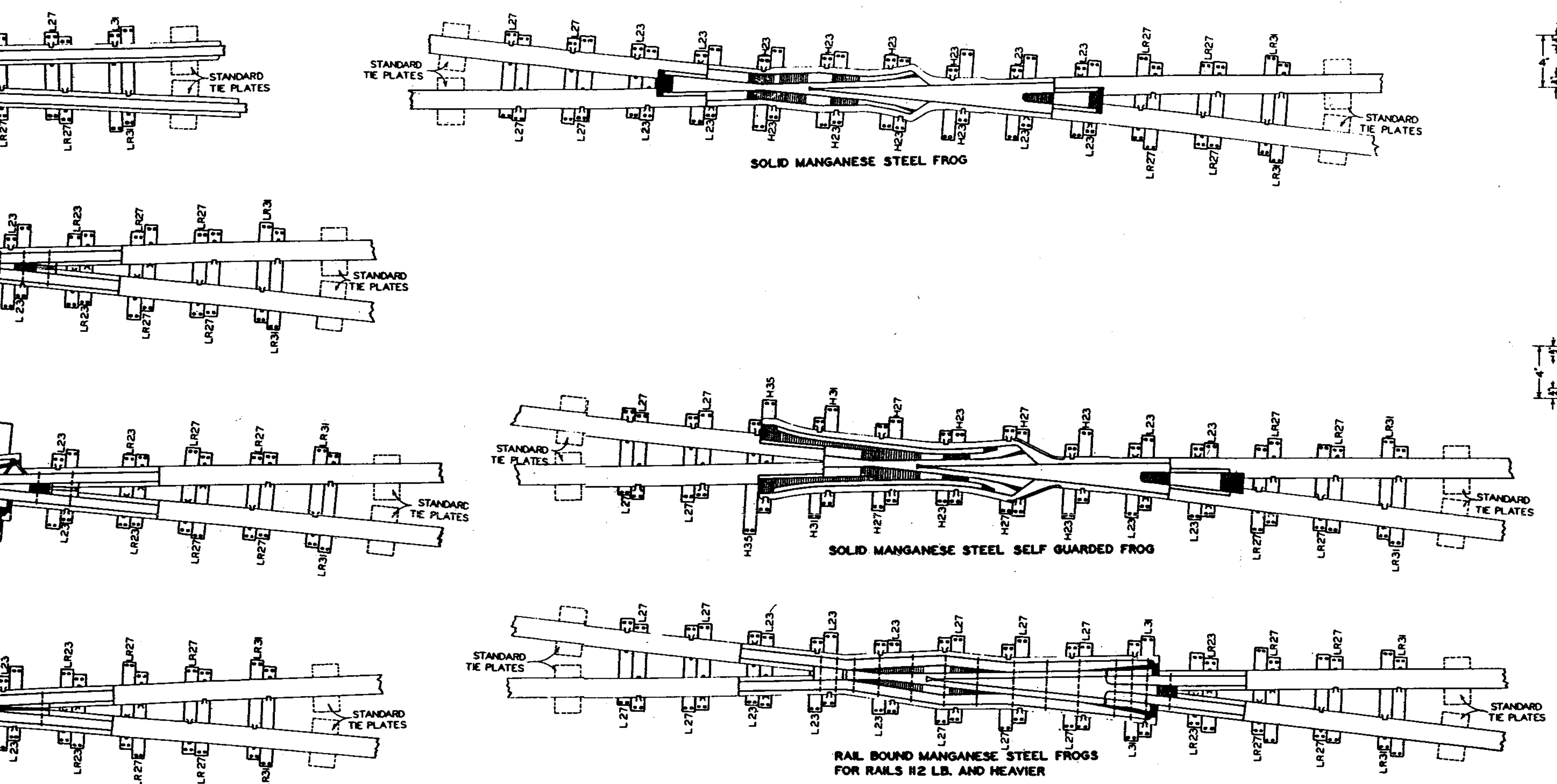
1—Hook

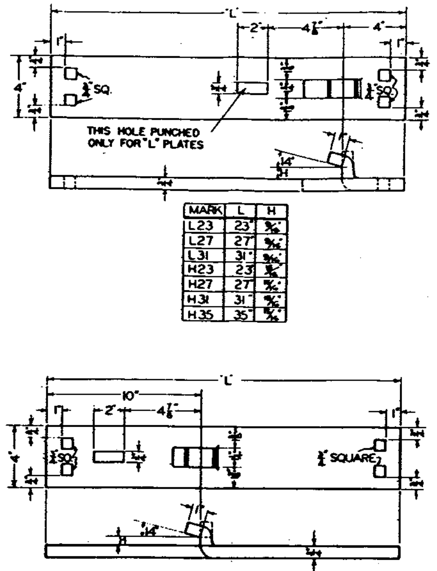
2—Quant

3—SPECI

American R

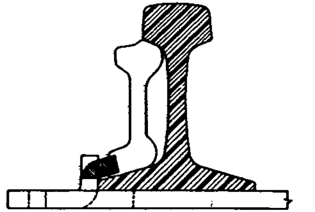
DETAILS A
OF H





MARK	L	H
L23	23"	[illegible]
L27	27"	[illegible]
L31	31"	[illegible]
H23	23"	[illegible]
H27	27"	[illegible]
H31	31"	[illegible]
H35	35"	[illegible]

MARK	L	H
LR23	23"	[illegible]
LR27	27"	[illegible]
LR31	31"	[illegible]



WHERE HOOK ON TIE PLATE INTERFERES WITH SPLICE BAR, BEND HOOK UP TO VERTICAL POSITION OR BURN HOOK OFF AS SHOWN BY SHADING

NOTES

1—Hook Twin Tie Plates shown on this plan are universal and shall be applied as indicated with frogs and graduated riser switches at all locations where special plates are not required and where standard tie plates cannot be used without cutting.

2—Quantities: See plans of frogs and plans of switches with graduated risers for the quantity of hook twin tie plates to be furnished with each unit.

Alternate—The distance (4⅞") to the elongated spike hole and the length of this hole (2") shown on hook twin tie plates marked LR-23, LR-27, and LR-31 to be modified as specified to suit various rail sections used by purchaser.

3—SPECIFICATIONS—See Appendix "A".

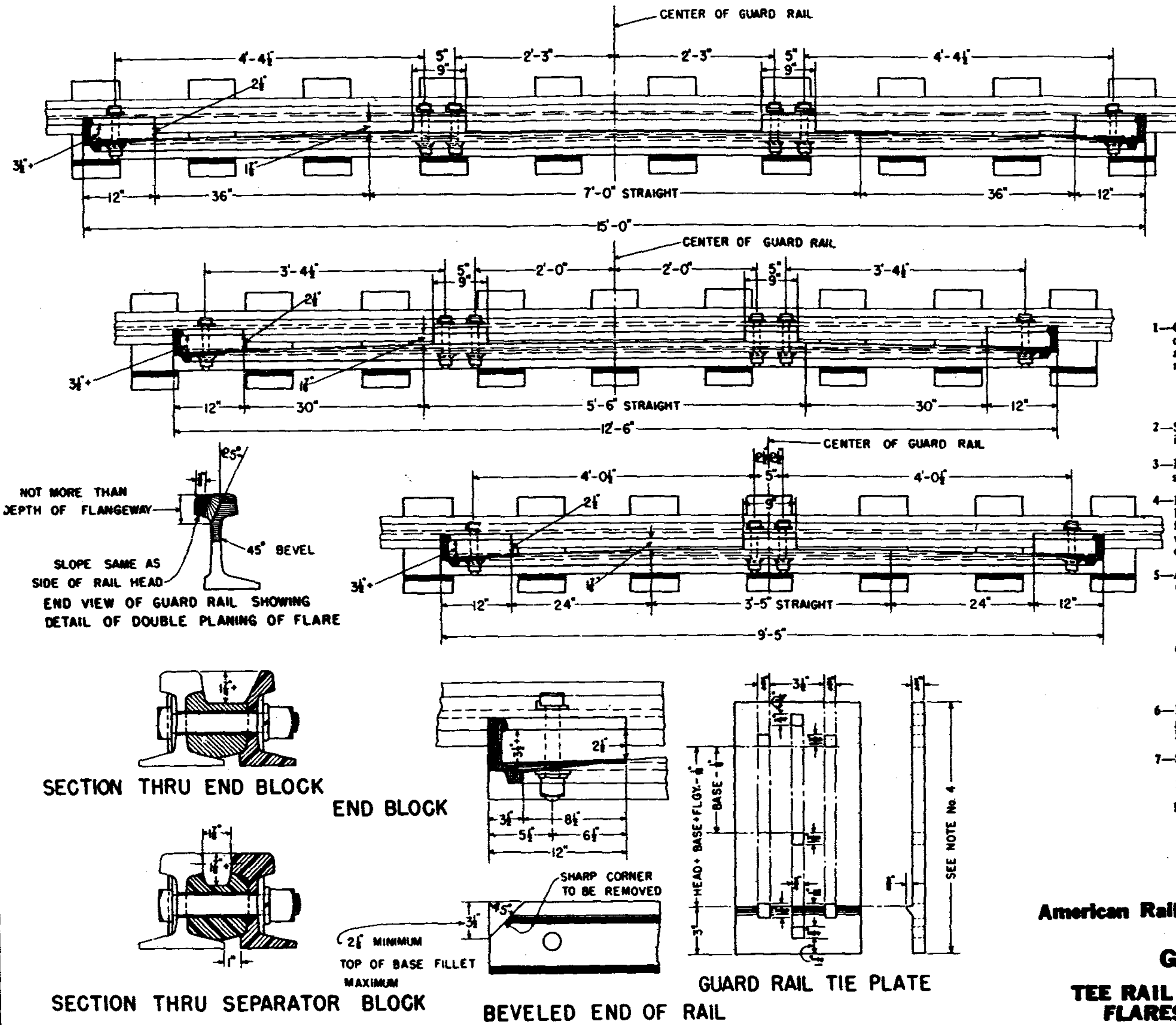
Courtesy of

American Railway Engineering Association

DETAILS AND TYPICAL APPLICATIONS OF HOOK TWIN TIE PLATES

PLAN NO. 241-55

Figure 3-59



NOTES

1—GUARD RAILS shall be furnished to length called for and, unless otherwise specified, with accessories as illustrated in plan views and per notes below as follows:
   Separator blocks and bolts per Note No. 2
   End blocks and bolts per Note No. 3
   Tie plates per Note No. 4

2—SEPARATOR BLOCKS may be of steel, cast iron or malleable iron, of suitable design.

3—END BLOCKS may be of cast iron as shown, steel or malleable iron, of suitable design.

4—PLATES—Shall be 7" x ¾" x 16" for rails less than 100 lb. per yd., and 8" x ¾" x 17" for rails 100 lb. per yd. and heavier, except when combined width of head and base exceeds 8⅝", plates shall be 18" long.

5—ALTERNATES.
(a) CLAMP GUARD RAILS—Clamps per Plan Basic No. 505 may be used instead of separator blocks and bolts in approximately the same locations, and shall be furnished when specified.
(b) RAIL BRACES—Approved type of guard rail braces to be furnished when required; purchaser shall specify details and state on which plates they are to be used.

6—For setting of guard rails, width of flangeway, guard check gage and guard face gage, see Plans Basic No. 502 and 790.

7—SPECIFICATIONS—See Appendix "A".
Bolt sizes and details shall be per Section 1402, Appendix "A".
Spike hole details not otherwise shown to be per Section 40, Appendix "A".

Courtesy of

American Railway Engineering Association

GUARD RAILS

TEE RAIL DESIGN WITH PLANED FLARES AND FLAT PLATES

PLAN NO. 504-71

Adopted March 1971. Revision of Plan No. 504-55.

Figure 3-6

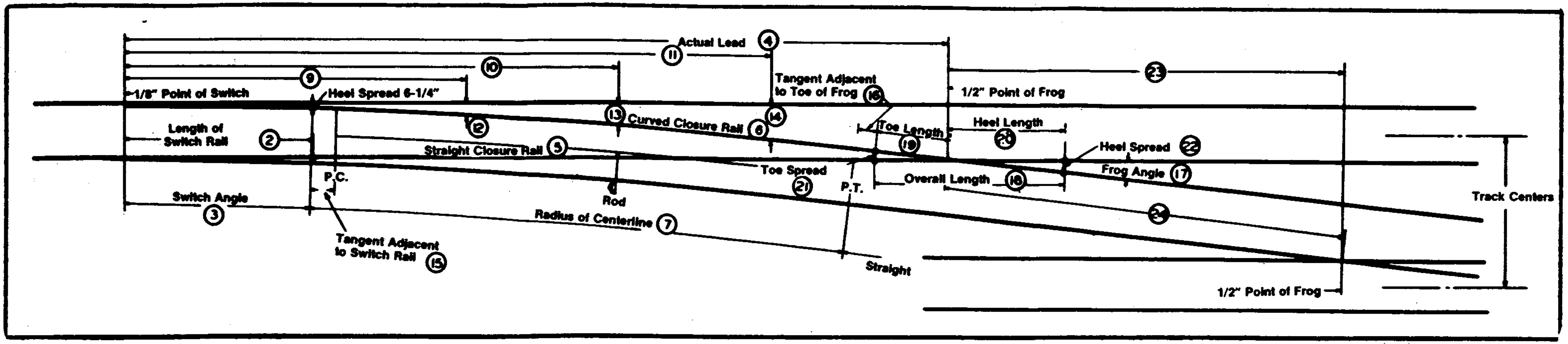


Figure D-1. Diagram of turnout (numbers in circles correspond with Table D-1).

Table D-1. Turnout and Crossover Data for Straight Split Switches

(1) Frog No.	(2) Properties of Switches: Length of Switch Rail ft	(2) in.	(3) Switch Angle deg	min	sec	(4) Actual Lead ft	in.	(5) Closure Distance: Straight Closure Rail ft	in.	(6) Curved Closure Rail ft	in.	(7) Lead Curve: Radius of Centerline ft	(8) Degree of Curve deg	min	sec	(9) Gage Line Offsets ft	in.	(10) ft	in.	(11) ft	in.	(12) in.	(13) in.	(14) ft	in.
5	11	0	2	39	34	42	6-1/2	28	0	28	4	177.80	32	39	56	18	0	25	0	32	0	11-13/16	20-5/8	2	8-7/8
6	11	0	2	39	34	47	6	32	9	33	0	258.57	22	17	58	19	2-1/4	27	4-1/2	35	6-3/4	12-3/8	21-5/8	2	10
7	16	6	1	46	22	62	1	40	10-1/2	41	1-1/4	365.59	15	43	16	26	2-1/4	35	10-1/2	45	6-3/4	11-3/8	19-9/16	2	6-7/8
8	16	6	1	46	22	68	0	46	5	46	7-1/2	487.28	11	46	44	27	7-1/4	38	8-1/2	49	9-3/4	11-7/8	20-9/16	2	8-5/16
9	16	6	1	46	22	72	3-1/2	49	5	49	7-1/4	615.12	9	19	30	28	10-1/4	41	2-1/2	53	6-3/4	12-5/16	21-3/8	2	9-7/16
10	16	6	1	46	22	78	9	55	10	56	0	779.39	7	21	24	29	11-3/4	43	5-1/2	56	11-1/4	12-1/4	21	2	8-5/8
11	22	0	1	19	46	91	10-1/4	62	10-1/4	63	0	927.27	6	10	56	37	8-1/2	53	5	69	1-1/2	12-1/4	21-3/8	2	9-3/4
12	22	0	1	19	46	96	8	66	10-1/2	67	0	1104.63	5	11	20	38	8-1/2	55	5	72	1-1/2	12-7/16	21-5/8	2	9-7/8
14	22	0	1	19	46	107	0-3/4	76	5-1/4	76	6-3/4	1581.20	3	37	28	41	1-1/4	60	2-1/2	79	3-3/4	12-7/8	22-5/16	2	10-1/2
15	30	0	0	58	30	126	4-1/2	86	11-1/2	87	0-3/4	1720.77	3	19	48	51	9	73	6	95	3	12-1/8	21-1/4	2	9-3/4
16	30	0	0	58	30	131	4	91	11	92	0	2007.12	2	51	18	53	0	76	0	99	0	12-7/16	21-13/16	2	10-5/16
18	30	0	0	58	30	140	11-1/2	99	11	100	0	2578.79	2	13	20	55	0	80	0	105	0	12-3/4	22-1/8	2	10-7/8
20	30	0	0	58	30	151	11-1/2	110	11	111	0	3289.29	1	44	32	57	9	85	6	113	3	13-1/16	22-11/16	2	11-3/16

(1) Frog No.	(15) Tangent Adjacent to Switch Rail ft	(16) Tangent Adjacent to Toe of Frog ft	(17) Properties of Frogs: Frog Angle deg	min	sec	(18) Overall Length ft	in.	(19) Toe Length ft	in.	(20) Heel Length ft	in.	(21) Toe Spread in.	(22) Heel Spread in.	Data for Crossovers, 13 ft-0 in. Track Centers: (23) Straight Track ft	in.	(24) Crossover Track ft	in.	For Change of 1 ft-0 in. in Track Centers: Straight Track ft	in.	Crossover Track ft	in.
5	0.00	0.78	11	25	16	9	0	3	6-1/2	5	5-1/2	7-15/16	13-9/16	16	10-5/16	18	1-7/8	4	11-7/16	5	0-5/8
6	0.00	1.75	9	31	38	10	0	3	9	6	3	7	13	20	5-1/2	21	6-1/2	5	11-1/2	6	0-1/2
7	0.01	0.00	8	10	16	12	0	4	8-1/2	7	3-1/2	7-9/16	13	24	0-3/8	24	11-5/8	6	11-9/16	7	0-7/16
8	0.64	0.00	7	09	10	13	0	5	1	7	11	7-1/8	12-3/8	27	7-1/8	28	4-7/8	7	11-5/8	8	0-3/8
9	0.00	0.17	6	21	35	16	0	6	4-1/2	9	7-1/2	8	13-5/16	31	1-5/8	31	10-3/8	8	11-11/16	9	0-5/16
10	2.08	0.00	5	43	29	16	6	6	5	10	1	7-3/16	12-5/8	34	8-1/8	35	3-7/8	9	11-11/16	10	0-5/16
11	0.00	0.13	5	12	18	18	8-1/2	7	0	11	8-1/2	7-1/8	13-1/4	38	2-1/2	38	9-1/2	10	11-3/4	11	0-1/4
12	0.00	0.50	4	46	19	20	4	7	9-1/2	12	6-1/2	7-5/16	13-1/16	41	8-3/4	42	3-1/4	11	11-3/4	12	0-1/4
14	0.24	0.00	4	05	27	23	7	8	7-1/2	14	11-1/2	6-7/8	13-5/16	48	9-1/4	49	2-13/16	13	11-13/16	14	0-1/4
15	1.56	0.00	3	49	06	24	4-1/2	9	5	14	11-1/2	7	12-7/16	52	3-7/16	52	8-5/8	14	11-13/16	15	0-3/16
16	0.66	0.00	3	34	47	26	0	9	5	16	7	6-9/16	12-15/16	55	9-5/8	56	2-1/2	15	11-13/16	16	0-3/16
18	0.57	0.00	3	10	56	29	3	11	0-1/2	18	2-1/2	6-7/8	12-5/8	62	9-7/8	63	2-3/16	17	11-13/16	18	0-3/16
20	2.47	0.00	2	51	51	30	10-1/2	11	0-1/2	19	10	6-1/8	12-3/8	69	10	70	2	19	11-7/8	20	0-1/8

NOTE: Recommended turnouts and crossovers. Data shown are computed for turnouts out of straight standard 4-foot 8-1/2-inch gage track. If wheelbase of equipment used requires wider gage for switch alignment or curvature shown, maintain lead and alignment of curved closure rail and move inside stock and curved rails out the required amount. Increase gage of straight track through switch, and bend the straight closure rail to true alignment ahead of toe of frog.

Frog designs. For short spring-rail type frogs, lengthen the straight closure to conform; for solid manganese frogs, lengthen the straight and curved closures.

FROG LENGTHS

WHEEL RISER DIMENSIONS: FROG NO.	R^1	R^2	R^3	R^4
4	11"	0"	2"	4"
5	13¾"	0"	2½"	5"
6	16½"	0"	3"	6"
7	18"	1½"	3½"	7"
8	18"	4"	4"	8"
9	20¼"	4½"	4½"	9"
10	22½"	5"	5"	10"

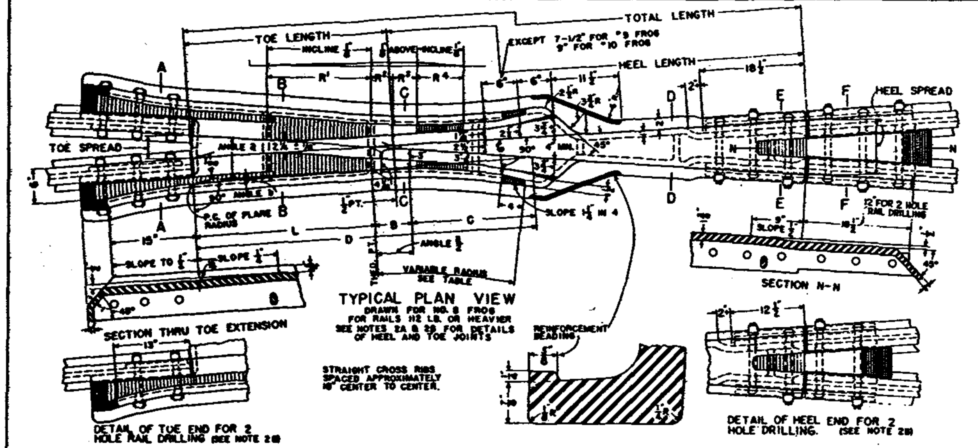
FROG NO.	GROUP A RAILS: TOTAL LENGTH	TOE LENGTH	HEEL LENGTH	VAR. RADIUS	GROUP B RAILS: TOTAL LENGTH	TOE LENGTH	HEEL LENGTH	VAR. RADIUS
4	5'-1"	15"	3'-10"	23"	5'-1"	15"	3'-10"	23"
5	5'-6"	18"	4'-0"	3'-2"	5'-5"	17"	4'-0"	3'-2"
6	6'-0"	22"	4'-2"	4'-10"	5'-11"	21"	4'-2"	4'-10"
7	6'-10"	2'-1"	4'-9"	6'-9"	6'-7"	2'-0"	4'-7"	6'-8"
8	7'-10"	2'-5"	5'-5"	8'-11"	7'-7"	2'-4"	5'-3"	8'-10"
9	8'-10"	2'-9"	6'-1"	11'-5"	8'-5"	2'-7"	5'-10"	11'-3"
10	9'-9"	3'-0"	6'-9"	14'-2"	9'-4"	2'-10"	6'-6"	14'-0"

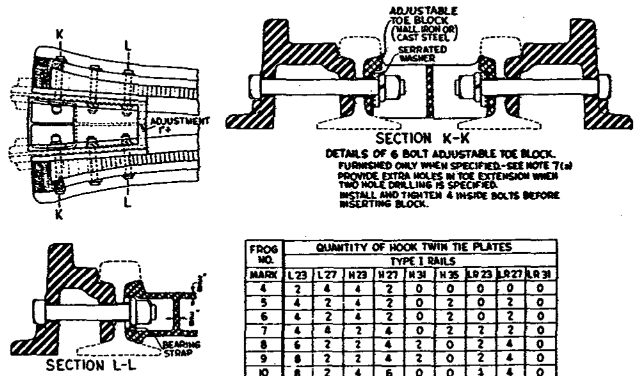
FROG NO.	GROUP C RAILS: TOTAL LENGTH	TOE LENGTH	HEEL LENGTH	VAR. RADIUS	GROUP D RAILS: TOTAL LENGTH	TOE LENGTH	HEEL LENGTH	VAR. RADIUS
4	5'-1"	15"	3'-10"	23"	5'-1"	15"	3'-10"	23"
5	5'-5"	17"	4'-0"	3'-2"	5'-5"	17"	4'-0"	3'-2"
6	5'-10"	20"	4'-2"	4'-9"	5'-10"	20"	4'-2"	4'-9"
7	6'-3"	23"	4'-4"	6'-8"	6'-2"	22"	4'-4"	6'-6"
8	7'-3"	2'-3"	5'-0"	8'-9"	6'-11"	2'-1"	4'-10"	8'-7"
9	8'-1"	2'-6"	5'-7"	11'-2"	7'-9"	2'-4"	5'-5"	11'-0"
10	8'-11"	2'-9"	6'-2"	13'-11"	8'-7"	2'-7"	6'-0"	13'-8"

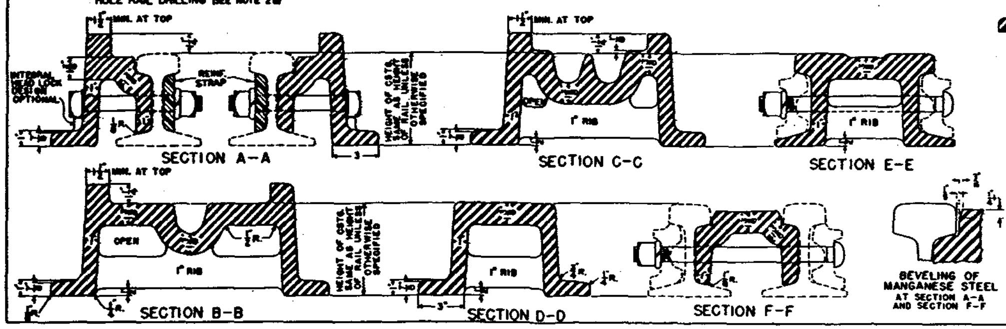
FROG NO.	RAILS 112 LB. OR HEAVIER: TOTAL LENGTH	TOE LENGTH	HEEL LENGTH	VAR. RADIUS
4	5'-11"	2'-1"	3'-10"	23"
5	6'-5"	2'-1"	4'-4"	3'-3"
6	7'-4"	2'-11"	4'-5"	5'-0"
7	8'-1½"	2'-11"	5'-2½"	7'-0"
8	8'-11"	2'-11"	6'-0"	9'-2"
9	9'-9"	2'-11"	6'-10"	11'-6"
10	11'-4½"	3'-9"	7'-7½"	14'-8"

GROUPING OF RAILS

RAILS 112 LB. OR HEAVIER	RAILS 110 LB. TO 90 LB. INCL.: GROUP A RAILS	GROUP B RAILS	GROUP C RAILS	GROUP D RAILS
LENGTHS SHOWN WILL ACCOMODATE SECTIONS SPECIFIED BELOW. FOR OTHER RAILS 112 LB. OR HEAVIER SEE NOTE 5-A	BASE 5-3/4" DOWN TO BUT NOT INCLUDING 5-1/2". HEAD 2-7/8" TO 2-5/8" INCLUSIVE. OR HEAD AT OR EXCEEDING 2-7/8" WHEN HEAD + BASE DOES NOT EXCEED 8-5/8".	BASE 5-1/2" DOWN TO BUT NOT INCLUDING 5-1/4". HEAD 2-13/16" TO 2-9/16" INCLUSIVE. OR HEAD AT OR EXCEEDING 2-13/16" WHEN HEAD + BASE DOES NOT EXCEED 8-5/16".	BASE 5-1/4" DOWN TO BUT NOT INCLUDING 5". HEAD 2-11/16" TO 2-7/16" INCLUSIVE. OR HEAD AT OR EXCEEDING 2-11/16" WHEN HEAD + BASE DOES NOT EXCEED 7-15/16".	BASE 5" DOWN TO BUT NOT INCLUDING 4-1/2". HEAD 2-11/16" TO 2-7/16" INCLUSIVE. OR HEAD AT OR EXCEEDING 2-11/16" WHEN HEAD + BASE DOES NOT EXCEED 7-11/16".
112 R.E. 112 T.R. 113 H.F.S.P. 115 R.E. 127 DUD. 129 T.R. 130 P.S. 131 R.E. 132 H.F.S.P. 132 R.E. 133 R.E. 136 L.V. 140 R.E.	100 A.S.C.E. 105 DUD.	90 A.S.C.E. 100 A.R.A.-A. 100 P.& R. 100 N.H. 100 R.E. 107 N.H. 110 R.E.	90 A.R.A.-A. 90 H.F.R.-A. 90 C.& N.W. 90 I.R.T. 100 A.R.A.-B. 100 C.& N.W.	90 A.R.A.-B. 100 P.S.







FORMULA FOR VARIABLE RADIUS OF RAISED GUARDS

$$\text{TAN. ANGLE } b = \frac{5/16''}{L}$$

$$\angle a = \angle b + \text{FROG ANGLE}$$

$$D = \frac{\text{TOE SPREAD} + 4\text{-}3/8''}{\text{TAN. } a}$$

$$C = \frac{3''}{\text{SIN. } a}$$

$$B = D - (L + C)$$

$$\text{RADIUS} = \frac{B}{\text{TAN. } a/2}$$

FROG NO. / MARK	QUANTITY OF HOOK TWIN TIE PLATES — TYPE I RAILS: L23	L27	H23	H27	H31	H35	LR23	LR27	LR31
4	2	4	4	2	0	0	0	0	0
5	4	2	4	2	0	2	0	2	0
6	4	2	4	2	0	2	0	2	0
7	4	4	2	4	0	2	2	2	0
8	6	2	2	4	2	0	2	4	0
9	8	2	2	4	2	0	2	4	0
10	8	2	4	6	0	0	3	4	0

MARK	TYPE II RAILS: L23	L27	H23	H27	H31	H35	LR23	LR27	LR31
4	2	4	4	2	0	0	0	0	0
5	4	2	4	2	0	2	0	2	0
6	4	2	4	2	0	2	0	2	2
7	4	4	2	4	0	2	2	2	2
8	6	4	4	4	2	0	0	4	2
9	6	4	4	6	0	0	2	4	2
10	6	4	6	6	2	0	2	4	2

MARK	TYPE III RAILS: L23	L27	H23	H27	H31	H35	LR23	LR27	LR31
4	2	2	4	2	0	2	0	0	0
5	4	2	4	2	0	2	0	2	0
6	4	2	4	2	2	2	0	2	2
7	4	2	4	4	2	2	0	2	2
8	4	4	4	4	2	2	0	4	2
9	4	4	6	6	2	0	0	4	2
10	6	4	6	6	2	0	2	4	2

NOTES

1—RAIL AND JOINT BARS. Purchaser shall specify weight and designation of rail section and joint drilling and shall supply complete details of joint bars.

2—DETAIL OF HEEL AND TOE JOINTS.
(a) No. 7, 8, 9 and 10 frogs for rails 112 lb. and heavier shall be designed as illustrated in main plan view for three-hole rail drilling and six-hole joint bars 36" long.
(b) Frogs other than those mentioned in 2(a) shall be designed as illustrated in cut-away views for two-hole rail drilling and four-hole joint bars 24" long.
(c) Joint bars for heel end are not furnished with frog unless called for. Purchasers joint bars if longer than specified in 2(a) or 2(b) should be cut to the lengths stated or joint bars of the required lengths called for with frogs. For proper support of the upper fishing projections shown as 18½" long joint bars at least 32" long shall be furnished with frog if purchasers standard bars are shorter than this length.
(d) TRACK BOLTS shall be furnished at heel end and square head machine bolts at toe end to suit joint bar detail specified, other details conforming to Section 1402, Appendix "A".

3—PLATES. Hook twin tie plates as listed in table shall be furnished with frogs unless otherwise specified. For details and applications of these plates see Plan Basic No. 241. Quantities shown are based on 19½" tie spacing with center of one tie 4" back of ½" point. Rails in table are classified by the following widths.
TYPE 1 RAILS. Rails having base up to 5⅛" and head 2⅝" inclusive.
TYPE 2 RAILS. Rails having base up to 5½" and head 2¾" inclusive.
TYPE 3 RAILS. Rails having base up to 6" and head 3" inclusive.

4—WIDTH OF FLANGEWAY. Flangeways up to 2" width shall be obtained by moving the guard line and modifying only the throat opening and length of flare: for flangeways wider than 2" increase flare and throat openings accordingly, but do not change the width of body or other dimensions.

5—LENGTH OF FROGS.
(a) Rails 112 lb. and heavier. Lengths in table (except No. 4) have been designed for uniform tie spacing 19½". For rail sections with width of base plus head exceeding heel spread or base minus head exceeding toe spread, longer frogs shall be specified by increasing toe and/or heel lengths, or corner of rail base removed in field.
(b) Rails lighter than 112 lb. Lengths in table provide clearance for abutting rails; those below heavy lines were determined by this requirement, those above heavy lines are minimum and were fixed by other considerations.

6—SPECIAL ANGLE FROGS. For fractional numbered frogs use lengths and data for the next smaller numbered frog; if these will not provide joint clearance, use lengths and data for the next larger numbered frog (in the required rail grouping in either case).

7—ALTERNATES AND ADDITIONAL EQUIPMENT. To be furnished as specified.
(a) Six Bolt Adjustable Toe Block with serrated washers and bearing straps, and omit reinforcing straps shown in Section A-A.
(b) WITHOUT WING WHEEL RISERS. Omit Wing Wheel Risers and crown of point and depress point as described on Plan Basic No. 600-B.
(c) WITH SQUARE END HEEL AND TOE EXTENSIONS.
(d) BASE EXTENSIONS. For additional support base flange extensions of approved design shall be provided at tie locations.
(e) HOOK TWIN TIE PLATES. For use with joint bars having toe extending beyond rail base. Type H plates of suitable length to be substituted for Type L plates at heel joint and quantities listed in table modified to agree.

8—GENERAL REFERENCES.
(a) POINT AND FLANGEWAY DIMENSIONS. See Plan Basic No. 600B for details.
(b) BEVELING OF ENDS ABUTTING RAILS. See Plan Basic No. 1005.
(c) BONDING. Per details specified by purchaser.

9—SPECIFICATIONS. See Appendix "A".

Courtesy of

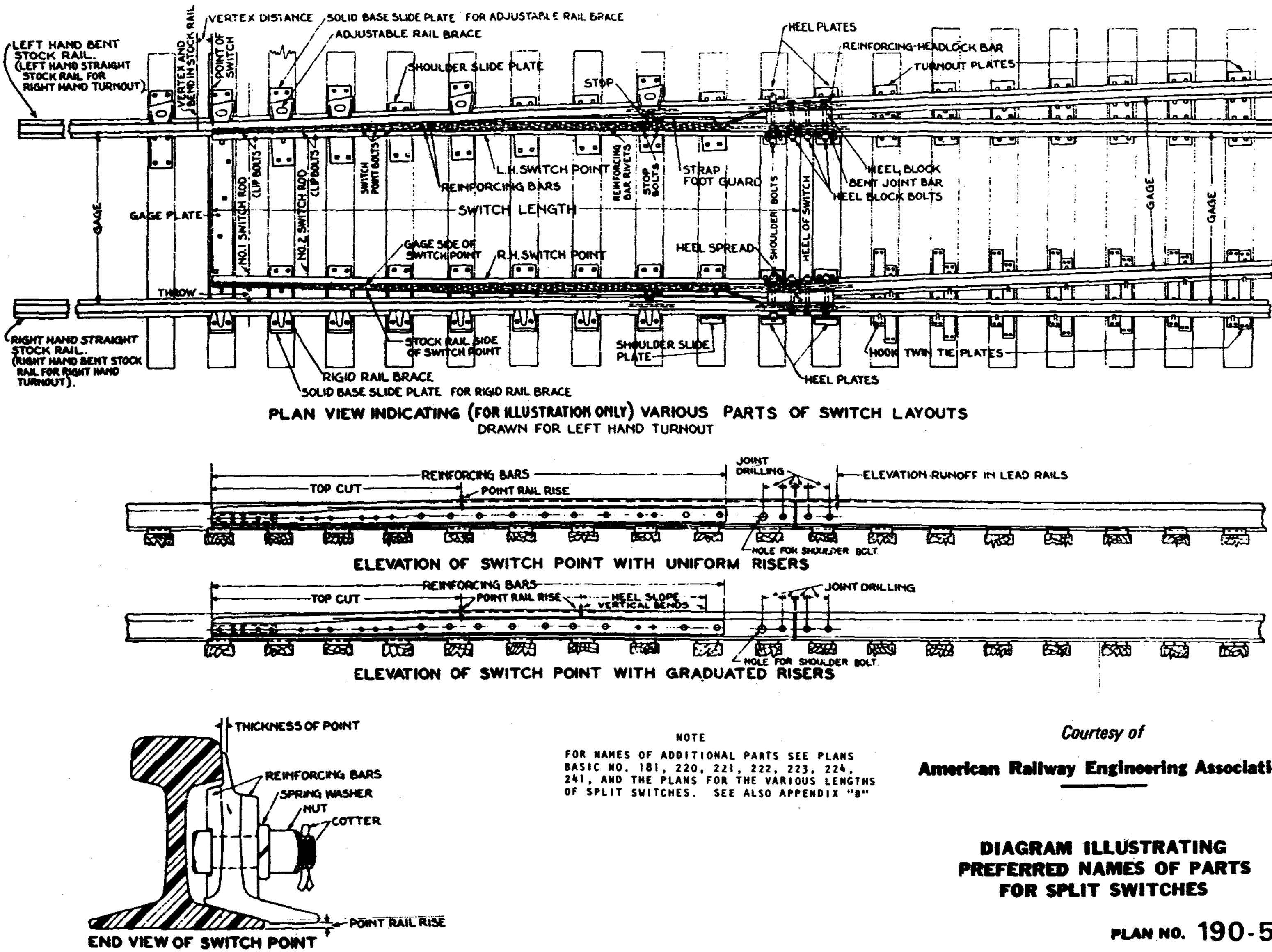
American Railway Engineering Association

SOLID MANGANESE STEEL SELF GUARDED FROGS

PLAN NO. 641-55

Adopted March 1955. Revision of Plan No. 641-51.

Figure D-5



NOTE

FOR NAMES OF ADDITIONAL PARTS SEE PLANS BASIC NO. 181, 220, 221, 222, 223, 224, 241, AND THE PLANS FOR THE VARIOUS LENGTHS OF SPLIT SWITCHES. SEE ALSO APPENDIX "B"

Courtesy of

American Railway Engineering Association

DIAGRAM ILLUSTRATING PREFERRED NAMES OF PARTS FOR SPLIT SWITCHES

PLAN NO. 190-59

Adopted March 1959. Revision of Plan No. 190-55.

Figure D-6

APPENDIX A. REFERENCES

A-1. Manuals.

TM 5-618/MO-110/ AFM 85-3.	Paints and Protective Coatings.
TM 5-624/MO-102/ AFM 85-8.	Maintenance and Repair of Surface Areas.
TM 5-622/MO-104/ AFM 91-34.	Maintenance of Waterfront Structures.
TM 5-850-2.	Engineering and Design; Railroads.
AFM 85-1.	Resources and Work Force Management.
AFM 86-1, Resources.	Programming Civil Engineering Chap. 2.
AFR 127-101.	Ground Accident Prevention Handbook
NAVFAC DM 5.	Civil Engineering; Chapter 6, Railroad Trackage, and Chapter 7, Wide Gage Portal Crane Trackage. (1)
NAVFAC DM 25.	Waterfront Operational Facilities; Chapter 1, Rail Installation Criteria. (1)
NAVFAC DM 38.	Weight Handling Equipment. (1)
NAVFAC MO-322.	Inspection of Shore Facilities. (1)
EM 385-1-1.	General Policy, Safety Office Functions, and Program Elements.

A-2. Specifications, Regulations, and Standards.

CE 804.	Guide Specification for Military Construction; Railroads. (2)
AR 420-72.	Surfaced Areas, Railroads, and Associated Structures.

(1) Available from: Defense Industrial Supply Center, Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pa. 19102.

(2) Available from: Corps of Engineers Publication Depot, 890 South Picket St., Alexandria, Va. 22304.

A-2. Specifications, Regulations, and Standards.

AR 420-10.	General Provisions, Organization, Functions, and Personnel.
MIL-R-3518C.	Rails, Tee; Railway.
MIL-R-3911B.	Rails, Tee, Railway: Relayer Rail.
MIL-R-3964A.	Bolts and Nuts; Track.
MIL-T-1129B.	Turnout; Railway (Unassembled, Complete with Low Stand Throw and Rigid bolted Frog.).
MIL-D-11302C.	Derail; Railway.
MIL-J-12368C.	Joint Bar; Rail.
MIL-STD-271.	Magnetic Particle Test.
MIL-STD-615A.	Turnouts, Railway, with Bolted Rigid Frogs.
MIL-STD-822A.	System Safety Program for Systems and Associated Subsystems and Equipment.
MM-T-371E	Tie; Railroad, Wood (Cross and Switch).
NAVFAC P-300.	Management of Transportation Equipment. (1)
NAVFAC INST 11200.1.	Maintenance Management of Weight Handling. (1)
NAVSEA/NAVFAC INST 11230.1.	Inspection, Certification, and Audit of Crane and Railroad Trackage. (1)
RPMA Guide Spec 32850-32858	Railroad and Appurtenances. (2)
TT-W-00571J	Wood Preservation: Treatment Practices.

A-3. Other.

Manual for Railway Engineering, Construction and Maintenance Section, AREA Portfolia of Trackwork Plans, American Railway Engineering Asso-

ciation, Engineering Division, 59 East Van Buren St., Chicago, Ill. 60605.

Roadmasters and Maintenance, Way Association of America, 18154 Harwood Ave., Homewood (South Chicago), Ill. 60430.

A-3. Other.

Railway Track and Structures (Monthly), P. O. Box 530, Bristol, Conn. 06010.

Manual of Uniform Traffic Control Devices for Streets and Highways, U S Department of Transportation, Federal Highway Adminstration, 400 7th St., SW, Washington, D. C. 20590.

FRA Standards, Department of Transportation, Federal Railroad Adminstration, Track Safety Standards in the Code of Federal Regulations, Title 49, Transportation, Chapter II, Federal Railroad Administration, Part 213, Track Safety Standards, Appendix B.

APPENDIX B: FEDERAL RAILROAD ADMINISTRATION TRACK SAFETY STANDARDS

PART 213—TRACK SAFETY STANDARDS

AUTHORITY: Secs. 202 and 209, 84 Stat. 971, 975 (45 U.S.C. 431 and 438) and Sec. 1.49(n) of the Regulations of the Office of the Secretary of Transportation. 49 CFR 1.49(n).

SOURCE: 36 FR 20336, Oct. 20, 1971, unless otherwise noted.

Subpart A—General

§ 213.1 Scope of part.

This part prescribes initial minimum safety requirements for railroad track that is part of the general railroad system of transportation. The requirements prescribed in this part apply to specific track conditions existing in isolation. Therefore, a combination of track conditions, none of which individually amounts to a deviation from the requirements in this part, may require remedial action to provide for safe operations over that track.

§ 213.3 Application.

(a) Except as provided in paragraphs (b) and (c) of this section, this part applies to all standard gage track in the general railroad system of transportation.

(b) This part does not apply to track—

(1) Located inside an installation which is not part of the general railroad system of transportation; or

(2) Used exclusively for rapid transit, commuter, or other short-haul passenger service in a metropolitan or suburban area.

(c) Until October 16, 1972, Subparts A, B, D (except § 213.109), E, and F of this part do not apply to track constructed or under construction before October 15, 1971. Until October 16, 1973, Subpart C and § 213.109 of Subpart D do not apply to track constructed or under construction before October 15, 1971.

§ 213.5 Responsibility of track owners.

(a) Any owner of track to which this part applies who knows or has notice that the track does not comply with the requirements of this part, shall—

(1) Bring the track into compliance; or

(2) Halt operations over that track.

(b) If an owner of track to which this part applies assigns responsibility for the track to another person (by lease or otherwise), any party to that assignment may petition the Federal Railroad Administrator to recognize the person to whom that responsibility is assigned for purposes of compliance with this part. Each petition must be in writing and include the following—

(1) The name and address of the track owner;

(2) The name and address of the person to whom responsibility is assigned (assignee);

(3) A statement of the exact relationship between the track owner and the assignee;

(4) A precise identification of the track;

(5) A statement as to the competence and ability of the assignee to carry out the duties of the track owner under this part; and

(6) A statement signed by the assignee acknowledging the assignment to him of responsibility for purposes of compliance with this part.

(c) If the Administrator is satisfied that the assignee is competent and able to carry out the duties and responsibilities of the track owner under this part, he may grant the petition subject to any conditions he deems necessary. If the Administrator grants a petition under this section, he shall so notify the owner and the assignee. After the Administrator grants a petition, he may hold the track owner or the assignee or both responsible for compliance with this part and subject to penalties under § 213.15.

§ 213.7 Designation of qualified persons to supervise certain renewals and inspect track.

(a) Each track owner to which this part applies shall designate qualified persons to supervise restorations and renewals of track under traffic conditions. Each person designated must have—

(1) At least—

(i) One year of supervisory experience in railroad track maintenance; or

(ii) A combination of supervisory experience in track maintenance and training from a course in track maintenance or from a college level educational program related to track maintenance;

(2) Demonstrated to the owner that he—

(i) Knows and understands the requirements of this part;

(ii) Can detect deviations from those requirements; and

(iii) Can prescribe appropriate remedial action to correct or safely compensate for those deviations; and

(3) Written authorization from the track owner to prescribe remedial actions to correct or safely compensate for deviations from the requirements in this part.

(b) Each track owner to which this part applies shall designate qualified persons to inspect track for defects. Each person designated must have—

(1) At least—

(i) One year of experience in railroad track inspection; or

(ii) A combination of experience in track inspection and training from a course in track inspection or from a college level educational program related to track inspection;

(2) Demonstrated to the owner that he—

(i) Knows and understands the requirements of this part;

(ii) Can detect deviations from those requirements; and

(iii) Can prescribe appropriate remedial action to correct or safely compensate for those deviations; and

(3) Written authorization from the track owner to prescribe remedial actions to correct or safely compensate for deviations from the requirements of this part, pending review by a qualified person designated under paragraph (a) of this section.

(c) With respect to designations under paragraphs (a) and (b) of this section, each track owner must maintain written records of—

(1) Each designation in effect;

(2) The basis for each designation; and

(3) Track inspections made by each designated qualified person as required by § 213.241.

These records must be kept available for inspection or copying by the Federal Railroad Administrator during regular business hours.

[36 FR 20336, Oct. 20, 1971, as amended at 38 FR 875, Jan. 5, 1973]

§ 213.9 Classes of track: operating speed limits.

(a) Except as provided in paragraphs (b) and (c) of this section and §§ 213.57(b), 213.59(a), 213.105, 213.113 (a) and (b), and 213.137 (b) and (c), the following maximum allowable operating speeds apply:

[In miles per hour]

Over track that meets all of the requirements prescribed in this part for—	The maximum allowable operating speed for freight trains is—	The maximum allowable operating speed for passenger trains is—
Class 1 track	10	15
Class 2 track	25	30
Class 3 track	40	60
Class 4 track	60	80
Class 5 track	80	90
Class 6 track	110	110

(b) If a segment of track does not meet all of the requirements for its intended class, it is reclassified to the next lowest class of track for which it does meet all of the requirements of this part. However, if it does not at least meet the requirements for class 1 track, no operations may be conducted over that segment except as provided in § 213.11.

(c) Maximum operating speed may not exceed 110 m.p.h. without prior approval of the Federal Railroad Administrator. Petitions for approval must be filed in the manner and contain the information required by § 211.11 of this chapter. Each petition must provide sufficient information concerning the performance characteristics of the track, signaling, grade crossing protection, trespasser control where appropriate, and equipment involved and also concerning maintenance and inspection practices and procedures to be followed, to establish that the proposed speed can be sustained in safety.

[36 FR 20336, Oct. 20, 1971, as amended at 38 FR 875, Jan. 5, 1973; 38 FR 23405, Aug. 30, 1973]

§ 213.11 Restoration or renewal of track under traffic conditions.

If, during a period of restoration or renewal, track is under traffic conditions and does not meet all of the requirements prescribed in this part, the work and operations on the track must be under the continuous supervision of a person designated under § 213.7(a).

§ 213.13 Measuring track not under load.

When unloaded track is measured to determine compliance with requirements of this part, the amount of rail movement, if any, that occurs while the track is loaded must be added to the measurement of the unloaded track.

[38 FR 875, Jan. 5, 1973]

§ 213.15 Civil penalty.

(a) Any owner of track to which this part applies, or any person held by the Federal Railroad Administrator to be responsible under § 213.5(c), who violates any requirement prescribed in this part is subject to a civil penalty of at least $250 but not more than $2,500.

(b) For the purpose of this section, each day a violation persists shall be treated as a separate offense.

§ 213.17 Exemptions.

(a) Any owner of track to which this part applies may petition the Federal Railroad Administrator for exemption from any or all requirements prescribed in this part.

(b) Each petition for exemption under this section must be filed in the manner and contain the information required by § 211.11 of this chapter.

(c) If the Administrator finds that an exemption is in the public interest and is consistent with railroad safety, he may grant the exemption subject to any conditions he deems necessary. Notice of each exemption granted is published in the FEDERAL REGISTER together with a statement of the reasons therefor.

Subpart B—Roadbed

§ 213.31 Scope.

This subpart prescribes minimum requirements for roadbed and areas immediately adjacent to roadbed.

§ 213.33 Drainage.

Each drainage or other water carrying facility under or immediately adjacent to the roadbed must be maintained and kept free of obstruction, to accommodate expected water flow for the area concerned.

§ 213.37 Vegetation.

Vegetation on railroad property which is on or immediately adjacent to roadbed must be controlled so that it does not—

(a) Become a fire hazard to track-carrying structures;

(b) Obstruct visibility of railroad signs and signals;

(c) Interfere with railroad employees performing normal trackside duties;

(d) Prevent proper functioning of signal and communication lines; or

(e) Prevent railroad employees from visually inspecting moving equipment from their normal duty stations.

Subpart C—Track Geometry

§ 213.51 Scope.

This subpart prescribes requirements for the gage, alinement, and surface of track, and the elevation of outer rails and speed limitations for curved track.

§ 213.53 Gage.

(a) Gage is measured between the heads of the rails at right-angles to the rails in a plane five-eighths of an inch below the top of the rail head.

(b) Gage must be within the limits prescribed in the following table:

Class of track	The gage of tangent track must be—		The gage of curved track must be—	
	At least—	But not more than—	At least—	But not more than—
1	4′8″	4′9¾″	4′8″	4′9¾″
2 and 3	4′8″	4′9½″	4′8″	4′9¾″
4	4′8″	4′9¼″	4′8″	4′9½″
5	4′8″	4′9″	4′8″	4′9½″
6	4′8″	4′8¾″	4′8″	4′9″

§ 213.55 Alinement.

Alinement may not deviate from uniformity more than the amount prescribed in the following table:

Class of track	Tangent track: The deviation of the mid-offset from 62-foot line[1] may not be more than—	Curved track: The deviation of the mid-ordinate from 62-foot chord[2] may not be more than—
1	5"	5"
2	3"	3"
3	1¾"	1¾"
4	1½"	1½"
5	¾"	⅝"
6	½"	⅜"

[1]The ends of the line must be at points on the gage side of the line rail, five-eights of an inch below the top of the railhead. Either rail may be used as the line rail, however, the same rail must be used for the full length of that tangential segment of track.

[2]The ends of the chord must be at points on the gage side of the outer rail, five-eighths of an inch below the top of the railhead.

§ 213.57 Curves; elevation and speed limitations.

(a) Except as provided in § 213.63, the outside rail of a curve may not be lower than the inside rail or have more than 6 inches of elevation.

(b) The maximum allowable operating speed for each curve is determined by the following formula:

$$V_{max} = [\sqrt{(E_a+3)/0.0007d}$$

where

V_{max}=Maximum allowable operating speed (miles per hour).

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

d=Degree of curvature (degrees).

Appendix A is a table of maximum allowable operating speed computed in accordance with this formula for various elevations and degrees of curvature.

§ 213.59 Elevation of curved track; runoff.

(a) If a curve is elevated, the full elevation must be provided throughout the curve, unless physical conditions do not permit. If elevation runoff occurs in a curve, the actual minimum elevation must be used in computing the maximum allowable operating speed for that curve under § 213.57(b).

(b) Elevation runoff must be at a uniform rate, within the limits of track surface deviation prescribed in § 213.63, and it must extend at least the full length of the spirals. If physical conditions do not permit a spiral long enough to accommodate the minimum length of runoff, part of the runoff may be on tangent track.

§ 213.61 Curve data for Classes 4 through 6 track.

(a) Each owner of track to which this part applies shall maintain a record of each curve in its Classes 4 through 6 track. The record must contain the following information:

(1) Location;

(2) Degree of curvature;

(3) Designated elevation;

(4) Designated length of elevation runoff; and

(5) Maximum allowable operating speed.

[38 FR 875, Jan. 5, 1973]

§ 213.63 Track surface.

Each owner of the track to which this part applies shall maintain the surface of its track within the limits prescribed in the following table:

Track surface	Class of track: 1	2	3	4	5	6
The runoff in any 31 feet of rail at the end of a raise may not be more than	3½"	3"	2"	1½"	1"	½"
The deviation from uniform profile on either rail at the midordinate of a 62-foot chord may not be more than	3"	2¾"	2¼"	2"	1¼"	½"
Deviation from designated elevation on spirals may not be more than	1¾"	1½"	1¼"	1"	¾"	½"
Variation in cross level on spirals in any 31 feet may not be more than	2"	1¾"	1¼"	1"	¾"	½"
Deviation from zero cross level at any point on tangent or from designated elevation on curves between spirals may not be more than.	3"	2"	1¾"	1¼"	1"	½"
The difference in cross level between any two points less than 62 feet apart on tangents and curves between spirals may not be more than.	3"	2"	1¾"	1¼"	1"	¾"

Subpart D—Track Structure

§ 213.101 Scope.

This subpart prescribes minimum requirements for ballast, crossties, track assembly fittings, and the physical condition of rails.

§ 213.103 Ballast; general.

Unless it is otherwise structurally supported, all track must be supported by material which will—

(a) Transmit and distribute the load of the track and railroad rolling equipment to the subgrade;

(b) Restrain the track laterally, longitudinally, and vertically under dynamic loads imposed by railroad rolling equipment and thermal stress exerted by the rails;

(c) Provide adequate drainage for the track; and

(d) Maintain proper track crosslevel, surface, and alinement.

§ 213.105 Ballast; disturbed track.

If track is disturbed, a person designated under § 213.7 shall examine the track to determine whether or not the ballast is sufficiently compacted to perform the functions described in § 213.103. If the person making the examination considers it to be necessary in the interest of safety, operating speed over the disturbed segment of track must be reduced to a speed that he considers safe.

§ 213.109 Crossties.

(a) Crossties may be made of any material to which rails can be securely fastened. The material must be capable of holding the rails to gage within the limits prescribed in § 213.53(b) and distributing the load from the rails to the ballast section.

(b) A timber crosstie is considered to be defective when it is—

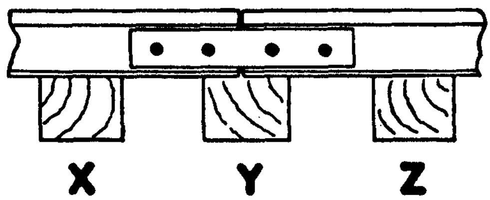
(1) Broken through;

(2) Split or otherwise impaired to the extent it will not hold spikes or will allow the ballast to work through;

(3) So deteriorated that the tie plate or base of rail can move laterally more than one-half inch relative to the crosstie;

(4) Cut by the tie plate through more than 40 percent of its thickness; or

SUPPORTED JOINT



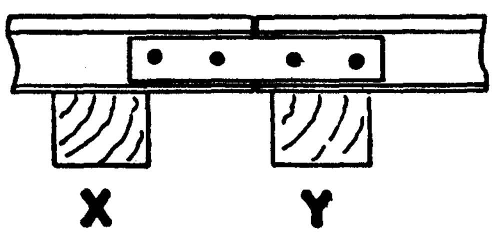
(5) Not spiked as required by § 213.127.

(c) If timber crossties are used, each 39 feet of track must be supported by nondefective ties as set forth in the following table:

Class of track	Minimum number of nondefective ties per 39 feet of track	Maximum distance between n ndefective ties (center to center) (inches)
1	5	100
2, 3	8	70
4, 5	12	48
6	14	48

(d) If timber ties are used, the minimum number of nondefective ties under a rail joint and their relative positions under the joint are described in the following chart. The letters in the chart correspond to letters underneath the ties for each type of joint depicted.

SUSPENDED JOINT



Class of track	Minimum number of nondefective ties under a joint	Required position of nondefective ties	
		Supported joint	Suspended joint
1	1	X, Y, or Z	X or Y.
2, 3	1	Y	X or Y.
4, 5, 6	2	X and Y, or Y and Z.	X and Y.

(e) Except in an emergency or for a temporary installation of not more than 6-months duration, crossties may not be interlaced to take the place of switch times.

[36 FR 20336, Oct. 20, 1971, as amended at 38 FR 875, Jan. 5, 1973]

§ 213.113 Defective rails.

(a) When an owner of track to which this part applies learns, through inspection or otherwise, that a rail in that track contains any of the defects listed in the following table, a person designated under § 213.7 shall determine whether or not the track may continue in use. If he determines that the track may continue in use, operation over the defective rail is not permitted until—

(1) The rail is replaced; or

(2) The remedial action prescribed in the table is initiated:

REMEDIAL ACTION

Defect	Length of defect (inch)		Percent of railhead cross-sectional area weakened by defect		If defective rail is not replaced, take the remedial action prescribed in note—
	More than	But not more than	Less than	But not less than	
Transverse fissure			20		B.
			100	20	B.
				100	A.
Compound fissure			20		B.
			100	20	B.
				100	A.
Detail fracture			20		C.
Engine burn fracture			100	20	D.
Defective weld				100	A, or E and H.
Horizontal split head	0	2			H and F.
	2	4			I and G.
	4				B.
Vertical split head	(Break out in railhead)				A.
Split web	0	½			H and F.
Piped rail	½	3			I and G.
	3				B.
Head web separation	(Break out in railhead)				A.
	0	½			H and F.
	½	1½			I and G.
Bolt hole crack	1½				B.
	(Break out in railhead)				A.
Broken base	0	6			E and I.
	6				(Replace rail).
Ordinary break					A or E.
Damaged rail					C.

NOTE:

A—Assign person designated under § 213.7 to visually supervise each operation over defective rail.

B—Limit operating speed to 10 m.p.h. over defective rail.

C—Apply joint bars bolted only through the outermost holes to defect within 20 days after it is determined to continue the track in use. In the case of classes 3 through 6 track, limit operating speed over defective rail to 30 m.p.h. until angle bars are applied; thereafter, limit speed to 50 m.p.h. or the maximum allowable speed under § 213.9 for the class of track concerned, whichever is lower.

D—Apply joint bars bolted only through the outermost holes to defect within 10 days after it is determined to continue the track in use. Limit operating speed over defective rail to 10 m.p.h. until angle bars are applied; thereafter, limit speed to 50 m.p.h. or the maximum allowable speed under § 213.9 for the class of track concerned, whichever is lower.

E—Apply joint bars to defect and bolt in accordance with § 213.121 (d) and (e).

F—Inspect rail 90 days after it is determined to continue the track in use.

G—Inspect rail 30 days after it is determined to continue the track in use.

H—Limit operating speed over defective rail to 50 m.p.h. or the maximum allowable speed under § 213.9 for the class of track concerned, whichever is lower.

I—Limit operating speed over defective rail to 30 m.p.h. or the maximum allowable speed under § 213.9 for the class of track concerned, whichever is lower.

(b) If a rail in classes 3 through 6 track or class 2 track on which passenger trains operate evidences any of the conditions listed in the following table, the remedial action prescribed in the table must be taken:

Condition	Remedial action	
	If a person designated under § 213.7 determines that condition requires rail to be replaced	If a person designated under § 213.7 determines that condition does not require rail to be replaced
Shelly spots Head checks Engine burn (but not fracture). Mill defect	Limit speed to 20 m.p.h. and schedule the rail for replacement.	Inspect the rail for internal defects at intervals of not more than every 12 months.
Flaking Silvered Corrugated Corroded	do	Inspect the rail at intervals of not more than every 6 months.

(c) As used in this section—

(1) "Transverse Fissure" means a progressive crosswise fracture starting from a crystalline center or nucleus inside the head from which it spreads outward as a smooth, bright, or dark, round or oval surface substantially at a right angle to the length of the rail. The distinguishing features of a transverse fissure from other types of fractures or defects are the crystalline center or nucleus and the nearly smooth surface of the development which surrounds it.

(2) "Compound Fissure" means a progressive fracture originating in a horizontal split head which turns up or down in the head of the rail as a smooth, bright, or dark surface progressing until substantially at a right angle to the length of the rail. Compound fissures require examination of both faces of the fracture to locate the horizontal split head from which they originate.

(3) "Horizontal Split Head" means a horizontal progressive defect originating inside of the rail head, usually one-quarter inch or more below the running surface and progressing horizontally in all directions, and generally accompanied by a flat spot on the running surface. The defect appears as a crack lengthwise of the rail when it reaches the side of the rail head.

(4) "Vertical Split Head" means a vertical split through or near the middle of the head, and extending into or through it. A crack or rust streak may show under the head close to the web or pieces may be split off the side of the head.

(5) "Split Web" means a lengthwise crack along the side of the web and extending into or through it.

(6) "Piped Rail" means a vertical split in a rail, usually in the web, due to failure of the sides of the shrinkage cavity in the ingot to unite in rolling.

(7) "Broken Base" means any break in the base of a rail.

(8) "Detail Fracture" means a progressive fracture originating at or near the surface of the rail head. These fractures should not be confused with transverse fissures, compound fissures, or other defects which have internal origins. Detail fractures may arise from shelly spots, head checks, or flaking.

(9) "Engine Burn Fracture" means a progressive fracture originating in spots where driving wheels have slipped on top of the rail head. In developing downward they frequently resemble the compound or even transverse fissure with which they should not be confused or classified.

(10) "Ordinary Break" means a partial or complete break in which there is no sign of a fissure, and in which none of the other defects described in this paragraph are found.

(11) "Damaged rail" means any rail broken or injured by wrecks, broken,

flat, or unbalanced wheels, slipping, or similar causes.

(12) "Shelly spots" means a condition where a thin (usually three-eighths inch in depth or less) shell-like piece of surface metal becomes separated from the parent metal in the railhead, generally at the gage corner. It may be evidenced by a black spot appearing on the railhead, over the zone of separation or a piece of metal breaking out completely, leaving a shallow cavity in the railhead. In the case of a small shell there may be no surface evidence, the existence of the shell being apparent only after the rail is broken or sectioned.

(13) "Head checks" mean hair fine cracks which appear in the gage corner of the rail head, at any angle with the length of the rail. When not readily visible the presence of the checks may often be detected by the raspy feeling of their sharp edges.

(14) "Flaking" means small shallow flakes of surface metal generally not more than one-quarter inch in length or width break out of the gage corner of the railhead.

[36 FR 20336, Oct. 20, 1971, as amended at 38 FR 875, Jan. 5, 1973; 38 FR 1508, Jan. 15, 1973]

§ 213.115 Rail end mismatch.

Any mismatch of rails at joints may not be more than that prescribed by the following table:

Class of track	Any mismatch of rails at joints may not be more than the following—	
	On the trend of the rail ends (inch)	On the gage side of the rail ends (inch)
1	1/4	1/4
2	1/4	3/16
3	3/16	3/16
4, 5	1/8	1/8
6	1/8	1/8

§ 213.117 Rail end batter.

(a) Rail end batter is the depth of depression a. one-half inch from the rail end. It is measured by placing an 18-inch straightedge on the tread on the rail end, without bridging the joint, and measuring the distance between the bottom of the straightedge and the top of the rail at one-half inch from the rail end.

(b) Rail end batter may not be more than that prescribed by the following table:

Class of track	Rail end batter may not be more than— (inch)
1	1/2
2	3/8
3	5/16
4	1/4
5	1/8
6	1/8

§ 213.119 Continuous welded rail.

(a) When continuous welded rail is being installed, it must be installed at, or adjusted for, a rail temperature range that should not result in compressive or tensile forces that will produce lateral displacement of the track or pulling apart of rail ends or welds.

(b) After continuous welded rail has been installed it should not be disturbed at rail temperatures higher than its installation or adjusted installation temperature.

§ 213.121 Rail joints.

(a) Each rail joint, insulated joint, and compromise joint must be of the proper design and dimensions for the rail on which it is applied.

(b) If a joint bar on classes 3 through 6 track is cracked, broken, or because of wear allows vertical movement of either rail when all bolts are tight, it must be replaced.

(c) If a joint bar is cracked or broken between the middle two bolt holes it must be replaced.

(d) In the case of conventional jointed track, each rail must be bolted with at least two bolts at each joint in classes 2 through 6 track, and with at least one bolt in class 1 track.

(e) In the case of continuous welded rail track, each rail must be bolted with at least two bolts at each joint.

(f) Each joint bar must be held in position by track bolts tightened to allow the joint bar to firmly support the abutting rail ends and to allow longitudinal movement of the rail in the joint to accommodate expansion and contraction due to temperature variations. When out-of-face, no-slip, joint-to-rail contact exists by design, the requirements of this paragraph do not apply. Those locations are considered to be continuous welded rail track and must meet all the requirements for continuous welded rail track prescribed in this part.

(g) No rail or angle bar having a torch cut or burned bolt hole may be used in classes 3 through 6 track.

§ 213.123 **Tie plates.**

(a) In classes 3 through 6 track where timber crossties are in use there must be tie plates under the running rails on at least eight of any 10 consecutive ties.

(b) Tie plates having shoulders must be placed so that no part of the shoulder is under the base of the rail.

§ 213.125 **Rail anchoring.**

Longitudinal rail movement must be effectively controlled. If rail anchors which bear on the sides of ties are used for this purpose, they must be on the same side of the tie on both rails.

§ 213.127 **Track spikes.**

(a) When conventional track is used with timber ties and cut track spikes, the rails must be spiked to the ties with at least one line-holding spike on the gage side and one line-holding spike on the field side. The total number of track spikes per rail per tie, including plateholding spikes, must be at least the number prescribed in the following table:

MINIMUM NUMBER OF TRACK SPIKES PER RAIL PER TIE, INCLUDING PLATE-HOLDING SPIKES

Class of track	Tangent track and curved track with not more than 2° of curvature	Curved track with more than 2° but not more than 4° of curvature	Curved track with more than 4° but not more than 6° of curvature	Curved track with more than 6° of curvature
1	2	2	2	2
2	2	2	2	3
3	2	2	2	3
4	2	2	3	....
5	2	3	....	....
6	2	....	....	....

(b) A tie that does not meet the requirements of paragraph (a) of this section is considered to be defective for the purposes of § 213.109(b).

[36 FR 20336, Oct. 20, 1971, as amended at 38 FR 876, Jan. 5, 1973]

§ 213.129 **Track shims.**

(a) If track does not meet the geometric standards in Subpart C of this part and working of ballast is not possible due to weather or other natural conditions, track shims may be installed to correct the deficiencies. If shims are used, they must be removed and the track resurfaced as soon as weather and other natural conditions permit.

(b) When shims are used they must be—

(1) At least the size of the tie plate;

(2) Inserted directly on top of the tie, beneath the rail and tie plate;

(3) Spiked directly to the tie with spikes which penetrate the tie at least 4 inches.

(c) When a rail is shimmed more than 1½ inches, it must be securely braced on at least every third tie for the full length of the shimming.

(d) When a rail is shimmed more than 2 inches a combination of shims and 2-inch or 4-inch planks, as the case may be, must be used with the shims on top of the planks.

§ 213.131 **Planks used in shimming.**

(a) Planks used in shimming must be at least as wide as the tie plates, but in no case less than 5½ inches wide. Whenever possible they must extend the full length of the tie. If a plank is shorter than the tie, it must be at least 3 feet long and its outer end must be flush with the end of the tie.

(b) When planks are used in shimming on uneven ties, or if the two rails being shimmed heave unevenly, additional shims may be placed between the ties and planks under the rails to compensate for the unevenness.

(c) Planks must be nailed to the ties with at least four 8-inch wire spikes. Before spiking the rails or shim braces, planks must be bored with ⅝-inch holes.

§ 213.133 Turnouts and track crossings generally.

(a) In turnouts and track crossings, the fastenings must be intact and maintained so as to keep the components securely in place. Also, each switch, frog, and guard rail must be kept free of obstructions that may interfere with the passage of wheels.

(b) Classes 4 through 6 track must be equipped with rail anchors through and on each side of track crossings and turnouts, to restrain rail movement affecting the position of switch points and frogs.

(c) Each flangeway at turnouts and track crossings must be at least 1½ inches wide.

[36 FR 20336, Oct. 20, 1971, as amended at 38 FR 876, Jan. 5, 1973]

§ 213.135 Switches.

(a) Each stock rail must be securely seated in switch plates, but care must be used to avoid canting the rail by overtightening the rail braces.

(b) Each switch point must fit its stock rail properly, with the switch stand in either of its closed positions to allow wheels to pass the switch point. Lateral and vertical movement of a stock rail in the switch plates or of a switch plate on a tie must not adversely affect the fit of the switch point to the stock rail.

(c) Each switch must be maintained so that the outer edge of the wheel tread cannot contact the gage side of the stock rail.

(d) The heel of each switch rail must be secure and the bolts in each heel must be kept tight.

(e) Each switch stand and connecting rod must be securely fastened and operable without excessive lost motion.

(f) Each throw lever must be maintained so that it cannot be operated with the lock or keeper in place.

(g) Each switch position indicator must be clearly visible at all times.

(h) Unusually chipped or worn switch points must be repaired or replaced. Metal flow must be removed to insure proper closure.

§ 213.137 Frogs.

(a) The flangeway depth measured from a plane across the wheel-bearing area of a frog on class 1 track may not be less than 1⅜ inches, or less than 1½ inches on classes 2 through 6 track.

(b) If a frog point is chipped, broken, or worn more than five-eighths inch down and 6 inches back, operating speed over the frog may not be more than 10 miles per hour.

(c) If the tread portion of a frog casting is worn down more than three-eighths inch below the original contour, operating speed over that frog may not be more than 10 miles per hour.

§ 213.139 Spring rail frogs.

(a) The outer edge of a wheel tread may not contact the gage side of a spring wing rail.

(b) The toe of each wing rail must be solidly tamped and fully and tightly bolted.

(c) Each frog with a bolt hole defect or head-web separation must be replaced.

(d) Each spring must have a tension sufficient to hold the wing rail against the point rail.

(e) The clearance between the hold-down housing and the horn may not be more than one-fourth of an inch.

§ 213.141 Self-guarded frogs.

(a) The raised guard on a self-guarded frog may not be worn more than three-eighths of an inch.

(b) If repairs are made to a self-guarded frog without removing it from service, the guarding face must be restored before rebuilding the point.

§ 213.143 Frog guard rails and guard faces; gage.

The guard check and guard face gages in frogs must be within the limits prescribed in the following table:

Class of track	Guard check gage	Guard face gage
	The distance between the gage line of a frog to the guard line[1] of its guard rail or guarding face, measured across the track at right angles to the gage line,[2] may not be less than—	The distance between guard lines,[1] measured across the track at right angles to the gage line,[2] may not be more than—
1	4'6⅛"	4'5¼"
2	4'6¼"	4'5⅛"
3, 4	4'6⅜"	4'5⅛"
5, 6	4'6½"	4'5"

[1]Aline along that side of the flangeway which is nearer to the center of the track and at the same elevation as the gage line.
[2]Aline ⅝ inch below the top of the center line of the head of the running rail, or corresponding location of the tread portion of the track structure.

Subpart E—Track Appliances and Track-Related Devices

§ 213.201 Scope.

This subpart prescribes minimum requirements for certain track appliances and track-related devices.

§ 213.205 Derails.

(a) Each derail must be clearly visible. When in a locked position a derail must be free of any lost motion which would allow it to be operated without removing the lock.

(b) When the lever of a remotely controlled derail is operated and latched it must actuate the derail.

§ 213.207 Switch heaters.

The operation of a switch heater must not interfere with the proper operation of the switch or otherwise jeopardize the safety of railroad equipment.

Subpart F—Inspection

§ 213.231 Scope.

This subpart prescribes requirements for the frequency and manner of inspecting track to detect deviations from the standards prescribed in this part.

§ 213.233 Track inspections.

(a) All track must be inspected in accordance with the schedule prescribed in paragraph (c) of this section by a person designated under § 213.7.

(b) Each inspection must be made on foot or by riding over the track in a vehicle at a speed that allows the person making the inspection to visually inspect the track structure for compliance with this part. However, mechanical, electrical and other track inspection devices may be used to supplement visual inspection. If a vehicle is used for visual inspection, the speed of the vehicle may not be more than 5 miles per hour when passing over track crossings, highway crossings, or switches.

(c) Each track inspection must be made in accordance with the following schedule:

Class of track	Type of track	Required frequency
1, 2, 3	Main track and sidings.	*Weekly* with at least 3 calendar days interval between inspections, or *before use*, if the track is used less than once a week, or *twice weekly* with at least 1 calendar day interval between inspections, if the track carries passenger trains or more than 10 million gross tons of traffic during the preceding calendar year.
1, 2, 3	Other than main track and sidings.	*Monthly* with at least 20 calendar days interval between inspections.
4, 5, 6		*Twice weekly* with at least 1 calendar day interval between inspections.

(d) If the person making the inspection finds a deviation from the requirements of this part, he shall immediately initiate remedial action.

[36 FR 20336, Oct. 20, 1971, as amended at 40 FR 8558, Feb. 28, 1975]

§ 213.235 Switch and track crossing inspections.

(a) Except as provided in paragraph (b) of this section, each switch and track crossing must be inspected on foot at least monthly.

(b) In the case of track that is used less than once a month, each switch and track crossing must be inspected on foot before it is used.

§ 213.237 Inspection of rail.

(a) In addition to the track inspections required by § 213.233, at least once a year a continuous search for internal defects must be made of all jointed and welded rails in Classes 4 through 6 track, and Class 3 track over which passenger trains operate. However, in the case of a new rail, if before installation or within 6 months thereafter, it is inductively or ultrasonically inspected over its entire length and all defects are removed, the next continuous search for internal defects need not be made until 3 years after that inspection.

(b) Inspection equipment must be capable of detecting defects between joint bars, in the area enclosed by joint bars.

(c) Each defective rail must be marked with a highly visible marking on both sides of the web and base.

[36 FR 20336, Oct. 20, 1971, as amended at 38 FR 876, Jan. 5, 1973]

§ 213.239 Special inspections.

In the event of fire, flood, severe storm, or other occurrence which might have damaged track structure, a special inspection must be made of the track involved as soon as possible after the occurrence.

§ 213.241 Inspection records.

(a) Each owner of track to which this part applies shall keep a record of each inspection required to be performed on that track under this subpart.

(b) Each record of an inspection under §§ 213.233 and 213.235 shall be prepared on the day the inspection is made and signed by the person making the inspection. Records must specify the track inspected, date of inspection, location and nature of any deviation from the requirements of this part, and the remedial action taken by the person making the inspection. The owner shall retain each record at its division headquarters for at least 1 year after the inspection covered by the record.

(c) Rail inspection records must specify the date of inspection, the location, and nature of any internal rail defects found, and the remedial action taken and the date thereof. The owner shall retain a rail inspection record for at least 2 years after the inspection and for 1 year after remedial action is taken.

(d) Each owner required to keep inspection records under this section shall make those records available for inspection and copying by the Federal Railroad Administrator.

APPENDIX A—MAXIMUM ALLOWABLE OPERATING SPEEDS FOR CURVED TRACK

Degree of Curvature	Elevation of outer rail (inches)												
	0	½	1	1½	2	2½	3	3½	4	4½	5	5½	6
	Maximum allowable operating speed (mph)												
0°30′	93	100	107										
0°40′	80	87	93	98	103	109							
0°50′	72	78	83	88	93	97	101	106	110				
1°00′	66	71	76	80	85	89	93	96	100	104	107	110	
1°15′	59	63	68	72	76	79	83	86	89	93	96	99	101
1°30′	54	58	62	66	69	72	76	79	82	85	87	90	93
1°45′	50	54	57	61	64	67	70	73	76	78	81	83	86
2°00′	46	50	54	57	60	63	66	68	71	73	76	78	80
2°15′	44	47	50	54	56	59	62	64	67	69	71	74	76
2°30′	41	45	48	51	54	56	59	61	63	66	68	70	72
2°45′	40	43	46	48	51	54	56	58	60	62	65	66	68
3°00′	38	41	44	46	49	51	54	56	58	60	62	64	66
3°15′	36	39	42	45	47	49	51	54	56	57	59	61	63
3°30′	35	38	40	43	45	47	50	52	54	55	57	59	61
3°45′	34	37	39	41	44	46	48	50	52	54	55	57	59
4°00′	33	35	38	40	42	44	46	48	50	52	54	55	57
4°30′	31	33	36	38	40	42	44	45	47	49	50	52	54

Appendix A—Maximum Allowable Operating Speeds for Curved Track—Continued

Elevation of outer rail (inches)

Degree of Curvature	0	½	1	1½	2	2½	3	3½	4	4½	5	5½	6
	Maximum allowable operating speed (mph)												
5°00′	29	32	34	36	38	40	41	43	45	46	48	49	51
5°30′	28	30	32	34	36	38	40	41	43	44	46	47	48
6°00′	27	29	31	33	35	36	38	39	41	42	44	45	46
6°30′	26	28	30	31	33	35	36	38	39	41	42	43	45
7°00′	25	27	29	30	32	34	35	36	38	39	40	42	43
8°00′	23	25	27	28	30	31	33	34	35	37	38	39	40
9°00′	22	24	25	27	28	30	31	32	33	35	36	37	38
10°00′	21	22	24	25	27	28	29	31	32	33	34	35	36
11°00′	20	21	23	24	26	27	28	29	30	31	32	33	34
12°00′	19	20	22	23	24	26	27	28	29	30	31	32	33

[36 FR 20336, Oct. 20, 1971, as amended at 38 FR 876, Jan. 5, 1973]

Appendix B—Schedule of Civil Penalties

Appendix B reflects a statement of policy by the Federal Railroad Administration in making applicable to Part 213 a specific civil penalty for a violation of particular sections of this part.

		Violation	Haz.[1] viol.
Subpart A—General:			
213.5	Responsibility of track owners	$1,000	$2,000
213.7	Designation of qualified persons to supervise certain renewals and inspect track	500	1,000
213.9	Classes of track: operating speed limits	1,000	2,000
213.11	Restoration or renewal of track under traffic conditions	1,000	1,000
213.13	Measuring track not under load	500	1,000
Subpart B—Roadbed:			
213.33	Drainage	500	1,000
213.37	Vegetation	500	1,000
Subpart C—Track geometry:			
213.53	Gage	750	1,500
213.55	Alinement	750	1,500
213.57	Curves; elevation and speed limitations	750	1,500
213.59	Elevation of curved track; runoff	750	1,500
213.61	Curve date for classes 4 through 6	500	1,000
213.63	Track surface	750	1,500
Subpart D—Track surface:			
213.103	Ballast; general	500	1,000
213.106	Ballast; disturbed track	500	1,000
213.109	Crossties	750	1,500
213.113	Defective rails	1,000	2,500
213.115	Rail end mismatch	500	1,000
213.117	Rail end batter	500	1,000
213.119	Continuous welded rail	500	1,000
213.121	Rail joints		
213.121a		500	1,000
213.121b		500	1,000
213.121c		1,000	2,500
213.121d		500	1,000
213.121e		500	1,000
213.121f		500	1,000
213.121g		500	1,000
213.123	Tie plates	500	1,000
213.125	Rail anchoring	750	1,500
213.127	Track spikes	750	1,500
213.129	Track shims	500	1,000
213.131	Planks used in shimming	500	1,000
213.133	Turnouts and track crossings generally	500	1,000
213.135	Switches	500	1,000
213.137	Frogs	500	1,000
213.139	Spring rail frogs	750	1,500
213.141	Self-guarded frogs	500	1,000
213.143	Frog guard rails and guard faces; gage	500	1,000
Subpart E—Track appliances and track-related devices:			
213.205	Derails	500	1,000
213.207	Switch heaters	500	1,000
Subpart F—Inspection:			
213.233	Track inspections	500	1,000
213.235	Switch and track crossings inspections	500	1,000
213.237	Inspection of rail	750	1,500
213.239	Special inspections	500	1,000
213.241	Inspection records	750	1,500

Note:[1] For the purposes of this appendix, a hazardous violation is one involving an immediate hazard of death or injury, or when an actual accident, death or injury results from the violation. The Administrator reserves the authority to assess the maximum penalty of $2,500 for a violation of any section or subsection contained in Part 213.

[39 FR 12351, Apr. 5, 1974]

APPENDIX C. GLOSSARY

A

Acid Bessemer.—Steel made by the bessemer process in a furnace having an acid lining, usually ganister or other highly siliceous material. Phosphorus and sulfur are not removed in the refining process.

Acid Open-Hearth.—Steel made by the open-hearth process in a furnace lined with acid or siliceous material. Because of the character of the furnace, an acid slag must be employed for refining the bath in this process. Since phosphorus and sulfur are not removed by an acid steel making process, the metallic charge must be made up of specially selected pig iron and scrap.

Adzing Machine.—Portable power-operated machine designed to adz the rail seat on ties to provide proper bearing for rail or tie plates.

Alignment.—The horizontal location of a railroad as described by curves and tangents.

Antisplitting Iron.—A piece of steel strip, bevelled on both sides at one edge, and bent to a desired shape, for application by driving into the end (cross section) of a tie or timber to control its splitting.

Asphalt Cement.—A fluxed or unfluxed asphaltic material, especially prepared as to quality and consistency, suitable for direct use in the manufacture of asphaltic pavements, and having a penetration of between 5 and 250.

B

Ballast.—Selected material placed on the roadbed for the purpose of holding the track in line and surface.

Ballast Curb.—A longitudinal timber placed along the outer edge of the floor on ballast deck bridges to retain the ballast.

Batter.—The deformation of the surface of the head of the rail in the immediate vicinity of the end.

Batter.—A deviation from the vertical in upright members of a trestle bent.

Batter Pile.—One driven at an inclination to resist forces which are not vertical.

Bent.—The group of members forming a single vertical support of a trestle, designated as pile bent where the principal members are piles, and as framed bent where of framed timbers.

Berm.—(a) The space left between the top or toe of slope and excavation made for intercepting ditches or borrow pits; (b) An approximately horizontal space introduced in a slope.

Bond.—In stone or brick masonry, the mechanical disposition of stone, brick, or other building blocks by overlapping to break joints. (See English Bond; Flemish Bond.)

Borrow (noun).—All material used in making embankments, which does not come from necessary excavation.

Borrow Pit.—An excavation made for the purpose of obtaining embankment material.

Branch Line.—The secondary line or lines of a railway.

Branding.—The identification markings hot rolled in raised figures and letters in the rail web indicating the weight of rail and section number, type of rail, kind of steel, name of manufacturer and mill, and year and month rolled.

Bridge Tie.—A transverse timber resting on the stringers and supporting the rails.

Broken Base.—Any break in the base of a rail.

Brush.—Trees less than 4-inch stump-top diameter, shrubs or branches of trees that have been cut off.

Bulkhead.—A structure to prevent sliding of natural ground or fill material into the water; the limiting wall or structure along a waterfront.

Bulkhead.—Timbers placed against the embankment side of an end trestle bent to retain the embankment.

Burrs.—The rough edges left at the end of a rail when sawed; or on the side of the web when drilling bolt holes.

C

Camber.—Slight convexity built into a span to counteract sag resulting from elastic deflections.

Cant.—The inward inclination of a rail, effected by the use of inclined-surface tie plates, usually expressed as a rate of inclination, such as 1 in 40, etc.

Cap.—A horizontal member on the top of piles or posts, connecting them to form a bent.

Cap-Stringer Strap.—A piece of round, square, or structural shape iron or steel, either straight or bent, used to fasten stringers to a cap by means of horizontal bolts without the use of drift bolts.

Car Retarder.—A braking device, usually power-operated, built into a railway track to reduce the speed of cars by means of brakeshoes which, when set in braking position, press against the sides of the lower portions of the wheels.

Cast Iron.—Alloys of iron containing 1.7 to 4.5 percent carbon as cast, and usually not appreciably malleable at any temperature.

Cinders.—The fused residue from coal burned in locomotives and other furnaces.

Closure Rails.—The rails between the parts of any special trackwork layout, as the rails between the switch and the frog in a turnout (sometimes called the Lead Rails or Connecting Rails); also the rails connecting the frogs of a crossing or of adjacent crossings, but not forming parts thereof.

Compound Fissure.—A progressive fracture originating in a horizontal split head which turns up or down in the head of the rail as a smooth, bright or dark surface, progressing until substantially at a right angle to the length of the rail. Compound fissures require examination of both faces of the fracture to locate the horizontal split head from which they originate.

Compressive Strength.—The maximum compressive stress which a material is capable of sustaining.

Compromise Joint (Bar).—Joint bars designed to connect rails of different fishing height and section, or rails of the same section but of different joint drillings.

Compromise Joint (Rail).—A joint for uniting the abutting ends of contiguous rails of different sections, or of rails of the same section but of different joint drillings.

Continuous Welded Rail.—A number of rails welded together in lengths of 400 feet or longer (CWR). (See also **Welded Rail.**)

Contract.—A written agreement between two or more parties specifying terms, conditions, etc., under which certain obligations must be performed. (Specifications are a part of the contract.)

Conventional Sign.—A symbol, such as a mark, character, abbreviation, or letter, selected or sanctioned by general agreement or common use to indicate upon map or plan certain forms, conditions, or objects, both natural and structural.

Corrosion.—The dissolving or eating away of the surface of metal through chemical action, either regularly and slowly as by rusting in air, or irregularly and rapidly as by pitting and grooving in the interior of boilers.

Corrugated Rail.—A rough condition on the rail tread of alternate ridges and grooves, which develops in service.

Coupler.—The device by means of which any car or machine to be towed is connected to the towing agency. Coupler includes draw head, and coupler links and pins, or other device for connecting two draw heads.

Coupler Drawbar.—The portion of a coupler used to connect the draw heads of two cars or other units of roadway machinery.

Coupler Drawhead.—That portion of a coupler that is rigidly attached to motor car, trailer, or unit of roadway machinery designed to be towed.

Creosote.—As used in wood preserving, creosote is a distillate of coal tar produced by high-temperature carbonization of bituminous coal; it consists principally of liquid and solid aromatic hydrocarbons, and contains appreciable quantities of tar acids and tar bases; it is heavier than water; and has a continuous boiling range of at least 125° C beginning at about 200° C.

Crop End.—A piece cut from the end of a bloom or rail during manufacture.

Crossing (Track).—A structure, used where one track crosses another at grade, and consisting of four connected frogs.

Bolted Rail.—A crossing in which all the running surfaces are of rolled rail, the parts being held together with bolts.

Manganese Steel Insert.—A crossing in which a manganese steel casting is inserted at each of the four intersections, being fitted into rolled rails and forming the points and wings of the crossing frogs.

Solid Manganese Steel.—A crossing in which the frogs are of the solid manganese steel type.

Movable Point.—A crossing of small angle in which each of the two center frogs consists essentially of a knuckle rail and two opposed movable center points with the necessary fixtures.

Single-Rail.—A crossing in which the connections between the end frogs and the center frogs consist of running rails only.

Two-Rail.—A crossing in which the connections between the end frogs and the center frogs consist of running rails and guard rails.

Three-Rail.—A crossing in which the connections between the end frogs and the center frogs consist of running rails, guard rails, and easer rails.

Crossing Plates.—Plates interposed between a crossing and the ties or other timbers to protect the ties and to better support the crossing by distributing the loads over larger areas. (For names and descriptions of various styles, see Plan Basic. No. 700-D in the Portfolio of Trackwork Plans.)

Center Frogs.—The two frogs at the opposite ends of the short diagonal of a crossing.

End Frogs.—The two frogs at the opposite ends of the long diagonal of a crossing.

Knuckle Rail.—A bent rail, or equivalent structure, forming the obtuse point against which the movable center points, of a movable point crossing or slip switch, rest when set for traffic.

Movable Center Point.—One of the movable tapered rails of a movable point crossing or slip switch.

Running Rail.—The rail or surface on which the tread of the wheel bears.

Crossover.—Two turnouts with the track between the frogs arranged to form a continuous passage between two nearby and generally parallel tracks.

Double.—Two crossovers which intersect between the connected tracks.

Cross Section.—A vertical section of the ground at right angles to the centerline.

Crushed Head.—A "flattening" or crushing down of the head of a rail.

Curve-Compound.—A continuous change in direction of alignment by means of two or more contiguous simple curves of different degrees having a common tangent at their junction points.

Degree of.—The angle subtended at the center of a simple curve by a 100-foot chord.

Easement.—A curve whose degree varies either uniformly or in some definitely determined manner so as to give a gradual transition between a tangent and a simple curve, which it connects, or between two simple curves.

Reverse.—Two contiguous simple curves in opposite directions, with a common tangent at their junction point.

Simple.—A continuous change in direction of alignment by means of an arc of a single radius.

Vertical.—An easement curve in the track to connect intersecting grade lines.

Curved Lead.—The distance between the actual point of switch and the half-inch point of the frog measured on the outside gage line of the turnout.

D

Damaged Rail.—Any rail broken or injured by wrecks, broken, flat or unbalanced wheels, slipping or similar causes.

Dating Nail.—A nail with a head having a raised or depressed number or symbol which is driven into a longitudinal surface of a pile, pole, tie, or timber to identify the year in which the material was treated.

Decay.—Disintegration of the wood substance due to the action of wood destroying fungi.

Depth (Ballast).—The distance from the bottom of the tie to the top of the subgrade.

Derail.—A track structure for derailing rolling stock in case of an emergency. (See also Switch Point Derail.)

Detail Fracture.—A progressive fracture originating at or near the surface of the rail head. These fractures should not be confused with transverse fissures, compound fissures, or other defects which have internal origins. Detail fractures usually have their origins in the following types of defects, and progress crosswise into the head of the rail.

Shell.—Where a thin shell of metal becomes separated from the head, usually at the gage corner.

Head Checks.—Usually at or close to the gage corner where movement or flow of surface metal is sufficient to start a hairline crack.

Diesel (see Engine).

Dock.—(a) A natural or artificial inlet or basin used by boats, including both the water and the protecting sides. (b) A structure against which boats land to discharge cargoes and passengers. Synonymous with wharf and used very generally on the Great Lakes.

Drift Bolt.—A piece of round or square metal, with or without head or point and of specified length, driven as a spike.

E

Electrolysis.—The process whereby an electric current passing from an electrode to an electrolyte or vice-versa, causes chemical changes to take place in the electrolyte. Electrolysis is also the process of decomposition which is aided by the passage of an electric current.

Elevation (of Curves) (Superelevation).—The vertical distance that the outer rail is above the inner rail.

Embankment (or Fill).—A bank of earth, rock, or other material constructed above the natural ground surface.

End Chipping.—The loosening of the metal on the top or gage side of the end of a rail.

End Hardening.—Heat treatment of the top portion of the heads of rails at the ends to minimize rail batter.

End Overflow.—A projection of metal into the joint gap at the top or side of the head of a rail.

Engine Burn Fracture.—A progressive fracture originating in spots where driving wheels have slipped on top of the rail head. In developing downward they frequently resemble the compound or even transverse fissure with which they should not be confused or classified.

Equipment.—Motive power and other rolling stock, floating equipment, and highway vehicles used in transportation service.

F

Facility.—Property physically distinct and capable of rendering a specific service.

Fastenings.—Joint bars, bolts, and spikes.

Auxiliary.—Nutlocks, spring washers, tie plates, rail braces, and anticreeping devices.

Fishing Space.—The space between the head and base of a rail occupied by the joint bar.

Fish-Plate.—A short piece lapping a joint, secured to the side of two members, to connect them end to end.

Flare.—A tapered widening of the flangeway at the end of the guard line of a track structure, as at the end of a guard rail or at the end of a frog or crossing wing rail.

Opening.—The distance between the gage line and the guard line of a track structure at the wider end of the flair.

Flangeway.—The open way through a track structure which provides a passageway for wheel flanges.

Depth.—The depth of the wheel flange passageway, or the vertical distance from the top of the tread surface to the top of the filter or separator introduced between the tread portion and the guard portion of a track structure.

Width.—The distance between the gage line and the guard line of a track structure, which provides a passageway for wheel flanges.

Flowed Head.—A rolling out of the metal on top of the head of a rail toward the sides without showing any indication of a breaking down of the head structure.

Footing.—A structural unit used to distribute wall or column loads to the foundation materials.

Foundation.—Material, including piling or other special construction, which supports the structure and its loads.

Framed Trestle.—A structure in which the upright members or supports are framed timbers.

Frog.—A track structure used at the intersection of two running rails to provide support for wheels and passageways for their flanges, thus permitting wheels on either rail to cross the other.

Bolted Rigid.—A frog built essentially of rolled rails, with fillers between the rails, and held together with bolts. (For names of detail parts, see Plan Basic No. 390 in the Portfolio of Trackwork Plans.)

Spring-Rail.—A frog having a movable wing rail which is normally held against the point rail by springs, thus making an unbroken running surface for wheels using one track, whereas the flanges of wheels on the other track force the movable wing rail away from the point rail to provide a passageway.

Spring-Rail, Right Hand and Left Hand.—Standing at the toe end of a spring-rail frog and looking toward its point, a right-hand frog has the movable wing rail located on the right-hand side, and a left-hand frog has the movable wing rail located on the left-hand side.

Railbound Manganese Steel.—A frog consisting essentially of a manganese steel body casting fitted into and between rolled rails and held together with bolts.

Solid Manganese Steel.—A frog consisting essentially of a single manganese steel casting.

Self-Guarded (Flange Frog).—A frog provided with guides or flanges, above its running surface, which contact the tread rims of wheels for the purpose of safely guiding their flanges past the point of the frog.

Clamp.—A frog built essentially of rolled rails, with fillers between the rails, and held together with clamps.

Angle.—The angle formed by the intersecting gage lines of a frog.

Number.—One-half the cotangent of one-half the frog angle, or the number of units of centerline length in which the spread is one unit.

Point.—That part of a frog lying between the gage lines extending from their intersection toward the heel end.

Theoretical.—The point of intersection of the gage lines of a frog.

Half-inch.—A point located at a distance from the theoretical point toward the heel equal in inches to one-half the frog number, and at which the spread between the gage lines is 1/2 inch. It is the origin from which measurements are usually made.

Guard.—The point formed by guards introduced or extended into the toe portion of a frog.

Heel End of.—That end of a frog which is the farther from the switch; or, the end which has both point rails or other running surfaces between the gage lines.

Heel Length.—The distance between the heel end and the half-inch point of a frog, measured along the gage line.

Heel Spread.—The distance between the gage lines at the heel end of the frog.

Throat of.—The point at which the converging wings of a frog are closest together.

Toe End of.—That end of a frog which is nearer the switch; or, the end which has both gage lines between the wing rails or other running surfaces.

Toe Length.—The distance between the toe end and the half-inch point of a frog, measured along the gage line.

Toe Spread.—The distance between the gage lines at the toe end of the frog.

Wing Wheel Risers.—Raised portions provided on the top surfaces of the wings of a frog, more particularly when of manganese steel design, directly opposite the point and gradually sloping down to the general level of the running surface, thereby providing additional metal at those parts of the frog which usually wear out first, and also making the transverse contour conform more closely to that of the tread of a tapered wheel.

G

Gage (Track Tool).—A device by which the gage of a track is established or measured.

Gage (of Track).—The distance between the gage lines, measured at right angles thereto. (Standard gage is 4 feet 8-1/2 inches.)

Gage Line.—A line 5/8 inch below the top of the centerline of head of running rail or corresponding location of tread portion of other track structures along that side which is nearer the center of the track.

Gagging.—The work done on a rail at the straightening press with a steel "gag" or tool for the purpose of taking out a bend.

Grade (noun).—The ratio of rise, or fall, of the grade line to its length. (NOTE.—The term "Grade" is sometimes used to designate the finished roadbed, but such use conflicts with the meaning of "Grade" as given above and it should not be so used.)

Grade (verb).—To prepare the ground for the reception of the ballast and track.

Grade Line.—The line on the profile representing the tops of embankments and the bottoms of cuttings ready to receive the ballast; and is the intersection of the plane of the roadbed with a vertical plane through the centerline.

Gradient.—The rate of inclination of the grade line from the horizontal.

Grooved.—A cross tie which has had machine-gouged depressions across its top into which ribs on the bottom of a tie plate may fit.

Grout (noun).—A fluid mixture of cement and water or of cement, sand, and water, with or without admixture.

Guard Line.—A line along that side of the flangeway which is nearer the center of the track and at the same elevation as the gage line.

Guard Check Gage.—The distance between guard line and gage line, measured across the track at right angles to the gage lines.

Guard Face Gage.—The distance between guard lines, measured across the track at right angles to the gage lines.

Guard Rail.—A rail or other structure laid parallel with the running rails of a track to prevent wheels from being derailed; or to hold wheels in correct alignment to prevent their flanges from striking the points of turnout or crossing frogs or the points of switches.

A rail or other structure laid parallel with the running rails of a track to keep derailed wheels adjacent to running rails.

Frog.—A rail or other device to guide the wheel flange so that it is kept clear of the point of the frog.

Switch.—A rail or other track structure laid parallel with the running rail ahead of a split switch and forming a flangeway with the running rail, to hold the wheels of rolling stock in correct alignment when approaching the switch.

One-Piece.—A guard rail consisting of a single complete unit, either fabricated or cast, so designed that no auxiliary parts or fastenings other than spikes are required for its installation.

Adjustable Separator.—A metal block of two or more parts acting as a filler between the running rail and the guard rail and so designed as to provide varying widths of flangeways.

Brace.—A metal shape designed to fit the contour of the side of the guard rail and extend over the tie, with provision for fastening thereto, to restrain the moving or tilting of the guard rail away from the running rail.

Brace, Adjustable.—A guard rail brace which may be adjusted laterally with respect to the rail, to vary the distance between the guard rail and the running rail.

Clamp.—A device consisting of a yoke and fastenings designed to engage the running rail and the guard rail and hold them in correct relation to each other.

Guard Timber.—A longitudinal timber placed outside of the track rail, to maintain the spacing of ties.

H

Hammer Blow.—A periodic vertical force due to the centrifugal force of the unbalanced parts on the revolving drivers of a locomotive.

Harbor Line (Inner and Outer).—(a) The lines defining the limits of a port or haven with regard to inner or best protected area and outer or less protected area. Often referred to in port regulations. (b) In certain locations of the country inner harbor line is synonymous with bulkhead line and outer harbor line with pier head line.

Hardness.—That physical property which enables a material to resist indentation or abrasion.

Hardwood.—One of the group of trees which has broad leaves. The term has no reference to the hardness of the wood.

Haul.—The distance grading material is moved in the construction of the roadway.

Heartwood.—Inner core of the tree trunk comprising the annual rings containing nonliving elements; usually darker in color than sapwood.

Heat or Melt.—The steel resulting from one charge of the melting furnace.

Helper Stringer.—A stringer added to an existing panel of stringers.

Horizontal Split Head.—A horizontal progressive defect originating inside of the rail head, usually 1/2 inch or more below the running surface and progressing horizontally in all directions, and generally accompanied by a flat spot on the running surface. The defect appears as a crack lengthwise of the rail when it reaches the side of the rail head. (See Compound Fissures.)

Hotbed.—A series of skids on which rails are placed for cooling after rolling, sawing, and cambering.

Hydraulic Grade Line.—A line joining the points to which water flowing through a pipe line under pressure will rise at various points at atmospheric pressure.

I

Imperviousness.—The quality of being completely resistant to penetration by water or other liquid.

Incline.—An inclined track or tracks and their supporting structure leading to the adjustable apron or bridge at a transfer slip.

Ingot.—A special form of casting poured direct from the teeming ladle for subsequent rolling or forging.

Bled.—An ingot which has fallen over while solidifying, or has met with some other mishap, allowing the liquid interior to escape but leaving the walls intact. It may bleed at the top or at the bottom, but usually at the top.

Butt.—A short ingot, usually the last one poured from a heat, for which there is not sufficient steel to fill the mold. The lower end of an ingot is sometimes called the butt of the ingot.

Hot Top or Sink Head.—A type of ingot cast in a mold the top of which is extended with refractory or nonconducting material designed to minimize the piping within the ingot proper.

Ingot Mold.—A cast metal form, either square or rectangular in section, and usually 6 feet or more in height, into which the molten steel is poured or teemed for the purpose of solidification. The mold rests on a cast metal stool or base, mounted on a buggy, for transfer to the stripper and soaking pits.

Ingot Stool.—The plate or base on which an open bottom ingot mold stands.

Inner Guard Rail.—A longitudinal member, usually a metal rail, secured on top of the ties inside of the track trail, to guide derailed car wheels.

Insulation.—A device or material that prevents the flow of electric current in a track circuit from passing from one rail to the other or through switches and other track structures.

Intake.—That portion of a pipe or other apparatus through which water enters from the source of supply, such as the end of an intake pipe. A structure built out into a body of water for the purpose of providing a place from which the water may be pumped without interruption.

Intercepting Ditch.—An open artificial waterway for diverting surface water from the natural course of flow.

Intermediate Sill.—A horizontal member in the plane of the trestle bent forming the cap of a lower section and the sill of an upper section.

Intrados.—The inner or concave surface of an arch.

Inventory (noun).—A list in detail of the units (land, roadway, and equipment) comprising the physical property of a carrier as of the date of valuation.

Inventory (verb).—The act of counting, computing, compiling, and recording fixed and movable property of a railway.

J

Joint, Rail.—A fastening designed to unite the abutting ends of contiguous rails.

Insulated.—A rail joint designed to arrest the flow of electric current from rail to rail by means of insulation so placed as to separate the rail ends and other metal parts connecting them.

Joint Bar.—A steel member, embodying beam-strength and stiffness in its structural shape and material; commonly used in pairs for the purpose of joining rail ends together, and holding them accurately, evenly, and firmly in position with reference to surface and gage-side alignment.

Joint Gap.—The distance between the ends of contiguous rails in track, measured at a point 5/8 inch below the top of the rail on the outside of the head.

L

Ladle Test Ingot.—A small casting made when metal is teemed, to be used for chemical test purposes.

Lap.—A surface defect on metal appearing as a seam caused from folding over hot metal, fins, or sharp corners and then rolling or forging, but not welding them to the surface.

Lead.—The distance between the actual point of the switch and the half-inch point of the frog. (See Plans Basic Nos. 910 and 920 in the Portfolio of Trackwork Plans.)

Actual.—The length between the actual point of the switch and the half-inch point of the frog measured on the line of the parent track.

Curved.—The distance between the actual point of the switch and the half-inch point of the frog, measured on the outside gage line of the turnout.

Theoretical.—The distance from the theoretical point of a uniform turnout curve to the theoretical point of the frog, measured on the line of the parent track.

Lead Curve.—The curve in a turnout interposed between the switch and the frog.

Level.—The condition of the track in which the elevation of the two rails transversely is the same.

Line.—The condition of the track in regard to uniformity in direction over short distances on tangents, or uniformity in variation in direction over short distances on curves.

Lining Track.—Shifting the track laterally to conform to the established alignment.

Location.—The established position of the centerline and grade line of a railroad preparatory to its construction.

Longitudinal Strut of Girt.—A stiffening member running horizontally, or nearly so, from bent to bent.

Longitudinal X Brace.—A member extending diagonally from bent to bent in a vertical or battered plane.

M

Main Line.—The principal line or lines of a railway.

Main Track.—A track extending through yards and between stations, upon which trains are operated by time table or train order, or both, or the use of which is governed by block signals.

Mate.—A track structure having a fixed or immovable point and used on the opposite side of the track from a tongue switch, as its companion piece. (A mate is termed "outside" or "inside" depending upon whether it is placed on the outside or inside of the curve, the "inside mate" being comparatively little used.)

Mattress.—A strong mat consisting of various materials, bound or woven together, used for the protection of the surface of the eroding banks or bottom of an alluvial river.

Ballast.—Stone riprap placed on any wood mattress to sink it and make it conform to the riverbed.

Brush and Wire Envelop.—Brush laid in two layers between woven wire netting which is tied together with wires. Bottom of netting envelop parallel to bank, top normal to bank. Bottom brush layer normal to bank, top parallel.

Milling Rail.—The cutting of the ends of rails with a milling hob to eliminate roughness and inaccuracies of sawing.

Modulus of Elasticity.—The ratio, within the elastic limit of a material, of unit stress to corresponding unit strain or deformation.

Mud-Sill or Sub-Sill.—A timber bedded in the ground to support a framed bent.

N

Normalizing.—Heating iron-base alloys to approximately 100° F above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

Nosing.—A transverse, horizontal motion of a locomotive which exerts a lateral force on the supporting structure.

O

Open-Hearth Furnace.—A rectangular furnace built of brick, lined with acid or basic materials and having a hearth on which metal is generally openly exposed to the action of burning gases.

Open-Hearth Process.—The conversion of solid pig iron with the addition of iron or steel scrap to steel through exposure to burning gases in a reverberatory furnace. In the refining of the molten metal, the carbon is generally reduced considerably below the percentage ultimately required and the metal is thereafter recarburized. Usually additions of manganese and silicon are also made.

Ordinary Break (Square or Angular Break).—Any partial or complete fracture in which there is no sign of a fissure, and in which none of the other defects or damage is visible.

Out of Face (Referring to Track Work).—Work that proceeds completely and continuously over a given piece of track as distinguished from work at disconnected points only.

P

Pass.—The passage of any piece of metal through the rolls of a rolling mill as an ingot through the blooming rolls; or the openings in the various rolls or roll trains, which give the hot metal the desired shape.

Percolation.—The act of water descending through the earth from the ground surface.

Permanent Set.—The strain or deformation remaining in a body after being stressed beyond the elastic limit.

Pig Iron.—The product, either cast or in a molten state, resulting from heating iron ore, limestone, and coke together in a blast furnace, after removal of the molten impurities as slag.

Pig iron contains a high percentage of carbon ranging from 3.0 to 4.0 percent.

Pile.—A member usually driven or jettied into the ground and deriving its support from the underlying strata, and by the friction of the ground on its surface.

The usual functions of a pile are: (a) To carry a superimposed load; (b) To compact the surrounding ground; (c) To form a wall to exclude water and soft material, or to resist the lateral pressure of adjacent ground.

Bearing.—One used to carry a superimposed load.

Butt of Pile.—The larger end of a pile.

Foot of Pile.—The lower end of a pile.

Head of Pile.—The upper end of a pile.

Tip of Pile.—The smaller end of a pile.

Pile Cap, Hood of Bonnet.—A block used to protect the head of a pile and to hold it in the leads during driving.

Pile Driver.—A machine for driving piles.

Pile Hammer.—A weight used to drive piles. It may be designated as a steam hammer, diesel hammer, or drop hammer, depending on the source of energy.

Pile Trestle.—A structure in which the upright members of supports are piles.

Piles, Anchor.—Piles driven on the land side of a bulkhead or pier to which the bulkhead or pier is anchored or tied by rods, cables, chains, or other devices.

Piped Rail.—One with a vertical split, usually in the web, due to failure of the sides of the shrinkage cavity in the ingot to unite in rolling.

Piping.—The formation of a cavity in the upper interior of an ingot, caused by shrinkage of the liquid metal when solidifying.

Pitting.—Localized corrosion.

Platform-Trucking.—A platform on which freight, baggage, mail, and express are handled to and from cars.

High.—A platform at or near car floor elevation.

Low.—A platform at or near top of rail elevation.

Plug, Tie.—Rectangular sections of wood, shaped somewhat like spikes, for driving into holes from which spikes have been withdrawn.

Post.—One of the vertical or battered members of the bent of a framed trestle.

Profile.—A line representing the ground surface or an established grade line, or both, in relation to the horizontal.

R

Rail Saw.—A power machine, provided with a saw of either tooth or friction type, used to cut steel rails.

Rail Section.—The shape of the end of a rail cut at right angles to its length. The rail mills identify the different shapes and types of rails by code numbers, as for example 131-28 for the 131 RE rail section.

Rail (Track).—A rolled steel shape, commonly a T-section, designed to be laid end to end in two parallel lines on crossties or other suitable supports to form a track for railway rolling stock.

Girder.—See Plans Basic Nos. 1002 and 1003 in the Portfolio of Trackwork Plans.

Tee.—See Plan Basic No. 1001 in the Portfolio of Trackwork Plans. Heavy Rails as used in the Portfolio: those sections weighing over 110 pounds per yard. Medium Weight Rails as used in the Portfolio: those sections weighing 80 to 110 pounds per yard., incl.

Railway Track Scale.—A scale especially designed for weighing railway equipment.

Retarder, Car.—A braking device, usually power operated, built into a railway track to reduce the speed of cars by means of brakeshoes which, when set in position, press against the sides of the lower portions of the wheels.

Retarder, Inert.—A braking device, without external power, built into a railway track to reduce the speed of cars by means of brakeshoes against the sides of the lower portions of the wheels and sometimes provided with means for opening it to nullify its braking effect.

Right-of-Way.—Lands or rights used or held for railroad operation.

Roadbed Shoulder.—That portion of the subgrade lying between the ballast covered portion and the ditch in cuts and the top of slope on embankments.

Roadway Sign.—Any marker displayed on or near the right-of-way for instruction or information of employees or others.

Running Rail.—The rail or surface on which the tread of the wheel bears.

Runoff.—The term applied to that part of the precipitation which is carried off from the land upon which it falls.

S

Sash Brace.—A horizontal member secured to the posts or piles of a bent.

Scoremark.—An incision in a longitudinal surface of a hewed tie resulting from a stroke of the axe used in its manufacture.

Segregation-Positive.—The concentration of the carbon and impurities during solidification in the part of an ingot or other casting which solidifies last.

Negative.—The condition existing where any part of an ingot or casting has less than the average amount of carbon and impurities.

Self-Guarded Frog (Flange Frog).—A frog provided with guides or flanges, above its running surface, which contact the tread rims of wheels for the purpose of safely guiding their flanges past the point of the frog.

Settlement (noun).—The term settlement as applied to grading material is the reduction in elevation of an embankment caused by shrinkage or subsidence.

Shatter Cracks.—Minute cracks in the interior of rail heads, seldom closer than 1/2 inch from the surface, and visible only after deep etching or at high magnification. They may extend in any direction. They are caused by rapid (air) cooling, and may be prevented from forming by control cooling the rail. Shatter cracks also occur in other steel products.

Sheet Piles.—Piles driven in close contact in order to provide a tight wall, to prevent leakage of water and soft materials, or driven to resist the lateral pressure of adjacent ground.

Shim.—A small piece of wood or metal placed between two members of a structure to bring them to a desired relative elevation.

Shoe.—A metal protection for the point or foot of a pile.

Shoulder.—That portion of the ballast between the end of the tie and the toe of the ballast slope.

Shrinkage (noun).—The term shrinkage as applied to grading material is the difference in volume between the material excavated and the ultimate volume of the same material in the embankment after it has reached a state of equilibrium, when the latter is the smaller.

Skrinkage Allowance.—The excess length to which a hot rail is cut when leaving the rolls to allow for shrinkage to required length when cold.

Siding.—A track auxiliary to the main track for meeting or passing trains.

Sill.—The lowest horizontal member of a framed bent.

Skew.—Having an axis at any other angle than right.

Angle of.—The angular deviation of one of two intersecting lines from a right angle to the other.

Slide.—A superficial, gravitational earth movement.

Slip Switch-Double.—A combination of a crossing with two right-hand and two left-hand switches and curves between them within the limits of the crossing and connecting the two intersecting tracks on both sides of the crossing and without the use of separate turnout frogs.

Single.—A combination of a crossing with one right-hand and one left-hand switch and curve between them within the limits of the crossing and connecting the two intersecting tracks without the use of separate turnout frogs.

Slope.—The inclined face of a cutting or embankment.

Slope Stakes.—Stakes set to indicate the top or bottom of a slope.

Snow Sweeper.—A car equipped with brushes, near the rails, and the necessary machinery to revolve them; used for sweeping snow from the rails.

Soaking Pit.—A vertical reheating furnace in which the ingots, after being stripped, are placed in an upright position for the purpose of uniformly reheating them to the temperature required for rolling.

Special Trackwork.—All rails, track structures, and fittings, other than plain unguarded track that is neither curved nor fabricated before laying.

Specification.—That part of the contract describing the materials for or the details of construction.

Spiral (When used with respect to track).—A form of easement curve in which the change of degree is uniform throughout its length.

Ten Chord.—An approximate spiral measured in 10 equal chords and whose change of degree of curve is directly proportional to the length measured along the spiral by such chords.

Splice Drilling.—The spacing of holes in the ends of rails or other track structures to receive the bolts for the fastening of joint bars.

Split Web.—A longitudinal or diagonal transverse crack in the web of a rail.

Spot Board.—A sighting board placed above and across the track at the proposed height to indicate the new surface and insure its uniformity.

Spring Washer.—A member designed to prevent backward movement of the nut and looseness in the bolted members of a rail joint due to wear, stretch, rust, or other deterioration.

Stamping.—The figures and letters indented after hot sawing in the center of the rail web, parallel with the direction of rolling, indicating the serial heat number, the ingot number as cast or rolled, and one letter designating the position of each rail with reference to the top of the ingot.

Steel.—A ferrous material produced in a fluid condition, usually by the bessemer, open-hearth, electric furnace, or basic-oxygen process. It is practically free from slag, distinguishing it from wrought iron, and in general contains less than 1.70 percent of carbon, distinguishing it from cast iron.

Stock-Guard.—A barrier of wood, metal, or other material placed between and alongside of track rails to prevent the passage of livestock on or along the railroad track or tracks.

Stock Rail.—A running rail against which the switch rail operates.

Stock Rail Bend.—The bend or set which must be given the stock rail at the vertex of a switch to allow it to follow the gage line of the turnout.

Stress.—The sum of the forces acting in the interior of a body which resist external forces tending to change its form or shape. Stress is measured in force per unit area (pounds per square inch, kilograms per square millimetre, etc.).

Stringer.—A longitudinal member extending from bent to bent and supporting the track.

Subballast.—Any material of a superior character, which is spread on the finished subgrade of the roadbed and below the top ballast, to provide better drainage, prevent upheaval by frost, and better distribute the load over the roadbed.

Subdrain.—A covered drain, below the roadbed or ground surface, receiving water along its length through perforations or joints.

Subgrade (noun).—The finished surface of the roadbed below the ballast and track.

Subsidence (noun).—That portion of an embankment which has settled below the original surface of the ground.

Subsurface Drainage.—The control and removal of excess moisture contained in the soil.

Surface (Track).—The condition of the track as to vertical evenness or smoothness.

Running (Tread).—The top part of track structures on which the treads of the wheels bear.

Sway Brace.—A member bolted or spiked to a bent and extending diagonally across its face.

Sweep, Rail.—Two flexible parts attached to the front of a track car in such a location as to brush from the rail, as the car moves forward, any easily removable obstruction on the top of the rail.

Swell.—The term swell as applied to grading material is the difference in volume of the same material in the embankment after it has reached a state of equilibrium, when the latter is the greater.

Switch.—A track structure used to divert rolling stock from one track to another.

Split.—A switch consisting essentially of two movable point rails with the necessary fixtures.

Split, with Uniform Risers.—A split switch in which the switch rails have a uniform elevation on riser plates for the entire length of the switch, and therefore not having a heel slope, the point rail rise being run off back of the switch in the closure rails.

Split, with Graduated Risers.—A split switch in which the switch rails are gradually elevated by means of graduated riser plates until they reach the required height above the stock rail, and therefore having a heel slope.

Split, Manganese Tipped.—A split switch in which the head of one or both of the switch rails is cut away in the point portion and manganese steel pieces fastened to the rail to form the point.

Split, Insulated.—A switch in which the fixtures, principally the gage plates and the switch rods, connecting or reaching from one rail to the opposite rail are provided with insulation so that the electric track circuit will not be shunted.

Spring.—A switch in the operating mechanism of which is incorporated a spring device so arranged as to automatically return the points to their original or normal position after they have been thrown over by the flanges of trailing wheels passing along the other track from that for which the points are set for facing movements.

Tongue.—A switch piece consisting essentially of a movable tongue with a suitable enclosing and supporting body structure, designed for use on one side of the track while on the other side there is used either a mate or another tongue switch. (A tongue switch is termed "inside" or "outside" depending upon whether it is placed on the inside or on the outside of the curve, the "outside tongue switch" being comparatively little used.)

Angle.—The angle included between the gage lines of the switch rail at its point and the stock rail.

Detector Bar.—A strip of metal mounted alongside the track rail and connected with the throwing mechanism of the switch to prevent the moving of the switch under trains.

Head Separation.—The point on a switch rail where the head of the rail attains its full width.

Heel of.—That end of a switch rail which is the farther from its point, and nearer the frog.

Heel Spread.—The distance, at the heel, between the gage line of a switch rail and the gage line of its stock rail. (This has been standardized at 6-1/4 inches for straight switches.)

Heel Slope.—The inclination produced by graduated risers in that part of the switch which reduced the elevation (as the height of the risers decreases) toward the heel of the switch.

Point of, Actual.—That end of the switch rail which is the farther from the frog; the point where the spread between the gage lines of the stock rail and the switch rail is sufficient for a practicable switch point.

Point of, Theoretical or Vertex.—The point where the gage line of the switch rail, if produced, would intersect the gage line of the stock rail.

Point Rail, Switch Rail, or Switch Point.—The tapered rail of a split switch.

Point Rail Rise.—The elevation of a switch rail to allow the overhanging part of hollowed-out treads of worn wheels to pass over the stock rail.

Planing, Bottom.—The cut planed at an angle on the bottom of the base of the switch rail from the point and toward the heel to allow the switch rail to rest on the top of the base of the stock rail when the switch rail is closed.

Planing, Side.—The cuts made on the sides of the head of the switch rail to form the taper.

Planing, Top.—The cut made on the top of the head of the switch rail from the point and to approximately the head separation.

Planing, Chamfer Cut.—The vertical beveling of the gage side of the switch point to produce a sharp edge, so as to prevent wheel flanges from striking the point.

Rail Brace.—A metal shape designed to fit the contour of the side of the stock rail and extend over the switch plate, with provision for fastening through the plate to the tie, to restrain the movement of the stock rail.

Rail Brace, Adjustable.—A rail brace which may be adjusted laterally with respect to the stock rail, to compensate for variations in the dimensions of the rail and to permit of adjusting for wear.

Throw of.—The distance through which the points of switch rails are moved sidewise, measured along the centerline of the No. 1 switch rod or head rod. (This distance is standardized at 4-3/4 inches.)

Switch Point Derail.—A derail consisting essentially of a split switch point with the necessary fixtures.

Switch Stand.—A device for the manual operation of switches, or of movable center points.

T

Tangent.—Any straight portion of a railway alignment.

Tapping.—The removal of the molten steel from the open-hearth furnace by opening the tap hole and allowing the metal to run into the ladle.

Teeming.—The pouring of molten steel from the ladle into ingot molds.

Templet.—Usually a piece of thin metal of the exact size and shape of the rail section when hot, or the reverse of the shape to be fitted over a hot or cold rail to check its shape.

Fishing.—A templet shaped to fit between the head and base of the rail and used to determine whether the rail section is accurately formed in the fishing spaces to receive the joint bars.

Tensile Strength.—The maximum tensile stress which a material is capable of sustaining.

Tie, Adzed.—A tie which has had the plate-bearing areas of its top made plane and smooth by passage through a machine designed for the purpose.

Bored.—A tie which has had holes for spikes provided by passage through a machine designed for the purpose.

Cross.—The transverse member of the track structure to which the rails are spiked or otherwise fastened to provide proper gage and to cushion, distribute, and transmit the stresses of traffic through the ballast to the roadbed.

Grooved.—A crosstie which has had machine-gouged depressions across its top into which ribs on the bottom of a tie plate may fit.

Heart.—A tie with sapwood no wider than one-fourth the width of the top of the tie between 20 and 40 inches from the middle of the tie.

Sap.—A tie with sapwood wider than one-fourth the width of the top of the tie between 20 and 40 inches from the middle of the tie.

Slabbed.—A tie sawed on top and bottom only. (Known also as "pole" tie and "round" tie.)

Substitute.—A tie of any material other than wood or of wood in combination with any other material.

Switch.—The transverse member of the track structure which is longer than but functions as does the crosstie and in addition supports a crossover or turnout.

Tie Plate.—A plate interposed between a rail or other track structure and a tie.

Toe of Slope.—The intersection of a slope with the ground surface in embankments, and the plane of roadbed in cuts.

Tolerance.—An allowable variation from dimensions or requirements specified.

Topballast.—Any material of a superior character spread over a subballast to support the track structure, distribute the load to the subballast, and provide a good initial drainage.

Top of Slope.—The intersection of a slope with the ground surface in cuts, and the plane of roadbed on embankment.

Track.—An assembly of rails, ties, and fastenings over which cars, locomotives, and trains are moved.

Body.—Each of the parallel tracks of a yard upon which cars are placed or stored.

Classification.—One of the body tracks in a classification yard, or a track used for classification purposes.

Connecting.—Two turnouts with the track between the frogs arranged to form a continuous passage between one track and another intersecting or oblique track or another remote parallel track.

Crossover.—Two turnouts with track between, connecting two nearby and usually parallel tracks.

Departure.—One of the tracks in a departure yard on which outgoing cars are placed.

Drill.—A track connecting with the ladder track, over which locomotives and cars move back and forth in switching.

Hold.—One of the body tracks in a hold yard or a track used for hold purposes.

House.—A track alongside of, or entering a freight house, and used for cars receiving or delivering freight at the house.

Interchange.—A track on which cars are delivered or received, as between railways.

Ladder.—A track connecting successively the body tracks of a yard.

Lead.—An extended track connecting either end of a yard with the main track.

Passing.—A track auxiliary to the main track for meeting or passing trains. Same as a **Siding.**

Repair.—A track on which cars are placed for repairs.

Running.—A track reserved for movement through a yard.

Scale.—A track leading to and from and passing over a track scale.

Side.—A track auxiliary to the main track for purposes other than for meeting and passing trains.

Sorting.—One of the body tracks in a sorting yard or a track used for sorting purposes.

Spur.—A stub track diverging from a main or other track.

Storage.—One of the body tracks in storage yards or one of the tracks used for storing equipment.

Stub.—A track connected with another one at one end only.

Team.—A track on which cars are placed for transfer of freight between cars and highway vehicles.

Wye.—A triangular arrangement of tracks on which locomotives, cars, and trains may be turned.

Track Bolt.—A bolt with a button head and oval, or elliptical, neck and a threaded nut designed to fasten together rails and joint bars.

Track Capacity.—The number of cars that can stand in the clear on that track.

Transverse Defect.—For defects found by detector cars, a tentative group classification, applied prior to the breaking of the rails, of all types of rail defects which have transverse components, such as transverse fissures (TF), compound fissures (CF), and detail fractures (DF).

Transverse Fissure.—A progressive crosswise fracture starting from a crystalline center or nucleus inside the head from which it spreads outward as a smooth, bright or dark, round or oval surface substantially at a right angle to the length of the rail. The distinguishing features of a transverse fissure from other types of fractures or defects are the crystalline center or nucleus and the nearly smooth surface of the development which surrounds it.

Tread.—The top surface of the head of a rail which contacts wheels.

Turnout.—An arrangement of a switch and a frog with closure rails, by means of which rolling stock may be diverted from one track to another.

Equilateral.—A turnout in which the diversion due to the angle of the turnout is divided equally between the two tracks.

Lateral.—A turnout in which the diversion due to the angle of the turnout is entirely on one side of the track from which the turnout is made.

Turnout Number.—The number corresponding to the frog number of the frog used in the turnout.

V

Vertical Split Head.—A split along or near middle of the head of a rail and extending into or through it. A crack or rust streak may show under the head close to the web, or pieces may be split off the side of the head.

W

Waste of Spoil Banks.—Banks outside the roadway formed by waste.

Welded Rail.—Two or more rails welded together to form a length less than 400 feet (CWR). (See also Continuous Welded Rail.)

Wing Fence.—A fence connecting the apron of the stockguard with the right-of-way or line fence.

Wingwall.—An extension of an abutment wall to retain the adjacent earth.

Wood Trestle.—A wood structure composed of bents supporting stringers, the whole forming a support for loads applied to the stringers through the deck.

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron, with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Wye.—A triangular arrangement of tracks on which locomotives, cars, and trains may be turned.

Y

Yard.—A system of tracks within defined limits provided for making up trains, storing cars, and other purposes, over which movements not authorized by time table or by train-order may be made, subject to prescribed signals and rules, or special instructions.

Capacity-Standing.—The sum of the capacities of all the tracks in that yard on which cars may be permitted to stand.

Classification.—A yard in which cars are classified or grouped in accordance with requirements.

Departure.—A yard in which cars are assembled in trains for forwarding.

Hold.—A yard for the temporary holding of cars.

Receiving.—A yard for receiving cars.

Storage.—A yard in which idle equipment is held awaiting disposition.

APPENDIX D. ENGINEERING DATA

D-1. Alignment.

Normally, curvature of track should be limited to a minimum radius of approximately 300 feet or to the minimum recommended by the serving railroad. The following rules for alignment should be followed:

D-1.1. Running tracks and body tracks are 15 feet center to center from parallel tracks. For siding tracks, allow 13 feet between parallel tracks. For siding and main line tracks, allow 15 feet between parallel tracks. Figures D-1 through D-4 and Tables D-1 through D-4 are engineering drawings and information concerning turnouts and track layouts. Figures D-5 and D-6 show names of parts for bolted frogs and split switches, respectively.

D-1.2. Beginning with a 10-degree curve, track centers are widened 1 inch for each degree of curvature, to allow for overhanging and tilting of cars. A special engineering analysis should be made when longer than standard (60 feet) cars are moved. (Middle ordinates for curved rails for various lengths of rail and degrees of curves are shown in Table D-5.)

D-2. Superelevation.

Superelevation is, in general, based on the degree of curvature and the train speed. Usually, an elevation of 6 inches is not exceeded for tracks carrying both fast and slow traffic. Speed of trains is reduced if necessary. See Table D-6 for the maximum allowable operating speeds for curved track. **NOTE:** Curves in industrial or heavily congested areas may be installed level without superelevation.

D-2.1. Simple Curves. Full elevation will be carried uniformly throughout the length of simple curves.

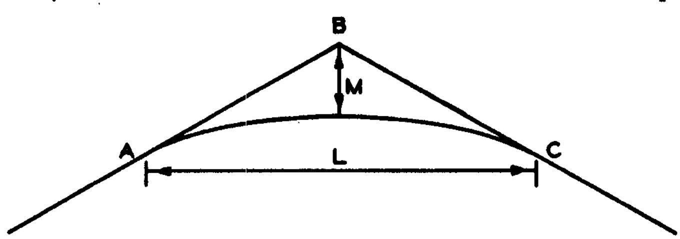
D-2.2. Compound Curves. Each section of a compound curve will be given its correct elevation, but the change from one elevation to another will be uniformly distributed.

D-2.3. Reverse Curves. The elevation from one rail to the other will be changed so that rails are level at the point of reversal.

D-2.4. Transition Approach. Superelevation of a spiral easement or tangent transition approach to a simple curve will be made in successive stages at a rate of 1/4 to 1/2 inch in 30 feet for a maximum length of 360 feet. Changes from zero to full elevation at the start of a simple unspiraled curve will be made within the transition approach so that full elevation is attained at the start of the curve. Spiral easements will be given to all curves where layout conditions permit. Table D-7 gives spiral lengths for various elevations and train speeds.

D-3. Vertical Curves.

Vertical curves are used for all changes in gradient. The maximum allowable rate of change is 0.10 foot per 100 feet in sags and 0.20 foot per 100 feet in summits. For tracks of lesser importance, the rate of change may be larger but shall be not greater than practicable considerations will permit. One such form of vertical curve is developed as follows:



L = Length of vertical curve in 100-foot stations
M = Correction in elevation at B
R = Rate of change per station
D = Algebraic difference of rates at grade
L = D/R

When vertical curve is concave downwards:

$$M = \frac{(\text{el. B} \times 2) - (\text{el. A} + \text{el. C})}{4}$$

When vertical curve is concave upwards:

$$M = \frac{(\text{el. A} + \text{el. C}) - (\text{el. B} \times 2)}{4}$$

The correction for any other point on a vertical curve is proportional to the square of the distance from A or C to B. Corrections are minus (−) when the vertical curve is concave downwards and plus (+) when the vertical curve is concave upwards.

D-4. Grades.

Maximum grades of 0.5 percent (6 inches in 100 feet) are recommended for house and storage tracks; grades will not exceed 0.8 percent (9-1/2 inches in 100 feet). Grades on access or running tracks are limited to those recommended by the serving railroad. All changes in gradient are made through vertical curves (para D-3).

D-5. Space Allowance for Rail Expansion.

To insure proper space allowance for expansion when laying or replacing rail, the openings between the ends of rail listed in Table D-8 shall be developed through the use of standard metal, fiber, or wood shims placed between the ends of adjacent rails. When shims are used they shall be removed to within 12 rails of the laying.

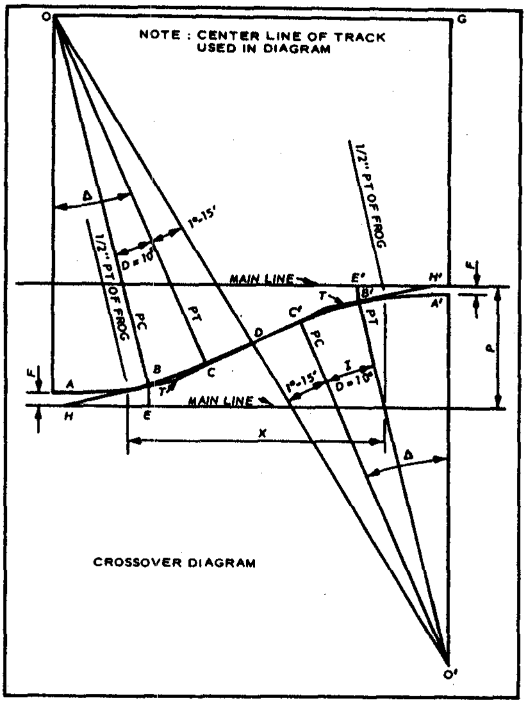


Figure D-2. Curve details for standard No. 8 crossover (see Table D-2 for dimensions).

Table D-2. Dimensions of Standard No. 8 Crossover

Dimensions are between parallel tracks, at P distance apart, using 10-degree curves and 25-foot tangent between frogs.
R = 573.69; Frog angle = 7°09';
CC' (tangent) = 25.00;
$OD = O'D = \sqrt{R^2 + 125^2} = 573.83$
Continue curve I to tangent parallel to main track.

Then F = BE - 573.69 versine 7°09' = 1.48'. O'G = 2R - P + 2F = 1,150.34 - P

$\Delta = \cos^{-1} \frac{1150.34}{1147.66} - P - 1°15'$

I = Δ - 7°09'; T = R tan 1/2 I
X = Distance between actual points of frogs = (2T + 25) cos Δ + 2T cos 7°09' + 18.75.

P	X	I	P	X	I
30	124.75	4°07'	51	205.35	8°17'
31	129.21	4°21'	52	208.67	8°27'
32	133.60	4°35'	53	211.95	8°38'
33	137.90	4°48'	54	215.20	8°48'
34	142.12	5°01'	55	218.42	8°58'
35	146.28	5°14'	56	221.60	9°08'
36	150.37	5°26'	57	224.74	9°18'
37	154.40	5°39'	58	227.87	9°28'
38	158.37	5°51'	59	230.96	9°37'
39	162.28	6°03'	60	234.01	9°47'
40	166.13	6°15'	61	237.04	9°56'
41	169.93	6°27'	62	240.04	10°06'
42	173.68	6°38'	63	243.02	10°15'
43	177.37	6°50'	64	245.97	10°25'
44	181.03	7°01'	65	248.89	10°34'
45	184.62	7°12'	66	251.78	10°43'
46	188.18	7°23'	67	254.66	10°52'
47	191.70	7°34'	68	257.51	11°01'
48	195.17	7°45'	69	260.33	11°10'
49	198.60	7°56'	70	263.13	11°19'
50	201.99	8°06'			

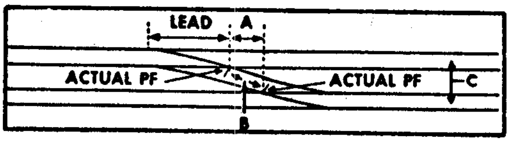


Figure D-3. Diagram of lead and coordinates of crossovers (see Table D-4 for dimensions).

Table D-3. Lead and Coordinate Distances by Frog Number and Distance Between Tracks

Frog No.	Leads		Frog Angles		Distance Between Track Centers (C)											
					12 Feet				13 Feet				14 Feet			
					A		B		A		B		A		B	
	ft	in.	deg	ft	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.
5	42	6	11	25	11	10-3/4	13	1-1/4	16	10-1/4	18	1-3/4	21	9-3/4	23	2-1/2
6	47	6	9	32	14	6	15	6	20	5-1/2	21	6-1/2	26	5	27	7
7	62	1	8	10	17	1	17	11	24	0-1/2	24	11-3/4	31	0	32	0
8	68	0	7	09	19	7-1/2	20	4-1/2	27	7	28	5	35	6-3/4	36	5-1/4
9	72	3	6	22	22	2	22	10	31	1-3/4	31	10-1/2	40	1-1/2	40	10-3/4
10	78	9	5	43	24	8-1/4	25	3-3/4	34	8	35	4	44	8	45	4-1/4
12	96	8	4	46	29	9	30	3	41	8-3/4	42	3-1/4	53	8-1/2	54	3-1/2
14	107	1	4	05	34	9-1/2	35	2-1/2	48	9-1/4	49	2-3/4	62	9	63	3
15	126	4	3	49	37	3-1/4	37	8-1/2	52	3-1/2	52	8-1/2	67	3-1/4	67	8-3/4
16	131	4	3	35	39	9-1/2	40	2-1/4	55	9-3/4	56	2-1/2	71	9-1/2	72	2-3/4
18	140	11	3	11	44	10	45	2	62	10	63	2-1/4	80	9-3/4	81	2-1/2
20	151	11	2	52	49	10	50	1-3/4	69	10	70	2	89	10	90	2

Frog No.	Leads		Frog Angles		Distance Between Track Centers (C)											
					15 Feet				18 Feet				20 Feet			
					A		B		A		B		A		B	
	ft	in.	deg	ft	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.	ft	in.
5	42	6	11	25	26	9	28	3	41	7-1/4	43	5	51	6	53	6
6	47	6	9	32	32	4-1/2	33	7-1/2	50	3	51	9	62	2	63	10
7	62	1	8	10	37	11-3/4	39	0-1/2	58	10-1/4	60	2	72	9-1/2	74	2-3/4
8	68	0	7	09	43	6-1/2	44	5-3/4	67	5-1/4	68	6-3/4	83	4-1/2	84	7-1/2
9	72	3	6	22	49	1	49	11	76	0	77	0	93	11-1/2	95	0-1/2
10	78	9	5	43	54	7-1/2	55	4-1/2	84	6-1/2	85	5-1/2	104	6-1/4	105	6
12	96	8	4	46	65	8-1/4	66	3-3/4	101	7-1/2	102	4-1/2	125	4-1/2	126	5
14	107	1	4	05	76	9	77	3-1/4	118	8-1/4	119	4	146	8	147	4-1/2
15	126	4	3	49	82	3	82	9	127	2-1/2	127	9-3/4	157	2	157	10
16	131	4	3	35	87	9-1/4	88	3	135	8-3/4	136	3-1/2	167	8-1/4	168	3-3/4
18	140	11	3	11	98	9-1/2	99	2-1/2	152	9	153	3	188	8-1/2	189	3-1/2
20	151	11	2	52	109	9-3/4	110	2-1/4	169	9-1/2	170	2-3/4	209	9	210	3

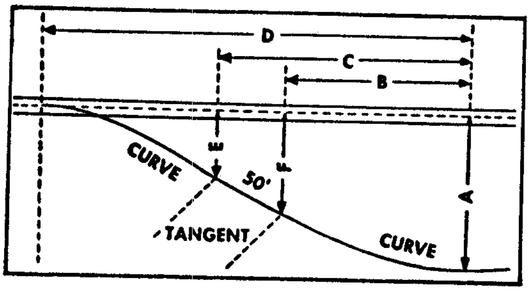


Figure D-4. Diagram for laying temporary tracks around obstructions.

Table D-4. Dimensions for Laying Temporary Tracks Around Obstructions

A	B	C	D	E	F
		10-Degree Curves			
10	53.6	103.3	156.9	2.5	7.5
20	84.0	133.5	217.5	6.3	13.7
30	107.3	156.5	263.8	10.3	19.7
40	127.3	176.0	303.3	14.4	25.6
50	144.8	193.1	337.9	18.7	31.3
60	160.3	208.3	368.6	23.0	37.0
70	174.5	222.1	396.6	27.4	42.6
80	187.8	235.0	422.8	31.8	48.2
90	200.2	247.0	447.2	36.2	53.8
100	211.9	258.3	470.2	40.7	59.3
		15-Degree Curves			
10	42.2	92.0	134.2	2.3	7.7
20	66.2	115.4	181.6	5.7	14.3
30	85.0	133.7	218.7	9.5	20.5
40	100.8	149.2	250.0	13.5	26.5
50	114.7	162.6	277.3	17.5	32.5
60	127.2	174.4	301.6	21.5	38.3
70	138.7	185.6	324.3	26.0	44.0
80	149.4	195.6	345.0	30.3	49.7
90	159.2	204.8	364.0	34.6	55.4
100	168.5	213.5	382.0	39.0	61.0

Note: All dimensions in feet.

Table D-5. Radius of Curves and Middle Ordinates for Curved Rails

Radius of Curve (ft)	Degree of Curve	Middle Ordinate (in.) for Rail Length (ft)		
		30	33	39
955.4	6	1-3/8	1-3/4	2-3/8
819.0	7	1-5/8	2-7/8	2-3/4
716.8	8	1-7/8	2-1/4	3-1/8
637.3	9	2-1/8	2-1/2	3-5/8
573.7	10	2-3/8	2	4
521.7	11	2-5/8	3-1/8	4-3/8
478.3	12	2-7/8	3-3/8	4-3/4
441.7	13	3	3-3/4	5-1/8
410.3	14	3-1/4	4	5-1/2
383.1	15	3-1/2	4-1/4	6

NOTE: To find the middle ordinate of a curved rail, stretch a line from ends of rail on inside of curvature. Distance from edge of rail to line at exact center of rail is middle ordinate.

Table D-6. Maximum Allowable Operating Speeds for Curved Track

Degree of Curvature	Elevation of Outer Rail (in.)												
	0	½	1	1½	2	2½	3	3½	4	4½	5	5½	6
	Maximum Allowable Operating Speed (mph)												
0°30'	93	100	107	--	--	--	--	--	--	--	--	--	--
0°40'	80	87	93	98	103	109	--	--	--	--	--	--	--
0°50'	72	78	83	88	93	97	101	106	110	--	--	--	--
1°00'	66	71	76	80	85	89	93	96	100	104	107	110	--
1°15'	59	63	68	72	76	79	83	86	89	93	96	99	101
1°30'	54	58	62	66	69	72	76	79	82	85	87	90	93
1°45'	50	54	57	61	64	67	70	73	76	78	81	83	86
2°00'	46	50	54	57	60	63	66	68	71	73	76	78	80
2°15'	44	47	50	54	56	59	62	64	67	69	71	74	76
2°30'	41	45	48	51	54	56	59	61	63	66	68	70	72
2°45'	40	43	46	48	51	54	56	58	60	62	65	66	68
3°00'	38	41	44	46	49	51	54	56	58	60	62	64	66
3°15'	36	39	42	45	47	49	51	54	56	57	59	61	63
3°30'	35	38	40	43	45	47	50	52	54	55	57	59	61
3°45'	34	37	39	41	44	46	48	50	52	54	55	57	59
4°00'	33	35	38	40	42	44	46	48	50	52	54	55	57
4°30'	31	33	36	38	40	42	44	45	47	49	50	52	54
5°00'	29	32	34	36	38	40	41	43	45	46	48	49	51
5°30'	28	30	32	34	36	38	40	41	43	44	46	47	48
6°00'	27	29	31	33	35	36	38	39	41	42	44	45	46
6°30'	26	28	30	31	33	35	36	38	39	41	42	43	45
7°00'	25	27	29	30	32	34	35	36	38	39	40	42	43
8°00'	23	25	27	28	30	31	33	34	35	37	38	39	40
9°00'	22	24	25	27	28	30	31	32	33	35	36	37	38
10°00'	21	22	24	25	27	28	29	31	32	33	34	35	36
11°00'	20	21	23	24	26	27	28	29	30	31	32	33	34
12°00'	19	20	22	23	24	26	27	28	29	30	31	32	33

Table D-7. Spiral Lengths on Curves for Various Elevations and Train Speeds

Elevation in.	Spiral Length (ft) for Train speeds (mph)											
	15	20	25	30	35	40	45	50	55	60	65	70
1	18	23	29	35	41	47	53	59	64	70	76	82
1-1/2	26	35	44	53	62	70	79	88	97	106	114	123
2		47	59	70	82	94	106	117	129	141	152	164
2-1/2		59	73	88	103	117	132	147	161	176	191	205
3		70	88	106	123	141	158	176	193	211	229	246
3-1/2			103	123	144	164	185	205	226	246	267	288
4			117	141	164	188	211	235	258	282	305	
4-1/2			132	158	185	211	238	264	290	317	343	
5				176	205	235			322		381	
5-1/2				194	225						419	

Table D-8. Space Allowance for Rail Expansion

33-Foot Rail 160 Joints per Mile		39-Foot Rail 135 Joints per Mile	
Rail Temperature °F	Rail Expansion in.	Rail Temperature °F	Rail Expansion in.
Below −10	5/16	Below 6	5/16
−10 to 14	1/4	6 to 25	1/4
15 to 34	3/16	26 to 45	3/16
35 to 59	1/8	46 to 65	1/8
60 to 85	1/16	66 to 85	1/16
Over 85	None	Over 85	None

D-6. Derails.

Derails are installed on sidings to derail any cars rolling beyond a specified safe distance from the adjacent running track. The use of derails is governed by such local conditions as the relative grades of turnout and running tracks, and the amount and type of traffic on the track to be protected. Derails are installed on the rail farthest from the running track and far enough from the clearance point to insure that derailed equipment will not foul the running track (Chapter 3).

D-7. Guardrails Over Bridges or Trestles.

D-7.1. Installation. Guardrails are installed between running rails over open deck bridges and trestles, on all curves over 4 degrees, or on tangents and curves under 4 degrees if the clear span is 40 feet or more. They are installed according to the following rules:

D-7.1.1. Single Track. Two guardrails placed on the ties between traffic rails to provide a 10-inch space between the head of the guardrail and the gage side of the traffic rail.

D-7.1.2. Two Tracks. One guardrail for each track, placed on the ties 10 inches from the gage of the traffic rails farthest from the parapets.

D-7.1.3. Three or More Tracks. One guardrail for each outside track, placed on the ties 10 inches from the gage of the traffic rails farthest from the parapets.

D-7.2. Weights. The relationship between weights of guardrails and traffic rails is as follows:

Traffic Rail	Guardrail
130	100
100	85
90	75
85	70
75	60

D-8. General.

Tables D-9 thrugh D-12 give information regarding rail and track accessories.

Table D-9. Rail Accessories for 1,000 Feet of Track

Weight of Rail		No. of Ties		Joint-Bars[a]		Bolts (Square Nuts), 4 per Joint		Lock Washers		Spikes[b] (4 per Tie)				Ballast	Tie Plates
										16 Ties per 39-Foot Rail		18 Ties per 39-Foot Rail			
Weight per Yard lb	Weight Long Tons	16 per 39-Foot Rail	18 per 39-Foot Rail	No. of Pairs	Weight Net Tons	Kegs	Weight Net Tons	No.	Weight Net Tons	Kegs	Weight Net Tons	Kegs	Weight Net Tons	15% Shrinkage Allowed 6 inches Deep, cu yd	Weight Net Tons
75	22.32	410	461	51.13	1.1	1.38	0.138	205	0.0171	4.97	0.497	5.59	0.559	391.10	3.946
80	23.81	410	461	51.13	1.1	1.473	0.1473	205	0.0171	4.97	0.497	5.59	0.559	391.10	3.946
85	25.30	410	461	51.13	1.38	1.473	0.1473	205	0.0171	4.97	0.497	5.59	0.559	391.10	3.946
90	26.79	410	461	51.13	1.38	1.76	0.176	205	0.0184	4.97	0.497	5.59	0.559	391.10	5.887
100	29.76	410	461	51.13	1.71	1.76	0.176	205	0.0184	4.97	0.497	5.59	0.559	391.10	6.550
115	34.76	410	461	51.13	1.61	2.47	0.247	205	0.0184	6.98	0.698	7.85	0.785	391.10	7.914

NOTES: Corrections in track materials to be made for each turnout:

1. Measure track to switch point.
2. On standard turnout, add 59 feet of track or 118 feet of rail.
3. Deduct 95 cross.
4. Add 7 pairs of joint bars.
5. Add 28 track bolts.
6. Add 28 lock washers.
7. Add 1/3 keg of spikes.
8. Standard turnout plan shows D-bars for joints in turnouts. When angle bars can be used, it is preferable to use them.
9. Add 136 tie plates.
10. Measurement of standard track begins at end of switch ties (87 feet from PS).

[a] No allowance made for shorts.
[b] Additional spikes needed on curves (2 per tie).

Table D–10. Size and Weight of Rail Accessories

Weight of Rail lb	Joint Bars: Length (4 Hole) in.	Joint Bars: Weight per Pair lb	Bolts (Square Nuts): Average Number in 200-lb Keg	Bolts (Square Nuts): Size in.	Bolts (Square Nuts): Weight Each lb	Lock Washers (1/2 in. Wide, 1/4 in. Thick): Size in.[a]	Lock Washers (1/2 in. Wide, 1/4 in. Thick): Weight Each in.	Spikes (5/8×6 in.)
75	24	43	148	7/8×4	1.35	1 ID 2 OD	0.16705	Weight each 0.8264 lb
80	24	43	139	7/8×4-1/2	1.44	1 ID 2 OD	0.16705	
85	24	54	139	7/8×4-1/2	1.44	1 ID 2 OD	0.16705	Average number per 200-lb keg = 242
90	24	62	109	1×5-1/4	1.724[b]	1-1/8 ID 2-1/8 OD	0.18097	
100	24	67	109	1×5-1/2	1.724[b]	1-1/8 ID 2-1/8 OD	0.18097	
115	24	63	109	1×5-1/2	1.724	1-1/8 ID 2-1/8 OD	0.18097	

[a] Inside dimension; outside dimension.
[b] Hexagonal nuts.

Table D–11. Dimensins and Weights of Standard Railroad Spikes

Dimensions, in.: Diameter	Length	Head: Length	Head: Width	Head: Thickness	Thickness of Heel	Length of Hook	Length of Taper of Point, in.	Approximate Number per 200-lb Keg	Number of Kegs per Mile of Single Track	Rails Used, Weight per Yard lb
1/2	3-1/2	1-5/16	1-1/8	1/2	5/16	11/16	7/8	624	17.9	20 to 30
1/2	4	1-5/16	1-1/8	1/2	5/16	11/16	7/8	550	18.0	20 to 30
1/2	4-1/2	1-5/16	1-1/8	1/2	5/16	11/16	7/8	504	20.0	30 to 40
1/2	5	1-5/16	1-1/8	1/2	5/16	11/16	7/8	472	21.6	30 to 40
9/16	4-1/2	1-1/2	1-1/4	9/16	5/32	3/4	1-1/8	408	25.8	40 to 50
9/16	5	1-1/2	1-1/4	9/16	5/32	3/4	1-1/8	365	32.6	50 to 60
9/16	5-1/2	1-1/2	1-1/4	9/16	5/32	3/4	1-1/8	330	37.1	60 to 100
5/8	5	1-9/16	1-5/16	21/32	7/32	3/4	1-1/4	288	38.4	85 to 100
5/8	5-1/2	1-9/16	1-5/16	21/32	7/32	3/4	1-1/4	272	42.7	85 to 130
5/8	6	1-9/16	1-5/16	21/32	7/32	3/4	1-1/4	242	47.6	85 to 130

NOTE: Number of spikes in this table based on tie spacing of 24 inches for rails up to and including 45 pounds and 22 inches for rails 50 pounds and heavier.

Table D-12. Dimensions and Weights of Standard Track Bolts

Dimensions, in.									Nuts		With Square Nuts			With Hexagon Nuts			
		Head				Shoulder											
Diameter	Length	Wide	Deep	Diameter Side	Diameter Top	Deep	Wide	Length Thread	Thickness in.	Short Diameter of Square and Hexagon, in.	Weight, Pounds per 100	Number in 200-lb Keg	Number of Kegs per Mile of Track	Weight, Pounds per 100	Number in 200-lb Keg	Number of Kegs per Mile of Track	Rail Used on Weight lb/yd
1/2	1-3/4	15/16	5/16	9/32	15/16	5/16	11/16	1-1/8	1/2	7/8	22.0	909	1.6	20.3	986	1.5	12 to 20
1/2	2	15/16	5/16	9/32	15/16	5/16	11/16	1-1/8	1/2	7/8	22.7	881	1.7	21.7	923	1.6	12 to 20
1/2	2-1/4	15/16	5/16	9/32	15/16	5/16	11/16	1-1/8	1/2	7/8	24.0	834	1.8	22.9	874	1.7	12 to 20
5/8	2-3/4	1-1/8	13/32	3/8	1-1/8	3/8	7/8	1-1/4	5/8	1-1/16	44.5	448	3.2	43.0	466	3.1	25 to 35
5/8	3	1-1/8	13/32	3/8	1-1/8	3/8	7/8	1-1/4	5/8	1-1/16	47.3	439	3.3	45.5	440	3.3	25 to 35
3/4	3	1-3/8	17/32	1/2	1-3/8	1/2	1	1-3/4	3/4	1-1/4	73.5	273	5.3	70.0	286	5.0	40 to 45
3/4	3-1/4	1-3/8	17/32	1/2	1-3/8	1/2	1	1-3/4	3/4	1-1/4	76.0	264	5.0	72.3	277	4.8	50 to 75
3/4	3-1/2	1-3/8	17/32	1/2	1-3/8	1/2	1	1-3/4	3/4	1-1/4	80.3	249	5.3	76.0	264	5.0	50 to 75
3/4	3-3/4	1-3/8	17/32	1/2	1-1/8	1/2	1	1-3/4	3/4	1-1/4	83.7	239	5.5	79.1	252	5.2	50 to 75
3/4	4	1-3/8	17/32	1/2	1-3/8	1/2	1	1-3/4	3/4	1-1/4	86.9	231	5.7	81.9	245	5.4	50 to 75
7/8	4	1-9/16	19/32	9/16	1-9/16	9/16	1-3/16	2	7/8	1-7/16	124.1	162	8.0	118.5	169	7.7	75 to 85
7/8	4-1/4	1-9/16	19/32	9/16	1-9/16	9/16	1-3/16	2	7/8	1-7/16	129.4	155	8.4	122.2	164	8.0	75 to 85
1	4-1/2	1-23/32	5/8	19/32	1-23/32	5/8	1-5/16	2-1/4	1	1-5/8	175.0	115	11.3	166.3	121	10.8	90 to 100
1	4-3/4	1-23/32	5/8	19/32	1-23/32	5/8	1-5/16	2-1/4	1	1-5/8	187.9	109	12.0	187.9	109	12.0	90 to 100
1	5-1/2	1-11/32	5/8	19/32	1-11/16	9/16	1-3/8	2-1/4	1	1-5/8	187.9	109	12.0	187.9	109	12.0	115

APPENDIX E. TRACK CHARTS

E-1. Scale.

Track charts are prepared to the most convenient scale and of such a size to permit filing with real property records. If total track mileage is over 10 miles or 50,000 feet, the scale may be either 2 inches to 1 mile or 2 inches to 5,000 feet. If total length is less than 10 miles, the scale may be 4 inches to 1 mile or 1 inch to 1,000 feet. In congested or industrial area any format or scale can be used (7-7.2).

E-2. Title.

The chart should contain the name and location of the installation, name of the serving railroad or railroads, scale used, and title block of the office preparing the chart.

E-3. Legend.

All symbols will conform to standard military symbols.

E-4. Track Data Included.

The following trackage and structures will be included:

E-4.1. Main lines or running tracks.
E-4.2. Crossovers within main lines.
E-4.3. Turnouts from main lines.
E-4.4. Sidings, spurs, ladder tracks, and yards.
E-4.5. Buildings, bridges, trestles, culverts, and other structures.
E-4.6. Highway and road crossings.
E-4.7. Connections to serving railroad.
E-4.8. Installation property lines.

NOTE: Any important tracks leading from main or running tracks are made the basis for a separate chart, identified by name or number of the track and added as an extension to the main chart.

E-5. Method of Representation.

E-5.1. For simplification, the main or running tracks may be represented by a heavy horizontal line in the center of the chart. Double track should be represented by two parallel lines. Where double tracks change to single track, the two lines converge to a single line. The curvature of the tracks is represented by a series of arcs, and the tangents by straight lines at the bottom of the chart. The vertical lines running the full width of the sheet are the reference points, either mileposts or survey station numbers (usually 1,000-foot stations). The number of the station or milepost is indicated in the circle at the top of the vertical line.

E-5.2. A space 1-1/2 inches wide is used for indicating the profile of the track. Elevation and grade are indicated as shown in Figure E-1.

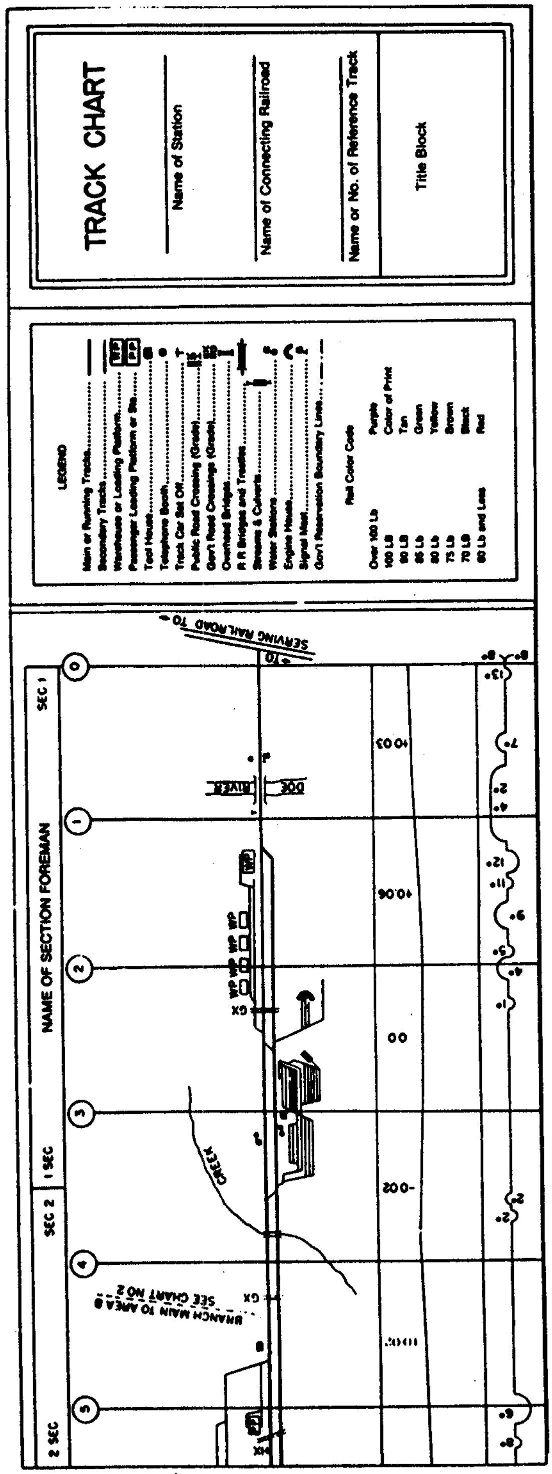


Figure E-1. Typical track chart.

APPENDIX F

String Lining of Curves Made Easy*

A Method of Correcting Alinement Which Is Quicker and More Convenient Than Use of Engineering Instruments

By CHARLES H. BARTLETT

This is the first of a series of articles describing a new method for relining curves by means of a string in place of a transit. In view of the increasing importance of accurate curve maintenance and the necessity for checking curve alinement frequently, it is believed that this method will be of interest and help to division engineers; roadmasters and foremen. It has been adopted by a large western road after extensive trial and is employed in the maintenance of several thousand miles of this line. Each article will be complete in its description of the particular portion of the method, while the series as a whole will constitute a manual of instruction to which anyone using the method may refer as much as he finds necessary. The author developed this system when an instrumentman in the office of the division roadmaster of the St. Louis division of the Illinois Central.—Editor.

IT is a well known fact that all railroad curves are made up of circular curves and easements or spirals. The circular curves are staked out by engineers before the track is built; while the easements are more usually installed after the curve is laid. The above statement is especially true of curves which were laid out many years ago, when the use of an easement curve was considered an unnecessary refinement of engineering. It is an equally well known fact that no curve, no matter how well it may be ballasted or how carefully it may be maintained, will remain as it was originally staked out. This change, due to many different forces (such as temperature changes, continual pounding by passing trains, shifting of the roadbed, etc.), produces what are known as "sharp" and "flat" spots in the original curve. By a sharp spot is meant a portion of the curve whose curvature is greater or "sharper" than that of neighboring portions of the curve, or, less commonly, than the curvature as first staked out. Similarly, a flat spot is one whose curvature is less than that of the adjacent portions of the same curve. It is obvious that such a condition is not desirable, and equally obvious that the sooner it is corrected, the less discomfort will be caused to passengers and the safer the track will be for all trains, passenger and freight. It is the purpose of string lining to correct the defects of alinement and to give to the curve that uniformity which insures both good riding qualities and safety, restoring the curve to its original shape or nearly so.

Although string lining, in one form or another, has been in use on some of the railroads of this country for many years, its usehas not been widespread and many roads have preferred to leave the work of realigning curves to the engineering department, or else entirely to the track foremen, each of whom has had his individual way of accomplishing the work.

This practice has resulted in a condition found on almost every road in the country, whereby on one section all curves will be well lined and properly elevated, while on the next section they will be just the opposite—the reason, of course, being the difference in the ability of the two section foremen to line their curves. Such a condition could be remedied quite easily if a standard procedure for curve lining could be adopted. Natually it follows that any system adopted as standard must be easily learned and easily remembered by all foremen and supervisors; and, moreover, that such a system must reduce to a minimum not only the time required for calculations, but also the effect of judgment or experience. In other words, it must be nearly "mechanical" in its application. It is claimed for the system described in this series of articles that it possesses to a high degree all these qualifications. The proof will, of course, rest in the application of the principles to actual conditions.

It should be pointed out at this place that this system is not that commonly known as "cording a curve." The latter method consists of measuring the middle ordinates to a curve from a cord stretched between points on the curve, averaging what appears to be the predominating ordinate, and then throwing the track, by means of lining bars or similar devices, back and forth until it is approximately uniform. While this method will undoubtedly work, after a fashion, any foreman who has ever tried it knows that he will have to go over the curve several times before a satisfactory result can be obtained, and the labor required and the time involved must surely have struck him as so much wasted effort. Such a man will readily concede that if the proper throw could be made the first time much needless work would be saved. The proposed method points out exactly what correction is needed at each point in order to make a true curve.

Another point which should be emphasized here is that no eleborate equipment is necessary. No piano wire and no delicate measuring instruments are required. All that is needed is a good stout piece of cord, similar to that used by bricklayers or masons, and an ordinary ruler whose divisions start at the end of the rule in order to allow it to be placed against the gage line of the high rail, as explained later. Moreover, there are no complicated mathematical expressions to use, as the process consists in the addition and subtraction of small numbers representing the middle ordinates as measured. Frequent checks on the work can be made, as explained later, so that if a mistake is made it will be detected quickly, before the work has gone too far.

Finally, the system *works*. This has been demonstrated in actual practice by re-alining nearly a thousand curves by its use. And it works, not only from the standpoint of the maintenance man, by giving him better track in less time and with less expenditure of labor and money, but also from the standpoint of the engineer, inasmuch as by its use can be determined all the properties of a curve which can be ascertained by using an instrument. That is, the central angle between tangents, the central angles of all spirals, the points of spiral, points of curve, degree of curvature, rate of change of curvature of spiral, etc.—all can be computed readily and easily within satisfactory limits of error. When to this fact are added the many other advantages—such as the fact that the system is from five to ten times as rapid as transit lining, the engineer as well as the foreman will realize that it will pay him to investigate the possibilities of this method of string lining.

The Method Is Rapid

The time required to master the fundamental principles of the entire method varies from two or three hours to about eight or nine hours. One day's working time has always been found sufficient to enable a new man to obtain a thorough understanding of all the rules and necessary operations.

The various operations in setting stakes for a curve, such as taking the original data, figuring the curve, and setting the stakes, have all been carefully timed. It takes, on an average, about 1/4 minute per station to take the original ordinates of a curve. This is an average figure, and takes into account delays due to waiting for trains to pass, walking between stations, rechecking any doubtful ordinates, and finding the point of ending and beginning of the curve (by trial method to be outlined).

It takes, on an average, about 1-1/2 minutes to distribute stakes at each string lining station (from the original bundles), drive an iron pin into rock ballast, shake the pin to make a good hole, drive a wooden stake, and set the tack in the stake. In cinder ballast the average time per stake set in the field is about 1 to 1-1/4 minutes, depending upon the firmness and density of the ballast. This makes the total time required to perform all the field operations in lining a curve equal to about 1-3/4 minutes per stake in rock ballast, and 1-1/4 to 1-1/2 minutes per stake in cinder ballast.

Several Trials Are Required

It is obvious that in attempting to line a curve which is badly out of shape, several trials will be required before the best curve can be found. If a foreman and his gang of men set out to reline a curve by eye only, several attempts will be required before a satisfactory curve can be obtained; and the same is true of the computations required by the system described in this series of articles, the only difference being that instead of the actual track on the curve beng changed, only the figures representing the curve are changed. It has been found, consequently, that an ordinary school slate, ruled into columns (as described later), furnishes the easiest and most satisfactory way of making the changes required, inasmuch as it requires more time to make erasures from a sheet of paper. The length of time required to make the computations on the slate will, of course, depend upon the individual and upon the number of curves he has lined. Curves requiring no more than a foot throw either in or out, can ordinarily be lined upon a slate at the rate of from 1 to 2 stations a minute. The author has lined (on the slate) curves of 86 to 90 rails in 20 and 30 min. time, whereas some harder and shorter curves which were badly out of line have taken as much as three or four hours, in order to obtain a curve which would not throw beyond a certain fixed limit. The figure of 1 to 2 stations a minute includes the entire time required to line the curve on the slate, from the time of starting until the curve is fully lined; it includes making all changes, erasures, etc.

Thus, according to the above average figures, a curve in rock ballast, a mile long, would require about seven hours to re-line, from the time of starting in to get the original data until the last stake was set. As a matter of record, several curves a mile long have been lined by this method at the rate of six hours per mile. All of these curves were compound curves (before lining), and were spiraled. In relining them by the string system, proper spirals were placed at each end and between the branches of the compounds. The author's experience in lining curves with a transit has led him to believe that the time it would require to line a compound curve (with two branches), spiral both ends and insert a spiral between the branches of the compound, and drive a stake every 33 ft. in rock ballast, would be anywhere from three to five working days of eight hours each. On such a curve (a mile long), the intersection angle could not be run, in all probability, and the matter of lining an entire mile without "running off the embankment" would be quite a problem.

In addition to the fact that a curve can be figured and the stakes set much more quickly by the string lining method than by the transit method, there are other advantages which make for a considerable saving in time. For example, passing trains and motor cars do not cause any serious loss of time. With an instrument, every time a train or motor car goes by, a new set-up must be made, which takes from three to eight or ten minutes, depending upon how far the flagman has to go for a second backsight. With the string lining method, the only time lost is that which it takes the train or motor car to pass the working point. This is an advantage of considerble weight on heavy traffic lines.

String lining is cheaper than transit lining because of the time save, because fewer mistakes are made, because a better curve is obtained, and because the throws are kept to a minimum. In transit lining, a party must necessarily consist of an instrumentman, a rodman and chainman. The combined salaries of these men will equal about two to three times that of a chainman and two section laborers for the same length of time. Adding to this fact the saving in time effected, we have, considering string lining as say four times as rapid as transit lining, the cost in engineering labor to use the string method as approximately one-eighth of that with the transit method. These figures, if anything, are conservative. The actual saving will run as high as 9/10 in most cases. Not only are the salaries of the instrumentman and rodman saved on each curve, but these two men are than available for other work in the engineering department.

Facilitates Compounding

Further, string lining permits compounding a revised curve slightly for a given distance, usually quite short, in such a manner that the saving in throw effected is marked. This is a valuable property for the maintenance man, since it enables him to install a smooth-riding curve with a minimum of throw, and consequently, with a minimum of time and labor. The time of a section gang can be cut down by several hours in this way, thus realizing a big saving. Suppose that at string lining station number 10 of a curve, we change a revised ordinate by 1 (tenth of an inch) in order to decrease the throws, then as will be explained later, at the end at some such station as 67, say, we have effected a saving in throw of twice 67-10 or 114 tenths of an inch (11.4 in.); yet we have compounded the curve only 5-1/4 minutes and for a length of only one rail. It would never have occurred to an instrumentman with a transit to make such a compound, and he would have carried his curve through to the end, with the consequent big throws. String lining, then, permits of keeping the track close on the old bed (a big advantage) and yet obtaining a smooth-riding curve.

By making it easier for the trackman to line his curve (by placing the stakes every 33 ft. instead of every 50 or 100 ft.), we avoid the small sharp and flat spots which creep in because of the fact that a foreman has to line between the 100 ft. transit stakes by his eye. We accordingly prevent the curve from getting so quickly into bad line once more, and thus effect another saving in maintenance cost.

Work Can Be Inspected in Advance

Since a record of the throws required at each joint or string lining station to line a curve into a new and better shape is obtained from the slate or calculation paper, the operator has a record, in black and white, of how much he proposes to throw the curve. He can take this record to the roadmaster or assistant engineer, as the case may be, to look over at his leisure and inspect the changes necessary.

If the work were to be done with a transit, the instrumentman would first have to set spikes or stakes, and then go to every transit station and measure the throw, if such a record were to be given his superior officers before the curve was actually lined in the field. The advantage of having such a record as string lining gives is readily understood by anyone who handles such matters on a railroad. The size of the gang required to do the work of lining, the approximate amount of time required to do the work, and all other arrangements or information relative to the task of re-alining the curve are known and determined before a start is made.

String lining permits of so compounding a curve (if necessary, of course) that the throws at or near a permanent track structure can be made either zero or negligible. This also is a means of avoiding a great deal of unnecessary work and of saving time and expense. Such small throws as are required can be made upon the slate, so that the entire amount of shifting of such obstacles can been seen by the man in change of moving them before the curve is lined. To do this with a transit would require a great deal of time and the running in of many trial curves before a final curve is selected.

The equipment necessary to do string lining is much simpler and much cheaper than that required with a transit. In addition to this, it is easier to carry around, no care need be felt for its safety or adjustment; and, finally, expensive errors in instrument work done by more or less inexperienced men are entirely avoided.

Summary

The principal advantages of string lining, then, are as follows:

(1) It is much *cheaper* than any other method.

(2) It is much *quicker* than any other method.

(3) It is much *easier* than any other method.

(4) It is *easily learned, easily remembered,* and *easy to use.*

(5) *Errors are* readily *detected by several checks on the work.*

(6) *Throws can be governed almost at will.*

(7) Spirals are no longer an "affliction" to install, but are so easy, and help to decrease the throws required to line a curve by so great an amount that their installation becomes easy and automatic.

(8) A record of proposed changes or throws is obtained and is ready for inspection before any work is done.

(9) It lowers maintenance costs.

(10) It permits of relining curves annually at small expense of time and labor.

(11) It gives a more satisfactory curve.

(12) No expensive or easily breakable equipment is required.

(13) Less men are needed to do the work of figuring the curve.

How to Measure a Curve

A Description of the Steps to Be Taken in Securing Data Regarding an Existing Curve

THE WORK of string lining a curve falls into three natural subdivisions. These are, in the order of their occurrence:

1. The taking of the necessary field data of the existing curve, and their arrangement and recording in such manner that the necessary computations will be shortened and facilitated as much as possible, in order that mistakes will be rendered improbable.
2. The computation of the throws required to correct the various defects of alinement of the existing curve.
3. From the corrections computed, the setting of stakes or other guides by means of which the section foreman and his gang will be enabled to re-aline the curve.

Of course, a fourth subdivision might be added—namely, the checking of the revised curve after the work of re-alining has nominally been completed. However, this is practically never done and, as a matter of fact, is needless if the work has been carefully done throughout.

This article deals with the methods of taking the required information—that is, the characteristics—of the existing curve. Before discussing these methods it seems advisable to recall certain properties of the circular curve.

Basis of String Lining

Railway curves can be divided into two broad classes: (1) circular curves and (2) spiral or easement curves. In the original location of a line, before the track is laid, the circular curve only is staked out; the spiral is left until the greater portion of the curve is actually laid and is then staked out by the engineer or is left to the track foreman to put in by eye. For this reason, and also because the spiral requires special treatment, the circular curve will be considered first.

Both theory and experience prove that, in order to provide and maintain good riding qualities in a curve, it is necessary to keep truly circular that portion which was originally constructed as a circle. This can be done in several ways. With a transit, advantage is taken of the principle that, for equal chord lengths along a circle, the deflections from a tangent at the point of curve are (angularly) equal. String lining takes advantage of the principle that, for equal chord lengths along a circle, the ordinates from the center point of the chord, measured perpendicularly thereto, are equal. And, just as for a given degree of curve there is a characteristic deflection for each chord length, so for that same degree of curve and same chord length there is a single characteristic middle ordinate. Therefore, if the middle ordinates of a given curve, measured from equal chord lengths, are all equal, that curve is a true circle.

It is well known that a curve which is a true circle when originally laid will eventually, as a result of outside forces such as engine and car wheels, temperature changes, etc., become a series of curves, some or all of which may be of different degrees of curvature. This naturally makes for rough riding track. It is the purpose of string lining to restore the circular character of the curve by making the unequal middle ordinates of the actual curve all equal. In order to do this with the minimum of expense, time and interruption of traffic, it is first necessary to obtain a record of the middle ordinates, for a given chord length, on the entire curve.

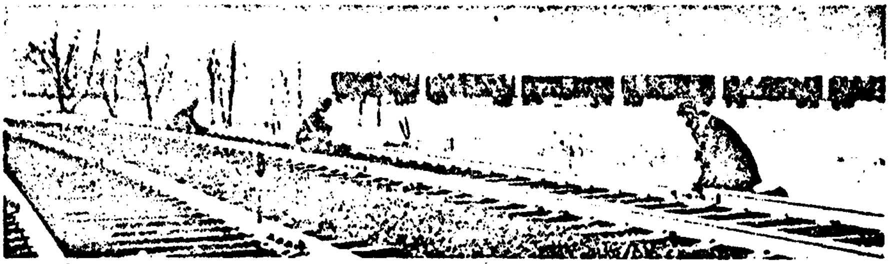
Selecting the Chord Lengths

The best length of chord depends on certain factors, chief of which is the length of rails in the track. If the entire curve is composed of rails of equal length, such as 30 or 33 ft., the best chord length is equal to twice the length of rail; that is, 60 or 66 ft. Since all ordinates are measured from the chord to the high rail of the curve (because measurements can then be taken to the gage line of the rail) only the length of rails in the outer rail need be considered. If, however, the rails vary in length (as sometimes happens) the writer recommends a chord length of 66 ft., because all the tables used by him are based on the use of that length of chord and, therefore, such data as may be required can be obtained directly from tables, without computation.

The reason for selecting a chord equal in length to two rails is that this permits of setting a stake at every joint, if desired. The advantages of a center stake every rail length, at the joint, over a center stake every 50 or 100 ft., are readily realized, and are fully appreciated by the track foremen who have to do the work of lining. A much more uniform curve is secured with the expenditure of no more time or labor. Only the very best of foremen are able to line 100 ft. of curve of any degree without having

*This is the second of a series of articles on the string lining of curves, describing the manner in which the line can be corrected by trackmen without the use of instruments other than a piece of string and an ordinary rule. The first article of this series, which appeared in the January issue, page 4, presented the merits of this practice in contrast with the use of a transit. The third article will appear in the April issue.

for String Lining*†



slight sharp and flat spots. These irregularities, although almost unnoticeable at first, lead very quickly to generally poor alinement.

The accompanying table gives the middle ordinate in tenths of an inch, for a one-degree curve for a number of chord lengths.

Measuring the Curve

Theoretically, on perfectly straight track, the middle ordinate (for any length of chord) is zero. If the actual tangent track was perfectly straight, the first ordinate with which we should have to deal would be a zero, at the end of the curve. However, for reasons explained later, it is frequently advisable to start well back on the straight track—say five or six rail lengths—to measure the middle ordinates. Although string lining does not undertake to change tangent alinements, it does permit of making detailed corrections thereto at the ends of curves, if there are small variations in the straight track.

For example, it will nearly always be found that the last ordinates—the first and last on the curve, and the next adjoining ones just off the curve—are not zero. A typical case, taken from an actual curve, measured with a 66-ft. chord is as follows:

Joint	Joint Number	Middle Ordinate
Joint	Number 1	0.2 in.
"	" 2	0.2 "
"	" 3	0.0 "
"	" 4	0.1 "
"	" 5	0.2 "
"	" 6	0.0 "
"	" 7	0.4 "
"	" 8	1.2 "

The joints below the horizontal line are on the curve, while those above are on what is supposed to be perfectly straight track. It is possible in string lining to make all of the ordinates above the line equal to zero, thereby making a perfect tangent track and contributing materially to both the appearance and the riding qualities of the curve at the ends.

With the above in mind, let us assume we have an actual curve to measure. The steps are as follows:

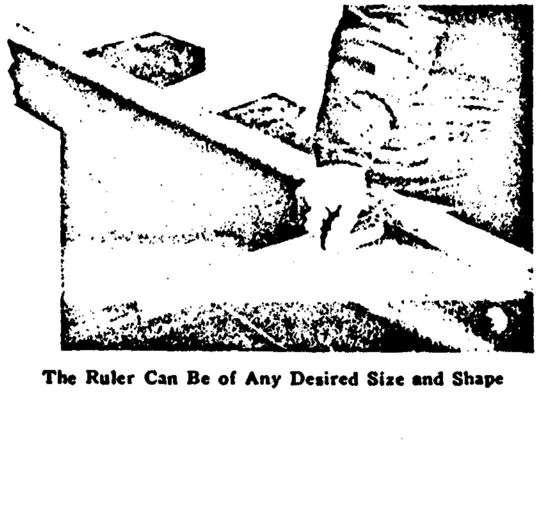
First, locate by eye the end of the curve; then go to that point, have one man hold one end of the string against the gage line of the high rail at the joint next farther from the curve than the joint to be measured. Another man holds the other end at the gage line of the high rail two joints nearer the curve. The third man then measures with a rule the middle ordinate at the intervening joint. If the ordinate is zero, and the track back of him (on the tangent) appears to be in fairly straight line, he can call this Joint No. 1. All three men then move up *one* joint nearer the curve, so that the ordinate at every joint is measured. (See Fig. 1.) Care should be exercised that no joints are omitted. A natural error for a beginner would be to move up a whole chord length, instead of half a chord length, as outlined above.

In order to identify the different joints, it is well to number them consecutively. It has proved very satisfactory to number the first joint and every fifth one thereafter until the end of the curve is reached. The last joint is given its proper number, whether that number is a multiple of five or not.

It is obvious from the foregoing description that three men will be needed to measure a curve. Only one of these men need be conversant with the principles of string lining, since the only duty of the other two is to hold the ends of the string tightly against the gage line of the high rail and to see that the string is properly taut at the time an ordinate is measured. Laborers from the section gang are gen-

Middle Ordinates of Different Chords for a One-degree Curve

Length of chord in feet	10	20	30	31	33	39	50	54	60	62	66	78	100
Middle ordinates in tenths of an inch	0.26	1.05	2.36	2.52	2.85	3.98	6.54	7.63	9.42	10.06	11.40	15.93	26.18



The Ruler Can Be of Any Desired Size and Shape erally selected for this duty because of their being close at hand and readily available for the short time required to measure the curve.

The man who measures the middle ordinate should select the points of beginning and ending of the curve, and should check the numbering of the rails. The numbers can be marked on the web or base of the rail with chalk or keel by one of the men holding the end of the string, preferably the man at the rear.

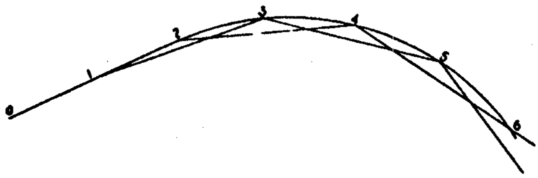


Fig. 1—Method of Measuring the Middle Ordinates of a Curve

The numbers indicate the string lining stations along the curve.
Joints or stations 0, 1 and 2 are on straight track.
The ordinate at station 1 is measured with one end of the string at station 0 and the other end at station 2.
The ordinate at station 2 is measured with one end of the string at station 1 and the other end at station 3.
The same procedure is used to take all the ordinates of the curve.

The recorder can then call off the numbers in some such fashion as: "Going to No. 45" or "You're at No. 45 now."

The recorder should provide himself with a sheet of paper upon which are ruled horizontal rows of lines. These he should number consecutively to correspond with the joint numbers. It is, of course, desirable for him to estimate beforehand the approximate number of rails in the curve, as this is a timesaver. Opposite each joint number is placed the middle ordinate, for the given chord, at that joint. This should be put down as soon as measured, to avoid the possibility of errors due to an effort to remember some of the ordinates.

Correctness of the original ordinates is a prime essential to the success of the string lining method, and care should be used to see that the measurements are uniformly accurate. Experience will show just what tension of string is required to secure an accurate measurement in the shortest possible time. If the string is not taut enough in the opinion of the recorder, he should call to one man to pull up on it slightly. If the ordinate changes, it is then apparent that the proper tension of the string had not been secured. Too great a tension will, naturally, break the string, but little fear is to be anticipated from this source after the proper pull is once ascertained. If the string does break, however, it should not be tied between the ends of the chord, as this obviously impairs the accuracy of the measured middle ordinates.

The Necessary Equipment

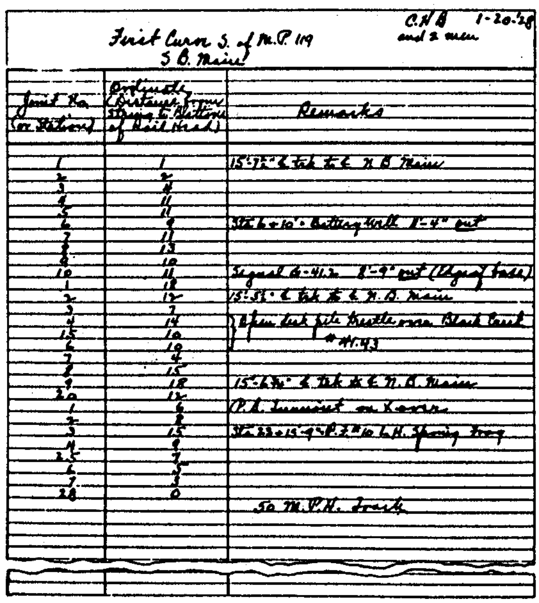
In order to obtain an unbroken length of string 60 ft. or more in length, it will usually be necessary to purchase 100 ft. of cord. The author's experience has been that all the ordinary varieties of cords purchasable at hardware stores or stationery stores will stretch appreciably at first. This need not be a source of worry, however, as long as the string is taut. A good plan to follow is to buy 100 ft. of string, such as that used by masons and bricklayers, tie both ends securely to wooden handles—which enable the ends to be gripped tightly and pressed securely against the gage of the rail—and then wind the unused portion on one stick. After a short period of use, the string will no longer stretch, and a fairly accurate chord will be determined by the length of the string itself, although this is not the guiding factor in fixing the proper chord length. Where all the rails are equal, the determining length is that of two rails.

Where the rails in the high rail of the curve are of different lengths, it will be necessary to chain or measure out the curve before taking any of the ordinates. This should be done with a steel tape or, if none is handy, with a metallic tape. Stations of 33 ft. are marked along the high rail, and numbered as before. The string should not be used for measuring the length of the curve because of the accumulative errors caused by stretching of the string and inequality of tension between different stations.

The ruler by which the ordinates are measured can be of any convenient size or shape. A triangular scale, of the type used by engineers or architects, makes an excellent rule, if the excess at one end is cut off so that the zero of the rule is at the end of the scale, although any rule whose graduations start at the end can be used. Whether an engineer's or an architect's rule is used depends upon the unit of measurement adopted. This leads naturally to the question of what is the best unit for the purpose.

Unit of Measurement of Middle Ordinate

Middle ordinates can be measured in any unit which appeals to the man who makes the calculations and takes the measurements of a curve. However, the selection lies almost entirely between the three



First Curve S. of M.P. 119 S.B. Main — C.H.B 1-20-28 and 2 men

Joint No. (or Station)	Ordinate (Distance from String to Bottom of Rail Head)	Remarks
1	1	15'-7½" ℄ Tk to ℄ N.B. Main
2	2	
3	4	
4	11	
5	11	
6	9	Sta 6+10' [illegible] 1'-4" out
7	11	
8	13	
9	10	
10	11	Signal 6-41.2 8'-9" out (Edge of base)
1	12	
2	12	15'-5½" ℄ Tk to ℄ N.B. Main
3	7	
4	14	Open deck pile trestle over Black Creek
15	10	#41.43
6	10	
7	4	
8	15	
9	18	15'-6¾" ℄ Tk to ℄ N.B. Main
20	12	P.C. [illegible] on Xover
1	6	
2	8	
3	15	Sta 23+15'-9" P.T. #10 L.H. Spring Frog
4	9	
25	7	
6	5	
7	3	
28	0	
		50 M.P.H. Track

Fig. 2—A Specimen Page of Notes

following units: (1) the tenth of an inch, (2) the eighth of an inch and (3) the hundredth of a foot.

Engineers are accustomed to measuring small quantities in hundredths of a foot, and this unit is suitable for practical purposes from their standpoint. However, the track foreman is not accustomed to this unit and, since he is vitally interested in the amount of throw required to correct the alinement of a curve it appears best to use either the tenth or the eighth of an inch. Further, the hundredth of a foot is not quite as accurate (by about 20 per cent, regardless of the relative numerical values of the two units) as either of the other two.

The eighth of an inch is a practical unit from the standpoint of the track man, and suitable enough for the engineer. The chief objection—and it is an important one—against its use is that middle ordinates must be written first as inches and eighths of an inch (as 4⅞ in.) and then reduced to eighths only (as 4⅞ in. becomes 39/8 in., or more simply, 39). The work of reduction assumes important dimensions as the curves become longer.

The tenth of an inch has the advantages of both the above units, and the disadvantages of neither. It is equally suited to the needs of the engineer and trackman, it is sufficiently accurate to permit of obtaining correct measurements and securing excellent results. It has, too, the big advantage that ordinates written in this unit can be written directly as whole numbers. For example, an ordinate of 5.4 in. can be written down immediately, without further reduction, as 54. The advantage of this feature can be appreciated only after the reader has actually lined one or two curves.

Practical Hints

1. When taking the data on the actual curve, the recorder should make pencil notes of the station numbers of fixed structures, located on or near the curve, which are apt to govern or restrict the permissible throwing of the track. For example, a trestle or steel bridge, the edge of a building, a deep cut, a high fill and other such obstacles form more or less serious impediments to the free throwing of a curve. Their position and extent should be noted by string lining station and plus.

The station and plus and the number of turnouts must also be noted for it occasionally happens that when a curve is re-alined, it it advisable or even necessary to change the number of one or more frogs and the corresponding turnouts.

2. The kind and quantity of ballast (per cent of standard ballast section) should be roughly noted down or remembered, in case it is necessary to throw portions of the curve a foot or more from their position before being re-alined. Although the road supervisor or road master is generally supposed to care for such matters as ballast requirements, after he has seen the stakes or otherwise learned the amount of throw at the various points of the curve, it is well to be able to give an approximate estimate of the quantity of new ballast, if any, which will be required.

3. Mental note should be taken of the grade line of the track through the entire curve, especially at the entering and leaving ends of the curve, for reasons explained in a subsequent article.

4. Ascertain from a timetable or other reliable source the speed of trains operated over the curve to be lined, as their speed affects the spirals or easements to be used.

5. If certain ordinates measure a half unit more or less than a whole number (as 5.75 in.=57.5 tenths of an inch) attempt to balance them by increasing some by a half and decreasing others by a half, as the sum of the ordinates is a measure of the total angular change of alinement, and should be constant.

6. The recorder should call "all right" as soon as he has finished measuring an ordinate, so that all three men may move up to the next joint or station without loss of time.

7. It will sometimes happen that the greater part of a curve will have rails of uniform length, but that near one end will be a turnout or road crossing where some short rails will be found. In such a case, it is usually not necessary to chain or measure with a tape the remainder of the curve, if the measurements be started at the opposite end and carried toward the point where the short rails are located. For example, suppose a curve to have 67 rails, 57 of which are all 33 ft. long, after which there are 3 short rails, the remainder being again 33 ft. rails. Measure the rails from the end where the lengths are uniform, and then continue the stationing through the short rails by means of the string. This, of course, presupposes that the man pulling the string has learned very approximately the right amount of tension to give him a chord of exactly 66 ft.

8. On double or multiple track roads, it is wise to take track centers at intervals around the curve, in order that the man making the computations may know definitely whether a certain maximum throw will be such as to affect the clearance distance or minimum track centers.

9. On double or multiple track roads, it is always better to line separately the same curve on the different tracks than to line one track and attempt to line the others by maintaining a uniform center distance. There are several reasons for this. First, the existing track centers may not be uniform, as is usually the case, and a relatively small throw on the one track may entail a much larger (even a prohibitively large) throw on the next adjacent track. Second, most track foremen do not have steel tapes, but have cloth tapes which stretch as much as 3 or 4 in. in 25 ft.; consequently, the foreman cannot maintain really uniform track centers by means of such a tape. Third, it is nearly impossible to measure the center-to-center distance of curved tracks along the true radial line; and a small error in angular direction of measurement means an appreciable error in true radial distance. Fourth, the entering and leaving spirals are of different lengths and different spiral characteristics, which makes it impracticable to maintain uniform centers on spirals, even though the degrees of the circular curves are the same. For these reasons, where it is desired to line two or more tracks on the same curve, it is best to take the data separately for each curve as an entity.

10. Before going out to measure a given curve, the recorder or his superior should ascertain if any work is contemplated on the curve, and, if there is to be some work done, he should defer the measuring until such time as the track will remain undisturbed between the time of measuring it and the time of setting the stakes. It sometimes happens that data will be taken for a curve, and then a portion or all of that curve will be moved, relaid, or otherwise disturbed materially, rendering the data taken worthless—even a liability, in case stakes are set from throws computed from these data.

11. While the author strongly recommends using the tenth part of an inch as the unit for measuring the distance from the string to the gage line of the high rail, because of the fact mentioned above that such readings can be written as whole numbers without any further change (as, for example, 6.2 inches is 62), nevertheless, he is fully aware that most track men do not have a ruler graduated in

THE STRING LINING OF CURVES

tenths of an inch and cannot easily secure one. Consequently, for their purpose it will be best to use an eighth of an inch as the unit, and then reduce the ordinates measured to whole numbers in order to work with them more easily. It is obvious that it requires some little thought to subtract 3⅞ inches from 4¼ inches and get ⅜ inch; and it is equally obvious that it is much easier to reduce 3⅞ inches to 31/8 and 4¼ inches to 34/8 and then subtract 31 from 34, leaving ⅜. The best way to do this is to make a little table, which can be referred to at any time, and which gives the "whole numerators" for the inches and eighths of an inch. The foreman should start out and make his own table, thus:

⅛ in.	1	1 in.	8
¼ in.	2	1⅛ in.	9
⅜ in.	3	1¼ in.	10
½ in.	4	1⅜ in.	11
⅝ in.	5	1½ in.	12
¾ in.	6	etc.	etc.
⅞ in.	7		

Such a table will pay for the labor required to make it many times over. In fact, it is almost a necessity if the ordinates are measured in eighths of an inch.

12. Throughout this entire series of articles, wherever the word gage is used to indicate a point on the head or ball of the rail, it should be taken to mean the lowest point on the head of the rail on the gage side, rather than the theoretical gage line of the rail, which is about ⅝ of an inch from the top of the rail. The reason for this is that almost all curved rails wear unevenly and the only point which is definitely determined is the lowest point of the head, where the wheels do not touch or at least touch but a little.

13. The foreman must not get the idea that this system will work only for 33-foot rails. Any chord length at all will do, just so the same chord is used to measure the entire curve. If a curve happens to be laid with sawed rail only 27 ft. long, then the proper chord to use is twice 27 or 54 ft. As far as the foreman or trackman is concerned, one chord length is just as good as another; but for the purposes of any engineers using the method, the best length is 33 ft., because all the tables giving the engineering data have been worked out for that length rail (that is, for a 66-ft. chord), and considerable time and computation will be saved when figuring central angles, spiral functions, etc. For relining purposes only, however, no tables are needed and any length will do.

The Arithmetic of String Lining Curves

High Grade Passenger Service Demands Good Curve Alinement

IN THE TWO previous articles of this series the manner of taking the measurements of an actual curve has been presented. In this article it is assumed that it has been decided to change the actual curve in certain ways so as to rectify any errors of curvature that may exist, such as sharp and flat spots. This article will set forth the fundamental principles underlying the means of effecting the change from the actual curve to the revised one. In the following discussion, no mathematical analysis is given for any of the principles stated, except the simple geometrical proof for the theorem regarding the throwing of a joint or station, although complete and satisfactory proof can be given mathematically for all of the rules given. These proofs are omitted from this series of articles as it is thought that they will not be desired by most of the readers.

Sum of Ordinates Must Remain Constant

The first principle of string-lining is that the sum of the ordinates of a curve must remain constant throughout any series of operations designed to correct the alinement of that curve. In other words, if a curve is measured and the ordinates taken in the field total 656 tenths (or eighths, quarters or any other units) of an inch, the total 656 must remain the same for any revised curve. It can be proved that this total represents the actual angle between the two tangents or pieces of straight track at each end of the curve; and inasmuch as it is obvious that the angle between the straight tracks cannot be changed, the total of the measured ordinates must not be changed.

The second principle is that the sum of the errors between the figures for the original curve and the figures for the revised curve must equal zero, the error at any station being defined as the difference between the original ordinate and any revised ordinate selected by the man lining the curve. It is, briefly, the original ordinate less the revised. Suppose that at some station of a curve the ordinate measured in the field is 48 eighths of an inch, or 6 in. If, for reasons explained later, it is desired to change this ordinate when re-lining the curve, to some such figure as 41 eighths of an inch (or 5⅛ in.) the *error* at that station will be 48 less 41 or 7 eighths of an inch. If the revised ordinate is larger than the original, the difference or error is termed negative and a minus sign placed in front of it. For example, if the revised ordinate in the above case happened to be 53 instead of 41, the error would be 48 less 53 or minus 5 eighths of an inch. In view of the above explanation, it will be clear to the reader that, if the total of the revised ordinates must equal the total of the original ordinates, the total difference between the two must be zero, the total difference being merely the sum of the separate differences or errors at each station. In other words, the second principle is practically the same as the first, but is merely a more convenient way of expressing it.

Effect of Throw on Adjacent Stations

The third principle is very important, and should be thoroughly understood before the reader attempts to line any curve. It is as follows:

Rule: If one joint (or station) of a curve is moved in or out a certain distance (which distance is called the throw), the middle ordinates at the stations on each side of the one moved will be changed by half the amount of the throw, and in the direction opposite to the throw.

The above rule is best explained by a diagram. Let

*This is the third of a series of six articles on the string lining of curves, describing the manner in which the line can be corrected by the track men without the use of instruments other than a piece of string and an ordinary rule. The first article of this series, which appeared in the January issue, page 4, presented the merits of this practice in contrast with the use of a transit. The second article, which was published in the February issue, page 62, describes the methods of taking the measurements. The fourth and fifth articles, which will appear in the May and June issues, respectively, will describe the method of selecting the ordinates for the revised curve and the sixth and concluding article will describe the manner of placing the stakes preliminary to the lining of the curve.

THE STRING LINING OF CURVES

the reader refer to the accompanying figure, in which is shown a portion of a circular curve ABC, whose chord is AC and middle ordinate MB. The arc ABC can be taken, if desired, as the length of two rails of the high side of a curve, with AB as one rail and BC as the other, with the joint at B. It is plain, therefore, that as a practical matter, the rail BC can be moved without disturbing the rail AB. Therefore, consider that the joint (or station) C is moved or thrown out—that is, away from the center of the curve—to the point D, so that the rail BC now occupies the position BD. The new chord (or line representing the position of the string) is now the line AD, and the new middle ordinate is BE. In actual practice, the length BE is so closely equal to MB (the original middle ordinate) less MF that the difference is negligible. But MF, from geometry, is almost exactly one-half of CD, the amount of throw. This is because in the triangle ACD, M is the middle point of AC, and therefore AM is one-half of AC, so that MF is one-half of CD. Therefore, BE equals MB less MF; or, in words, the ordinate *after* throwing equals the ordinate *before* throwing, less one-half of the throw. In the same way, it can be shown that the joint (or station) the other side of C (on the right) is similarly affected. Hence, an out throw at any joint increases the ordinate at the joint by the full amount (CD in the diagram) and decreases the ordinates at each of the joints on the two adjoining sides by one-half the amount of the throw. Conversely, if the throw is in, the ordinate at the station thrown is decreased by the full amount of the throw, and the ordinates at the stations on each side are increased by one-half the amount of the throw.

From the above demonstration it is seen that the operation so described consists in the *addition* or *subtraction* from the measured middle ordinate at a station of a certain quantity, known as the throw, and in the *subtraction* or *addition* of half that amount to the ordinates at the two stations on either side of the one thrown.

A Simple Example

For example, suppose that at any three consecutive stations or joints of a curve we have the following three ordinates:

18	24	18

These indicate a typical sharp spot, which, of course, it is desired to eliminate by making all three as nearly equal as possible, and thus making a uniform curvature. We can "throw" the middle joint in by subtracting a certain amount and adding half as much to the two figures 18 on each side. Note: It is obvious that the 24 must be reduced and the two 18s increased, so that all three can be made equal.

We can subtract 4 from 24, which will add 2 to both figures 18. We then have:

18	24	18
+2	−4	+2
20	20	20

Thus, we have equalized all three ordinates and made this section of the curve a true circle, which is one of the purposes of string-lining.

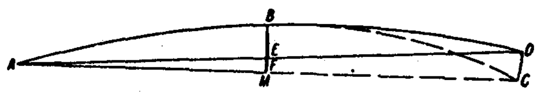
The process of lining a curve (on a slate or a sheet of paper) consists in repeating the above operation at every station, with certain modifications as explained later. It is logical to conclude that from the simplicity of the above operation there must be some definite relation between error and correction; and, in fact, such is the case. However, it is not the purpose of this article to give a detailed mathematical analysis, but simply a set of working rules for the performance of the mechanical operations of string-lining.

In connection with the above rule, it should be noted that the throws at the first and last stations of a curve must be zero. If the first or last stations are thrown, the resulting half-throws will be imparted to the tangent or straight track, throwing it out of alinement. For example, if the first station of a curve has an ordinate of 0, and we throw the track 2 (units of any kind) out, the straight track at the left of the 0 will have a half-throw of -1, which will put a small kink in it. Consequently, we must correct the first station by throwing the second, making the throw such that the half-throw at the first station will correct it.

Relation Between Error and Throw

If, at each station, we add all the errors to and including that station and write them down opposite their station numbers, we obtain a column which we can call the "Sum of Errors." If now we obtain the sum of all of these from the first station to any given station, and write that sum opposite the *following* station, we obtain the half-throw required at that following station.

Let us suppose a curve having 53 stations, opposite each of which is written an actual and a revised ordi-



The Effect of Throw on Adjacent Stations

nate, in two columns, and in the third column the differences, or errors, between the actual and the revised ordinate at each station. Let us now put down opposite the first station the error at that station; opposite the second station, the sum of the first and the second errors; opposite the third station, the sum of the first three errors; and so on, until at station 53, we have the sum of the errors for the entire curve, which must, of course, equal zero. The addition of the errors is algebraic; that is, due regard is taken of the sign of the error. For example, if the first error is (5), the second (-3), and third (-6), the sums of the errors at the first three stations are, in order (5); (5)+(-3)=(2); and (5)+(-3)+(-6)=(-4). It is, of course, not necessary to add all the errors every time, since the sum at any station is obtained directly by adding to the sum of the errors at the previous station, the error at the station. For example, the above would be obtained actually as 5; 5-3=(2); 2-6=(-4); etc., etc.

Having obtained the column headed sum of errors, we next add this column to and including each station and bring the total into the next column under the *following* station. To illustrate (remembering that the throw at the first station is zero), we have for the above figures, the following half throws:

First station		0
Second station	0+5	= +5
Third station	0+5+2	= +7
Fourth station	0+5+2−4	= +3

Once again, it is not necessary to add the figures from the first station on, since the same result is obtained

THE STRING LINING OF CURVES

more easily by adding to the sum previously obtained the adjacent figure in the next row. For example:

First station		0
Second station	0+5	= +5
Third station	5+2	= +7
Fourth station	7—4	= +3

A resumé of the above operations may make the process clearer. Consider the following hypothetical curve:

Station or Joint Number	Actual Original Ordinate in Tenths of an Inch	Revised Ordinate for Re-alined Curve	Error	Sums Errors	Half Throw
1	1	0	+ 1	+ 1	0
2	3	2	+ 1	+ 2	+ 1
3	7	4	+ 3	+ 5	+ 3
4	3	6	- 3	+ 2	+ 8
5	4	8	- 4	- 2	+10
6	7	8	- 1	- 3	+ 8
7	10	8	+ 2	- 1	+ 5
					+ 4

In the first column are the station numbers.

In the second column are the middle ordinates of the actual curve, measured in the field as outlined in the second article.

In the third column are the revised ordinates selected for the curve, in accordance with certain principles explained later.

In the fourth column are the errors, e, obtained as explained above. For instance, at station 3, 7—4=3; at station 5, 4—8=-4; etc.

In the fifth column are the sums of the errors to and including each station. These are obtained by writing down the error at the first station, and then at each station thereafter writing down the sum of the preceding figure and the figure on the next line in the column headed "Error." Thus writing down 1 in the first station, we next add 1 and the 1 shown on line 2 as error at station 2. This makes 2. To this 2, we add the 3 on the next line below, in the error column, making a total of 5.

In the sixth column are the half-throws. To obtain these we add horizontally instead of diagonally downward as we previously did to obtain the sum of the errors. Thus, 0+1=1, at station 2; 1 plus the 2 at station 2, is carried as 3 and written under station 3; 3 plus the 5, at station 3, is written as 8 at station 4, etc. The arrows indicate the direction of the additions and the position of the results.

In this way a final half-throw is obtained at the last station. This half-throw must be zero, as we have seen above. However, because it is nearly impossible to pick the correct ordinates at the first trial, this half-throw will not generally be zero, and we must make it so.

It can be shown that the sums of the products of the error at each station by that station number must be equal to zero, which is a condition that the curve is lined. That is, if at a given station the error (difference between the actual and the revised ordinate) is -5, and the number of the station is 21, the product of these two quantities, is -105. The sums of all such products for the entire curve must equal zero as a condition that the curve is really lined.

It can likewise be shown that the sum of all these products is equal to the half-throw at the last station, whether that half-throw is zero or not. This being the case, it is immediately evident that if the final half-throw is not equal to zero, it can be made so by making equal to zero the sums of the products above referred to.

If we have a certain curve, of any number of stations, and we find that the final half-throw is not equal to zero, but some such number as, say, 46, let us consider a way of changing that 46 to zero. Let us say that the ordinate at the 5th station is 23 on the original curve and 25 on the revised curve. The difference is -2; the product of -2 and the station number, 5, is -10. Now let us say that the ordinate at some other station, as the 37th for instance, is 31 on the original curve and 26 on the revised curve. The error is +5; +5 times 37=+185.

If, now, we change the revised ordinate at station 5 from 25 to 24, and that at station 37 from 26 to 27, we have kept the total of the ordinates the same, for we have subtracted one at station 5 and added one at station 37. But what effect has this had on the products of the error and station number? The error at station 5 is decreased from -2 to -1, making the product now -5 instead of the previous -10; at station 37, the error is decreased from +5 to +4, making the product now 148, instead of the previous 185. Thus, while maintaining the total of the ordinates of the revised curve the same, we have changed the total of the products from the first +175 (-10+185) to the second, 143 (148—5); that is, we have *decreased* the final half-throw by an amount equal to 175—143, or 32. This leaves the final half-throw now 14 (46 -32). The same process can now be repeated, the only difference this time being that the station numbers of the ordinates changed must be different. The reader will note that the net difference in the sums of the products, which amounts to 32, is the difference between the station numbers of the revised ordinates which were changed; that is 32=37—5. This will always be the case. Consequently, to diminish the final half-throw by the remaining 14, we have but to choose two stations whose numbers differ by 14, and repeat the above process, with the assurance that the final half-throw will now be zero, and the curve will be lined.

The rule for changing the final half-throw to zero can now be announced. It is:

When the final half-throw is positive, subtract from the revised ordinates having high station numbers and add an equal amount to the ordinates having low station numbers, choosing stations in pairs such that the sum of the differences of the station numbers taken in pairs equals the numerical amount of the final half-throw. When the final half-throw is negative, reverse the procedures, subtracting from the ordinates having low station numbers, and adding to those having high station numbers.

Thus, if we have a curve of 63 stations, wherein the final half-throw, obtained with a trial set of revised ordinates, is 59, we could add 1 to the revised ordinate at station 6 and subtract 1 from the revised ordinate at station 48, thereby making a difference of 48-6 or 42, in the final half-throw. We could then repeat the process, choosing this time stations 8 and 25, whose difference is 17, which difference, added to the previously obtained 42, makes the total of 59 and reduces the final half-throw to 0.

The reader will note that the only condition attached to the above method of change is that the sum of the differences of the station numbers of the revised ordinates changed must equal the final half-throw. The operator, therefore, is wholly at liberty to choose the stations which he will change. This is a valuable property of the system—one which cannot be over-emphasized, as its understanding enables the operator to obtain a much better solution than he otherwise would be able to achieve.

Determining the Throw for a Curve*†

The Explanation of the Steps Entering Into the Selection of the Ordinates for the Revision of Line

IT IS a well known fact that a spiral or some other sort of easement curve is necessary to connect a circular curve with a tangent at each end. There are several reasons for this, chief of which is the fact that if the spiral was not there, there would be a considerable jolt as the train passed from the straight track to the curve.

Various forms of easement curves have been established and have enjoyed more or less extended usage. The two commonest forms of easement, however, are the Talbot spiral, and the cubic parabola. The mathematical properties of these two curves, insofar as they concern string lining, are so nearly the same that they may be considered identical for the purposes and scope of this discussion. As is the case with the circular curve, there is an analogy between the transit deflections, and the middle ordinates measured with a string. However, it is obvious that the ordinates at the several points of the spiral will not all be equal, but will vary according to some rule or law. It can be demonstrated that the ordinates vary according to the law:

1/6, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, etc., etc., where the ordinate at the point of spiral is 1/6.

Since for all practical purposes the first ordinates and the second also are usually quite small the first ordinate in the above series can be written as 0 without material error. Thus, in order to have a true spiral it is only necessary to vary the stringline ordinates in a series whose terms are multiples of the natural numbers in their proper order.

In previous articles we have considered the methods of making the computations required to line a given curve; that is, we have established rules for the mechanical operations which are absolutely the same for all curves, no matter what the degree of curve or how bad the alinement. The next question arising is therefore: How shall the revised ordinates be selected so that the best solution for a given curve is obtained? We have seen that, since the choice of the ordinates to be used for the revised curve is left absolutely to the discretion of the operator, there are several different solutions for any given curve. The problem is to pick the *best* one. This will depend largely upon what is meant by the term "best."

Depends on What Is Wanted

If that solution is desired which will make the maximum necessary throw a required amount (which is by far the commonest case in actual practice), one line of work will be followed. If it is desired to have a perfectly regular curve, or to eliminate certain branches of a compound curve in order to make a simple curve, it will generally be necessary to sacrifice small throws and use large throws to accomplish the result; accordingly, a different method of attack must be followed. If it is required to install a spiral in an existing unspiraled curve, the line of procedure is again changed. As still another example, if it is required to install a spiral which can be operated by trains at a certain fixed maximum speed (given by the railway timetable), the solution will be obtained in another manner.

It might be thought at first glance that the logical method to use in beginning to line a curve on paper would be to take the original ordinates as measured in the field, pick out a spiral to fit each end of the curve, subtract the sums of the ordinates used in these two spirals from the total of the original ordinates and divide the remainder by the number of ordinates remaining in the curve. For example, if

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we assume a curve of 50 stations, the total of original ordinates for which is 978, we might pick a spiral for the beginning end (say, for purposes of this illustration, 0, 3, 6, 9, 12, 15, 18, 21) and a spiral for the leaving end (say, a spiral such as 0, 4, 8, 12, 16, 20). The sum of the ordinates in the first spiral is 3 + 6 + 9 + 12 + 15 + 18 + 21 which equals 84; in the same way, the sum of the ordinates of the second spiral is 60. Thus, the sum of the ordinates for the two spirals is 84 + 60 which equals 144. From our first principles, we have the theorem that the sum of the ordinates of the revised curve must equal the sum of the ordinates of the original curve. Hence, we have as the sum of all the ordinates of the revised *curve proper* (that portion between the two spirals), a total of 978 — 144 = 834. But the first spiral occupies 8 stations; the second occupies 6; so that the two together occupy 14 stations. This leaves 50 — 14 = 36 stations remaining for the circular curve itself. Thus, we see that the total of the 36 stations must be 834, which gives us an average ordinate of 834/36 = 23 6/36. We could, then (other things being disregarded), obtain a correct total for the revised ordinates by using 30 ordinates of 23 and 6 ordinates of 24 = 690 + 144 = 834.

May Require Excessive Throwing

The foregoing procedure, while (as pointed out above), appearing to a beginner as being more or less the logical thing to do, does not as a rule give a curve which can be obtained from the existing curve without excessive throwing of the original curve. The reasons for this can scarcely be understood unless the theory of string lining is studied.

Accordingly, we must seek another method. Actual practice in lining curves on paper has revealed that the best method consists in trying a certain spiral and a certain average ordinate for the circular curve, and in watching the throws as the lining progresses. That is, given a set of figures representing a curve, the operator will select a spiral, write it down and figure the throws it entails as he puts it down. Then he will progress to the circular curve, picking a trial ordinate and computing the required throws as he goes along. Of course, the selection of the proper spiral will be rather a hard task for a beginner, but it will be found that for each curve there is only a very limited number of spirals which can be used without entailing prohibitive throws. After having lined one or two curves, the operator will be able to see practically at a glance the spiral which best fits the curve.

Procedure to Be Followed

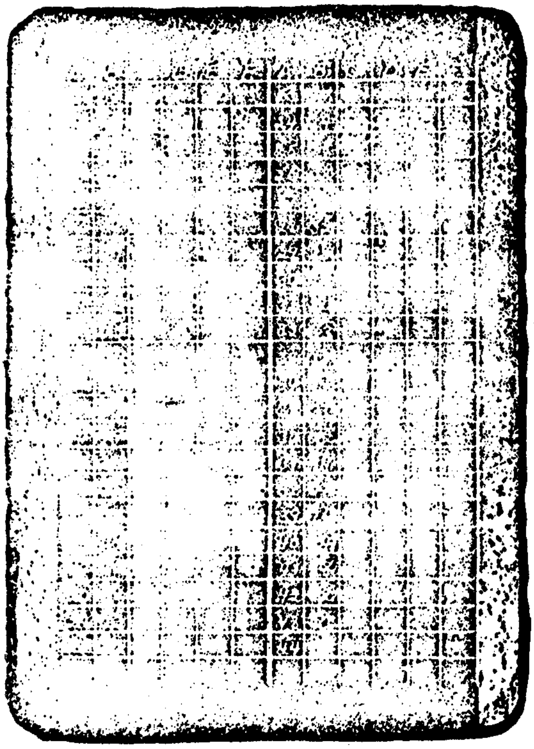
The reader should, by this time, be prepared to follow the steps in the solution of an actual numerical curve, inasmuch as he should now be familiar with the mechanical processes to be followed, once the revised ordinates have been selected. Since the commonest case met is that wherein the operator attempts to keep the throws below a certain arbitrary limit, we shall first take up this case.

In the curve in question, there are 43 stations. The chord length used was 66 ft. (length of two 33-ft. rails), and the ordinates were measured in tenths of an inch, and recorded as whole numbers, each unit number shown representing one-tenth of an inch. Thus, the ordinate 15 at station 10 represents an ordinate of an inch and a half.

Let us assume that the limiting throw has been fixed at 6 in. in both directions; that is, the actual curve may be thrown either 6 in. in (toward the center of the curve) or 6 in. out (away from the center of the curve). Since the figures we obtain are always exactly one-half the actual required throws, we shall have the condition that our half-throws cannot exceed + or — 3 in. Written as tenths of an inch, this means that our largest throws cannot be greater than + or — 30.

The Effect of Changing an Ordinate

An explanation of the actual effect of changing an ordinate should be explained here. Suppose we have a curve wherein the ordinate which seems to predominate in our solution of the revised curve is 42. If it appears, as we work along, that the throws are going to run up too high in a positive direction,



A Slate Will Be Found Convenient

[Note: One applying this method of lining curves will find it a great saving of time and labor to write down the original ordinates on a slate which has been ruled off into lines and columns. The work of making the changes necessary to the calculation of a curve is of such a character that erasures must necessarily be easy to make. The author has found that a slate, ruled into six vertical columns (one column each for A, B, C, D, E, and F) and with horizontal lines at intervals of about a quarter of an inch, makes an admirable board upon which to make the necessary changes and calculations. The lines should be cut into the slate with a knife or other sharp instrument, and station numbers should be scratched in with a pin.]

which means that the revised ordinate is too small, we can easily change the ordinate to 43. Either one or several ordinates can thus be changed. Frequently it is necessary to change only one or two of the ordinates to obtain the proper reduction in throw. This procedure, in effect, is equivalent to compounding the curve very lightly for a short distance, such as two or three rail lengths. For a 66-ft. chord, changing the middle ordinate one-tenth of an inch changes the degree of curvature 5 min. and 15 sec. In the case above, if we changed three 42s to 43s, we would be compounding the curve from 3 deg., 40 min. and 30 sec. to 3 deg., 45 min. and 45 sec., for a length of 99 ft. Actually, on the track, no change of curvature would be apparent. Here, then, is one of the most valuable features of string-lining. By lightly compounding a curve for a short distance, we can cut down the throws required to line the curve, and yet not affect the riding qualities adversely. This could not be done with a transit except at great expense of time and labor.

With these points in mind, let us glance at the following curve.

On the slate the following notation has been used for brevity:

A is the station number of any station.
B is the original ordinate at each station.
C is the revised ordinate at each station.
D is the error or difference, B minus C, at each station.
E is the sum of the errors, to and including each station.
F is the half-throw at each station.

Station Number (A)	Original Ordinate (B)	Station Number (A)	Original Ordinate (B)
1	0	23	17
2	5	24	34
3	7	25	18
4	9	26	13
5	9	27	10
6	16	28	32
7	34	29	18
8	23	30	20
9	12	31	20
10	15	32	33
11	25	33	13
12	20	34	14
13	13	35	31
14	19	36	22
15	28	37	17
16	25	38	17
17	28	39	16
18	24	40	4
19	16	41	8
20	8	42	2
21	13	43	0
22	17		

Selection of Initial Spiral

Let us, first of all, consider the spiral which best fits the entering end of the curve. The first step is to make a mental note of the point where the spiral appears to end, and of what the average ordinate for the entire curve seems to be. It is evident immediately that the spiral must start at Station 1, and must end either at Station 6 or Station 7. Inspection of the ordinates of the original curve shows that the average ordinate for the revised curve will have to be approximately 20, or close to 20, either one way or the other.

If we try a spiral with a factor of 4, we shall have as the revised ordinates, 0, 4, 8, 12, 16, 20. Let us try this and see what the consequent throws will be at the point where the spiral ends and the circular curve begins.

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
1	0	0	0	0	0
2	5	4	1	1	0
3	7	8	—1	0	1
4	9	12	—3	—3	1
5	9	16	—7	—10	—2
6	16	20	—4	—14	—12
					—26

The throw at the first station must be zero, on all curves, for the reason explained above. Accordingly, we write 0 at the first station, and proceed to compute the throw at the second station. At Station 2, the original ordinate is 5 and the revised ordinate is 4, which makes the difference, D, equal to +1. Since the error at the first station was 0, the sum of the errors to and including Station 1 is 0, and to and including Station 2 is 0+1=1. The throw at Station 2 is obtained by adding to the throw at Station 1 the sum of the errors in the opposite column. That is, 0+0=0, and this second zero is brought down in the throw column as the throw at Station 2. In this same way, the throw at Station 3 is obtained by adding to the 0 in the throw column at Station 2 the 1 in the sum of errors column at Station 2 and bringing the sum down in the throw column at Station 3.

Continuing in this fashion we arrive at a half-throw of —26 at Station 6. This means that the full throw at Station 6 is —5.2 in., which is nearly the limiting throw fixed at the outset. Consequently, we look at the next station to see what is going to happen there, and to see if the throw is going to run over our limit. The revised ordinate of 20 at Station 7 will give us an error at Station 7 of 34—20, or +14. This +14, added to the —14 which was the sum of the errors to and including Station 6, reduces the sum of errors to 0, thus making the throw at Station 8 the same as at Station 7. Accordingly, we shall try the revised ordinate of 20 for a few stations and see if it is suitable.

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
7	34	20	14	0	—26
8	23	20	3	3	—26
9	12	20	— 8	— 5	—23
10	15	20	— 5	—10	—28
					—38

It is evident, from the —38 at Station 11, that we have exceeded our limiting half-throw of 30. Now, we can change the half-throws and bring them within the assigned limits in several ways. For example, we have the choice either of changing the spiral in such a way as to reduce the negative throws, or we can change the ordinates of 20, making some or all of them, since so far there are only a few, 19. Let us try this latter method first. We have

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
7	34	19	15	1	—26
8	23	19	4	5	—25
9	12	19	— 7	— 2	—20
10	15	19	— 4	— 6	—22
					—28

We have, then, by changing the revised ordinate from 20 to 19, reduced the negative throws until they are less than the assigned limit. However, the last throw, at Station 11, is so close to —30 that we should examine the next one or two stations to see whether there is a possibility that the throws will exceed —30. We see that at the next station the original ordinate is 25, which gives as the error +6, thus making the sum of the errors at Station 11 equal to zero. Consequently, the throw at Station 12 will be —28+0=—28. Now examine the following station. We see that the error will be +1, thus making the sum of errors equal 1; the throw at Station 13 will then be —27. However, at Station 13, the original ordinate is only 13, making the error —6, which will make the sum of errors at Sta-

THE STRING LINING OF CURVES

tion 13=–5, and the throw at Station 14=–32. The work is as follows:

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
11	25	19	6	0	—28
12	20	19	1	1	—28
13	13	19	— 6	— 5	—27
14	19	19	0	— 5	—32
					—37

Here, again, we have over run. Let us, therefore, try the method of reducing the spiral. Try a 0, 3, 6, 9, 12, 15, 18, (and, if necessary, 20 as an approximate final term) spiral. The work is as follows:

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
1	0	0	0	0	0
2	5	3	2	2	0
3	7	6	1	3	2
4	9	9	0	3	5
5	9	12	— 3	0	8
6	16	15	1	1	8
7	34	18	16	17	9
					26

It is immediately evident as soon as this point is reached that, with such a spiral, the throws will far exceed the assigned limit in the positive direction. Accordingly, we have now the information that a spiral of factor 4 is too large and a spiral of factor 3 is too small. It is obvious, therefore, that some spiral in between these two figures must be used to obtain good results. Any fractional multiplier can be used to obtain a spiral; but, since fractional ordinates are not used, we must add or drop the fractional part of the units in writing down the spiral. For example, a spiral of factor 2/3 would, theoretically, be as follows:

0, 2/3, 1 1/3, 2, 2 2/3, 3 1/3, 4, etc.

But, in order to have whole numbers, we may write this spiral in a number of different ways, choosing for our use that one which best fits the curve upon which we may be working at the time. Thus, we may write

0, 1, 1, 2, 3, 3, 4, etc.

If we choose a spiral of factor such as 4½ we may write either of the following:

(a) 0, 4, 9, 13, 18, 22, 27, 31, 36, etc.
(b) 0, 5, 9, 14, 18, 23, 27, 32, 36, etc.

In (a), the halves are dropped, and only the lower numbers used, while in (b) the halves are added to those figures in which they occur. Either of these may be called, with equal accuracy, a spiral of factor 4½—or, more simply, a 4½ spiral.

In the curve with which we are dealing, it was evident, from the above calculations, that the 4 spiral was better suited to the curve than the 3 spiral, since the sum of the errors did not increase as rapidly. Let us, therefore, try a 3½ spiral, adding the halves, as follows:

0, 4, 7, 11, 14, 18, etc.

We have the following:

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
1	0	0	0	0	0
2	5	4	1	1	0
3	7	7	0	1	1
4	9	11	— 2	— 1	2
5	9	14	— 5	— 6	1
6	16	18	— 2	— 8	— 5
7	34	20	14	6	—13
8	23	20	3	9	— 7
9	12	20	— 8	1	2
10	15	20	— 5	— 4	3
11	25	20	5	1	— 1
12	20	20	0	1	0
13	13	20	— 7	— 6	1
14	19	20	— 1	— 7	— 5
					—12

So far, the spiral and average ordinate picked out seem to fit the curve quite well. We shall go on with the same average ordinate, computing the throws as we proceed.

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
15	28	20	8	1	—12
16	25	20	5	6	—11
17	28	20	8	14	— 5
18	24	20	4	18	+ 9
19	16	20	— 4	14	27
					41

The Throw Is Excessive

At this point, we exceed the limiting throw in the positive direction. Since the first part of the curve fits so well, let us attempt to leave this part of the curve alone, and try to change the revised ordinates in such manner as to bring the 41 below 30. Let us change a few of the ordinates of 20 to 21, starting at some such place as Station 14. Try two ordinates of 21, at Stations 14 and 15, after which again change back to 20. We have

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
14	19	21	— 2	— 8	— 5
15	28	21	7	— 1	—13
16	25	20	5	4	—14
17	28	20	8	12	—10
18	24	20	4	16	+ 2
19	16	20	— 4	12	18
20	8	20	—12	0	30
21	13	20	— 7	— 7	30
22	17	20	— 3	—10	23
23	17	20	— 3	—13	13
24	34	20	+14	1	0
25	18	20	— 2	— 1	1
26	13	20	— 7	— 8	0
27	10	20	—10	—18	— 8
28	32	20	12	— 6	—26
					—32

Here, again, we over run. We shall try changing some of the 20s back to 19s, starting with Station 24 (selected at random, as were the others). It is evident, by an inspection of the rate at which the column headed sum of errors is changing that we shall need three or four 19s to reduce the negative throw properly. For we are carrying a negative total of —6 in the sum of errors column. If the reader will observe the following original ordinates, he will see at once that there is an 18, a 20, another 20, before the ordinate 33 is reached at Station 32. Thus, if we have a negative throw when entering this group, and our sum of errors is negative, we shall keep on adding to the negative throw, with an almost undiminished total error, inasmuch as the three ordinates mentioned are all close to the average of the revised curve and will not materially affect the total of the sum of errors.

Inserting four 19s, Station 24 to 27, inclusive, we have the following:

THE STRING LINING OF CURVES

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
23	17	20	— 3	—13	13
24	34	19	15	2	0
25	18	19	— 1	1	2
26	13	19	— 6	— 5	3
27	10	19	— 9	—14	— 2
28	32	20	12	— 2	— 16
29	18	20	— 2	— 4	—18
30	20	20	0	— 4	—22
31	20	20	0	— 4	—26
32	33	20	13	9	—30
33	13	20	— 7	2	—21
34	14	20	— 6	— 4	—19
35	31	20	11	7	—23
36	22	20	2	9	—16
37	17	20	— 3	6	— 7
38	17	20	— 3	3	— 1
39	16				2
40	4				
41	8				
42	2				
43	0				

The End of the Curve

At this point, it is time for us to consider the proper spiral for the leaving end of the curve. We have reached the point where the circular curve abviously ends, and the spiral begins. We are carrying at this point only a very small throw and also a very small sum of errors, so that the total of the ordinates for our spiral will need to be almost the same as for the actual curve. Strictly speaking, it is exactly the total of the remaining ordinates of the original curve plus the sum of the errors at our last station; that is, plus 3. Let us try a spiral such as 0, 5, 11, 16, 21. This will necessitate the changing of the last shown 20 to a 21, but that will not require much additional labor. Strictly speaking, the above spiral should read, 0, 5, 11, 16, 22 (such that the differences between the ordinates, taken two at a time, will read, 5, 6, 5, 6); but such a true spiral would necessitate the installation of an ordinate of 22, which appears nowhere alse in the curve, although not objectionable from the standpoint of actual track layout. This spiral, then gives us

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
38	17	21	— 4	2	— 1
39	16	16	0	2	+ 1
40	4	11	— 7	— 5	3
41	8	5	3	— 2	— 2
42	2	0	2	0	— 4
43	0	0	0	0	— 4

We have reached the end, and the total of the sum of errors column is zero, which proves that the total of the revised ordinates is the same as the total of the original ordinates. We have, however, a residual half-throw of —4, instead of the zero which is required as a condition that the curve is fully lined. It is necessary for us to change this —4 to 0. Remembering the rule given in the previous article, that when the residual half-throw at the end of the curve is *negative,* we subtract from the ordinates near the top of the curve (those having low station numbers) and add to those nearer the bottom of the curve, in such manner that the difference between the station numbers of the ordinates changed, when multiplied by the number of units change, equals the final residual half-throw. Applying this rule to the —4, we see that we must subtract one from a station somewhere, and add one to a station four stations nearer the bottom of the page. We are entirely at liberty to pick any two ordinates four stations apart; but if the reader will examine the curve, he will see that if we add to Station 27 and subtract from Station 23, we shall not introduce any more 21s or any 18s into the curve, as we would do if we picked up almost any other stations. Consequently, we shall subtract one from the ordinate at Station 23, and add one to that at Station 27. We then have the following:

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
23	17	19	— 2	—12	13
24	34	19	15	3	1
25	18	19	— 1	2	4
26	13	19	— 6	— 4	6
27	10	20	—10	—14	2
28	32	20	12	— 2	—12
29	18	20	— 2	— 4	—14
30	20	20	0	— 4	—18
31	20	20	0	— 4	—22
32	33	20	13	9	—26
33	13	20	— 7	2	—17
34	14	20	— 6	— 4	—15
35	31	20	11	7	—19
36	22	20	2	9	—12
37	17	20	— 3	6	— 3
38	17	21	— 4	2	3
39	16	16	0	2	5
40	4	11	— 7	— 5	7
41	8	5	3	— 2	2
42	2	0	2	0	0
43	0	0	0	0	0

The final residual half-throw is now zero, and the entire curve is lined. The predominating ordinate of the revised curve is 20, with but very few variations therefrom. But the reader will doubtless see, by this time, just what a saving in throw was effected by the insertion of the two ordinates 21 instead of 20s at Stations 14 and 15, and by the four ordinates of 19 at Stations 23 to 26, inclusive. Such a slight compounding could not possibly have been obtained by the use of a transit, for, with the instrument, it would have been necessary to install a curve of 1 deg. and 45 min. for a portion of the curve, and then to have compounded the remainder to something like 1 deg. and 30 min.

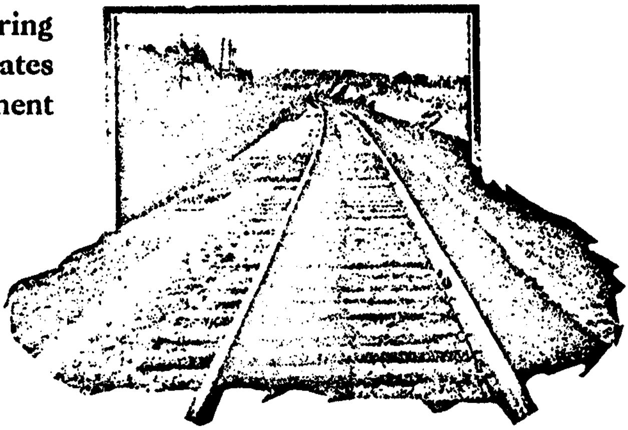
Requires Less Throwing

In other words, the same effect is secured with less throwing of the actual track by means of string lining than by using an instrument. When we add to this saving in throw the greater smoothness and regularity of line obtained by having a stake at every joint in place of every 50 or 100 ft., we begin to realize the true value of the method. Every one who is familiar with practical track work knows that if a curve is out of true alinement—that is, if it has numerous sharp and flat places—the track foreman will put in too much superelevation through the flat places of the curve and too little superelevation through the sharp places in order to secure a curve which "looks well" to his eye. The result is, naturally, rough riding track or even unsafe track. If a curve is re-alined by means of a transit, and stakes set every 50 or 100 ft. (as is customary), the foreman who lines the track is almost certain to have numbers of sharp and flat places between the stakes. It is quite true that these places will be so slightly out of line at first that their presence can scarcely be detected by the eye; but it is equally certain that these defects become greatly aggravated as time passes and the effects of high-speed trains are felt.

Determining the Throw for a Curve*†

Explanation of the Steps Entering into the Selection of the Ordinates for the Revision of the Alinement

Part 2



IF THE throws required to line a given curve are not excessive, or if it appears that, for reasons of its own, a railroad does not wish to limit the amount of throwing of the actual track, it is usually advisable to attempt to obtain a perfectly regular curve. If we take the curve used in the previous article, we shall see the method of applying the principles in order to obtain a curve which is regular throughout, without even the slight variations which characterized the solution described in the May issue. In addition to this we shall be able to find out just how much it would have been necessary to throw the track to obtain that regular curve and, therefore, what the amount of the throw would have been if the work had been done with a transit instead of with a string.

Let us assume for the purpose of this illustration that we carry straight through to the end of the curve the spiral 0, 4, 7, 11, 14, and 18, with the average revised ordinate of 20; that is, continue the curve which was started in the article in the May issue, Page 214, and then abandoned because the half-throws ran above the assigned limit at Station 19. We have the following:

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original and Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
1	0	0	0	0	0
2	5	4	1	1	0
3	7.	7	0	1	1
4	9	11	—2	—1	2
5	9	14	—5	—6	1
6	16	18	—2	—8	—5
7	34	20	14	6	—13
8	23	20	3	9	—7
9	12	20	—8	1	2
10	15	20	—5	—4	.3
11	25	20	5	1	—1
12	20	20	0	1	0
13	13	20	—7	—6	1
14	19	20	—1	—7	—5
15	28	20	8	1	—12
16	25	20	5	6	—11
17	28	20	8	14	—5
18	24	20	4	18	9
19	16	20	—4	14	27
20	8	20	—12	2	41
21	13	20	—7	—5	43
22	17	20	—3	8	38
23	17	20	—3	—11	30
24	34	20	14	3	19
25	18	20	—2	1	22
26	13	20	—7	—6	23
27	10	20	—10	—16	17
28	32	20	12	—4	1
29	18	20	—2	—6	—3
30	20	20	0	—6	—9
31	20	20	0	—6	—15
32	33	20	13	7	—21
33	13	20	—7	0	—14
34	14	20	—6	—6	—14
35	31	20	11	5	—20
36	22	20	2	7	—15
37	17	20	—3	4	—8
38	17	20	—3	1	—4
39	16	15	1	2	—3
40	4	10	—6	—4	—1
41	8	5	3	—1	—5
42	2	0	2	1	—6
43	0	0	0	1	—5

In the column headed sum of errors, we have a total of +1, which means that the total of the original ordinates is greater than the total of the revised ordinates by 1. In the half-throw column, we have a residual half-throw of —5. We must correct the column headed sum of errors first, in order to simplify the calculations. This can easily be done by making the last ordinate of 20 a 21. We then have

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original & Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half-Throw (F)
38	17	21	—4	0	—4
39	16	15	1	1	—4
40	4	10	—6	—5	—3
41	8	5	3	—2	—8
42	2	0	2	0	—10
43	0	0	0	0	—10

We can now correct the residual half-throw to zero by picking any two ordinates whose station numbers differ by ten, substracting unity from the one having the lower station number and adding unity to the one having the higher station number, in accordance with the rule that when the final half-

*This is the fifth of a series of six articles on the string lining of curves, describing the manner in which the line can be corrected by the track men without the use of instruments other than a piece of string and an ordinary rule. The first article of this series, which appeared in the January issue, Page 4, presented the merits of this practice in contrast with the use of a transit. The second article, which was published in the February issue, Page 62, described the methods of taking the measurements. The third article, which appeared in the April issue, Page 168, presented the basic principles underlying this method of determining curve alinement. The fourth article, which appeared in the May issue, Page 212, discussed the method of selecting the revised ordinates for a curve to give the minimum throw. The sixth and concluding article, which will appear in the July issue, will describe the manner of placing the stakes preliminary to the actual lining of the curve.

throw is negative we add to the ordinates near the bottom of the page and subtract from those near the top of the page. In order to reduce the work of making the change, let us pick the ordinates as close to the bottom as we can conveniently. We shall select, then the two ordinates at Stations 29 and 39, adding to the one at 39 and substracting from the one at 29. We have

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original and Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
29	18	19	— 1	— 5	— 3
30	20	20	0	— 5	— 8
31	20	20	0	— 5	—13
32	33	20	13	8	—18
33	13	20	— 7	1	—10
34	14	20	— 6	— 5	— 9
35	31	20	11	6	—14
36	22	20	2	8	— 8
37	17	20	— 3	5	0
38	17	21	— 4	1	5
39	16	16	0	1	6
40	4	10	— 6	— 5	7
41	8	5	3	— 2	2
42	2	0	2	0	0
43	0	0	0	0	0

The curve is now lined. In order to avoid making any more 21s out of the 20s, and because the 20 at Station 38 had previously been changed to 21, thus making it advisable to increase one of the ordinates of the spiral to keep the change between ordinates in keeping with that between other terms of the spiral, we increased the 15 of the spiral to a 16. As the station number of this ordinate was 39, we were compelled to pick Station 29 for the other station whose ordinate was to be changed.

An Important Point

In connection with the method of changing the final half-throw back to zero, the reader will note, if he examines the method closely, that at each succeeding station after the one whereat the first change was made, the half-throw is less by the difference in station numbers from the point of change than it was for the curve which had the residual half-throw. This is true for any curve, whether it is lined or not. That is, if we have a curve which is, say, half-finished, and we find that a certain group of throws is exceeding the desired limit, we can arbitrarily decrease that half-throw by any given amount simply by changing one or two of the ordinates a given distance ahead of the point where the half-throw is too large. To illustrate:

Suppose that we have reached the 49th station of a curve, with a half-throw of —71, which is too high to suit our purposes; we wish to change that half-throw so as to bring it to some such figure as —41. In order to do this, we have only to go back 30 stations to Station 19, and decrease the revised ordinate at that station by unity. This, also, is a valuable asset of the method.

Another valuable application of this same principle can be made when the column headed sum of errors, and the column of half-throws have the same sign at the last station. Suppose that we arrive at the last station with a sum of errors equal to +3, and a final residual half-throw of 46. We can divide 46 by 3, which gives us 2 units of 15 and one of 16. By increasing the ordinates by 2 at Station 15 back of the last station and by 1 at Station 16 back of the last station we make both columns equal to zero at the end, and the curve is lined. To make this a trifle clearer, let us suppose that the number of the last station is 53; then by adding 2 units to the revised ordinate at Station 38 (53—15) and 1 unit at Station 37 (53—16), we make the two columns referred to come out zero. Of course, the same principle applies if the sign of the last two columns is negative.

It will be noted by reference to the curve just lined that the maximum throws are now +41 and —21; the increase is small (over the first solution), and is not really indicative of the saving in throw which can generally be accomplished by the changing of a few of the ordinates by one or two. This can be more clearly realized, perhaps, if one considers that, for example, by changing by unity the tenth ordinate of a curve 93 stations long, a change of 83 in the final half-throw is effected.

Method of Compounding a Curve

In the following curve is demonstrated the method of changing the revised ordinates, and thus compounding the curve. It is usually convenient, and is a means of effecting a real saving in throw, to spiral between the two branches of the compound. As this is done merely by inserting a series between the branches, and as the operation is equally as simple as putting in all ordinates equal, one realizes almost immediately with what ease the operation can be performed. The task of realining a compound curve with an instrument (a transit) and at the same

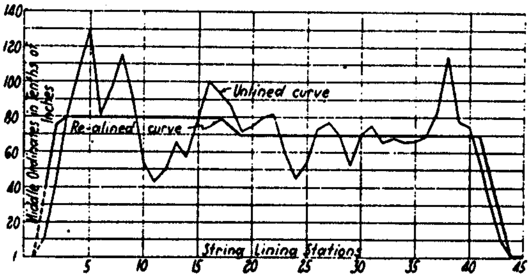


Chart of the Ordinates of a Compound Curve

time installing two spirals at each end and a spiral between the branches of the compound curves is one of great magnitude, as will be appreciated by anyone who has ever undertaken the task of doing this on an actual curve.

It might be well to state here that the track supervisor under whose jurisdiction this curve was, was entirely willing to throw the curve the large amounts required to install the revised curve. His reasons for so doing will doubtless be fully appreciated if the reader will glance at the accompanying graph of the original ordinates. It may truthfully be said that this curve can be considered as a "horrible example" of all that a good curve should not be, before it was realined. After the realining, which was made less troublesome than it would otherwise have been by the fact that the curve was relaid with new rail at the same time that the throws were made, this curve rode well.

In the case given below, the amount of change between the two branches of the compound was only 10 units, or 52.5 min. A very short spiral (0, 5, 10) was inserted, which suffices amply to effect the change. In general it may be said that the type and length of the spiral between the branches of the curves is determined by the effect of the different permissible spirals on the half-throws.

In compounding a curve the exact place at which to change the revised ordinate will always have to be determined by trial. This will not require more than two trials, as a rule, if the point first selected is anywhere close to the true point of compound.

Station Number (A)	Original Ordinate (B)	Revised Ordinate (C)	Difference Between Original and Revised Ordinates (D)	Sum of Errors to and Including Station (E)	Half Throw (F)
1	11	38	—27	—27	0
2	44	76	—32	—59	— 27
3	83	80	3	—56	— 86
4	109	80	29	—27	—142
5	130	80	50	23	—169
6	81	80	1	24	—146
7	96	80	16	40	—122
8	116	80	36	76	— 82
9	90	80	10	86	— 6
10	55	80	—25	61	80
11	43	80	—37	24	141
12	50	80	—30	— 6	165
13	66	80	—14	—20	159
14	57	80	—23	—43	139
15	79	80	— 1	—44	96
16	101	80	21	—23	52
17	94	80	14	— 9	29
18	87	75	12	3	20
19	72	70	2	5	23
20	75	70	5	10	28
21	80	70	10	20	38
22	82	70	12	32	58
23	60	70	—10	22	90
24	45	70	—25	— 3	112
25	54	70	—16	—19	109
26	74	74	4	—15	90
27	78	70	8	— 7	75
28	71	70	1	— 6	68
29	53	70	—17	—23	62
30	71	70	1	—22	39
31	76	70	6	—16	17
32	66	70	— 4	—20	1
33	68	70	— 2	—22	— 19
34	66	70	— 4	—26	— 41
35	67	70	— 3	—29	— 67
36	69	70	— 1	—30	— 96
37	83	70	13	—17	—126
38	116	70	46	29	—143
39	78	70	8	37	—114
40	75	70	5	42	— 77
41	55	70	—15	27	— 35
42	31	47	—16	11	— 8
43	10	23	—13	— 2	3
44	1	0	1	— 1	1
45	1	0	1	0	0

Note: Ordinate of 11 units at Station 1 because Station 1 is at point of reverse curve, the next station on the other side being on the reverse curve.

Spirals for Operation at a Fixed Speed

In order to install a spiral which can be run over by trains operating at a certain schedule speed, it is necessary to find a relation between the spiral series and that speed. It can be proved that such a relation can be readily derived. The relation is based on the results of tests made by the American Railway Engineering Association, as given in its bulletin No. 108 for February, 1911. In this bulletin it is stated that the maximum rate at which superelevation can be attained without discomfort to passengers is about 1 1/6 in. per second. From this fact, we derive a relation to the effect that the operating speed of a string lining spiral, in miles per hour, is given by

$$V = \frac{75.65}{\sqrt[3]{F}}$$

where V is the velocity in miles per hour and F is the factor of the string lining spiral to be used. This relation may be more conveniently written as

$$F = 432{,}975/V^3 \quad \text{or, accurately enough,}$$
$$F = 433{,}000/V^3$$

Suppose, for example, that it is required to install a spiral which can be operated by trains running at a fixed maximum schedule speed of 50 miles per hour. Substituting 50 for V in the above equation, we have $F = 433{,}000/125{,}000 = 3.464$. Thus, for such a case a 3.5 spiral can be used—either of the two following

(a) 0, 3, 7, 10, 14, 17, 21, 24, 28, etc. or
(b) 0, 4, 7, 11, 14, 18, 21, 25, 28, etc.

Having written this spiral down on the slate upon which have been transcribed the ordinates of the actual curve, we proceed to line the actual curve as was done in the foregoing cases, correcting the revised ordinates and making them the proper value.

Discussion of the Spiral

A word should be said here about the properties of the string lining spiral. It can be definitely shown that, for a given circular curve, and a given speed, there is only one transit spiral which can be used in realining a track. If other spirals are tried, one must of necessity change the degree of the circular curve slightly, or else change the direction of the tangent track line, or (as is most frequently done) compound the circular curve a short distance ahead of the point of spiral to curve.

The same thing can be done with the string line spiral, and is done, as we saw in lining the curve shown in the preceding article. Moreover, the variety of spirals which can be used in string lining far exceeds that which is available in transit lining, because of the fact that a change of only one ordinate of a revised curve in effect makes that revised curve an entirely different curve than if the change had not been made, and, inasmuch as in most curves upon which string lining computations are made there are numbers of such changes, no matter how slight or how short (in length), a number of different spirals is admissible; a fact which may at first seem contradictory of actual conditions.

For the same reason, different spirals can be used on the two ends of the same revised circular curve; in fact, the operator will generally find it a means of effecting a considerable saving in throw to use different spirals on the two ends, because of the condition of the actual track. This brings up the question of the relation of spirals to the circular curve, to the track in general, to traffic and the direction of preponderance of traffic, and to the grade line.

Relation of Spirals to Grade Lines and to Direction of Traffic

On double or multiple track roads it will almost always be found that the spiral on the entering end of the curve—that is, at the north end of a southbound track, etc.—is appreciably longer than the spiral on the leaving end. This is as might be expected, if one analyzes the causes for such a condition. Consequently, it is generally the case that the spiral on the entering end of the *revised* curve must be longer than the spiral on the leaving end. This means that the factor of the spiral on this end must be lower than the factor of the spiral on the other end.

Because of the ease with which it is possible to line a curve on paper by this method, it is practicable to take into account the grade line in conjunction with realining curves. This is a feature of realining to which practically no attention is ever paid, but which merits consideration because of its influence on the riding qualities of the curve and even on the safety of the curve.

For example, if a curve happens to be situated so that the leaving end is at or near the point of intersection of an ascending grade with a level grade or a descending grade (in other words, if the grade line appears in the form of an inverted V), it is practical to make the spiral to the curve at that end shorter and sharper than it would otherwise be. The train loses a great deal of its momentum and speed by the time it has reached the top of the grade (especially on ruling and maximum grades), which makes the value of V less in the formula given above and consequently, makes for a higher value of F, the spiral factor. On the other hand, when a descending grade meets another descending grade or a level grade (such that the grade line appears as an upright letter V) a long spiral is desirable. This is especially true if the grade line (on the descending grade) is such that the locomotive engineman will apply his train brakes, because a short spiral on the leaving end of such a grade, combined with the higher superelevation required by such a shorter and sharper spiral, tends to emphasize the tendency of the train to "ride" the low rail to an undesirable or even unsafe amount. This may or may not result in a derailment but is practically certain to result in throwing the spiral out of line and making for generally bad alinement throughout that entire portion of the curve.

Start at Entering End

In connection with the making of some spirals longer than others it has been the author's experience that it is quite easy to make a long spiral on that end of the curve upon which calculations are first begun, but more difficult on the other end. Consequently, it is usually a good practice to start lining (on paper, of course) all curves from the entering end of the curve, or *with* the direction of traffic. In this way, the proper spiral is secured almost automatically. In order to do this the ordinates of the original curve should preferably be taken in the field with this end in view, so that they will not have to be written backwards when they are put on the slate. This will obviate any confusion which might arise as to which end of the curve is which, and whether the throws are written opposite the right stations or whether they have been wrongly written opposite the stations in reverse order.

Setting the Stakes—the Last Step*†

Practical Suggestions for Placing Markers to Indicate the Amount of the Throw Preliminary to Lining the Curve

IN THE previous articles of this series the method of measuring the actual curve and the means of making detailed corrections in the alinement of the curve have been set forth. After these steps have been completed it is necessary, in every case, to set some sort of stakes or marks to indicate the location and amount of all corrections. It might be thought that it would be sufficient merely to start in and throw the curve at each string-lining station by the amount indicated on the slate; but such is not the case. It will be remembered that if any point on a curve is thrown either out or in, the adjacent points on either side move half as much in the opposite direction. Hence, after one station of a curve has been corrected, the original ordinate at the next one has been changed, and it is not sufficiently accurate to measure the correction from the new position of the rail.

Another argument in favor of setting stakes is that the actual work of re-alining the curve can be done at any time after the stakes have been set. It is quite apparent that every piece of track is subject to slight movements from day to day; but if stakes are set soon after the original measurements have been taken the amount of such movement is not enough to render the results untrustworthy. However, if no stakes are set, and the work of making the detailed corrections is allowed to be deferred until several months have elapsed, it is highly probable that the movement of the track will have been sufficient to render the results useless.

The Location of the Stakes

It is customary to set stakes opposite every string-lining station.. There are some permissible exceptions to this rule, and these are discussed in further detail below. The particular place in which the mark is to be placed opposite the string-lining station is to some extent at the option of the individual. Stakes can be set at almost any convenient distance from the gage line (5/8 in. below the top of the ball of the rail) of the high rail. However, of the different possible distances, only two have found much favor with track men. These are distances of one foot and of half the gage, respectively, from the correct or revised gage line of the high rail. Because of the fact that the setting of stakes for the center of the revised curve permits the roadmaster or supervisor to see at a glance the approximate distance that the track is to be shifted at each joint or station and because of the further fact that most railway engineering work uses the center line of track as the base line, and for numerous other reasons, the author is convinced that it is highly desirable to set all stakes so that they will represent the center line of the curve *after* it has been thrown.

In order to do this, it is necessary to compute the distance between the gage line of the actual curve before it is re-alined and the center line of the re-alined curve. This distance is a function of the throw at each string-lining station or joint of the curve.

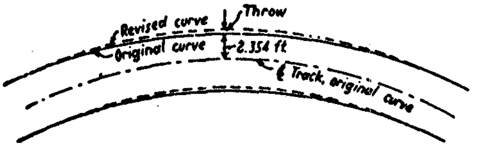
Standard gage or the distance between the gage line of the two running rails is 4 ft. 8½ in. Assuming for the time being that the gage is not widened on a curve it will then be necessary, in order to set a tack in a stake to represent the center line of the curve, to set the tack half-gage or 2 ft. 4¼ in. from the gage line of the high rail.

Now, if we assume that another stake is to be set to mark an outward throw of two inches, it is immediately obvious that the new stake must be set two inches nearer the gage line of the high rail; since, if the rail is to be shifted two inches out, the center will be shifted the same amount. Hence, in order to set a stake indicating an outward throw of two inches, the tack in the stake must be set a distance from the gage line of the high rail equal to half-gage *less* two inches, or 2 ft. 2¼ in. Conversely, if the throw is in, or toward the center of the curve, the tack will have to be set two

*This is the last of a series of six articles on the string lining of curves, describing the manner in which the line can be corrected by track men wthout the use of instruments other than a piece of string and an ordinary rule. The first article of this series, which appeared in the January issue, page 4, presented the merits of this practice in contrast with the use of a transit. The second article, which was published in the February issue, page 62, described the method of taking the measurements. The third article which appeared in the April issue, page 168, presented the basic principles underlying this method of determining curve alinement. The fourth article which appeared in the May issue, page 212, and the fifth article, which appeared in the June issue, page 258, described the method of selecting revised ordinates for a curve, to give the minimum throw.

inches *farther* from the gage line of the high rail, or 2 ft. 6¼ in.

Therefore, for every inch of throw in the outward direction, the stake for the revised curve will move one inch nearer than half-gage to the gage line of the high rail of the actual curve; and for every inch throw in an inward direction, the stake will move an inch farther than the half-gage. The rule is thus formulated that the center of the revised curve is distant from the gage



The Tack Distance

The tack distance for the string-lining stake is the distance between the gage line of the high rail before re-alining and the center line of the revised curve after re-alining.

line of the high rail of the actual or original curve an amount equal to one-half the gage *minus* the throw. The minus sign takes care of the sign of the throw; if the sign is plus (out), the distance will be less; but if the sign is negative, the minus sign changes it to a plus, thus adding the throw to the half-gage distance.

If we use half-throws instead of throws, the above rule should be changed to read: The center of the revised curve is distant from the gage line of the high rail of the original curve by an amount equal to one-half the gage minus twice the half-throw. Reducing half-gage to inches, we have:

Tack distance equals 28¼ in. minus twice the half-throw.

Tables showing the tack distances for different half-throws can be made very simply. It is usually more convenient to make these tables to show feet and decimals of a foot. In order to do this, it is necessary to reduce the 28¼ in. to feet, and reduce the half-throws in eighths or tenths of inches (whichever is being used) to feet. In order to illustrate the method, the author has done this for half-throws in tenths of inches. (Note: 28¼ in. equals 2.354 ft.)

The half-throws, as obtained by the methods outlined in the preceding articles of this series, are in tenths of an inch. A half-throw of 0.1 in. means a full throw of 0.2 in. Reduced to feet, this is 2/120 or 1/60 of a foot. Each unit of half-throw, then, means that the stake is set 1/60 of a foot farther or nearer to the gage line of the original track. If we denote the half-throw in tenths of an inch by F (as in the notation used thus far), we have the relation that the distance of the tack in the stake from the gage line of the high rail on the actual unlined curve if given by

$$\text{Distance} = d = 2.354 - \frac{F}{60}$$

The author has constructed, for use in the field, table giving values of this distance, d, as computed from the above formula, for each value of the half-throw from +1 to +149, and also from —1 to —139. These tables are given herewith.

Such tables are easily constructed by differences. Thus, the difference between any two tack distances for a unit difference in throw is 1/60 of a foot, as explained above. This equals 0.1666666 ft. By subtracting 0.016 from one value, 0.017 from the next and making a correction opposite every fourth value (that is, employing the values in the order, 0.017, 0.016, 0.017, 0.017, etc.) we are enabled to write down these values very quickly. Again, every time the half-throw reaches a multiple of 6, the track distance increases or decreases, as the case may be, by 0.1 ft., so that after having computed the first six values of the tack distances for throws out and throws in, the remainder of the table can be constructed simply by

Table Giving Distance in Feet of Tack From High Rail for Half-Throws in (—) in Tenths of Inches

0	0	1	2	3	4	5	6	7	8	9
0	2.354	2.371	2.387	2.404	2.421	2.437	2.454	2.471	2.487	2.504
1	2.521	2.537	2.554	2.571	2.587	2.604	2.621	2.637	2.654	2.671
2	2.687	2.704	2.721	2.737	2.754	2.771	2.787	2.804	2.821	2.837
3	2.854	2.871	2.887	2.904	2.921	2.937	2.954	2.971	2.987	3.004
4	3.021	3.037	3.054	3.071	3.087	3.104	3.121	3.137	3.154	3.171
5	3.187	3.204	3.221	3.237	3.254	3.271	3.287	3.304	3.321	3.337
6	3.354	3.371	3.387	3.404	3.421	3.437	3.454	3.471	3.487	3.504
7	3.521	3.537	3.554	3.571	3.587	3.604	3.621	3.637	3.654	3.671
8	3.687	3.704	3.721	3.737	3.754	3.771	3.787	3.804	3.821	3.837
9	3.854	3.871	3.887	3.904	3.921	3.937	3.954	3.971	3.987	4.004
10	4.021	4.037	4.054	4.071	4.087	4.104	4.121	4.137	4.154	4.171
11	4.187	4.204	4.221	4.237	4.254	4.271	4.287	4.304	4.321	4.337
12	4.354	4.371	4.387	4.404	4.421	4.437	4.454	4.471	4.487	4.504
13	4.521	4.537	4.554	4.571	4.587	4.604	4.621	4.637	4.654	4.671
14	4.687	4.704	4.721	4.737	4.754	4.771	4.787	4.804	4.821	4.837

To use this table read the distance of the tack from the gage line of the high rail in feet and thousandths of feet opposite the proper tens unit in the vertical column at the extreme left of the page and under the unit number across the top of the page. Thus 44, or a half-throw of 4.4 inches in, corresponds to a tack distance of 3.087, which is read on the horizontal line opposite the figure 4 and under the vertical column headed by the the figure 4.

Table Giving Distance in Feet of Tack From High Rail for Half-Throws Out (+) in Tenths of Inches

0	0	1	2	3	4	5	6	7	8	9
0	2.354	2.337	2.321	2.304	2.287	2.271	2.254	2.237	2.221	2.204
1	2.187	2.171	2.154	2.137	2.121	2.104	2.087	2.071	2.054	2.037
2	2.021	2.004	1.987	1.971	1.954	1.937	1.921	1.904	1.887	1.871
3	1.854	1.837	1.821	1.804	1.787	1.771	1.754	1.737	1.721	1.704
4	1.687	1.671	1.654	1.637	1.621	1.604	1.587	1.571	1.554	1.537
5	1.521	1.504	1.487	1.471	1.454	1.437	1.421	1.404	1.387	1.371
6	1.354	1.337	1.321	1.304	1.287	1.271	1.254	1.237	1.221	1.204
7	1.187	1.171	1.154	1.137	1.121	1.104	1.087	1.071	1.054	1.037
8	1.021	1.004	0.987	0.971	0.954	0.937	0.921	0.904	0.887	0.871
9	0.854	0.837	0.821	0.804	0.787	0.771	0.754	0.737	0.721	0.704
10	0.687	0.671	0.654	0.637	0.621	0.604	0.587	0.571	0.554	0.537
11	0.521	0.504	0.487	0.471	0.454	0.437	0.421	0.404	0.387	0.371
12	0.354	0.337	0.321	0.304	0.287	0.271	0.254	0.237	0.221	0.204
13	0.187	0.171	0.154	0.137	0.121	0.104	0.087	0.071	0.054	0.037

To use this table, read the distance of the tack from the gage line of the high rail in feet and thousandths of feet opposite the proper tens unit in the vertical column at the extreme left of the page and under the unit number across the top of the page. Thus 44, or a half throw of 4.4 inches *out*, corresponds to a tack distance of 1.621, which is read on the horizontal line opposite the figure 4 and under the vertical column headed by the figure 4.

adding or subtracting 0.1 ft., and using the remainder of the figures as they were in the first six values. Such a table will be found of immense value to any one who lines more than one curve, inasmuch as the savings in time and labor in computing the tack distances are tremendous.

Stakes and Equipment for Driving Them

The best type of stake for string-lining purposes has proved to be a stout wooden stake of suitable material such as oak, about 1¼ in. square on top and with ready-pointed bottom. A long, slender point helps the driving and speeds up the work of getting the stake down to a firm setting. A good length for the stakes is about 18 to 30 in. depending upon the type of ballast into which they are to be driven. If the ballast is cinders, the 30-in. stake is preferable because shorter stakes are too easily moved by the track gang when the ties are lined over for the new curve. If the ballast is rock the 18-in. stake is usually quite satisfactory, unless the ballast is quite new, in which case a longer stake should be used. For such materials as chats or screenings, an intermediate length of stake is best.

In rock ballast, or in very compact ballast of any kind, a long steel bar or pin, flat on one end and with a long tapering, hardened point on the other end, will be found to be a valuable aid in speeding up the work of getting the stakes in, as such ballast frequently splits a wooden stake before it reaches sufficient depth to insure firm penetration. An old lining bar, properly hardened at the tip (which should first be beaten out straight), and cut down to a length of about 38 or 40 in., makes an admirable tool for this purpose. The pin should be driven into the rock ballast first, and as it is drawn up out of the hole, the wooden stake should be inserted quickly to prevent loose rock and dirt from falling into the hole. A steel maul, with flat ends on both sides of the head, and weighing about eight pounds, will be found most satisfactory for the work of driving both the pin and the stakes.

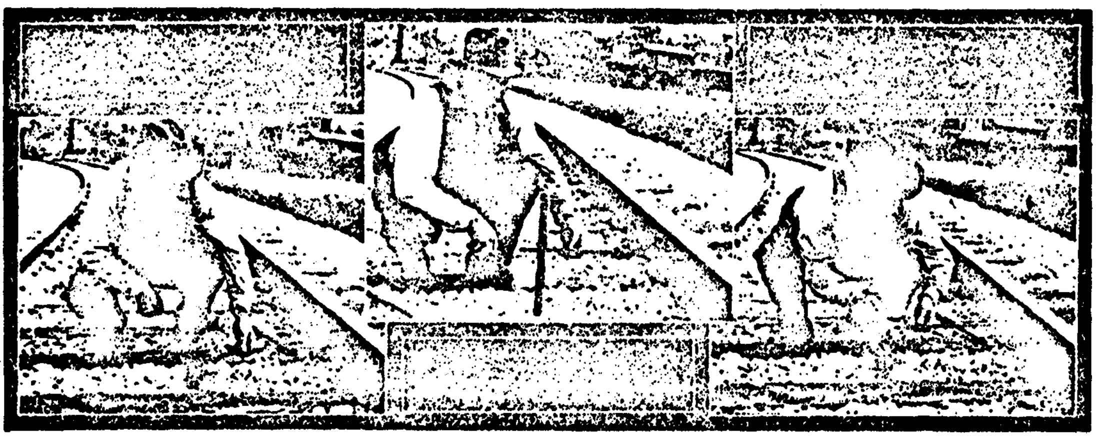
The pin should first be located by measuring from the gage of the high rail the tack distance, as shown below. Then the pin is driven in, followed by the stake. The stake should be driven quite low—so that it does not protrude more than 1½ in. above the top of the ties on each side—to prevent its being hit and broken or knocked down by the steam and air lines of passing trains, or by dragging brake beams, etc. This is especially true of those stakes which, because of small throws, are near the center of the unlined track, since such stakes are more directly in the line of the air and steam lines than those at one side.

At points where the throws are quite small, and all in the same direction—that is, either all out or all in for a distance of four or five rail lengths—some of the stakes can be omitted and the throw marked on the tie. In places where there is no throw (there are frequently such places on nearly all curves) it will suffice to write "O. K.—No Throw" on the nearest tie in yellow chalk or keel.

In setting center line stakes, the measurement from the gage line of the high rail to the tack in the stake should be made in the same manner as the original measurement was made when recording the data on the curve. In other words, if the tape was held about on a level with the tops of the two rails in taking the original ordinates before throwing, it should be held at about the same angle when the stakes are set. It goes without saying that, unless some precaution is taken to get approximately the same angle every time, the angle of measurement will be different on every stake set. As this is unsatisfactory, it is best to adopt some rule for the measuring, and then follow the rule as nearly as possible. In other words, all measurements should be made level (for example), or else all measurements should be made in the plane of the two rails. In either case, it will be necessary to sight down over the tape to the top of the stake, in order to locate the exact point at which to drive the tack. This can best be done by the aid of a small ruler or a pencil, as the eye can better determine whether the ruler or pencil is vertical than it can whether the line of sight alone is vertically over the tape graduation.

In driving the stake, the person driving it should stand near the center of the track and two feet or so away from the stake. In other words, he should stand in such a manner that he can see whether the stake is vertical and has not shifted across the track (between the two rails) as a small amount of shift this way is much more important than a greater amount along the center line of the track. Where there is any considerable amount of superelevation in the high rail, it will be found that there is a decided tendency for a stake to "slide" down-hill or toward the lower rail as it is being driven. In view of this fact, it is generally wise to set the point of the stake from a half inch to as much as three inches nearer the high rail than the actual point where it must finally be placed; after which it can be allowed to slide back to the desired point as it is being driven down.

Cases will frequently be encountered where the string-lining station or the joint is on a tie or is located between two ties where there is scarcely sufficient space in which to drive a stake. In this case, of course, it is necessary to set the stake to one side or the other. However, it should be remembered that this will change the effective length of the chord; and as the middle ordinates vary as the square of the chord length, some slight correction may be necessary where the ordinate is unusually large. For example: suppose that a curve has been measured with a 66-ft. chord, that the revised middle ordinate is found to be 56 (tenths of an inch), and that a stake cannot be set opposite a particular station, but must be set two feet farther away (toward the next station or joint). Then the actual chord length is not 66 ft., but 68 ft.; and the ordinates will vary as 66 squared is to 68 squared or as 4,356



Practical Hints for Setting Stakes

Wrong way to set the tack, the rule is at an angle — The pin used in rock ballast must be set carefully — Right way to set the tack, using pencil with rule horizontal is to 4,624 or 94.3 per cent. Consequently, 56, the ordinate to set is only 94.3 per cent of the ordinate that must be measured on account of the lengthening the chord; and, instead of measuring 56, the recorder or person driving the stakes, must measure 59 (tenths of an inch). By the same reasoning, if the next stake he drives is in the correct position, the chord length will be 2 ft. *less* (because the other one was 2 ft. longer) than 66 ft. or 64 ft.; and he must measure an ordinate of 94.0 per cent of 56 or 53. The correction for a move of 1 ft. either side of the joint is, for a chord of 66 ft., approximately 3 per cent; for a 2-ft. move and a 66-ft. chord, it is approximately 6 per cent. As even 6 per cent of a small ordinate such as 10 (or one inch) is practically negligible, the correction is advisable only when the ordinates are rather large, as illustrated.

Some roads make it a practice to set permanent track centers either in the center of the track, or at one side. On double and multiple track roads, it is usually the custom, where such stakes are set, to place them between the tracks.

As a rule, permanent track center stakes are not really permanent, but move with the ballast. Any movement obviously destroys their value. Moreover, if set in the center of the track, they cannot remain there long without being hit by some dragging part on a train—a further argument against them.

If uniform track centers are carried throughout the length of a tangent, they must necessarily be widened through the curve. Because of the poor tapes which section foremen commonly carry, and because it is very difficult for them to measure along the radial line of the curve, it usually happens that when the track centers are thus widened, they are not uniform around the curve. Added to this, is the fact that, because of the different spirals on the ends of the curve, the throws required to line two curves will not be such as to make the track centers also uniform. Small variations one way or the other from a uniformly widened center around a curve are not particularly noticeable, anyway. The value of permanent centers is, then, seen to be doubtful. In the author's opinion, they are not worth the time and labor to install them.

APPENDIX G: INSPECTION OF WOOD TIES

G-1. General.

Properly treated, sound, wood crossties and switch ties last many times longer than untreated material; therefore, procurement of high quality, preservative-treated materials is required to maximize service life. Acceptance criteria for wood ties is specified in Fed. Spec. MM-T-371E which includes a requirement that preservative-treated wood ties conform to Fed. Spec. TT-W-00571J. Detailed standards, rejection criteria, certification documentation, requirements for independent inspection agency, and other quality assurance clauses are contained in supply contrast specifications and are not shown herein. Technical assistance to prepare purchase contracts or to confirm tie rejection can be obtained through addressees listed in paragraph 1-3 of the main report.

G-2. Responsibility.

Ties shall be checked by receiving activity and spot checked by foreman or contract inspectors prior to installation. Defective ties shall not be installed in any trackage system, except when specifically purchased for temporary trackage. The following quick-checks should be preformed by the user after delivery:

G-2.1. Treaters Brand Mark. The brand identifying preservative, supplier, and year of treatment is required at least on one end of each tie. Ties lacking this brand mark should be rejected.

G-2.2. Tie Condition. Ties damaged more than 30 percent (1/3) of their thickness (approximately 2 inches) and split ties without antisplitting devices shall not be installed in any trackage system.

G-2.3. Preservation. Inspection after delivery to determine penetration conformance of treated wood ties is limited to evaluation of creosoted products. Other preservative treatments require special dyes to identify areas containing preservatives. Penetration analysis requires destructively cutting a tie or removal of a core sample with an increment borer, Figure G-1. The sample should be removed near the midsection to avoid effects of end penetration. The degree of penetration required for acceptance varies in accordance with wood species and intended use. These requirements are listed in Table G-1. Batches of ties that lack the required penetration shall not be used in trackage systems and formal complaint/rejection procedures shall be initiated.

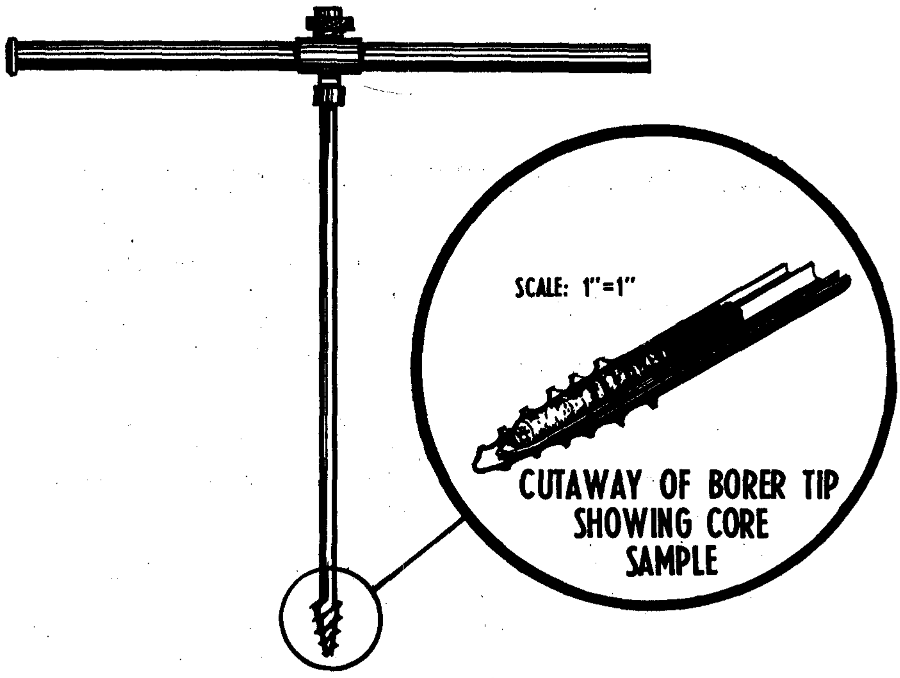


FIGURE G-1. INCREMENT BORER

WOOD SPECIES	MINIMUM PENETRATION IN INCHES	MINIMUM SAPWOOD PENETRATION
Southern or Ponderosa Pine	2.5	85%
Pacific Coast or Interior Douglas Fir; Western Hemlock; Western Larch; Redwood; Jack; Lodgepole; Red and Sugar Pine; and Northern or Western White Pine	0.5 (½)	90%
Red Oak	65% of annual rings	——
White Oak	——	95%
Black Oak or Red Gum	1.5	75%

TABLE G-1. ACCEPTANCE REQUIREMENTS FOR PRESSURE TREATED WOOD TIES

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